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October 4, 2010

VIA HAND DELIVERY

U.S. Environmental Protection Agency
5 Post Office Square, Suite 100
Boston, MA 02109-3912

Glenn Haas, Director
Massachusetts Department of Environmental Protection
1 Winter Street
Boston, MA 02108

Re: Comments on Draft NPDES Permit No. MA0100765
Town of Fairhaven Wastewater Pollution Control Facility

To Whom It May Concern:

On behalf of our joint client, The Town of Fairhaven, Massachusetts, Pierce Atwood, and Mackie Shea O'Brien are pleased to submit the attached comments to both U.S. EPA and MassDEP on the above-referenced draft NPDES permit and associated Fact Sheet and Massachusetts Water Quality Certification. These comments are timely filed pursuant to an extension of the comment period, published on August 6, 2010 (Public Notice Number MA-029-10). The Town of Fairhaven requests an opportunity to meet with the EPA and MassDEP permit writers to fully discuss these comments prior to a response to comments by EPA. Given the magnitude of uncertainty around the basis of the permit, we suggest the appropriate course of action would be to withdraw the permit at this time. This would allow meaningful discussion and comment on the issues contained in the permit by the Town and others, and the development of more effective and comprehensive strategies to meet water quality goals.

Sincerely,

Bill Taylor (BMR)

William E. Taylor
Pierce Atwood LLP

John Shea (by PMP)

John Shea
Mackie Shea O'Brien, PC

cc: Bryant Firmin, Chief, Surface Water Discharge Permit Program, MassDEP
Geoffrey Haworth, II, Chair, Fairhaven Board of Public Works
Charles Murphy Sr., Chair Fairhaven Board of Selectmen
William Fitzgerald, Fairhaven Public Works Superintendent
Linda Lima, Fairhaven Water Pollution Control Facility, Superintendent
Robert Peirent, Tighe & Bond

COMMENTS ON DRAFT NPDES PERMIT NO. MA0100765
SUBMITTED ON BEHALF OF THE TOWN OF FAIRHAVEN, MA
OCTOBER 4, 2010

These comments are provided on behalf of the Town of Fairhaven regarding the draft NPDES permit issued by EPA and MassDEP (collectively referred to as "the Agencies") on June 8, 2010 for the Fairhaven Wastewater Pollution Control Facility ("WPCF"). The draft permit imposes a new average monthly limit of 125 lbs/day for total nitrogen ("TN"). As will be explained below, the Town does not believe that this limit has been adequately explained by the Agencies in the Fact Sheet accompanying the draft permit, and, upon close review, cannot be justified scientifically. Moreover, it is not practicable (and may not even be possible) for the Town to meet this limit.

Accordingly, the Town of Fairhaven requests that the Agencies stop the permit process until additional information is developed and provided. If the permit process is not delayed than the Agencies should not impose a numeric criterion for TN in this NPDES permit, and instead provide a monitor-only requirement, while conducting a total maximum daily load ("TMDL") analysis that can instead be the basis for an equitable and defensible permit limit. At the same time, the Town would continue to take concrete steps to assure reasonable progress on improving water quality, including implementing a nitrogen optimization plan and an inflow and infiltration ("I/I") plan.

These comments begin by explaining why the technology-based TN limit is invalid and, in any event, cannot practicably be met. The Town then highlights the significant flaws in the water quality modeling that form the basis of the Agencies' apparent rush to over-regulate the WPCF. Finally, the Town provides several important reasons why a numeric TN limit is

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premature and why the Agencies should instead conduct a comprehensive TMDL for the New Bedford Inner Harbor that will result in fair load allocations.

I. The Technology-Based Limit for Total Nitrogen is Unexplained and Unsupported, and Cannot Practicably be Met.

As noted above, the draft permit imposes on the WPCF a new technology-based average monthly limit of 125 lbs/day for TN. The sole justification for this limit is the Agencies' statement in the Fact Sheet that this is the "limit of technology." Fact Sheet at 10. As will be discussed below, this failure to provide even a summary of the basis for the TN limitation precludes the Town's ability to fully comment on the draft permit and violates the Agencies's own rules. In any event, no matter what the actual basis, the Town cannot practicably meet such a permit limit.

A. The Failure to Explain the Basis for the TN Limitation Precludes the Town's Ability to Comment Effectively on the Draft Permit.

As an initial matter, EPA has failed completely to explain the basis of the new TN limit, thus precluding our ability to comment effectively on the draft permit and Fact Sheet. EPA's rules state that the Fact Sheet must provide at least a "summary of the basis for the draft permit conditions, including . . . appropriate supporting references to the administrative record." 40 C.F.R. § 124.8(b)(4). Moreover, in a permit involving case-by-case technology-based limits, such as for TN here, the Fact Sheet must explain "the reasons that such conditions are applicable." 40 C.F.R. § 124.56(b)(1)(iv). The purpose of these provisions is to ensure that the public, including the applicant, understands the basis for a proposed permit limit, and can thus effectively exercise the right to comment. Absent a reasonable explanation, the opportunity to comment is effectively rendered meaningless.

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Despite providing four pages of discussion about TN, most of which relates to in-stream water quality conditions, there is almost no explanation of the rationale for the technology-based average monthly TN limit. For example, page 9 of the Fact Sheet notes that EPA's regulations require that effluent limits be included for discharges that have the potential to cause or contribute to a water quality violation, but then abandons this discussion to conclude that a technology-based limit of 125 lbs/day is appropriate: "EPA and MassDEP have included a monthly average limitation of 57 kg/day (125 lbs/day), which corresponds to a treatment plant flow of 5.0 MGD and an effluent concentration of 3 mg/L TN." In the paragraph immediately above this provision, EPA simply asserts that the 3.0 mg/L TN proposed effluent concentration is "the limit of technology." The phrase "limit of technology" appears to be the entire basis for the effluent concentration upon which a new and very costly TN limitation is to be imposed on the Town of Fairhaven.[1]

The Fact Sheet, however, leaves unexplained exactly what the phrase "limit of technology" means in the context of this permit. As a legal matter, what is the regulatory standard that was applied in establishing this limit of technology – best available technology, best professional judgment, best practicable treatment, or some other determination? As a factual matter, what specific treatment technologies and facilities were considered to derive this limit of technology? Where are these reference facilities located, and how do they compare to the WPCF? What are the costs of the technologies that can achieve the effluent concentration of 3.0 mg/L TN?

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[1] In the event that the Agencies somehow consider the TN limit to be a water quality-based limit, in part or in whole, the Town reserves its right to challenge the basis of any such water quality-based TN limit. This reservation of rights includes, but is not limited to, the appropriate dilution factor for the Town, which may be different for TN than for other license parameters, the 0.5 mg/L TN target concentration, and the assertion that the Town is causing or contributing to actual impairment in the harbor or even whether there is actual water quality impairment related to nitrogen in areas of the harbor affected by the Town's discharge.

Without further information relating to all of the questions posed above, we cannot adequately respond to the proposed TN limit. There is not enough information in the Fact Sheet to provide the permittee a reasonable opportunity to comment, and thus, as the remainder of these comments demonstrates, we are left to guess at the basis for the TN limit. *In re Dominion Energy Brayton Point LLC*, 12 E.A.D. 490, 2006 WL 3361084 at 54 (E.A.B. 2006) (remanding permit where EPA provided only a conclusory basis for a limitation, stating that "[w]ithout an articulation by the permit writer of his analysis, we cannot properly perform any review whatsoever of that analysis and, therefore, cannot conclude that it meets the requirement of rationality"). Accordingly, we request that EPA provide additional information that will help the Town of Fairhaven understand the derivation of the proposed TN effluent limitation upon which significant legal, technical, and financial consequences may rest. Once the additional information is provided, an opportunity for comment on the new information must be provided.

B. The Agencies' Technology Determination is Unsupported and Inadequate.

Because there is no applicable effluent limitation guideline and TN is not a conventional pollutant, we assume, for purposes of these comments, that EPA's TN limit is based on the best available technology economically achievable ("BAT") requirements, 40 C.F.R. § 125.3(a)(2)(v), and that MassDEP's limit is based upon the highest and best practical treatment ("HBPT") standard, 314 C.M.R. 4.05(5)(c).

1. The Agencies Failed to Consider the Required Factors.

Both of these determinations, however, require extensive case-by-case consideration of whether a given limitation is practicable. Thus, for example, any BAT determination must include consideration of the following factors:

1. The age of equipment and facilities involved;

2. The process employed;
3. The engineering aspects of the application of various types of control techniques;
4. Process changes;
5. The cost of achieving such effluent reduction; and
6. Non-water quality environmental impact (including energy requirements).

40 C.F.R. § 125.3(d)(3). Likewise, HBPT is "the most appropriate means available on a regional basis" and must reflect the best performance technologies . . . that are economically achievable." 314 C.M.R. 4.02.

In this case, as demonstrated above, there is no evidence in the record that the Agencies have considered *any* of these factors. EPA and MassDEP must complete these evaluations before developing and imposing the technology-based permit limit.

Fairhaven has, however, on its own initiative, spent significant funds reviewing existing conditions, assessing potential methods to optimize nitrogen removal, and developing a number of preliminary scenarios to upgrade treatment processes. Because of the premature permit issuance, Fairhaven was not given the opportunity to review and discuss its findings with Agencies for use in the permitting process.

2. The WPCF Cannot Practicably Meet a TN Concentration Limit of 3 mg/L.

Regardless of how the "limit of technology" was derived here, a TN limitation based on 3 mg/L is not currently practicable or economically achievable by the WPCF. Years of monitoring data for TN indicate that the WPCF achieves on average TN effluent concentration of approximately 10. See Influent and Effluent Total Nitrogen Concentrations, attached as **Exhibit 1**. Further, as discussed below in detail, it would cost the Town over $50 million to reduce its effluent concentrations of TN to 3 mg/L.

3. The Agencies have Failed to Consider Affordability and the Potential for Substantial and Widespread Economic and Social Impact in Establishing the Proposed TN Permit Limits.

A preliminary estimate of the cost to upgrade the Fairhaven WPCF to meet an average monthly limit of 3 mg/L TN at design flow (the basis for the mass limit in the draft permit) is in excess of $50 million. Additional wastewater system improvements required to maintain permit compliance are expected to add several million dollars to this estimated cost of required capital improvements.

This estimate is based on a number of sources of cost information, including a recent Brown and Caldwell study of possible upgrades to the Town's secondary treatment process to meet a total nitrogen limit of 3 mg/L Attached as **Exhibit 2**; a 2008 WEFTEC publication titled, "Analysis of Nutrient Removal Costs in the Chesapeake Bay Program and Implications for the Mississippi-Atchafalaya River Basin;" and a study of "Engineering Feasibility & Cost Analyses of Nitrogen Reduction from Selected POTWs in Massachusetts," ("MassDEP Study") completed by a team of CDM/Stearns & Wheeler for MassDEP in 2008. A graph of the cost information derived from the Mass DEP study Attached as **Exhibit 3.**

The "best fit" unit costs developed from the CDM/Sterns & Wheeler study were adjusted upward to account for the significantly higher costs required to construct nitrogen removal facilities to meet an effluent limit of 3 mg/L versus a limit of 5 mg/L, which was the target of the MassDEP study, as well as to account for the considerable site limitations of the Fairhaven facility. At the higher end of the range of unit costs developed using the MassDEP study, upgrade costs could be even higher than $50 million. Due to site limitations, full reconstruction of the facility or construction of a new facility at an alternative site may be necessary to meet the proposed limit. Note a prior Fact Sheet developed by EPA in 2007, Biological Nutrient Removal Processes and Costs, EPA-823-R-07-002, cites lowest unit costs for some facilities; however, this Fact Sheet does not identify costs for facilities designed to achieve compliance with a TN limit of 3 mg/L with wastewater temperatures as cold as those regularly observed at the Fairhaven WPCF.

Using EPA's February 1997 financial capability guidance document (EPA 832-B-97-004), (verified as applicable by EPA staff, 7/26/10 meeting at MassDEP, Lakeville) a preliminary evaluation indicates that the cost of the required WPCF upgrade would *readily exceed 2.5%* of the adjusted median household income in Fairhaven and place a very high burden on the users of the Town's wastewater facilities. Other required upgrades to the Town's wastewater system would further burden users of the Town's wastewater facilities. The impact would be even greater to some users of the Town's facilities, a significant percentage whom are economically disadvantaged. The current unemployment rate in Fairhaven is at 11.3%, much higher than the national unemployment rate. Pursuant to a complete BAT or HBPT analysis, this high financial burden must be considered by EPA and MassDEP in developing the technology-based permit limitations.

4. The Agencies Have Failed to Consider the Effect Cold Temperatures Have on Total Nitrogen Removal.

To remove nitrogen from the wastewater, a two-step biological treatment process is employed: nitrification followed by denitrification. The nitrification reaction is highly dependent on temperature because the organisms have slow growth rates. The rate of nitrification at 20° C is approximately twice the rate at 10^{0} C,[2] requiring over two times the mass of microorganisms to maintain the same level of nitrification at the colder temperature. To keep the mass nitrifiers in the system, high solids and hydraulic detention times are required at cold temperatures.

If nitrification is lost during the cold temperatures, it cannot be re-established until the temperatures increase and the growth rate increases, allowing the population of nitrifiers to re-establish in the treatment system. With a very stringent monthly permit limit equivalent to 3 mg/L, the loss of nitrification could easily result in permit violations for many months. Therefore, basin sizes need to be large enough to ensure consistent nitrification even in cold weather and high flows.

At the Fairhaven WPCF, temperatures in the winter and spring, during snowmelt and runoff, often fall below 10^{0} C. See Wastewater Temperature Graph, **Exhibit 4**. Therefore, the basin sizes needed for nitrification at Fairhaven to provide consistent year-round nitrification would have to be significantly larger than those needed at facilities with warmer temperatures (such as in the Chesapeake Bay area and Florida) with similar permit limits.

5. The Agencies Failed to Consider Other Important Treatment Plant Factors.

In addition to low temperatures, the important factors that negatively affect a wastewater treatment plant's ability to meet low total nitrogen limits are: peak influent nitrogen loads, high wet weather flows, low alkalinity, and return streams.[3] These factors are present at the Fairhaven WPCF and will further complicate TN removal and greatly increase the cost of treatment. The Fairhaven WPCF has recorded significant I/I rates in its system during the late winter and early

[2] Water Environment Federation and the American Society of Civil Engineers/Environmental and Water Resources Institute. (2008) Biological Nutrient Removal Operation in Wastewater Treatment Plants, Manual of Practice No. 30. McGraw Hill, New York.
[3] See generally, Nutrient Control Design Manual, EPA/600/R-10/100, August 2010.

springtime, which results in sustained periods of high flow rates and very cold wastewater temperatures. Providing adequate volume to equalize and treat nitrogen during periods of high I/I will also significantly increase the cost of nitrogen removal at Fairhaven.[4] Additionally, Fairhaven is completing an $8 million upgrade to provide combined heat and power ("CHP") from captured digester gas. The return stream from this process will be high in ammonia, which will also require additional treatment.

The Fairhaven WPCF has significant space constraints that limit future expansion of treatment processes to accommodate nitrogen removal. As noted above, in 2009 the Town undertook a study of conceptual upgrades needed to the secondary treatment process to meet various total nitrogen restrictions, included at **Exhibit 2**. The study included process modeling of three upgrade alternatives, including a conventional 4-Stage Bardenpho activated process with filters; a Modified Ludzack-Ettinger ("MLE") process with denitrification filters; and an integrated fixed film activated sludge ("IFAS") process in an MLE configuration with a denitrification filter.

In all of these scenarios, significant additional tanks and equipment are required to meet the proposed monthly limit including additional primary and secondary clarifier capacity, filters, and modifications and/or additions to the aeration tanks. Based on these results, a conceptual opinion of cost for the upgrade is $50 million, and could easily be more due to I/I work, future sidestreams of concentrated ammonia from the anaerobic digester, modifications to the solids handling systems, land constraints, and limited yard piping space, and other factors.

Other technologies that minimize footprint and have other benefits have been discussed and would be evaluated and considered. However, most if not all these are in their infancy

[4] The Town has and continues to undertake significant I/I work well beyond any current permit requirements.

and/or would be even more costly. The Town believes it would not be a prudent course of action and use of ratepayer funds to select one of these newer technologies unless there has been full scale implementation for a number of years under similar conditions as the Fairhaven WPCF. These technologies would also need significant evaluation, including pilot testing, to evaluate their performance, reliability and costs.

Significantly, EPA and MassDEP have chosen to impose in a number of other NPDES permits a limit higher than the "limit of technology" assigned to the WPCF, where there has been far less uncertainty in the data used to support these permit limits than the data used to support the proposed Fairhaven limit. A notable, recent example of this is the permit issued to the Upper Blackstone Water Pollution Abatement District, which contains a TN limit of 5 mg/L, a limit that is almost twice that proposed for the Town of Fairhaven. This permit was appealed by a number of parties, some of whom sought a lower limit and others who sought a higher limit.

In a ruling dated May 28, 2010, the Environmental Appeals Board upheld the proposed limit citing uncertainties in supporting data as being a reasonable basis for EPA imposing a limit greater than what was cited as the limit of technology. As documented below, the supporting data for the proposed Fairhaven TN limit has numerous flaws, omissions and errors and is therefore fraught with uncertainty. Another example of EPA's imposition of TN limits less restrictive than the cited limit of technology is the permit recently issued to the Town of Wareham. In a nearly identical situation, where a study of the receiving water body had been drafted but not yet accepted by the MassDEP as the basis for establishment of a TMDL, EPA specifically chose to retain the existing permit limit instead of imposing a more restrictive limit, citing the lack of MassDEP approval of the study and adoption of a TMDL as the basis for not changing the permit limit.

6. EPA's Proposed Permit Fails to Recognize Overall Environmental Impacts.

In response to stringent permit conditions, a number of recent NPDES permittees have appropriately questioned whether or not the net environmental benefit of stringent permit conditions outweigh the overall environmental impacts that result from these permit conditions. To date, most of these arguments have been discounted by EPA as not being relevant to the objectives of the Clean Water Act. However, as evidenced through its Notice of Data Availability issued in April 2009, EPA has begun to acknowledge that the release of carbon to the atmosphere increases CO2 deposition and acidification of waterbodies, and a Clean Water Act mandate to restrict carbon dioxide emissions to protect the nation's waters from acidification is a likely future result. To reduce the likelihood that the Town would be required to make additional improvements to its treatment facility in the future to offset the increase in its carbon footprint, an evaluation of the net environmental benefit of the more stringent permit conditions should be completed before more stringent permit conditions are adopted.

Both higher electrical use and carbon addition add to carbon emissions and green house gases. Sustainability and wastewater experts are now actually calculating the carbon that can be offset by reducing nitrogen reduction targets. See, for example:

http://www.epa.gov/owow/tmdl/oceanfrMarch_2010/pdf/qa_ocean_acid_frn.pdf

http://www.theatlantic.com/technology/archive/2010/04/can-the-clean-water-act-cut-carbon-emissions/38502/

http://climateprogress.org/2009/04/17/clean-water-act-obama-epa-ocean-acidification-global-warming-geoengineering/

C. The Total Nitrogen Limit May Not Be Technically Achievable.

The nitrogen limit is based on a concentration of 3 mg/L, the so-called "limit of technology." Not all wastewater treatment facilities can meet this limit due to the presence of effluent dissolved organic nitrogen ("EDON") that is not removed by the nutrient removal treatment processes. According to the February 27, 2009 report titled "Establishing a Research Agenda for Assessing the Bioavailability of Wastewater Treatment Plant-Derived Effluent Organic Nitrogen in Treatment Systems and Receiving Water by the Scientific and Technical Advisory Committee ("STAC") and Water Environment Research Foundation ("WERF")" (attached as **Exhibit 5**). EDON concentrations from over 30 wastewater treatment facilities ranged from 0.10 mg/L to 2.80 mg/L, leading to the following conclusion:

> There is a wide range of observed EDON concentrations observed from BNR processes, and it appears that in some cases the EDON can be at a high enough concentration to make it impossible to meet an effluent TN concentration goal of 3.0 mg/L.

The report cited several areas of needed and on-going research related to EDON treatment and bioavailability including:

1. The fraction of EDON that is recalcitrant ("rEDON") and not bioavailable in surface water receiving streams;

2. The fate of dissolved organic nitrogen ("DON") in biological wastewater treatment and the relative effectiveness of different biological treatment processes on degradation of DON; and

3. The impact of DON in recycle streams from aerobic and anaerobic digestion and dewatering.

The Town continually tests for nitrogen, but EDON concentrations at the Fairhaven WWTF have not been characterized.

D. The Agencies Should Allow A Variance To The Limit of Technology-Based TN Permit Limitation.

Finally, if EPA and MassDEP continue to insist on imposing a technology-based limit of 125 lbs/day, despite the issues raised above, the Town hereby requests a variance to allow for a more reasonable monthly average limitation in the range of 334-417 lbs/day. Pursuant to federal law, EPA may grant such a variance from BAT limits if the applicant can show that the proposed alternative limit will (1) represent the maximum use of technology within the economic capability of the owner or operator, and (2) result in reasonable further progress toward the elimination of the discharge of pollutants. 33 U.S.C. § 1311(c).

Likewise, MassDEP has authority to grant a similar variance where dams, diversions, or other types of hydrologic modifications, such as, in this case, the hurricane barrier, preclude attainment of the use, human caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place; human caused conditions or sources of pollution (CSOs and PCBs) prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place; or where stringent controls will result in substantial and widespread economic and social impact as will be the case in Fairhaven. 314 C.M.R. 4.03(4)(c), (4)(d) & (4)(f). A variance is particularly appropriate in this case where boundary concentrations of TN approach 0.4 mg/L.

In sum, by failing to explain the derivation of the technology-based TN limit, or to consider adequately the technical and financial implications through a proper BAT or HBPT analysis, EPA and MassDEP have failed to justify the technology-based TN limit proposed in the draft permit. As a result, such a limit is legally and technically invalid. EPA and MassDEP are requested to defer any imposition of any TN limit at this time, or grant a variance to a level that can be more practicably achieved.

II. The Water Quality Model and the Draft MEP Report are Fatally Flawed.

Despite imposing a technology-based TN limitation, it is clear from the lengthy discussion on nutrients in the Fact Sheet that EPA and MassDEP place great weight on the draft water quality model prepared by the Massachusetts Estuaries Project ("MEP"). That draft model, entitled "Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the New Bedford Inner Harbor Embayment System, New Bedford, MA," and referred to as the "MEP Report," in the Fact Sheet, is deeply flawed, both procedurally and substantively. (For reasons outlined below, we will occasionally refer to the report referenced in the Fact Sheet as the "Draft July, 2009 MEP Report.") As a result, EPA and MassDEP have also failed to provide an adequate basis to regulate the WPCF's TN discharge as a water quality-based limit. In any event, a water-quality based limit cannot legally be based on a draft model.

A. The Agreed Upon MEP Report Process Was Not Followed and the Town's Involvement in Development of the Report was Limited.

Since at least 2003, the Town has been working collaboratively with the Massachusetts Estuaries Project, including UMass/SMAST, DEP and other involved agencies to develop a site-specific study for the Inner Harbor. The purpose of the study is to support development of a nutrient TMDL and ultimately a comprehensive, cost effective strategy for controlling nitrogen loads.

Seeking funding from the Town, Agency representatives explained several benefits of Town funding including deferral of regulatory action. Also noted was that limits, once developed, would traditionally be more stringent if no site-specific studies were available to reduce uncertainty. Other Towns in the MEP study area were provided similar descriptions of benefits, and this reasoning has been a basic underpinning of the MEP program itself. Based on these representations the Town appropriated $114,000.

Even after the Town contributed this significant financial resource as well as other resources to the effort, the process for developing the Draft, July 2009 MEP Report was somewhat disturbing. The Town was supposed to have the opportunity to review, comment, and get its questions answered on the MEP Report prior to it being finalized and used as the basis for further regulation. In 2008, the BPW hired Applied Science Associates and Brown and Caldwell to review the 216 page report. Because so much was unexplained, the first letter to the MEP Report authors, in December 2008, was a simple request for information so substantive questions could be developed and submitted. Following up in the spring, the Town was surprised to learn that the authors of the MEP Report did not intend to answer the Town's questions, mainly due to lack of funding.

The authors then called back and said they were getting additional funding to run more scenarios, and that the Town would have input into the choice of scenarios. 'Imminent' funding was continually delayed. As of May 2008, even the Coalition for Buzzards Bay hadn't heard there had been movement on developing the next draft of the MEP Report. The Town finally received a draft of what's called the Final Report (but which is in fact a July draft report) and it is this draft report that serves as a basis for the proposed TN permit limit.

Good science must be subject to free and open peer review, especially when it may ultimately be the basis for permitting considerations. Governmental agencies cannot act in secret, and thus the entire model and the assumptions in the model should be made publicly available for review.[5]

B. The Agencies are Using the Draft MEP Report for the Wrong Purposes.

EPA fails to acknowledge in the permit Fact Sheet that the draft MEP Report was not developed for the purpose of establishing a recommended nutrient limit for the Fairhaven WPCF, but rather as a planning tool "to test specific management scenarios and weigh the resulting

[5] The failure to make the model available for review reinforces the point made above about the difficulty of commenting on permit conditions that are not explained. How can the Town of Fairhaven understand EPA and MassDEP's analysis if it cannot review the underlying assumptions behind it?

water quality impact against the cost of that approach." MEP Report at 5. The following is also stated in the Executive Summary:

> It is important to note that load reductions can be produced by reduction of any or all sources or by increasing the natural attenuation of nitrogen within the freshwater systems to the embayment. The load reductions presented below represent only one of a suite of potential reduction approaches that need to be evaluated by the community.

MEP Report at 6.

The EPA cites the one and only scenario evaluated in the MEP Report relative to the WPCF, reduction of nitrogen discharges to a concentration of 3 mg/L, as if the MEP had concluded this reduction were the only scenario that could achieve the objectives of the study. However, as noted above, there are many other scenarios that could have been evaluated by the MEP, but were not. For example, the MEP did not include an evaluation of reduction of the WPCF's nitrogen concentrations to 8 mg/L or 10 mg/L instead or 3 mg/L. It is quite likely that the water quality goals of the MEP could be met more equitably with less reduction of nitrogen from the WPCF and greater reduction from other sources such as the New Bedford combined sewer overflows ("CSOs"), stormwater outfalls, or septic system discharges, particularly where water quality impacts in the lower basin are localized and related primarily to physical disturbance and flushing. MEP Report at pg. 7.

The arbitrary establishment of a mass limit based on 3 mg/L total nitrogen places an extremely high burden on Fairhaven to address the water quality goals of the MEP, without any consideration of other potential solutions.

C. The Draft MEP Report is Based on Faulty Assumptions.

There are other significant substantive deficiencies in the MEP Report that render suspect its conclusions about water quality in the New Bedford Inner Harbor. For example, as indicated in correspondence included at **Exhibit 6** from Dr. Joseph Costa, the Executive Director of the

Buzzards Bay National Estuary Program, the loading analysis is flawed because, among other things, the report overestimates both the number of dwellings and the number of septic systems in Fairhaven and Acushnet. Dr. Costa states that this may have caused nitrogen loading to be inflated by 20% or more. The rest of his report is to similar effect, for example suggesting "profound issues" with whether a 0.5 ppm TN standard is appropriate, identifying "outright GIS analysis errors," and stating that the report should have addressed the potential impact of planned dredging projects and the seasonality of flows from wastewater and CSO sources.

Dr. Costa also identifies impervious surface, and thus non-point source nitrogen pollution, as being underestimated by a factor of 50% to 100%., and the Fairhaven portion of the watershed having only 33 septic systems versus 3,092 utilized in the Draft July, 2009 MEP Report.

In other correspondence, Dr. Costa finds that stormwater contributions of nitrogen from densely urbanized areas of New Bedford Harbor are underestimated by as much as 5%. As Dr. Costa stated "these errors and omissions are startling." These significant discrepancies must be corrected prior to finalizing the MEP Report and utilizing it for NPDES permit limit development.

To better understand the draft MEP Report, the Town has retained Thomas Gallagher of HydroQual, one of the leading water quality modeling experts in the nation. Mr. Gallagher offered the following comments on the draft MEP Report and models used:

1. The RMA hydrodynamic and total nitrogen models of Inner New Bedford Harbor were two-dimensional (vertically mixed). If there are vertical gradients in dissolved oxygen and salinity within the harbor (which is likely) a three-dimensional model is required.

2. The calibration of the total nitrogen model was achieved by empirically varying the exchange of total nitrogen between the sediment and water column. This weakens the reliability of the total nitrogen model especially when these water column sediment nitrogen exchange rates are estimated under future nitrogen reduction scenarios.

3. A target average total nitrogen concentration of 0.50 mg/L near Popes Island has been established to allow restoration of an impaired benthic habitat. It was assumed that elevated nitrogen levels stimulate algae which consume water column oxygen by respiration and degradation on the bottom sediments. No quantitative link was established between New Bedford Inner Harbor dissolved oxygen and nitrogen levels.

4. The target nitrogen concentration of 0.50 mg/L was based on reference to other nearby rivers, ponds, and bays that had healthy to moderately impaired benthic habitats. This extrapolation of the nitrogen-benthic habitat impairment from other waterbodies is inappropriate because the quantitative link between nitrogen and benthic habitat depends on many site specific factors including: flushing time, depth, water clarity, other sources of dissolved and particulate organic carbon, atmospheric reaeration and water column stratification. The only scientifically defensible approach to regulating nitrogen loads to Inner New Bedford harbor is to establish that low dissolved oxygen is the cause of benthic habitat impairment and then to apply a mechanistic model that specifically computes the bottom water dissolved oxygen as a function of BOD and ammonia oxidation, sediment oxygen demand (SOD), algal photosynthesis and respiration, and atmospheric reaeration.

5. The potential impact of a nitrogen load to Upper New Bedford Harbor nitrogen and dissolved oxygen levels depends on both location and nitrogen components of the load. For example, Fairhaven nitrogen load is close to the hurricane barrier and subject to significant tidal dilution and therefore may have less of an impact than a similar load from the Acushnet River or upper basin. In addition, as total nitrogen reduction occurs at the Fairhaven STP, the fraction of the less reactive and unavailable nitrogen for algal growth remaining increases. Therefore, the same mass of nitrogen from Fairhaven may have a lesser impact in stimulating algal growth than the same mass of nitrogen in a bioavailable form (nitrate) from the Acushnet River.

Letter from T. Gallagher/HydroQual, attached as **Exhibit 7**.

In addition to Mr. Gallagher's comments, it should also be noted that the model's allocation of nitrogen loads does not appear to accurately represent the relationship between where the load originates within the watershed, transport mechanisms, and the ultimate mixed water quality in the harbor. In addition, the estimates for tidal flushing and mixing and the resulting mixed water quality also do not appear to accurately represent the harbor's existing conditions.

Another issue discussed with Mr. Gallagher is the .39 mg/L boundary quantity measured as background, outside of the Harbor. This concentration, coming through the Hurricane Barrier, makes it almost impossible to reach a goal that is only .1 mg/l higher than background.

Unfortunately, Mr. Gallagher and other modeling experts are not yet able to fully peer review the calculation details, source code, algorithms and assumptions behind the model because the model has not been made available to outside parties. Therefore, the presented information cannot be verified. As noted above, the MEP Report process and specific agreements with the Town included the Town's ability to request several selected mitigation scenarios. The Town was never given that opportunity and no Town selected scenarios are included in any of the Draft MEP Report.[6]

The Woods Hole Group, Inc., attempted to perform an independent review of the SMAST MEP Report for Pleasant Bay in Orleans, "Peer Review (Independent Technical Review) of The Massachusetts Estuaries Project Report on the Pleasant Bay System, June 2009" 'WHG Technical Review" Although severely hampered by limited access to data, and or no access to the models and analysis methods employed, they identify many problems with the report and its various components, and underlying science and assumptions. Virtually all comments are applicable to the Draft, July MEP Report for New Bedford Harbor, and the Town wishes to incorporate by reference the arguments in the WHG Technical Review in its entirety as supporting its argument that the Draft, July MEP Report cannot serve as the basis for the Fairhaven nitrogen permit limit.

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[6] Nine Cape Cod communities are requesting that the MEP reports be validated by the National Academy of Science given the complexity of the process and the large economic impact of the findings and conclusions. Thus, Fairhaven is not alone in questioning the wisdom and need to move too quickly to solutions that may cost tens of millions of dollars, or more, per community before adequate validation of the science achieved. See attached article from Cape Cod Times, August 21, 2010, attached as **Exhibit 8**.

In summary, the MEP Report was intended only as a means of developing a model and methodology for evaluating alternatives and resulting water quality enhancement. The MEP Report was not intended to present a recommended alternative for addressing water quality impacts. Of equal importance, the MEP Report was to form the basis for providing information necessary to complete TMDL and water quality standards, neither of which have been implemented. *See* MOU between MassDEP and the University of Massachusetts, Dartmouth, Attached as **Exhibit 9**. Thus, the model is fatally flawed.

III. The Development of A Proposed TN Limit Is Premature For Legal and Technical Reasons.

Given the uncertainties discussed above and lack of adequate consideration of alternatives for achieving technology requirements and water quality goals cited in the MEP Report, the EPA and MassDEP should defer adoption of any numeric TN limit for the WPCF until additional alternatives and other factors are considered.

A. EPA and MassDEP Did Not Conduct the Permit Re-issuance Process With Input from the Town.

For a number of years, it has been the standard practice of EPA Region 1 to contact permit holders to discuss the permit reissuance process, review likely significant permit changes, and provide an opportunity for resolution or errors or inaccuracies in the Fact Sheet and draft permit. Permittees are typically provided with a copy of a "predraft" version of the Fact Sheet and permit for review. This process was not followed by EPA for the Town of Fairhaven. As outlined in these comments, the Town has spent significant resources working with water quality agencies to develop the basis for a new permit. The Town was not contacted by and received no information regarding the permit renewal from EPA until the draft permit was issued for public comment. As evident from internal correspondence between MassDEP and MEP staff, as late as

June 2010, there were numerous errors and inaccuracies in data used as part of the MEP study of New Bedford Harbor, yet EPA and MassDEP went ahead and issued the draft permit for public comment anyway, citing the results of the MEP Report as a partial basis for the stringent nitrogen limit. Given the problems with the MEP study, the draft permit should be withdrawn and reissued once the MEP study is complete, accepted by MassDEP as the basis for a TMDL and a TMDL has been completed for New Bedford Harbor.

B. The Draft Permit Unfairly Places Primary Responsibility on The Town of Fairhaven To Redress A Perceived Problem That Should Instead Be Addressed With a TMDL.

A significant problem with the draft permit is that EPA and MassDEP are attempting to permit the WPCF in a vacuum, rather than conducting a legally-mandated TMDL and then allocating an appropriate load to the WPCF. The Town strongly believes that the better course is for MassDEP to complete a TMDL, which can then be the basis for an equitable permitting scheme for the entire Inner Harbor. At the same time, and as will be discussed in more detail below, to prevent unfairly triggering antibacksliding considerations, we request that the WPCF be subject to a monitor-only requirement for TN, along with requirements to take specified steps, such as authorizing implementation of the nitrogen optimization plan, that will ensure reasonable progress on nutrient issues in the Inner Harbor.

The New Bedford Inner Harbor has been listed as impaired for nutrients on Massachusetts' 303(d) list since 1998. Despite this long-standing listing, no TMDL has been prepared by either MassDEP or EPA. This violates the clear requirement of the Clean Water Act. 33 U.S.C. § 1313(d)(1)(C) (obligating states to establish TMDLs for impaired waters); *Hayes v. Whitman*, 264 F.3d 1017, 1024 (10^{th} Cir. 2001) (holding that failure of state to establish TMDL for water-quality limited segment triggers non-discretionary duty by EPA to do so).

In the Fact Sheet, EPA candidly acknowledges that "high levels of removal from CSO and septic tank sources are necessary" to bring the waterbody into compliance. Fact Sheet at 10. However, only Fairhaven's discharge is being cut to one-third of its current load, whereas non-point source contributions are not considered at all. If a thorough TMDL were conducted, there would be an opportunity to look at other point and non-point source allocations that may allow for a more equitable and effective distribution of the burdens in addressing water quality in the Inner Harbor. Based on the data presented in the MEP Report, the Fairhaven WPCF and the New Bedford CSOs are reported to be 32% and 8%, respectively, of the total controllable nitrogen load, leaving about 60% with no identified mitigation. Adequate study of how to manage all the controllable load and to best achieve the overall watershed goal should be completed before specific solutions are imposed in a NPDES permit. This would be consistent with the approach in the Town of Wareham's recent NPDES permit, in which EPA and MassDEP chose not to change nutrient criteria pending completion of a TMDL.

Additional study time would also allow for the consideration of creative, efficient alternative strategies to address nitrogen loading, such as storing treated effluent for release during the outgoing tide, similar to the practice permitted for brine discharges from the Swansea desalinization facility; relocation or extension of the Fairhaven outfall to allow for improved flushing and dilution; restoration of degraded wetland areas to enhance natural attenuation; retrofitting stormwater outfalls with LID strategies; and other techniques.

C. The Nitrogen Optimization Study Should Be Update, Approved and Implemented.

Pursuant to its existing NPDES permit, the Town of Fairhaven was required to complete a nitrogen optimization study and submit it to the EPA and MassDEP for review. NPDES Permit MA0100765 at 9. The permit clearly states that the recommendations were to be implemented "following EPA and DEP approval of the study," which never occurred. The Fact Sheet nonetheless incorrectly implies that the *Town* somehow neglected to act on implementation of the recommendations in the nitrogen optimization study, *see* Fact Sheet at 7 (stating that recent DMRs suggest "that the operational changes [in the study] were not implemented"), and fails to acknowledge that the EPA and MassDEP were the parties that failed to act.

The failure to act on the Town's final nitrogen optimization study, which cost the Town $85,000, and was submitted on-time and in accordance with the requirements of the Town's existing NPDES permit, has significantly impacted and delayed the Town's ability to proceed with implementation of the recommendations of this study, planned follow-up monitoring to gauge its effectiveness, and incorporation of the results of this optimization study in long term facility upgrade planning.

Given the significant time lapse between now and the completion and submittal of the optimization study, and changes in the plant (including the digester, below), the optimization study should be updated.

Thus, we suggest as a condition of the permit that EPA give the Town six months to update the nitrogen optimization study, one year to implement its recommendations once they have been approved, and a two-year period to monitor effectiveness and achieve optimization.

D. No TN Permit Limitation Should Be Imposed Until the WPCF's CHP Digester Project is Operational.

Deferring TN limitations will also allow the Town to analyze any changes in the effluent stream that may be caused by the anerobic digester and combined heat and power system scheduled to go on-line in May or June of 2011. That project, as you know, was recently funded by an $8M State Revolving Fund Green Reserve grant through the federal stimulus package, and is expected to have multiple environmental benefits, such as reducing the WPCF's sludge and generating renewal energy to offset the utilization of fossil fuel generated electricity at the WPCF. The Town expects that it will take at least a year after that project goes on-line to determine whether and how it affects the WPCF's effluent characteristics, and thus that information will be important in finally setting attainable numeric criteria for TN. As said above, it will also be important to update the optimization study at that time.

E. No TN Permit Limitation Should Be Imposed Until the Town's Northern Fairhaven/New Bedford Inner Harbor Watershed Stormwater Enhancement Program is Complete.

The Town has an aggressive stormwater management program. It is recognized for its highly accurate mapping, asset management, and maintenance program. Regulations for private development now require Low Impact Development Best Management Practices and groundwater recharge. With its belief that stormwater a major source of impairment to the Inner harbor, the Town began seeking various funding opportunities to implement Low Impact Development ("LID") stormwater treatment retrofits to enhance the water quality within the northern Fairhaven/New Bedford Inner Harbor Watershed. In June 2008, the Town was awarded $278,100 in grant funds from the MassDEP 319 Nonpoint Source Competitive Grants Program to design and implement various LID stormwater treatment processes. Fairhaven also committed another $185,400 in in-kind services match toward the project. The project is currently under construction and consists of 18 tree box filter retrofits, 4 leaching catch basins, a filtered catch basin unit, a rain garden, and a stormwater treatment unit to treat for nitrogen, total suspended solids and bacteria from stormwater runoff.

The Town applied for funding to construct Phase II of the LID stormwater improvements project for the northern Fairhaven/New Bedford Inner Harbor Watershed in May of 2009 and was awarded another $258,400 in MassDEP 319 grant funds. The Town has committed an additional $171,600 match to support the project. This project is currently in the design phase and is expected to consist of several tree box filter retrofits throughout northern Fairhaven and a rain garden at the Board of Public Works building, which will be used as a public education device to teach the local public about enhanced stormwater treatment techniques and their environmental benefits.

It is important to consider that these projects are specifically designed to address nutrient pollution upstream, rather than the more traditional 'end-of-pipe' treatments for conventional pollutants. Fairhaven will continue to seek further funding to implement the goals of the LID stormwater treatment program throughout the Northern Fairhaven New Bedford Inner Harbor Watershed. A complete assessment of the Inner Harbor watershed shows approximately 75% of the approximately 1,100 acre watershed can be addressed, reducing current stormwater runoff pollutant loads to the New Bedford Harbor significantly.

F. No TN Permit Limitation Should Be Imposed Until the I/I Reduction Efforts are Complete.

Over the past two years, the Town of Fairhaven has aggressively quantified and targeted sources of infiltration and inflow (I/I) within the sewer collection system through continuous flow monitoring and sewer system hydraulic modeling studies (using the town's highly accurate sewer GIS asset management system). The information gathered through these studies has provided the Town with an organized, focused and cost effective approach to reduce the amount of extraneous flow entering the collection system, which in turn will decrease both the average and peak flows treated at the Fairhaven Water Pollution Control Facility. Based on the recommendations of these studies, the Town is currently in development of seven separate infiltration reduction contracts. The seven contracts in total are anticipated to include the lining of approximately 16,000 linear feet of collection system piping, the rehabilitation of over 100 manholes, and service line replacements throughout the locations to be lined. The anticipated amount of I/I flow reduction is estimated to be 850,000 gallons per day ("gpd"). Preliminary cost estimates are in the $4M range. Private inflow sources were also addressed in the model, and the Town now has a data base of private sources which it can address.

With an appropriation of over $200,000 the Town has recently lined numerous sewer lines, based on the results of its in-house CCTV work.

IV. Conclusion.

In sum, EPA and MassDEP have failed to demonstrate that there is a defensible limit – whether technology-based or water quality-based – for the Fairhaven WPCF. The "limit of technology" standard is left entirely unexplained, and fails to address the necessary and difficult issues of technical and financial limitations, particularly in light of the inadequate modeling effort that forms the basis for the assumption that such drastic measures are required. Moreover, it is apparent that the Draft July, 2009, MEP Report itself is severely flawed and cannot serve as the basis for an expenditure in the range of $50 million to meet a standard that has yet to be scientifically justified, nor a solution that has not been proven to benefit receiving waters.

Accordingly, the Town of Fairhaven requests that EPA and MassDEP withdraw this draft permit, and instead discuss an interim a monitor-only requirement.[7] This will allow adequate

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[7] If EPA and MassDEP decline to provide a monitor-only requirement, the Town requests that it at least be granted a more reasonable methods of calculating nitrogen compliance, such as seasonal limits, rolling averages, and multi-year calculations, as used in the amep model. This would reflect the seasonal fluctuations in nitrogen and the nature of nitrogen as a longer-term acting input to the system, as included in the Town of Wareham permit.
If EPA and MassDEP decline to provide a monitor-only requirement, the Town requests that it at least be granted a more reasonable seasonal average standard to reflect the seasonal fluctuations in nitrogen and the nature of nitrogen as a longer-term acting input to the system, as included in the Town of Wareham permit. Also, similar to the approach used in the development of Long Term Control Plans for CSO discharges, the Town should be allowed to propose a phasing plan (compliance schedule) with intermediate review milestones with a duration of up to 20 years, subject to demonstration of affordability concerns. The magnitude of the economic impact of the NPDES permit conditions is equal to or perhaps greater than that for CSO compliance in many communities. This approach would be consistent with the approach likely being taken for elimination of the New Bedford CSOs and the PCB remediation of the Inner Harbor. Alternatives to the existing treatment and discharge configuration must be studied

time for MassDEP to conduct a legally-mandated TMDL for the Inner Harbor that can then equitably allocate appropriate loads based on sound science to the WPCF, the New Bedford CSOs, and other sources. It will also avoid placing overly stringent requirements on the Town that may not later be revised upwards due to antibacksliding provisions.[8]

At the same time, to ensure that there is reasonable progress toward achieving attainment in the Inner Harbor, the Town is willing to negotiate and commit to a schedule, including interim milestones, including such tasks as:

- Update and then implement Agency approved nitrogen optimization plan recommendations;
- Continue to implement its I/I plan, which includes the goal of reducing TN (and temperature impacts) in the WPCF's influent;
- Continue its work to require sewer tie ins in sensitive areas, including continuing its legal interventions to force compliance;
- Complete stormwater plans for the remainder of the Fairhaven portion of the watershed, and continue to implement on-going program of low-impact development requirements, including on municipally-owned properties, to reduce stormwater flow and address nutrient as well as conventional pollutants;
- Upon receipt of all necessary information, have its consultants prepare an independent review of the SMAST work in a timely manner, to assist in addressing the issues raised in this letter;
- Work aggressively with regulators to assist in developing a TMDL for the Inner Harbor; and;
- Other, to address other concerns or concepts raised by EPA and DEP during these negotiations prior to issuance of a permit.

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to find technical and economically feasible solutions. If WPCF process changes are needed, then a timeline of years, five or more, is necessary to study, test, design, permit and construct the first phase of modifications.

[8] If despite all the reasons to defer a TN limit the Agencies impose one, the Town requests specific permit language which allows the TN limit to be reopened and modified to be less stringent under both antibacksliding and antidegradation provisions.

If the Agencies proceed with this permit process, the Town respectfully requests a public hearing on those important issues of regional concern. We appreciate your attention to these comments and look forward to meeting with you to discuss a reasonable path forward.

LIST OF EXHIBITS

EXHIBIT 1

Fairhaven Wastewater Treatment Facility
Influent and Effluent Total Nitrogen Concentrations

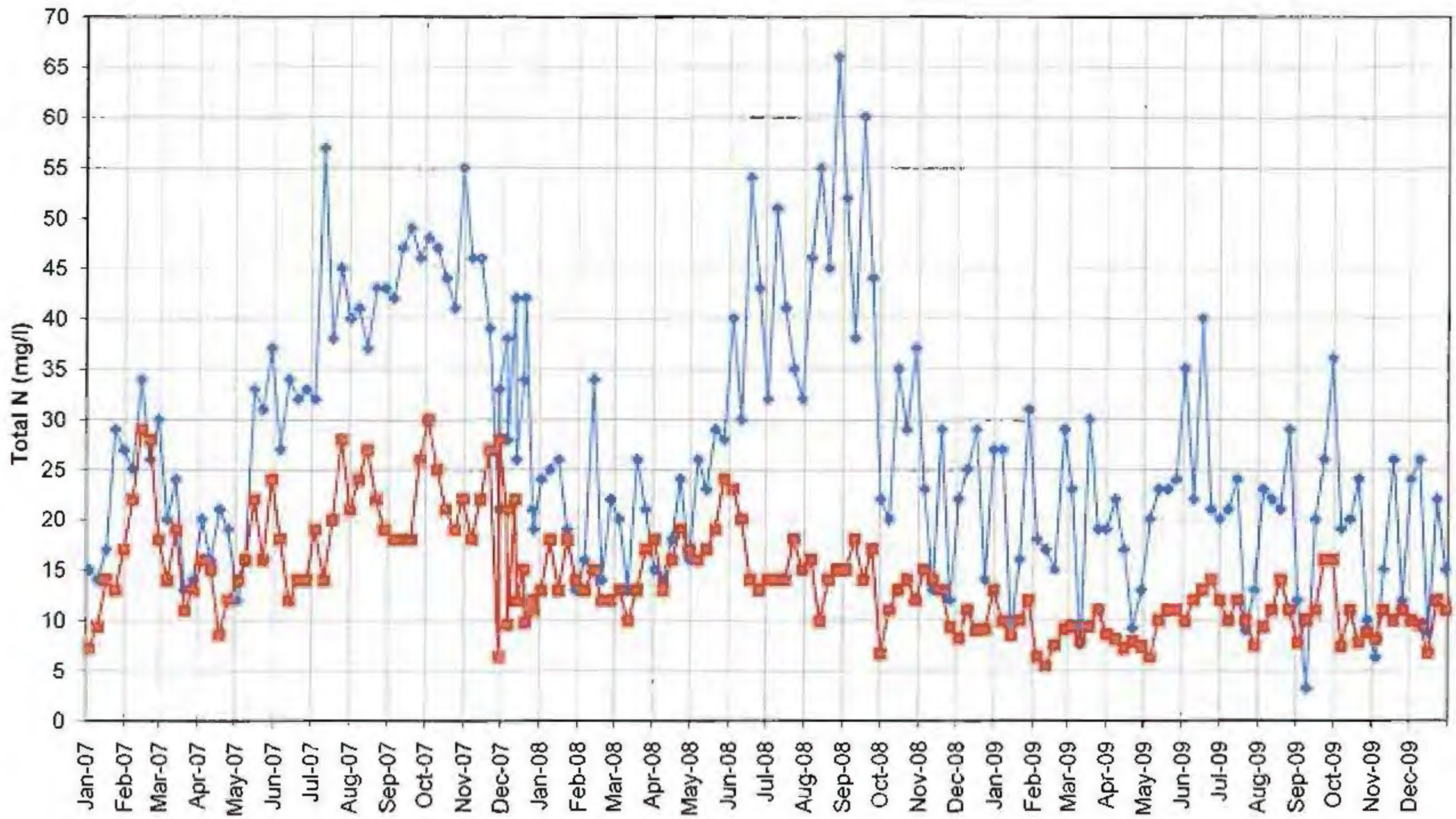


EXHIBIT 2

1 Corporate Drive
Andover, MA 01810
(978) 794-0336

Prepared for: Client Review

Project Title: Fairhaven Water Pollution Control Facility

Project No: 136883

Technical Memorandum No. 1

Subject: Nitrogen Removal Evaluation – Preliminary Modeling

Date: June 22, 2009

To: Bill Fitzgerald, Fairhaven Board of Public Works Superintendent

From: Brown and Caldwell: Alan Kirschner, P.E.; Jose Jimenez, P.E.; Elan Lynch; Mark Allenwood, P.E.

1. INTRODUCTION

This Technical Memorandum (TM) summarizes the results of a preliminary Nitrogen Removal Evaluation for the Fairhaven Water Pollution Control Facility (WPCF).

The Fairhaven WPCF currently has a rated capacity of 5 mgd based on annual average flow (AAF) conditions; however, it is currently treating approximately 2.5 mgd on an annual average basis. The facility consists of two primary clarifiers, a flow equalization facility, two aeration trains equipped with fine bubble diffusers, and four secondary clarifiers (only two are operational). Table 1.1 summarizes liquid treatment unit process dimensions and important design information for the Fairhaven WPCF.

Currently, the WPCF operates as an extended aeration facility meeting secondary wastewater quality standards for BOD_5 and TSS. However, the WPCF is facing an effluent total nitrogen (TN) requirement potentially based on maximum month conditions in their next National Pollutant Discharge Elimination System (NPDES) permit cycle. This limit could vary from a TN concentration of 8 mg/L as low as 3 mg/L and could be issued in the near future because the existing NPDES permit expired in April 2005.

The Nitrogen Removal Evaluation summarized herein presents options to meet a maximum month average TN concentration of 3 mg/L, which is currently considered the "Limit of Technology" for biological nitrogen removal systems by the US EPA. It should be noted this evaluation and the process requirements identified are based on a preliminary process analysis. Therefore, it is recommended to conduct a more thorough process evaluation including a wastewater characterization study and calibration of the preliminary BioWin model to refine the options identified herein.

Table 1.1 – Capacity of Liquid Treatment Processes		
Process Unit	**Number of Units**	**Capacity**
Primary Clarification	2	65-ft diameter; 11-ft SWD
Equalization Facility	--	--
- Primary Clarifier	1	65-ft diameter; 11-ft SWD
- Equalization Tank	4	495,000 gal. each
Aeration Trains	2	466,740 gal. each
Secondary Clarification	4	2 @ 45-ft diameter; 10-ft SWD (out of service) 2 @ 75-ft diameter; 13-ft SWD
RAS Pumps	7	9.7 mgd (with one large pump out of service)
WAS Pumps	4	120 gpm each

2. CAPACITY ASSESSMENT

A preliminary BioWin simulation model was constructed for the Fairhaven WPCF to estimate the current plant capacity as well as to evaluate process modifications to meet a possible future TN limit of 3 mg/L based on maximum month condition. The facility was designed to handle an average flow of 5 mgd and it is currently treating approximately 2.5 mgd as AAF.

2.1 Flows and Loads

Historical influent data for the WPCF, from January 2007 through December 2008, was reviewed to establish design loading conditions to the facility. Figure 2.1 summarizes daily and 30-day average flow rates to the facility. Figures 2.2 and 2.3 summarize daily and 30-day average BOD_5 loads and influent temperature to the facility.

Table 2.1 summarizes the influent flows and BOD_5 loading information for 2007 and 2008. Table 2.2 presents the plant influent flows and BOD_5 loading peaking factors for 2007 and 2008. It should be noted the influent BOD_5-to-TSS ratio averages 1.1. The peaking factors for any given year represent the ratio of the highest peak condition to the annual average load for a given year.

Influent flows at the Fairhaven WPCF have averaged approximately 2.2 mgd over the 2-year period. Maximum month flows (MMF) have averaged 4.1 mgd. The maximum day flow during the 2 years occurred in April 2007 with a flow of approximately 9.0 mgd. The maximum peak hour flow (PHF) to the facility occurred on March 2008 with a flow of 15.6 mgd.

Based on the data presented in Table 2.2, the year 2007 appears to be the most critical period in terms of maximum flow conditions with maximum month flow, maximum day and peak hour peaking factors of 1.92, 4.60 and 6.88, respectively. It should be noted these flow peaking factors are considered high for this facility; which could be the reflection of inflow and infiltration (I/I) problems in the collection system. In terms of BOD_5 loading peaking factors, 2008 appears to have higher factors. The maximum month and the maximum day peaking factors were based upon the 2008 data, with values of 1.43 and 2.55, respectively.

Figure 2.3 shows influent temperature information for the Fairhaven WPCF. Based on this, the average influent temperature to the WPCF is approximately 15°C. The maximum and minimum 30-day average influent temperatures are 22°C and 10°C.

Based on the limited influent nitrogen available for this analysis, the average influent ammonia (NH_3-N) and TKN concentrations are approximately 17 mg/L and 28 mg/L respectively with maximum values of 36 mg/L NH_3-N and 46 mg/L TKN. Historical influent NH_3-N-to-TKN ratio averages 0.60.

Influent BOD_5-to-NH3-N and BOD_5-to-TKN ratios for 2007 and 2008 are 5.8 and 5.15 and 3.36 and 3.24, respectively. Overall, these ratios are considered low compared to values often found at other locations.

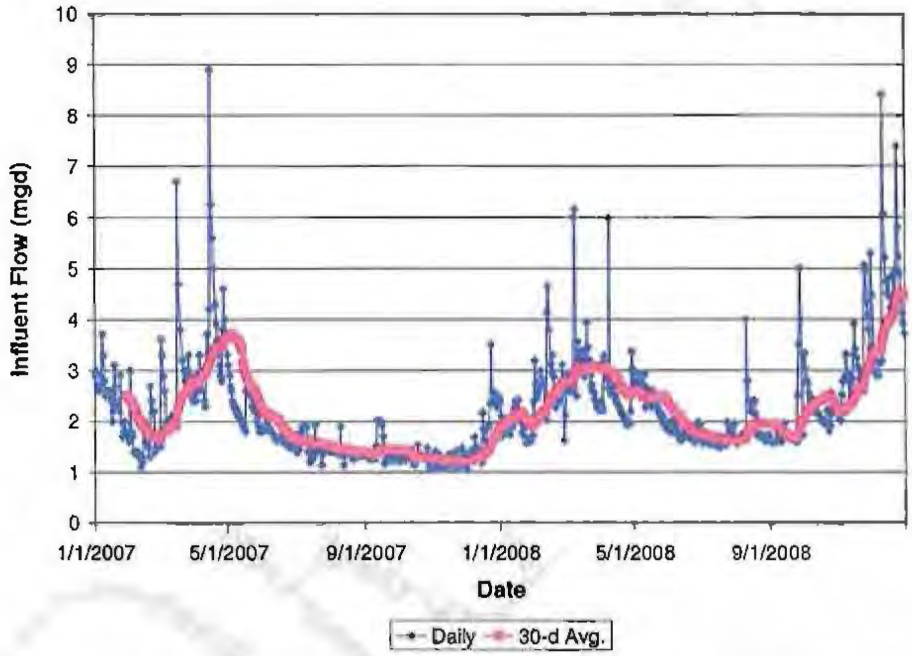


Figure 2.1 – Historical Flow Data from January 2007 through December 2008

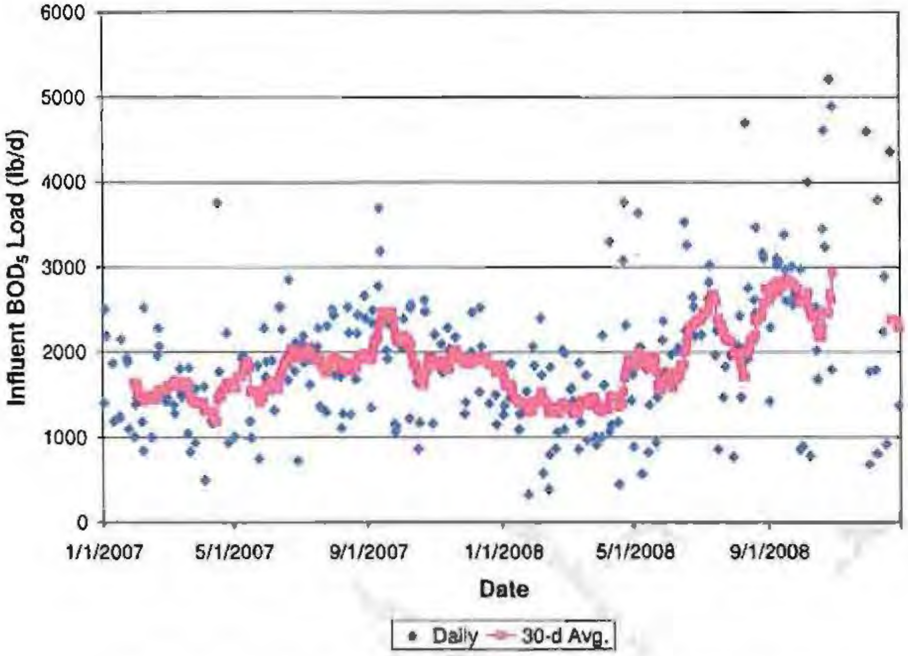


Figure 2.2 – Historical BOD₅ Load from January 2007 through December 2008

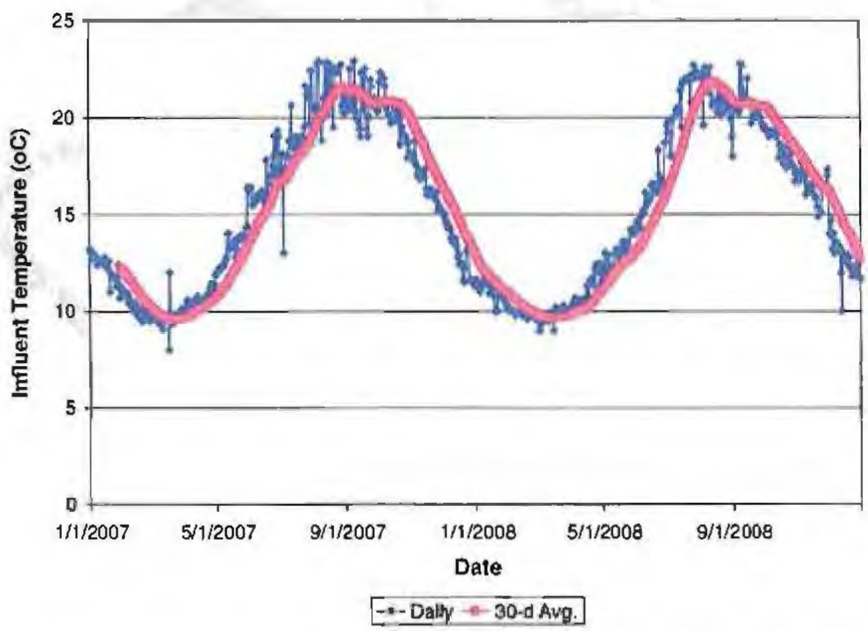


Figure 2.3 – Historical Influent Temperature from January 2007 through December 2008

Table 2.1. Historical Influent Flows and Loads			
Parameter	**Condition**	**2007**	**2008**
Flow (mgd)	Annual Average	1.93	2.50
	Maximum 30-d Average	3.71	4.53
	Maximum Day	8.9	8.41
	Peak Hour	13.3	15.6
$cBOD_5$ (lb/d)	Annual Average	1,787	2,043
	Maximum 30-d Average	2,476	2,928
	Maximum Day	3,753	5,212

Table 2.2. Historical Influent Peaking Factors			
Parameter	**Condition**	**2007**	**2008**
Flow	Maximum 30-d Average	1.92	1.81
	Maximum Day	4.60	3.37
	Peak Hour	6.88	6.25
$cBOD_5$	Maximum 30-d Average	1.39	1.43
	Maximum Day	2.10	2.55

2.2 Effluent Requirements

Table 2.3 summarizes the current effluent requirements for the Fairhaven WPCF. The capacity analysis was based on the ability of the facility to meet these effluent requirements.

Table 2.3. Summary of Effluent Limitations for the Fairhaven WPCF		
Parameter	**Discharge Limitations, mg/L (lb/d)**	
	Monthly Average	**Weekly Average**
Flow (mgd)	5	--
BOD_5	30 (1,252)	45 (1,878)
TSS	30 (1,252)	45 (1,878)

Note: Based on the NPDES Permit No. MA0100765.

2.3 Capacity Assessment of the Fairhaven WPCF

For the purpose of this analysis, the BioWin process modeling was focused on the primary and secondary treatment processes rather than on preliminary treatment or solids treatment.

Plant operational data on influent daily average flow rates and BOD_5 concentrations and influent wastewater temperature were used to develop the basis of design for the analysis of the Fairhaven WPCF. The basis of design represent the most rigorous conditions to meet the possible maximum month TN permit limit, which are simultaneous occurrence of maximum flow and maximum organic loading at the lowest monthly average temperature.

Table 2.4 summarizes the basis of design adopted for this analysis based on selected historical peaking factors for flow and BOD_5 loading conditions. A minimum 30-day influent temperature of 10°C was adopted based on historical data. It should be noted that for the purpose of this analysis, the influent peaking factors were reduced to account for I/I reduction or additional EQ volume on-site. The maximum day and peak hour flow peaking factors were reduced to reflect a 95-percetile of the historical flow peaking factors. It should be noted that if peak flows from I/I into the WPCF cannot be minimized, the capacity and process requirements presented in this TM cannot be realized.

Table 2.4. Influent Basis of Design for Maximum Month Condition

Parameter	Design Value
Flow (mgd)	
Annual Average	5.00
Maximum Month	9.05
Maximum Day	13.58
Peak Hour	20.36
BOD_5 Load (lb/d)	
Annual Average	4,629
Maximum Month	6,633
Maximum Day	8,158
Peak Hour	10,420
TKN Load (lb/d)	
Annual Average	1,398
Maximum Month	2,004
Maximum Day	2,465
Peak Hour	3,148
TP Load (lb/d)	
Annual Average	153
Maximum Month	219
Maximum Day	269
Peak Hour	344

Figure 2.4 shows the BioWin schematic for the existing configuration at the Fairhaven WPCF. For the purpose of the capacity assessment of the facility, it was assumed that all major units were online at all time. Flows in excess of 8 mgd were diverted to the wet weather equalization facility, based on common practice at the plant.

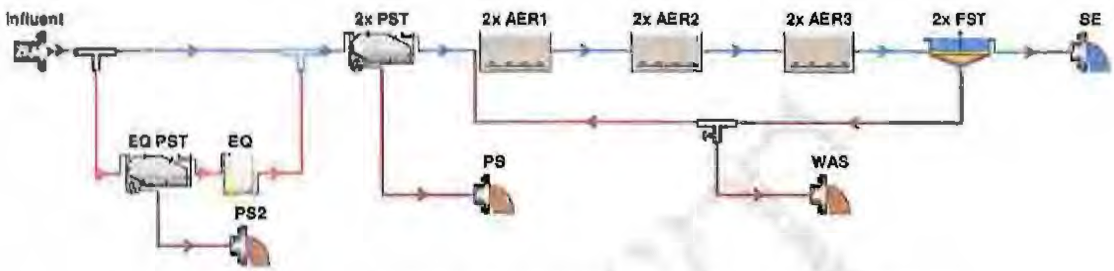


Figure 2.4 – BioWin Schematic for the Existing Configuration at the Fairhaven WPCF.

Currently, the WPCF is equipped with two primary clarifiers with a total surface area of approximately 6,345 ft^2 and a sidewater depth of 11 ft. Historically, the primary clarifiers have exhibited an average TSS removal efficiency of 50 percent, which is considered low compared to values often found at other facilities. Based on BC's experience at other facilities, similar primary clarifiers can handle surface overflow rates (SOR) up to 2,500 gpd/ft^2 without major effect on their performance; hence, this was adopted for the purpose of this analysis. Higher SOR values could reduce the efficiency of the primary clarifiers resulting in an increase loading to the secondary process.

Currently, the WPCF does not have an NH_3-N effluent limit; hence, no nitrification is required at this time at the facility. Therefore, the current configuration was simulated at a solids retention time (SRT) of 5 days.

The capacity of the secondary clarifiers was based on State-Point Analysis (SPA). The WPCF is equipped with two 75-ft diameter operational secondary clarifiers. These units have a sidewater depth 13 ft. The maximum RAS capacity of the secondary clarifiers, with one large pump out of service, is 9.7 mgd. For the purpose of this analysis, no historical data on sludge volume index (SVI) or settling characteristics of the mixed liquor were available; hence, a design SVI of 180 mL/g was adopted based on data from similar facilities. Based on SPA, the maximum allowable solids loading rate (SLR) to the secondary clarifiers would be approximately 30.5 lb/ft^2-d; therefore, this value was adopted for design purposes. For the purpose of this analysis, a maximum day and peak hour SOR of 1,200 gpd/ft^2 and 1,500 gpd/ft^2 were adopted for the secondary clarifiers. These design limitations are based on Brown and Caldwell's experience with similar secondary clarifiers.

The BioWin simulation model was used to establish the preliminary process capacity of the WPCF. Based on the influent characteristics selected for this analysis and peaking factors adopted, the overall capacity of the Fairhaven WPCF is approximately 7.2 mgd as MMF (or 4.0 mgd as AAF). During the maximum month condition adopted for the purpose of this evaluation, the current process limitation is secondary clarification system. Based on the results obtained during this analysis, the secondary clarifiers would be operating at over the capacity during maximum day and peak hour conditions. It should be noted that during peak hour conditions, the primary clarification and secondary clarification systems would be overloaded based on peak hour conditions; however, this could be acceptable based on current effluent requirements. No details on the current aeration system were available for this analysis; hence, this was not included in the assessment of the WPCF.

The WPCF currently has two smaller secondary clarifiers out of service. Therefore, as part of this assessment, the overall capacity of the facility was also determined assuming these two smaller clarifiers were functional. Based on the BioWin modeling results, the capacity of the secondary clarification system would increase from 4.0 mgd as AAF to approximately 5 mgd as AAF (or 9 mgd as MMF). At these flows the primary clarification system would be operating over the capacity during maximum day and peak hour conditions. However, this could be considered acceptable if provisions are in place in the secondary system to handle the possible higher loadings due to reduce capture efficiency during these events.

It should be noted the current capacity of the Fairhaven WPCF is based on the assumption that wet weather flows to the facility can be reduced by either I/I reduction program or by increasing the capacity of the current equalization system. If these can not be controlled, the preliminary capacity presented in this report may not be realized.

The preliminary capacity assessment results presented in this TM do not account for the possible hydraulic limitations at the WPCF. Therefore, it is recommended to perform a hydraulic analysis to identify possible hydraulic limitations at the facility.

3. NITROGEN REMOVAL EVALUATION

The Fairhaven WPCF is facing in the near future, a potential TN requirement based on maximum month conditions. This limit could vary from as high as 8 mg/L to as low as 3 mg/L. Hence, this section summarizes alternatives to lower the effluent TN levels at the WPCF so potential future effluent requirements can be met. It should be noted these process requirements are based on a preliminary process analysis. Therefore, it is recommended to conduct a more thorough process evaluation including a wastewater characterization study and BioWin model calibration to refine the options identified in this TM. In addition, this analysis does not account for possible impacts of changes in the solids processing facility on the liquid stream, such as the new anaerobic digestion facility that is currently in the design-phase.

For the purpose of this analysis, the basis of design presented in Table 2.4 was adopted for this evaluation. Therefore, it should be noted the process requirements for the different options presented herein, are based on the assumption that wet weather flows to the facility can be reduced by either I/I reduction program or by increasing the equalization capacity at the plant. If these can not be controlled, the preliminary capacity and additional process requirements presented in this report may not be valid.

Figure 3.1 shows the effect of the aerobic SRT on the maximum month effluent NH_3-N concentration at a temperature of 10°C. Based on the information depicted in this Figure, an aerobic SRT of at least 15 days should be maintained to ensure a high degree of nitrification at this low temperature (this SRT accounts only for the biomass in the aerobic reactors). Therefore, for the purpose of the nitrogen removal evaluation, the operating aerobic SRT was increased from 5 days (adopted during the preliminary capacity assessment) to 15 days.

In order to meet the possible maximum month TN concentration of 3 mg/L, modifications to the existing Fairhaven WPCF will be required. This evaluation does not include possible hydraulic modifications in the facility. The alternatives included in this evaluation are as follow:

- Modified Ludzack-Ettinger (MLE) Process followed by Deep-Bed Denitrification Filters
- Four-Stage Bardenpho Process followed by Filtration
- Integrated Fixed Film Activated Sludge (IFAS) Process followed by Deep-Bed Denitrification Filters

The BioWin modeling results for the three options included in this evaluation are summarized in Table 4.1.

It should be noted that based on the available historical influent data, the influent BOD_5-to-NH_3-N and BOD_5-to-TKN ratios are extremely low compared to values often found at other facilities. Therefore, supplemental carbon might be required for denitrification on all the options. It is recommended to confirm these finding through a wastewater characterization study.

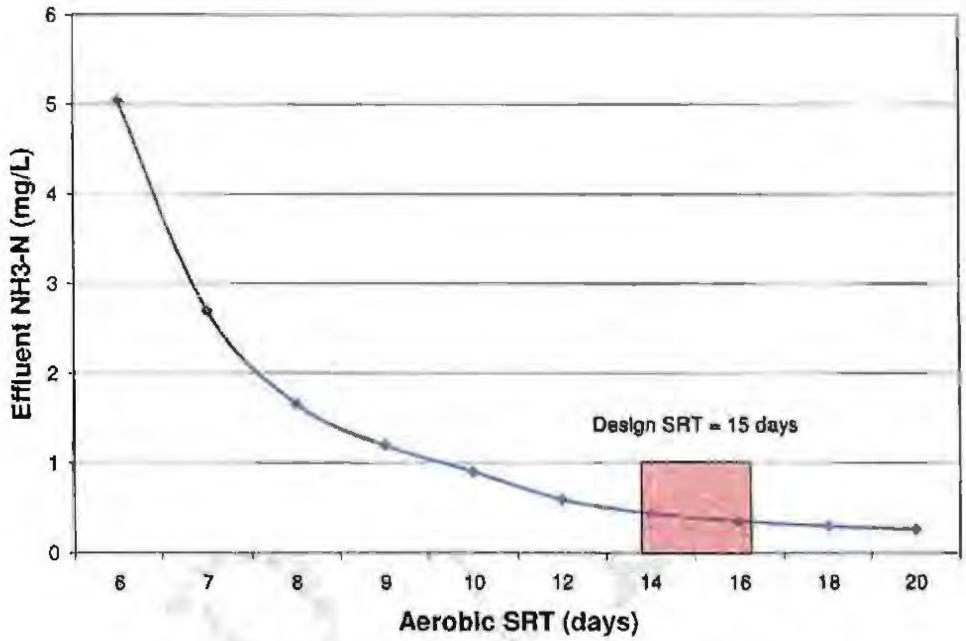


Figure 3.1 – Effect of SRT on Effluent NH3-N Concentrations at 10°C

Currently, the WPCF operates with two 65-ft diameter, 11-ft SWD primary clarifiers. It is recommended to determine the capacity of the primary clarifiers through field and stress testing. For the purpose of this analysis, it was assumed no additional primary clarification capacity would be provided. Instead, lower removal efficiency would be accepted during high flow conditions. Therefore, it is critical to ensure proper operation of these units at all time. It is highly recommended to maintain low sludge blankets in the primary clarifiers. This will maximize the removal efficiency of the existing units and will minimize biological reactions in the clarifier's blanket that could negatively affect the downstream secondary processes.

3.1 MLE Process followed by Deep-Bed Denitrification Filters

This configuration modifies the existing process at the Fairhaven WPCF by using the MLE process. This configuration uses an anoxic zone at the front end of the reactors followed by aerobic zones for nitrification and carbonaceous removal. An internal mixed liquor recycle system will be needed to bring nitrified mixed liquor from the back end of the aeration tanks to the anoxic zones for denitrification. After the secondary treatment by the MLE process, the secondary effluent will flow to a new deep-bed denitrification filter facility for additional denitrification. Figure 3.2 shows the BioWin configuration for the MLE process.

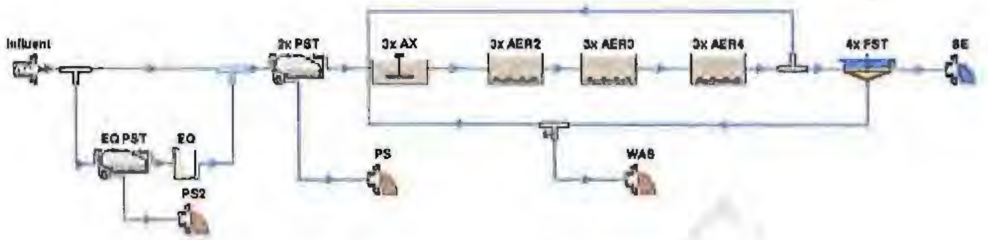


Figure 3.2 – BioWin Configuration for the MLE Process

Based on the preliminary process modeling, the existing aeration tanks would need to be modified and expanded to maintain adequate MLSS levels in the reactors. The Fairhaven WPCF currently has two aeration trains with a total volume of approximately 933,480 gal. The MLE configuration would require two additional reactor trains to maintain adequate MLSS levels. In addition, the MLE configuration requires an internal mixed liquor recycle system to provide approximately 15 mgd of nitrified mixed liquor concentration back to the anoxic zone.

The secondary clarification system at the WPCF would have to be expanded to provide adequate clarification capacity. Currently, the WPCF is equipped with two 75-ft diameter, 13-ft SWD secondary clarifiers. However, in order to provide adequate clarification capacity at all time, two additional 90-ft diameter secondary clarifiers would be required.

This alternative would require a new deep-bed denitrification facility with supplemental carbon addition. The overall filtration area for the denitrification biological filters would be approximately 4,000 ft^2. Supplemental carbon addition would be required for the denitrification filters at a rate of approximately 500 gpd of methanol.

3.2 Four-Stage Bardenpho Process followed by Filtration

This configuration modifies the current process by using a four-stage Bardenpho process for nitrification-denitrification. This process uses an anoxic zone at the front end of the reactors for denitrification followed by aerobic reactors for nitrification. Similar to the MLE process, an internal mixed liquor recycle system will be needed to promote denitrification in the anoxic zones located at the front end of the process. After the aerobic zones, a post anoxic zone with carbon addition would be used for additional denitrification follow by a post aerobic zone. Secondary effluent will flow to a new filtration facility to reduce the effluent solids. Figure 3.3 shows the BioWin schematic for the Bardenpho configuration.

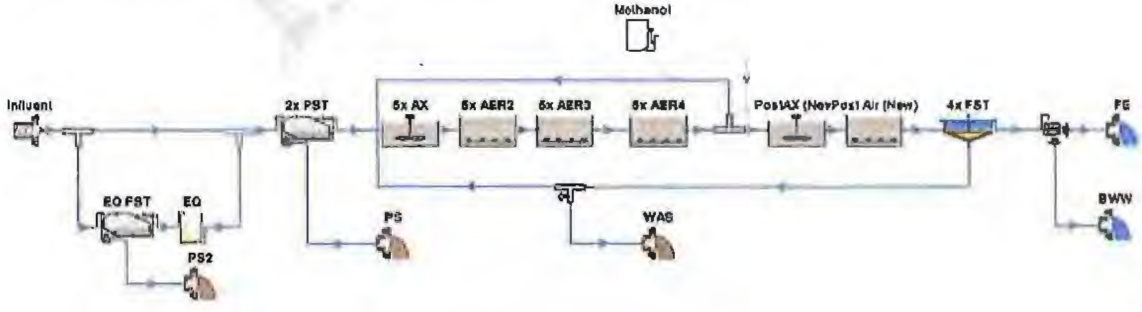


Figure 3.3 – BioWin Configuration for the Bardenpho Process

Based on the preliminary process modeling, the existing aeration tanks would need to be modified and expanded to maintain adequate MLSS levels in the reactors. The Bardenpho configuration would require three additional reactor trains to maintain adequate MLSS levels. In addition, a post anoxic and post aerobic zones would need to be added to the process with volumes of 400,000 gal and 150,000 gal, respectively. An internal mixed liquor recycle system will be needed to provide approximately 15 mgd of nitrified mixed liquor concentration back to the anoxic zone. Carbon addition will be required to the post anoxic zone to ensure adequate denitrification. For the purpose of this analysis, it has been assumed that methanol would be used for this purpose at a rate of 500 gpd.

The secondary clarification system at the WPCF would have to be expanded to provide adequate clarification capacity. Currently, the WPCF is equipped with two 75-ft diameter, 13-ft SWD secondary clarifiers. However, in order to provide adequate clarification capacity at all time, two additional 90-ft diameter secondary clarifiers would be required.

This alternative would require a new filtration facility to reduce effluent particles, especially those associated with particulate TKN so the effluent TN requirement can be met. The overall filtration area for this new filtration facility would be approximately 2,000 ft^2.

3.3 IFAS followed by Deep-Bed Denitrification Filters

This configuration uses an IFAS process combined with a wet-weather treatment alternative. This alternative was developed to minimize construction at the Fairhaven WPCF. This configuration uses an MLE process at the existing plant; anoxic zones followed by aerobic zones and an internal mixed liquor recycle system. The aerobic zones would be equipped with IFAS media (nitrifier carriers) to enhance nitrification at a lower aerobic SRT. The old secondary clarifiers (currently off-line) will be converted into aeration tanks for supplemental nitrification and to handle excess wet weather flow. Figure 3.4 shows the BioWin configuration for this option.

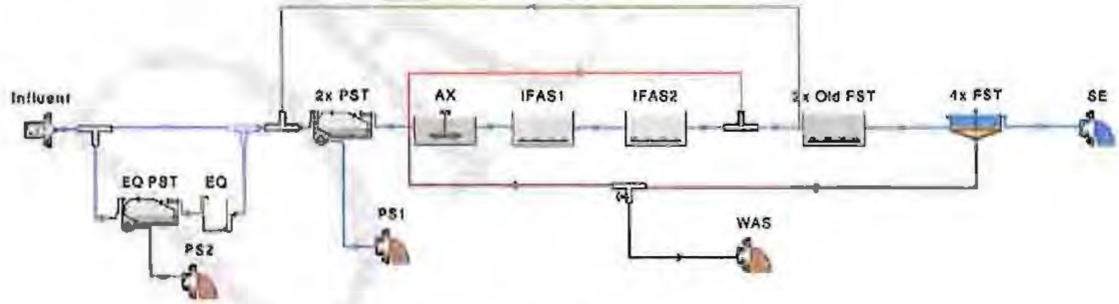


Figure 3.4 – BioWin Configuration for the IFAS Process

Based on the preliminary process modeling, the existing aeration tanks appear to have adequate volume for the options; however, modifications to the configuration would be required. Based on preliminary BioWin modeling, this alternative would be operated at an aerobic SRT of 10 days (instead of 15 days for the MLE and Bardenpho process). The first zone in the existing reactors will be converted to an anoxic zone for denitrification. Aeration zones 2 and 3 would be converted to IFAS reactors by installing sieve screens and IFAS median at both reactors. This configuration would use an internal mixed liquor recycle system to provide approximately 15 mgd of nitrified mixed liquor concentration back to the anoxic zone.

The existing off-line secondary clarifiers would be converted to aeration tanks by installing aeration systems. Excess wet weather flow (flows in excess of 15 mgd) would be bypassed around the primary clarifiers and the IFAS/MLE process for treatment into the retrofitted old clarifiers. These new reactors would provide supplemental nitrification and secondary treatment of the excess wet weather flows.

The secondary clarification system at the WPCF would need to be expanded to provide adequate clarification capacity. Two additional 75-ft diameter secondary clarifiers would be required for this option.

This alternative would require a new deep-bed denitrification facility with supplemental carbon addition. The overall filtration area for the denitrification biological filters would be approximately 4,000 ft^2. Supplemental carbon addition would be required for the denitrification filters at a rate of approximately 500 gpd of methanol.

4. SUMMARY

A preliminary process analysis of the Fairhaven WPCF was conducted to evaluate process modifications to meet a potential future TN effluent limit of 3.0 mg/L based on maximum month average conditions. During this analysis, a preliminary capacity assessment of the WPCF was performed, resulting in an overall plant capacity of between 4.0 mgd and 5.0 mgd (AAF) (or 7.2 mgd and 9.0 mgd as MMF). It should be noted the current capacity of the Fairhaven WPCF is based on the assumption that wet weather flows to the facility can be reduced by either I/I reduction program or by increasing the capacity of the current equalization system. If these can not be controlled, the preliminary capacity presented in this report may not be realized. These preliminary results do not account for the possible hydraulic limitations at the WPCF. Therefore, it is recommended to perform a hydraulic analysis to identify possible hydraulic limitations at the facility.

The results presented herein are considered preliminary since no wastewater characterization study has been conducted. The BioWin simulation model used for the purpose of this analysis has not been calibrated to simulate specific conditions at the Fairhaven WPCF. Therefore, it is recommended to conduct a more thorough process evaluation including a wastewater characterization study and BioWin process calibration to refine the options identified in this TM. In addition, this analysis does not account for possible impacts of changes in the solids processing facility on the liquid stream.

Based on the capacity assessment, the secondary clarification system appears to be limiting the process capacity at the Fairhaven WPCF. For the purpose of this analysis, design information for the secondary clarifiers was based on Brown and Caldwell's experience at similar facilities. However, in order to confirm these results and to maximize the capacity of the existing clarifiers, Brown and Caldwell recommends conducting field testing and computational fluid dynamic modeling of the secondary clarifiers. These would enable to maximize the throughput rates of the existing units while maintaining adequate performance during peak loading conditions.

The nitrogen removal evaluation presented in Section 3 was based on the assumptions lower flow peaking factors can be obtained in the future – similar to the capacity assessment. However, if this is not the case, additional primary and secondary clarification capacities (than those expressed in this report) will be required to handle the high flows and loading conditions.

Table 4.1 summarizes the preliminary results for the nitrogen removal evaluation. Three main alternatives were considered and presented in this evaluation, as follow:

- MLE Process followed by Deep-Bed Denitrification Filters
- Four-Stage Bardenpho Process followed by Filtration

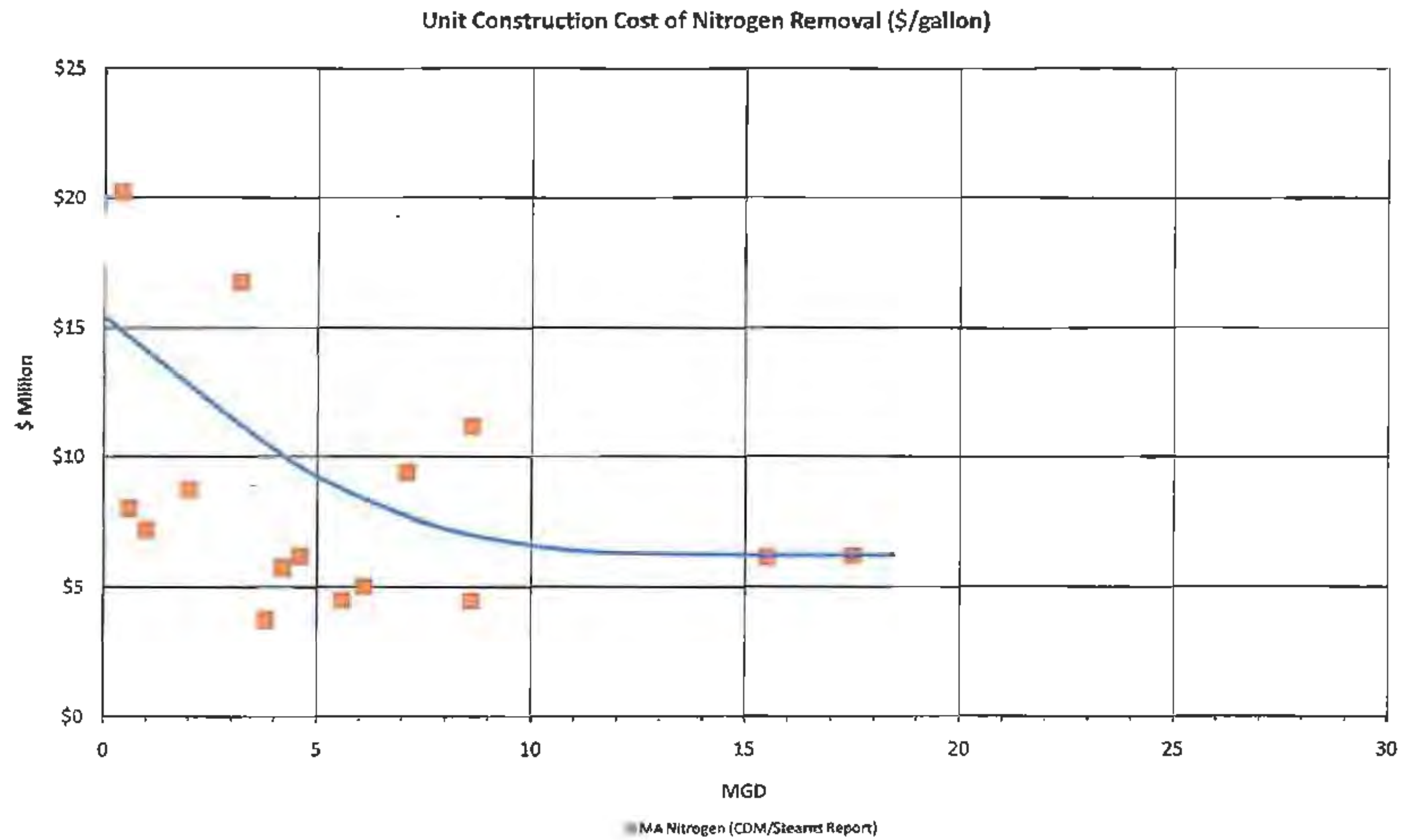
- IFAS Process followed by Deep-Bed Denitrification Filters

Overall, the IFAS process followed by deep-bed denitrification filters appears to be the least expensive option to retrofit the Fairhaven WPCF to meet a TN limit of 3.0 mg/L. This alternative does not require additional reactor capacity; however, major modifications to the existing aeration tanks would be needed. All the options require additional secondary clarification capacity and a new filtration system. Based on the results presented in this TM, the four-stage Bardenpho process appears to be the highest in capital costs due to number of additional reactors required.

To reduce the primary and secondary clarifiers requirements during peak loading conditions, BC recommends an evaluation of the possibility of operating the primary clarifiers as chemically enhanced primary units so higher loadings can be obtained. This would maximize the capacity and removal efficiency of the existing primary clarifiers. Additionally, BC recommends evaluating the use of processes such as BioMag to minimize the additional secondary clarification requirements.

Table 4.1 – Summary of Preliminary Results			
Process Unit	MLE with Denitrification Filters	Bardenpho with Filters	IFAS with Denitrification Filters
Primary Clarifiers			
No. of Units	2	2	2
Total Clarifier Area (ft2)	5,572	5,572	5,572
Biological Process			
No. of Reactors	4	5	2
Total Reactor Volume (MG)	1.88	2.89	1.28
Anoxic (MG)	0.47	0.78	0.31
Aerobic (MG)	1.41	1.56	0.97
Post Anoxic (MG)	--	0.4	--
Post Aerobic (MG)	--	0.15	--
Temperature (°C)	10	10	10
Anoxic SRT (days)	5	10	3.3
Aerobic SRT (days)	15	15	10
Total SRT (days)	20	25	13.3
MLSS (mg/L)	3,150	3,500	3,300
IMLR (mgd)	15	15	15
Methanol (gpd)	--	500	--
Secondary Clarifiers			
No. of Units	4 - 2 @ 75-ft dia., 2@ 90-ft dia.	4 - 2 @ 75-ft dia., 2@ 90-ft dia.	4 - 4 @ 75-ft dia.
Total Clarifier Area (ft2)	21,560	21,560	17,640
RAS (mgd)	10	10	10
SVI (mL/g)	150	150	150
Filtration System			
Type	Deep-Bed Denitrification	Deep-Bed	Deep-Bed Denitrification
Total Area (ft2)	4,000	2,000	4,000
Methanol (gpd)	500	--	500

EXHIBIT 3



1. Costs adjusted to Sept 2010 ENR of 8836
2. Costs are projections to achieve 5 mg/L year-round. Costs to acheve 3 mg/L are expected to be 10-25% higher.
3. Costs only include costs assocated with the nitrogen upgrade. Other portions of the WWTF may require upgrades to maintain compliance, increasing these projected costs.

EXHIBIT 4

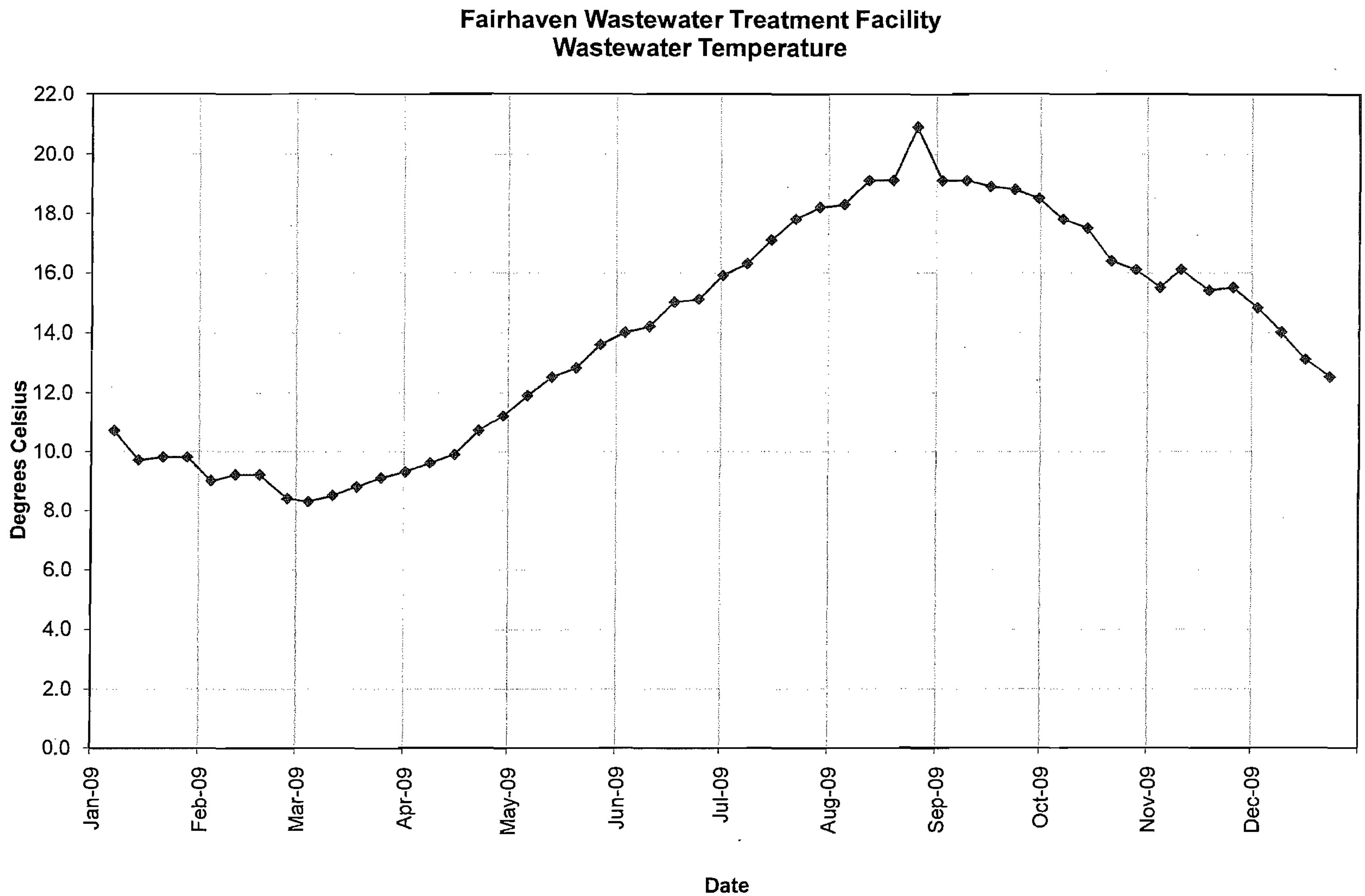

Fairhaven Wastewater Treatment Facility
Wastewater Temperature
Degrees Celsius
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Jan-09
Feb-09
Mar-09
Apr-09
May-09
Jun-09
Jul-09
Aug-09
Sep-09
Oct-09
Nov-09
Dec-09
Date

EXHIBIT 5

Dissolved Organic Nitrogen (DON) in Biological Nutrient Removal Wastewater Treatment Processes

Last Updated November 4, 2008

Acknowledgments

A formal technical review of the draft document was conducted by professionals with experience in wastewater treatment in accordance with WERF Peer Review Guidelines. While every effort was made to accommodate all of the Peer Review comments, the results and conclusions do not indicate consensus and may not represent the views of all the reviewers. The technical reviewers of this document included the following:

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Background (November 4, 2008)

Many municipal wastewater treatment facilities are being challenged to remove nitrogen and phosphorus to much lower effluent concentrations to help minimize eutrophication in surface waters. For nitrogen, point source discharge permits are typically based on limiting the effluent total nitrogen (TN) concentration, which includes organic and inorganic forms of nitrogen. Nitrogen in the influent to a wastewater treatment facility (WWTF) consist of ammonia (NH_3-N), particulate organic nitrogen (PON - see table of acronyms below), and dissolved organic nitrogen (DON). Biological transformations in biological nutrient removal (BNR) systems results in an effluent TN consisting of dissolved and particulate organic nitrogen and inorganic nitrogen components. The inorganic nitrogen components are ammonia (NH_3-N), nitrate (NO_3-N), and nitrite (NO_2-N). Biological nutrient removal (BNR) processes are specifically designed to oxidize NH_3-N to NO_3-N and/or NO_2-N and to biologically reduce these compounds to nitrogen gas by biological denitrification. Complex hydrolysis and deamination processes convert organic nitrogen to NH_3-N. To meet more stringent nitrogen removal requirements, biological nutrient removal (BNR) processes are pushed to their "limits of technology" (LOT) to biologically transform NH_3-N, NO_3-N, and NO_2-N. BNR LOT processes are aimed at meeting effluent TN concentrations well below the more traditional goal of 10 mg/L. In many cases, an effluent TN concentration of 3.0 mg/L is considered to represent the LOT for biological nitrogen removal. At lower effluent TN concentrations, the effluent organic nitrogen (EON) concentration is significant and has resulted in increased concern about what it is, how it can be minimized in a BNR facility effluent, and what its role is in eutrophication. As most LOT plants achieve minimal effluent suspended solids through the use of effluent filtration or membrane separate, the effluent dissolved organic nitrogen (EON) is of primary focus.

The purpose of this compendium is to summarize key current information on influent, in plant and effluent DON characteristics, including the impact of EDON on effluent TN goals, the composition of EDON, how DON is removed or produced in BNR processes, what fraction of EDON is accessible by bacteria, what fraction of EDON is available for algae growth, and the significance of EDON to eutrophication in surface waters. The information is presented in a format to answer key questions about the fate of DON and EDON. Much of the information provided here was presented in a collaborative workshop by the Scientific and Technical Advisory Committee (STAC) to the Chesapeake Bay Program and the Water Environment Research Foundation's (WERF) Nutrient Challenge Program - *Establishing a Research Agenda for Assessing the Bioavailability of Wastewater-Derived Organic Nitrogen in Treatment Systems and Receiving Waters*. Contributors to this compendium are listed at the end.

Definitions and Acronyms Used in this Compendium (November 4, 2008)

The organic nitrogen constituents of interest are shown below in Figure 1. The influent organic nitrogen (iON) equals the sum of the influent particulate organic nitrogen (iPON) and influent DON (iDON). The influent DON consists of biodegradable (biDON) and non-biodegradable or recalcitrant (riDON). The main organic nitrogen component of interest in the BNR treatment process is the dissolved organic nitrogen (DON), because most of the iPON will either be captured in solids removal processes or converted to DON. The DON in the BNR process is referred to as treatment process DON (tDON) and it consist of a biodegradable component (btDON) and a non-biodegradable component (rtDON). The organic nitrogen in the BNR process effluent is referred to as effluent organic nitrogen (EON) and this also consist of particulate (EPON) and dissolved organic nitrogen (EDON). The particulate portion is defined by the effluent filtration pore size, with 0.45 um commonly used for this application. The organic nitrogen in the filtrate is defined as dissolved but it may also contain some colloidal organic nitrogen. Of interest for the EDON is what portion is available for algae growth (i.e, bioavailable –denoted bEDON) and what portion is not available or recalcitrant (rEDON). The difference between btDON and bEDON is that the biodegradable DON in the BNR process is related only to bacteria activity and the effluent bEDON is bioavailable effluent DON that involves activities of both bacteria and algae in surface waters. These acronyms are summarized below along with others used in this compendium.

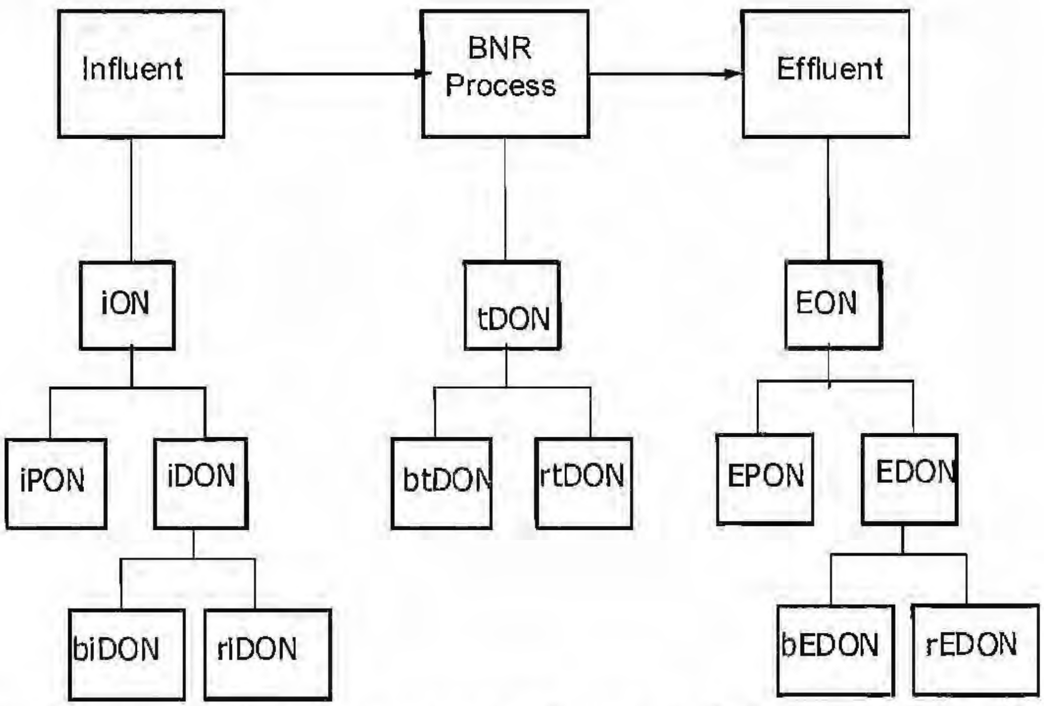

Figure 1. Organic nitrogen components of interest in BNR Process influent, in the treatment plant, and effluent

NH_3-N Total ammonia-nitrogen: includes both free ammonia (NH_3) and ionized ammonium (NH_4^+)

NO_2-N Nitrite-nitrogen

NO_3-N Nitrate-nitrogen

TIN Total inorganic nitrogen: sum of NO_2-N, NO_3-N, and NH_3-N.

TKN Total Kjeldhal nitrogen: measures sum of organic nitrogen and NH_3-N

TN Total nitrogen: Sum of inorganic and organic nitrogen as N

ON Organic nitrogen; nitrogen contained in organic compounds (i.e. amino acids, peptides, and protein) and can be in dissolved form or contained in particulate material

DON Dissolved organic nitrogen: organic nitrogen measured in the filtrate of a sample (influent, mixed liquor or effluent) following filtration

PON Particulate organic nitrogen: organic nitrogen contained in wastewater solids or biomass.

iON Influent organic nitrogen

iPON Influent particulate organic nitrogen

iDON Influent dissolved organic nitrogen

biDON Biodegradable influent dissolved organic nitrogen

riDON Non-biodegradable influent dissolved organic nitrogen

tDON Dissolved organic nitrogen in the BNR treatment system

btDON Biodegradable dissolved organic nitrogen in the BNR treatment system

rtDON Non-biodegradable dissolved organic nitrogen in the BNR treatment system

EON Effluent organic nitrogen: the sum of DON and PON in wastewater treatment plant effluent

EPON Effluent particulate organic nitrogen

EDON Effluent dissolved organic nitrogen

bEDON Bioavailable EDON is effluent dissolved organic nitrogen that can be used in surface waters due to bacteria activity and algae uptake of nitrogen

rEDON Recalcitrant EDON is effluent dissolved organic nitrogen that is resistant to biological transformation and uptake by algae in surface waters.

BNR Biological nutrient removal: includes biological process designs for nitrogen and phosphorus removal.

SRT Solids retention time: average time in days that solids are in the activated sludge system. It can be based on aerobic volume only or total volume.

Effluent Nitrogen Components in BNR Processes (November 4, 2008)

What nitrogen components make up the effluent TN concentration from a biological nutrient removal wastewater treatment facility?

Table 1 below shows the effluent nitrogen constituents that contribute to the effluent TN concentration from a BNR treatment process and the BNR process mechanism and factors that affect the respective effluent concentration. Note that key process design parameters that affect the ability to achieve minimal effluent TN concentrations (LOT performance) from BNR systems are longer SRTs, carbon addition for NO_3-N and NO_2-N removal, and enhanced effluent solids removal by membrane separation or filtration. Other factors may be the impact of variable loadings due to seasonal or wet weather conditions and the impact of in-plant recycle streams such as nitrogen-rich centrate return.

Table 1. BNR effluent nitrogen constituents and process removal mechanisms

Nitrogen constituent	Process removal mechanisms	Known factors affecting ability to reach minimum concentrations
NH3-N	Nitrification	Temperature, pH, dissolved oxygen, SRT
NO2-N	Oxidation to NH3-N Denitrification	Temperature, pH, dissolved oxygen, SRT Temperature, SRT, carbon source, anoxic detention time
NO3-N	Denitrification	Temperature, carbon source, anoxic detention time
EDON	Hydrolysis and ammonification	Temperature, SRT
EPON	Clarification, filtration or membrane separation	Liquid-solids separation process design

What filter pore size is used to define EDON, IDON and tDON?

The DON concentration measured for influent, treatment process or effluent samples will depend on the filter pore size used to separate particulate and colloidal solids from a sample. The common filter size for "dissolved constituents" is 0.45 μm and has been used to define EDON in many studies. In bioassays aimed at determining the biodegradable DON by bacteria in wastewater treatment processes (btDON) (Khan, 2007) and on the bioavailable EDON for freshwater algae consumption (Pehlivanoglu and Sedlak, 2004), a 0.20-0.22 μm filter size has been used. A 0.45 μm filter size has also been used to quantify EDON. An unquantified fraction of the total colloidal organic nitrogen passes through 0.45 μm filters and possibly through a 0.20 μm filter and ends up as part of the EDON. The only way to separate this from the truly dissolved fraction is with ultrafiltration, and to date those studies have not been done.

The following data presented by Pagilla (2007) shows the effect of filtration pore size on the organic nitrogen concentration for effluents from a number of wastewater treatment facilities. For some plants the effluent colloidal organic nitrogen contained in the so called DON can be significant. There is also the possibility of colloidal organic nitrogen in filtrate from 0.10 μm filtration.

What effluent TN concentration is possible from a BNR LOT process designed and operated for maximum nitrogen removal? What fraction of that is EDON?

Figure 1 illustrates effluent TN concentrations possible from a BNR LOT system and the relative contributions of the nitrogen constituents. In this case the EDON concentration is assumed to be 1.0 mg/L. The effluent TN concentration may range from 2.0 to 4.0 mg/L, depending on the ability to minimize the NO_3-N and NH_3-N concentrations and maximize effluent suspended solids removal. For BNR LOT processes filtration or membrane separation would be used, so the EPON contribution would be negligible or minimal. No single minimal TN concentration value can be projected for all facilities as the effluent value is affected by influent flow and strength variations, equipment malfunctions, recycle streams, process design, and plant operations.

Table 2. EDON measurements (mg/L) as a function of filter pore size (Pagilla, 2007)

	Filter pore size		
WWTP	**1.2 µm**	**0.45 µm**	**0.10 µm**
Stickney	2.9	1.7	1.6
Hinsdale	4.2	3.6	3.6
Elmhurst	2.1	2.0	2.0
Gdynia	3.4	2.4	1.5
Gdansk	1.9	1.3	0.4
Elblag	5.0	2.7	2.0
Slupsk	1.6	1.6	1.0

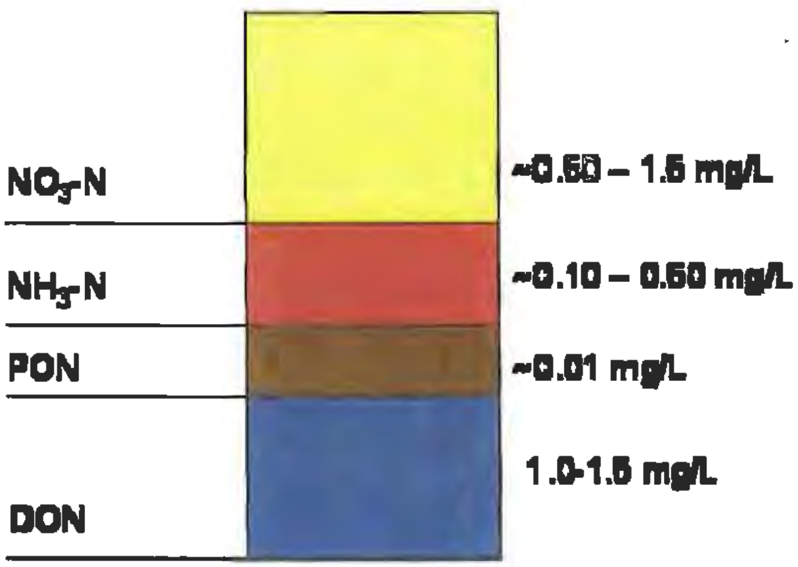

Figure 1. BNR effluent TN concentration possible and amount from nitrogen constituents

The figure shows that the EDON concentration can account for 25 to 50% of the effluent TN concentration and thus is very significant for systems needing to reach minimum TN concentrations. For applications with an effluent TN concentration goal of less than 10 mg/L (typical value for water reuse applications), the EDON concentration is not as great of a concern.

What are some observed EDON concentrations in BNR processes?

Table 3 summarizes EDON values from various BNR facilities and shows EDON concentrations ranging from 0.10 to 2.80 mg/L. The 50 and 90 percentile values are 1.2 and 2.1 mg/L, respectively. There is a wide range of observed EDON concentrations observed from BNR processes, and it appears that in some cases the EDON can be at a high enough concentration to make it impossible to meet an effluent TN concentration goal of 3.0 mg/L.

Furthermore Pagilla (2007) (Figure 2) indicated that about 65% of 188 facilities in Maryland and Virginia had EDON concentrations at 1.0 mg/L or less. The reasons for the higher EDON concentrations are not known at this time.

EDON Characteristics (November 4, 2008)

What is the composition of EDON?

Sedlak and Pehlivanoglu (2007) evaluated the molecular weight distribution of EDON and hypothesized that the high molecular fraction (molecular wgt greater than 1 kDa) was not biologically available. The composition of this fraction has not been determined but is expected to be made up of larger molecular weight humic substances. Of the lower molecular weight compounds that may be bioavailable, only about 1/3rd has been identified as free and combined amino acids and ethylenediaminetetraacetic acid (EDTA). Other N-containing compounds in BNR effluents may include N-containing pesticides, pharmaceuticals, and other trace organics.

Table 3. Summary of effluent dissolved organic nitrogen values reported.

	EDON	Percentile	Reference
Plant Location	mg/L	%	Number
Gordonsville, VA	2.80	97	Pagilla (2007)
Daytona Beach, Fl, Bethune	2.46	94	Jimenez et al. (2007a)
Back River WWTP	2.24	91	Parkin and McCarty (1981)
New Smyrna, Fl	2.10	88	Jimenez et al. (2007a)
Daytona Beach, Fl	2.00	85	Jimenez et al. (2007a)
City of Bradenton, Fl	2.00	82	Jimenez et al. (2007a)
JEA Black Fords, Fl	1.88	79	Jimenez et al. (2007a)
City of Palmetto, Fl	1.80	76	Jimenez et al. (2007a)
Stamford, CT	1.70	74	Sharp and Brown (2007)
Orange County, Fl, Eastern	1.55	71	Jimenez et al. (2007a)
Fort Meyers, Fl, Central	1.50	68	Jimenez et al. (2007a)
TMWRF, NV	1.50	65	Pagilla (2007)
Palo Alto, CA (2)	1.50	62	Randtke and Mccarty (1977)
Homestead, Fl	1.40	59	Jimenez et al. (2007a)
Lynn Haven, Fl	1.40	56	Jimenez et al. (2007a)
Bayou Marcus, Fl	1.37	53	Jimenez et al. (2007a)
City of Tarpon Springs, Fl	1.20	50	Jimenez et al. (2007a)

	EDON	Percentile	Reference
City of Clearwater, Fl	1.20	47	Jimenez et al. (2007a)
City of Largo, Fl	1.20	44	Jimenez et al. (2007a)
Chesapeake Beach, MD	1.20	41	Pagilla (2007)
Blue Plains, D.C.	1.20	38	Pagilla (2007)
City of Dunedin, Fl	1.18	35	Jimenez et al. (2007a)
Truckee Meadows, NV	1.00	32	Sedlak and Pehlivanoglu. (2007)
Titusville, Fl	0.95	29	Jimenez et al. (2007a)
Fort Meyers, Fl, south	0.94	26	Jimenez et al. (2007a)
Piscatway, MD	0.90	24	Pagilla (2007)
Palo Alto, CA	0.90	21	Randtke and McCarty (1977)
Orlando, Fl	0.88	18	Jimenez et al. (2007a)
Tampa, Florida	0.73	15	Jimenez et al. (2007b)
Alexandria, VA	0.70	12	O'Shaughnessy et al. (2006)
Boone WWTP, VA	0.69	9	Wikramanayake et al. (2007)
Fort Meyers, Fl	0.60	6	Jimenez et al. (2007a)
Upper Potomac R., MD	0.10	3	Pagilla (2007)

* DON in Jimenez et al. (2007a) reference estimated from effluent TN and TIN concentrations

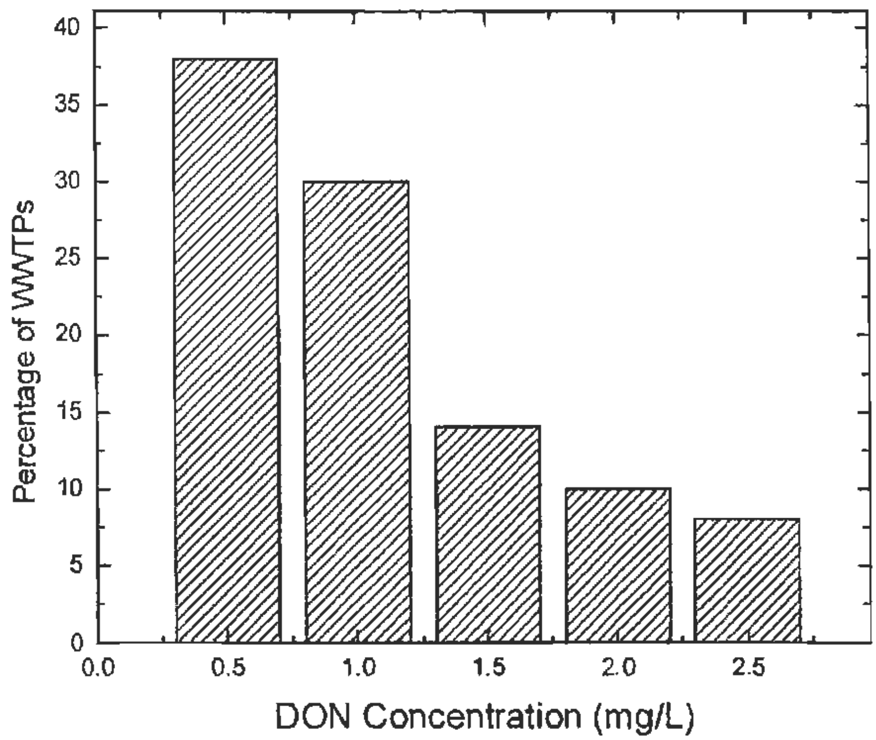

Figure 2. Summary of effluent dissolved organic nitrogen (DON) concentration (0.45 µm filtration) from 188 Maryland and Virginia wastewater treatment plants (Pagilla, 2007)

What are possible sources of DON in the BNR facility influent or in the treatment process?

DON originates in domestic wastewater influent as urea (60-80% of domestic influent TKN), amino acids, proteins, aliphatic N compounds and synthetic compounds, such as EDTA. DON may also be produced and released in the wastewater treatment biological processes, including sludge digestion, due to cell metabolism processes that excrete biomolecules, cell decay and cell lysis. Humic organic substances may be present in some drinking water supplies to eventually contribute to the wastewater DON. Little is known on industrial wastewater compounds that may contribute to DON in combined municipal-industrial wastewater treatment. Thus, EDON may consist of influent recalcitrant DON, DON produced by microbial activity in the BNR process and biodegradable DON that remains in the effluent.

Fate of DON in Biological Wastewater Treatment (November 4, 2008)

What is the fate of EDON in activated sludge treatment and BNR treatment processes?

In early work by Parkin and McCarty (1981), the composition and fate of DON at the Palo Alto, CA wastewater treatment plant was studied. The average EDON concentration was 1.5 mg/L. They claimed that 52% of it was recalcitrant from influent wastewater sources, 20% was produced from biomass endogenous decay in the activated sludge process, 15% was in equilibrium between that sorbed to biomass and the liquid and about 13% could be further degraded. However, they noted that increasing the activated sludge SRT could further degrade influent DON but DON could also be added via biomass endogenous respiration. They claimed that the optimal operating point that could lead to a minimal EDON concentration as a result of influent DON biodegradation and microbial DON release was at an SRT of 6-10 days. A number of important concepts regarding the fate of DON in wastewater treatment were revealed in this work; 1) some portion of the influent DON was not bioavailable, 2) increasing the system SRT could minimize the biodegradable DON concentration, and 3) increasing the SRT could increase the non-biodegradable DON concentration due to contributions from biomass endogenous decay.

What fraction of influent DON is expected to be biodegradable DON?

This is a subject of current research. Work reported by Khan (2007) suggested that 40-60% of influent DON is biodegradable. This is in the range of that given by Parkin and McCarty (1981) above. The relative effectiveness of different biological treatment process technologies on degrading influent or biomass-derived organic nitrogen has not been studied.

Controlling and Minimizing EDON from BNR Facilities (November 4, 2008)

How can the EDON concentration of a biological nutrient removal facility be minimized?

The design and operating conditions that can minimize EDON concentrations in BNR facilities is a current research topic. One issue is whether the optimal SRT required to achieve minimal EDON concentration is compatible with the SRT needed to maximize inorganic nitrogen removal efficiency. The impact of DON in recycle streams from aerobic or anaerobic digestion and dewatering needs to be further evaluated.

What process technologies may be used for EDON removal from a BNR process effluent and what is the effectiveness of these processes?

Randtke and Mccarty (1977) evaluated physical-chemical processes for EDON removal in the Palo Alto, CA. effluent. The EDON concentration in bench scale tests with the Palo Alto facility effluent was 1.3 mg/L. For chemical treatment the removal efficiencies were 33% with lime, 28% with 200-300 mg/L alum, and 40% with 200-300 mg/L ferric chloride. Removal efficiencies were lower for cation and anion exchange (less than 13%). About 71% of the EDON was removed with activated carbon adsorption.

The high MW EDON constituents are considered to be non-biodegradable or recalcitrant (rEDON). Other removal methods for rEDON constituents would be very expensive, requiring either chemical oxidation processes or reverse osmosis. The chemical oxidation processes would need to be followed by a biological treatment step to biodegrade the oxidation products.

Fate and Effect of effluent DON in Surface Waters (November 4, 2008)

What is the importance of nitrogen on surface water quality?

Nitrogen can contribute to eutrophication, which can lead to low dissolved oxygen (DO) concentrations that hinder fish and shell fish production and survival. In fresh waters phosphorus is considered the most limiting inorganic nutrient but at elevated phosphorus concentrations higher algae growth can occur when more nitrogen is available. In saline waters, such as estuaries, phosphorus is plentiful so that the role of nitrogen is more important.

How is the nitrogen in EDON used by algae?

Hydrolysis and deamination of EDON can produce inorganic forms of nitrogen that are readily consumed by algae. Dissolved free amino acids (DFAA) can be taken up directly by algae but dissolved combined amino acids (DCAA) must be hydrolyzed to monomers before uptake (Pehlivanoglu and Sedlak, 2004). There is less known about the availability of nitrogen in larger molecular weight humic substances; however, in general, it is considered less available and has been termed inert or recalcitrant EDON (rEDON).

What is effluent recalcitrant EDON (rEDON)?

rEDON is that portion of effluent DON that is considered not available for algal or bacterial growth over a time scale of days to weeks that represents the time of travel through the water area of interest. This could involve only fresh water conditions or both fresh water and estuary saline water conditions; for example, the Chesapeake Bay and its tributaries. The structural characteristics of rEDON are not known, but it is considered to be mainly in the unidentified high molecular weight humic fraction of effluent DON. However, for saline waters Bronk (2007) reports that humic compounds can be an available nitrogen source for algae growth. It is not known if the specific type of humic compounds and possibly other high molecular weight nitrogen compounds in BNR effluents are bioavailable in saline environments.

Impact of rEDON on meeting regulated effluent TN concentrations (November 4, 2008)

What fraction of BNR-derived EDON may be recalcitrant (rEDON)?

In view of the wide range of EDON concentrations possible from BNR faculties, as shown in Table 3, it is not possible to generalize on the possible rEDON fraction for all treatment plants. Using a bioassay procedure in fresh water conditions with algae and bacteria, the fraction of EDON available for algae growth over a 14-day incubation period was 56% (Pehlivanoglu and Sedlak, 2004) and 18 to 61% (Urgun-Demirtas et al. 2007) for low TN concentration effluents. Based on these observations, the potential fraction of rEDON in EDON from BNR facilities may be 40-80% for systems discharging into freshwater watersheds. A similar analysis has not been done for treatment plants that discharge into watersheds that are significantly estuarine, which constitutes all of the treatment plants in the Chesapeake Bay region and many others located on continental coasts.

How significant might be the effect of rEDON on the cost and ability to meet stringent effluent TN concentration permit values?

For eutrophication impaired surface waters, a common regulated effluent TN concentration value is 3.0 mg/L. Assuming that the EDON concentration is 1.0 mg/L, and that 50% is available for algae growth, the rEDON accounts for 0.50 mg/L of the effluent TN concentration. This is a significant concentration and affects the operational and design challenge for TIN removal. If the rEDON contribution is not included in the permit effluent TN concentration, the plant allowable effluent TIN concentration could be increased to 2.5 mg/L from the 2.0 mg/L concentration in this example; a reduction of 0.50 mg/L in the amount of NO_3-N that must be removed.

The impacts of removing 0.50 mg/L of NO_3-N are increased operating cost for carbon addition and increased carbon dioxide emissions to contribute to greenhouse gases. Therefore, if this nitrate did not need to be removed because 0.5 mg/L of the EDON is found to be recalcitrant, the annual savings can be estimated (see Table 4 for different plant sizes). The calculation assumed a methanol dose of 3.2 mg methanol per mg of NO_3-N removed and a methanol cost of $0.20/lb. For a 100 Mgal/d facility, the methanol cost savings is about $97,000 per year and for a 5 Mgal/d facility it is about $5,000 per year. If a nutrient trading program is in place, the value of selling the rEDON as a credit can increase significantly beyond the estimated values in Table 4.

Table 4. Annual reduction in operating cost if 0.50 mg/L NO_3-N is not removed from the effluent to compensate for an rEDON concentration of 0.50 mg/L for a plant with an effluent TN concentration goal of 3.0 mg/L.

Flowrate, Mgal/d	5	10	20	100
Annual Methanol Cost	$4,900	$9,700	$19,000	$97,000

Bioassays for Measuring DON (November 4, 2008)

At present, there is no consensus as to the appropriate way to determine bEDON or rEDON using bioassays. Two possible approaches are outlined below.

What are the goals of DON bioassays?

Bioassays are done to determine the biodegradability or bioavailability of DON. The recalcitrant DON in the wastewater influent and in the EDON is of major interest and is the difference between the sample DON and DON consumed in the bioassay. The type of bioassay depends on the application and goal of the test. For in plant issues the test goals may include 1) determining what portion of iDON is not subject to biotreatment or is recalcitrant (riDON), 2) what portion of the EDON from the treatment process may be biodegradable and thus removed with longer treatment time in the BNR process, and 3) what amount of recalcitrant DON may be in recycle streams to the treatment process. All of these goals involve the BNR treatment process and the biodegradability of DON by bacteria. Therefore, the bioassay procedure should incorporate biomass from the BNR process being assessed. This approach is referred to as a "technology-based bioassay" because it assesses the biodegradability of DON during the treatment process (Awobamise et al., 2007).

On the other hand, to evaluate the impact of EDON in wastewater treatment effluents, the bioassay goal is to determine the fraction of the EDON that is recalcitrant (rEDON) in receiving surface waters and thus will not contribute to eutrophication. In this case the bioassay needs to account for the effect of light, salinity, algae and bacteria on the bioavailability of EDON. This bioassay is referred heretofore as a "water quality-based bioassay." The recalcitrant fraction is determined directly by the difference in the EDON and amount of DON used in a bioassay with exposure to bacteria and algae and water quality conditions that are indigenous to various reaches of the receiving stream. The time period of this bioassay has to be long enough to allow for complete conversion of bEDON, or to evaluate the bioavailability along different water quality conditions indicative of passage time down a waterway.

What is the technology-based DON bioassay protocol presently used?

Khan (2007) used a technology-based assessment protocol (Table 5) to determine if activated sludge biomass could further biodegrade EDON in wastewater plant effluent samples The outcome from this test can be used to determine if treatment plant biomass can further degrade the EON if given more time than was provided through the treatment process. The test is in its early stages of development and application, so that future modifications to the protocol are possible. The test is done with 300 mL BOD bottles and follows changes in dissolved oxygen (DO) concentration to thus also determine the BOD satisfied in the sample over time. The test also requires DON measurements at time intervals. The bEDON concentration is the difference between the initial EDON concentration and that at time t. Because the method is a technology-based bioassay that looks at the potential for BNR mixed liquor to further biodegrade EDON if the process retention time were to be extended, it is appropriate to conduct the assays in the dark because photosynthetic metabolisms do not routinely occur in activated sludge treatment. This bioassay may be used to evaluate the impact of various BNR process designs on minimizing bEDON, the contribution and impact of recycle flows, and the potential for increasing the system SRT to further reduce the bEDON concentration.

Table 5. Biodegradable (bEDON) bioassay protocol[a] (Awobamise et al., 2007) (300 mL BOD bottles)

Test Components	Procedure	Comments
Sample preparation	Use filtrate from 0.22 µm glass fiber filtration	Effluent filtrate or primary effluent?
	Saturate DO by aeration or shaking	
	Add 2 mL inoculum	Inoculum is mixed liquor from the same treatment plant at 240 mg/L
Seed control	Add 2 mL inoculum to distilled water	
Test bottle incubation	Unmixed and at 200C	In the dark
	5-20+days	For ultimate bEDON, the time is not yet known
	Check and adjust DO periodically	Time intervals may be 0, 5, 10, 20 days or more*
DON measurements	Measure DON at sample time intervals	Time intervals may be at 0, 5, 10, 20 days or moreb

[a] Although this is listed as a bEDON method, unfiltered samples can be used to determine the bEON

[b]- Awobamise et al. (2007) found most bEDON to be gone by 20-30 days

What is the goal of the water quality-based bioassay?

A surface water quality-based assessment protocol under consideration is summarized in Table 6 below. It was first applied to measure bEDON by Pehlivanoglu and Sedlak (2004) and later by Urgun-Demirtas et al. (2007) for a number of BNR effluents. In both cases, more EDON was consumed when bacteria were present in the test with algae versus algae alone, indicating a synergistic relationship between algae and bacteria. The test uses a freshwater alga, thereby limiting its application to BNR plants that discharge into exclusively freshwater watersheds. Modifications to the protocol are needed to determine the bEDON (DON lost) or rEDON (DON retained) for treatment plants located in watersheds that ultimately discharge into freshwater or estuarine water bodies that exist within estuarine watersheds (Mulholland et al., 2007). The bEDON consumed by the algae is predicted by measuring the algal chlorophyll production in sample bottles. A set of control sample bottles are spiked with nitrate to obtain a correlation between chlorophyll production and the amount of nitrogen consumed by the algae. The bioassay protocol is summarized in Table 6. The test protocol is in its early stages of development and application, and future modifications are possible.

The value of this surface water quality-based assessment method is not presently fully understood due to the use of a single, non-indigenous lab-cultivated freshwater alga and activated sludge biomass that may not be indicative of biomass found in surface waters. Furthermore, application of the method is limited to treatment plants contained entirely in freshwater watersheds. A benefit of this method is that it is relatively easy to standardize and implement. If results from this method are found to correlate in a predictable way with more complex bioassays that use indigenous microbiota, then it could be valuable as an indicator.

What factors affect the bioavailability of EDON in surface waters and should be considered in the surface water quality-based assessment protocol developement?

Key parameters that appear to affect the bioavailability of EDON by bacteria and algae include the salinity and pH of the water receiving EDON. It appears that nitrogen-containing humic substances are more bioavailable in saline water versus fresh water. The sorption of ammonium on humic material is also affected by salinity and ammonium is likely to desorb in higher salinity waters. In addition to physical and chemical interactions of nitrogen species due to water chemistry, it is known that water chemistry affects the populations of bacteria and algae species present in surface waters, which in turn results in different abilities for DON transformation These variations in population dynamics across a receiving stream watershed are not captured in the previously mentioned protocols. Therefore, the ideal surface water quality-based assessment protocol should consider the receiving water quality and microbial diversity conditions present. Doing so with a protocol, however, complicates the method significantly beyond the other methods described here.

Another factor not addressed in the protocols presented above is whether the bacteria responsible for conversion of EDON to nitrogen forms that are bioavailable for algae need an additional carbon source to maintain their activity during the long incubation time periods used in the tests. Evidence from previous studies on natural (not effluent) DON bioavailability in surface waters suggests that such long assay times are not necessary and, in fact, may be detrimental to effective interpretation. Del Giorgio and Davis (2003) concluded that the only portion of a bioassay that can be compared to *in situ* metabolic rates is the initial stage when the pool of labile ON may still reflect *in situ* conditions. Additionally, bacteria can modify DOM, making it resistant to further degradation (Ogawa *et al.* 2001; Keil and Kirchman 1991). The net effect of long bioassays is simply to cycle N among dissolved and particulate pools in a closed system where there is tight coupling of N reactions. Thus, long incubation times under closed-bottle conditions likely reflect the accumulation of bacterial products – not true bioavailability of the initial starting material. The impact of incubation time on bioassay interpretation for assessing EON bioavailability or recalcitrance needs to be determined.

The dissolved inorganic nitrogen (DIN) content of the sample may also affect the accuracy of bioassay protocols that involve use of algae and rely upon measuring chlorophyll *a* production. High ratios of effluent DIN (EDIN) to EDON will result in very high levels of chlorophyll produced from DIN relative to chlorophyll produced by DON. It can be difficult to accurately quantify the amount of chlorophyll that actually was generated by the DON in a high background of DIN-generated chlorophyll, thereby compromising the method. To overcome this, DIN must be removed from or reduced in samples while retaining the DON, which is not a trivial feat.

Table 6. A water quality-based assessment protocol for determining rEDON using 500-mL sample flasks (Pehlivanoglu and Sedlak (2004)

Test Components	Procedure	Comments
Sample preparation	1. Chlorinated effluent samples dechlorinated with sulfur dioxide 2. Use filtrate from 0.20 µm glass fiber filtration and fractionate with ultrafilters down to 1 kDa MW. 3. Distilled water and EDON samples spiked with 1 mg/L NO3-N were run in parallel	
Bacteria inocula	1. Filter 3L of surface water first with 1 µm glass fiber filter 2. Filter 1 µm filtrate through 0.20 µm membrane filter 3. Suspend retentate of 0.20 µm membrane filter in 100 mL of 0.20 µm filtered surface water 4. Add 1 mL of bacteria suspension to 400 mL sample	Biomass is obtained from surface water samples
Algae inocula	1. A lab-cultivated freshwater algal species, Selanastrum Capricornutum, was used 2. Algae cultured per freshwater algae toxicity test protocol (APHA, 1998), amended with nutrients except nitrate. K2HPO4 added to media to give N/P molar ratio of 3.0. 3. 5 mL of algal suspension at logarithmic growth phase added to 400 mL sample	
Test flask incubation	1. In shaker at 20-220C 2. 12 hr light/dark cycle	
Algal growth	Monitor with vivo chlorophyll- α measurements using fluorometer until stationary growth phase reached	Stationary growth was found in about 14 days
DON measurements	Measure DON at sample time intervals	

Research Needs (November 4, 2008)

As regulations require more stringent effluent nutrient concentrations to protect impaired surface waters from eutrophication, the impact of EDON has become more important and represents a new challenge in the area of biological nutrient removal. Initial efforts to measure EDON and its availability for bacteria and algae and to understand its removal in BNR treatment processes has led to both useful findings and an awareness of the need for more research on this topic. The research needs are summarized here for the topic areas raised in this compendium.

Bioassay protocol to determine rEDON in freshwater or saline water

It appears that not all of the EDON from BNR treatment facilities is bioavailable for algae and that the rEDON fraction may vary for different receiving stream locations. Thus, regulators need a means to monitor plant effluent quality to assure that their goals for limiting the effect of nitrogen on eutrophication are being met for point dischargers and not overregulated. A possible approach would be to permit an effluent "effective" TN concentration that is equal to the measured effluent TN concentration minus the measured rEDON concentration.

The rEDON bioassay must provide a measurement of recalcitrant EDON that would indeed be inert in the receiving water over an exposure time frame that is deemed appropriate. The most reliable bioassay protocol for rEDON is one that would be accepted by the environmental engineering and science profession, utilities and regulators. Research is first needed to understand factors that influence the outcome of the rEDON protocol used, and if it is possible to overcome those factors that introduce both significant variability and inaccuracy into the bioassay results. It may be that different protocols are appropriate for dischargers who are wholly contained within freshwater watersheds versus those contained within estuarine watersheds (discharges in the latter may discharge locally into a freshwater receiving body that flows to the estuarine; therefore, the estuarine test condition is relevant even though the immediate receiving water condition is freshwater). The transport and degradation of EDON in surface waters along changing salinity gradients is important for modeling the effect of point discharged nitrogen on eutrophication. Research is needed to determine if rEDON changes along salinity gradients and how it changes to improve surface water models that include the impact of available nitrogen. This topic will be investigated under a recent National Science Foundation-sponsored research grant to support a collaborative effort headed by Professor Deborah Bronk.

The following table presents research issues that should be addressed in order to develop an acceptable rEDON bioassay or collection of bioassays.

Table 7. Research needs for rEDON bioassay test protocol

Test Parameter	Research Issue	Comment
Definition of filter pore size distributions needed to fractionate DON	Sample filter pore size to define dissolved portion	There may be a significant amount of colloidal organic nitrogen between 0.45 and 1.2 µm filter pore size, and below 0.45 µm.
pH control	Buffer addition and appropriate pH	Should the test alkalinity be similar to that of the receiving water?

Test Parameter	Research Issue	Comment
Incubation time	What is the appropriate time period for bioassays that measure rDON?	If the test is too long, general N cycling within the bottle will occur and can blind the interpretation.
Incubation temperature	Is 200C test condition satisfactory for predicting rEDON concentrations in receiving water?	
Light intensity and diurnal pattern	Is this a sensitive test parameter to affect the rEDON (...not sure where you were going here???	
Bacteria seed source	Can it be from wastewater plant or must it be from receiving water?	For rEDON fate in environment (freshwater or estuarine), seed would be obtained from receiving water
Need for carbon addition	Is a carbon source needed to maintain activity of bacteria needed for effective EDON hydrolysis and transformation? Would carbon addition reduce necessary test incubation time?	
Effect of total inorganic concentration in test sample	A sample preparation method must be developed to reduce the sample TIN concentration so that an acceptable portion of the test sample chlorophyll *a* production is from EDON	
Algae seed type and source	Is Selenastrum Capriconutum satisfactory for the fresh water rEDON protocol? What is the effect of collecting and using different algal seed sources along the fresh water to saline water gradient? Is there an acceptable standard pure or mixed culture that can be used?	
Algae growth condition prior to sample inoculation	Is the log growth condition the preferred state? What should the N/P ratio be for cultivating the algal enrichment to be used in the test?	

Test Parameter	Research Issue	Comment
Water quality conditions within bioassay	What is the appropriate solvent to use during the bioassay, and how does it differ for freshwater versus estuarine situations? Should the solvent composition change over time or with different bottles as part of the procedure?	It is expected that a salinity gradient influences amino bioavailability for some organic N compounds.
QA/QC methods	What EDON compound(s) could be used to test and demonstrate the accuracy of the bioassay? What other QA/QC methods should be employed in protocol?	

Bioassay protocol to determine influent wastewater (IDON) biodegradability (bIDON)

A protocol for this evaluation is not currently being studied, yet there is a significant need to address the role that constituents in influents play in contributing to EDON. It is not known how the plant design and operation, recycle streams and influent organic nitrogen characteristics affect EDON concentrations. A method is needed to characterize the organic nitrogen characteristics of wastewater influents. It is particularly important to characterize any riDON and to determine if rEDON concentrations are related to the riDON (especially if it comes from controllable sources, sueh as industrial wastewater inputs, reject water recycle streams, and/or additives in the water supply). A biDON bioassay would use biomass from the treatment plant being evaluated to assess the capacity of that biomass to transform the organic nitrogen in the influent. Because bacteria can produce organic nitrogen, it is possible to misinterpret results if only organic nitrogen is monitored because the organic nitrogen in the influent could be degraded while organic nitrogen is formed by the biomass as a consequence of metabolism. Therefore, it is envisioned that this protocol would include an assessment technique that differentiates in a general way the nature of the organic matter in the bioassay over time.

Bioassay protocol to determine if further wastewater treatment will eliminate bEDON.

The bEDON bioassay protocol is much less complex and much more developed than that for the rEDON bioassay; however, the methods give extremely different information. The research needs for further development of the bEDON bioassay method and for establishing an accepted protocol are:

- What is the contribution of colloidal matter to the bEDON? Filter pore sizes should be selected to allow for evaluating the bEDON of colloidal matter versus truly dissolved (<1 kDa) EDON. Colloidal matter would not necessarily be removed by the treatment facility or by effluent filtration.
- Should bottle conditions be altered to reflect actual metabolic conditions experienced during treatment? If supplemental readily biodegradable carbon is added to shorten the test time, how will that affect the measured bEDON concentration? How much and how often should it be added?
- What known DON standards could be used to gauge the precision of the bEDON test in order to establish a quality assurance protocol?

Removal and production of bEDON and rEDON in a BNR treatment process

Research is needed to determine what design and operating conditions for a BNR facility affect the effluent bEDON and rEDON concentrations? Key questions for this research are:

- Is there an optimal SRT for which the bEDON is minimized as a function of bEDON degradation and bEDON production from endogenous decay?
- If SRT is increased to decrease bEDON, will it cause a concomitant increase in rEDON? Can changes in the fraction of bEDON and rEDON be followed by changes in the proportion of high molecular weight EDON?
- What is the amount of bEDON and rEDON in recycle streams, such as that from anaerobic sludge digestion and aerobic sludge digestion?
- Is there an effect of the BNR design and configuration (anaerobic and anoxic contact) on rEDON and bEDON?
- Is the bEDON and rEDON removal efficiency different for membrane and granular media filtration processes?
- What are promising tertiary processes for bEDON and rEDON removal?

Non-bioassay methods to characterize rEDON

Research is needed to characterize the rEDON measured with the bioassay protocol. Previous work suggests that it is a higher molecular weight humic substance that also contains amide compounds as well as certain synthetic organics such as EDTA. If suitable progress can be made to characterize rEDON, it may be possible to develop surrogate measurements in lieu of a complex and time consuming bioassay method for rEDON.

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ESTABLISHING A RESEARCH AGENDA FOR ASSESSING THE BIOAVAILABILITY OF WASTEWATER TREATMENT PLANT-DERIVED EFFLUENT ORGANIC NITROGEN IN TREATMENT SYSTEMS AND RECEIVING WATERS

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ESTABLISHING A RESEARCH AGENDA FOR ASSESSING THE BIOAVAILABILITY OF WASTEWATER TREATMENT PLANT-DERIVED EFFLUENT ORGANIC NITROGEN IN TREATMENT SYSTEMS AND RECEIVING WATERS

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I. Introduction

Overview

This report summarizes the outcomes and recommendations from a two day workshop on wastewater treatment plant-derived effluent organic nitrogen (EON) that occurred in Baltimore, Maryland on September 26 and 27, 2007. The targeted outcomes from this workshop were to develop a prioritized research strategy for:

- implementing a reliable protocol(s) to determine the bioavailability of EON in receiving waters, and
- understanding how upstream treatment technologies influence the generation or removal of this bioavailable organic nitrogen fraction.

The participants, identified in Table 1, were a highly multidisciplinary mix of wastewater utility personnel, wastewater design engineers, watershed modelers, regulatory and government personnel, natural systems researchers, and wastewater engineering researchers. This mix of participants successfully articulated a research plan for EON that identifies the research needs in the treatment plant as well as downstream of the treatment plant (in the watershed).

The workshop was co-sponsored through a collaborative effort between the Scientific and Technical Advisory Committee (STAC) to the Chesapeake Bay Program and the Water Environment Research Foundation's (WERF's) Nutrient Challenge program.

Table 1. Workshop Participants.

Nitrogen Removal & Wastewater Design	*Organic Nitrogen Bioavailability Researchers*	*Nitrogen Biogeochemical Cycling Researchers*
James Barnard, Black and Veatch Nancy Love, Virginia Tech* JB Neethling, HDR Vikram Pattarkine, Brinjac Engineering* Amit Pramanik, WERF* Cliff Randall, Virginia Tech Tom Saddick, CH2M Hill David Stensel, Univ. Washington* Bev Stinson, Metcalf & Eddy	Debbie Bronk, College of William and Mary, Virginia Institute of Marine Science (VIMS)* April Gu, Northeastern University Eakalak Khan, North Dakota State Univ. Margaret Mulholland, Old Dominion Univ.* Krishna Pagilla, Illinois Institute of Technology David Sedlak, Univ California-Berkeley Robert Sharp, Manhattan College	Walter Boynton, Chesapeake Biological Laboratory Jack Brookshire, Princeton University Elizabeth Canuel, College of William and Mary, VIMS Sujay Kaushal, Chesapeake Biological Laboratory Leigh McCallister, Virginia Commonwealth Univ. Hans Paerl, Univ North Carolina
Regulatory and Government	***Modeling***	***Industry/Utility***
Rich Batiuk, EPA Chesapeake Bay Program Office Dave Clark, HDR, Regulatory Liaison Steve Luckman, Maryland Department of the Environment Mark Smith, EPA Region 3 Tonya Spanyo, Metropolitan Washington Council of Governments (MWCOG)* Kyle Winter or Allan Brockenbrough, VA DEQ Phil Zahreddine, EPA, Office of Water and Wastewater/Municipal Technology Branch+ Ning Zhao, EPA Chesapeake Bay Program Office	Dom DiToro, Univ. of Delaware Lewis Linker, EPA	Jeannette Brown, Stamford, CT Randal Gray, Truckee, Nevada Bernard Kiernan, Philip Morris Sudhir Murthy, DC WASA Jim Pletl, Hampton Roads Sanitation District Dipankar Sen, Santa Clara Valley Water District, California Keith Bailey, Smithfield Foods Dave Waltrip, Hampton Roads Sanitation District

* Represents planning committee members.
Some participants represent more than one category but are placed in their primary category

Rationale for the Workshop

The United States Environmental Protection Agency (EPA) requested guidance from the Scientific and Technical Advisory Committee (STAC) of the Chesapeake Bay Program regarding the bioavailability of organic nitrogen (ON) released through wastewater treatment plant effluents (effluent organic nitrogen or EON) and the appropriateness of a proposed assay for assessing its bioavailability. According to Virginia law (see below), dischargers can argue cases before a nutrient control board to increase their discharge allowances or caps based on their assessment of EON bioavailability. A facility in Virginia employed a bioassay in an attempt to demonstrate that a large fraction of their EON was biologically unavailable. In the short term, EPA requested guidance on: 1) whether EON is bioavailable in the proximate and ultimate receiving waters, and 2) whether the assay employed by the Virginia facility is appropriate for assessing EON bioavailability. In the longer term, the EPA has sought guidance on developing appropriate assays of EON bioavailability. In response to this request STAC created a sub-committee to formulate a report with the requested guidance for the short-term. Subsequently, members of this STAC sub-committee along with representatives from the Water Environment Research Foundation (WERF) teamed up to develop a workshop aimed at uniting distinct stakeholder communities to address the longer-term goal of developing appropriate bioassays that can be used by the regulated community to allow them to meet the demands of EPA's water quality criteria.

In many estuarine systems, freshwater end members tend toward phosphorous (P) limitation and marine end members tend toward nitrogen (N) limitation (e.g. Doering et al. 1995; Fisher et al. 1999). Most wastewater facilities discharge to fresh water. Therefore, decades of research and technological advances have been implemented to reduce P loads to receiving waters. Treatment to reduce P loads from wastewater treatment plants and the detergent ban in the mid-1980's have been a major success story nationwide. However, these successes have not improved the quality of estuarine systems, such as the Chesapeake Bay, because success is limited to the proximate receiving waters. The Chesapeake Bay, other estuarine systems, and the marine environment in general are more often N limited (Boynton et al. 1995; Howarth et al. 1996; Kemp et al. 2005). Consequently, P reductions in wastewater have "moved the problem downstream." This has been documented in a number of cases including the Neuse and Potomac Rivers (Paerl 1995) where P reductions were implemented without concomitant N reductions. In fact, reduced P inputs resulted in enhanced downstream N transport. Even in systems where discharges are to freshwater, material ultimately is transported downstream where it can enter the estuarine and marine environment where its reactivity changes and where N-limited organisms are adapted to using a broad spectrum of N compounds including organic N. Furthermore, unlike P, total N loads have increased since WWII as a result of increased use of N fertilizers (Howarth et al. 2002). In the Chesapeake Bay region, human activity has resulted in a 6 to 8-fold increase in N loading (Boynton et al. 1995), an increase that is typical of the region (Howarth et al. 1996).

In addition to the amount of N or P added to an estuary (e.g., loading), there are substantial differences in how N and P are cycled along the length of an estuary. Because freshwaters are often P-limited, P introduced at the head of an estuary may be rapidly removed by phytoplankton resulting in increased algal growth in the freshwater end members. In contrast, N delivered to freshwater systems is likely to move downstream until it reaches the N-limited estuarine portion of the watershed where it can result in excess algal production in more saline waters. An excellent example of this is the Neuse River estuary in NC; when P loadings were reduced during the mid-1980's, the chlorophyll maximum moved down-estuary from the P-limited freshwater end member to the more N-limited saline end member where nuisance phytoplankton blooms are now a regular feature (Paerl et al. 2004). As we alter nutrient loads to manage water quality, we need to determine the relative contribution of N versus P loading to water quality degradation in the upper versus lower estuary; we need a dual nutrient management strategy. In short, the spatial and temporal extent of downstream N limitation may be highly dependent on upstream nutrient management (Paerl et al. 2004).

In 2005, 370 million pounds of N were introduced into the Chesapeake Bay, more than twice the restoration target of 175 million pounds (Chesapeake Bay Program 2006). Although wastewater effluent from point sources represents only about 28% of the N load into the Bay (Kemp et al. 2005), effluents from wastewater treatment are the primary N load in many freshwater tributaries (e.g., Potomac, Rappahannock). Furthermore, controlling N at point sources (such as wastewater effluents) is logistically easier than controlling inputs from more diffuse sources, such as agriculture and atmospheric deposition. Accordingly, to ameliorate N pollution (and its effects) in the Bay, the Chesapeake Bay 2000 agreement mandated 48% reductions in N loads from point sources to the Bay and its tributaries (based on 1990 input levels). This agreement has resulted in increasingly stringent effluent discharge limits for wastewater utilities discharging into the Chesapeake Bay watershed; down to as low as 3 mg/L total N by January 1, 2011.

The capital cost to achieve this level of treatment by point sources discharging into Chesapeake Bay is estimated to be several billion dollars (Nutrient Reduction Technology Cost Task Force, 2002). Furthermore, the impact of implementing effluent guidelines down to 3 mg/L increases the cost of compliance substantially. The Nutrient Reduction Technology Cost Taskforce estimated that the capital cost to achieve effluent N levels of 5 mg/L at a 10 million gallon per day (MGD) plant that was not previously performing biological N removal was around $4.9 million. At the same plant, to implement limit of technology (LOT) treatment to achieve an effluent total N guideline of 3 mg/L would cost $9.6 million in capital costs. Operational costs also double for this scenario. Clearly, the economic impact of implementing LOT treatment levels is substantial. Consequently, the regulated community is unconvinced that reduction beyond that currently realized using conventional methods will provide substantial environmental benefits relative to the costs incurred given the uncertainty over whether all of the effluent N is bioavailable and therefore harmful to the Bay.

The regulated community has initiated an effort to determine, and discount from their total N loads, the fraction of total N in their effluent that is considered recalcitrant (Biological Nutrient Removal Boundary Conditions Workshop, Washington DC, March 2006; International Water Association/Water Environment Federation Nutrient Removal 2007, Baltimore, MD, March 2007). Much of the organic fraction of N in wastewater effluents has been considered to be recalcitrant. By extension, based on in-plant microbial processes, an argument has been made that this fraction is nonbiodegradable or bio-unavailable in the environment (Murthy et al. 2006). In concert with the perception that a fraction of EON may be inert, and therefore not harmful, dischargers are applying to regulatory agencies to amend their nutrient discharge allowances to exclude recalcitrant N. Indeed, a new Virginia regulation includes a provision that allows dischargers to argue for an increased discharge cap if they can demonstrate that nitrogen in their effluent is not bioavailable (9 VAC25-820). In order to safely apply this regulatory tool, it is necessary first to identify appropriate methods to assess the bioavailability of EON not just to treatment plant microbes but also within a watershed such as the Chesapeake Bay (STAC 2007) or any other N sensitive estuarine system around the world that contains a diverse microbial community. To be appropriate, any method that is developed must be applicable to not only the proximate receiving waters (typically freshwater), but also to the estuarine and marine systems downstream. Furthermore, it must be sensitive to changing environmental conditions along the length of the estuarine gradient. Finally, it must consider the impact of those changing conditions (salinity, changes in microbiota, generation of photodegradation products) on the overall bioavailability of EON.

At the same time, the ability of current LOT treatment plants to address the problem of bioavailable EON must be considered. Assays focused on assessing the fate of organic nitrogen in treatment processes over the time frame of the treatment technology used should be considered "technology-based assays" (Murthy, pers. comm.) while assays focused on assessing point source EON bioavailability in the receiving waters can be considered "water quality-based assays". A technology-based biodegradability assay is needed to determine the effect of treatment process factors and wastewater influent characteristics that impact what is finally released from the plant as EON. The nature of this assay may be very different from what is needed for a water quality-based assay assessing impact in the environment. Furthermore, information generated by the two different assays should advise each other. For instance, if the water quality-based assay identifies a fraction of EON from a given treatment plant (and, therefore, a given treatment technology) that is bioavailable somewhere along the freshwater to saltwater continuum, this material should be characterized to determine what makes it bioavailable. Subsequent assessment of where that type of organic nitrogen might be degradable within a plant (through the technology-based assay) *or generated* within treatment plants gives design engineers and operators key information toward understanding how their plant is contributing to removing bioavailable EON, and a pathway to finding a workable and realistic solution within the confines of LOT capability.

Definitions and Acronyms

The organic nitrogen constituents of interest are shown below in Figure 1. The influent organic nitrogen (iON) equals the sum of the influent particulate organic nitrogen (iPON) and influent DON (IDON). The influent DON consists of biodegradable (biDON) and non-biodegradable or recalcitrant (riDON). The main organic nitrogen component of interest in the wastewater treatment (WWT) process is the dissolved organic nitrogen (DON), because most of the iPON will either be captured in solids removal processes or converted to DON. The DON in WWT processes is referred to as treatment process DON (tDON) and it consists of a biodegradable component (btDON) and a non-biodegradable component (rtDON). The organic nitrogen in the WWT process effluent is referred to as effluent organic nitrogen (EON) and this also consists of particulate (EPON) and dissolved organic nitrogen (EDON). The particulate portion is defined by the effluent filtration pore size, with 0.45 μm commonly used for this application. The organic nitrogen in the filtrate is defined as dissolved but it may also contain some colloidal organic nitrogen. Of interest for the EDON is what portion is available for microbial growth (i.e, bioavailable –denoted bEDON) and what portion is not available or recalcitrant (rEDON) in the environment. The difference between btDON and bEDON is that btDON should be related to bacterial activity in the WWT process while the bEDON is should be related to the activities of microbes (both bacteria and algae) in receiving waters. These acronyms and their relationships are summarized in Figure 1 and defined below.

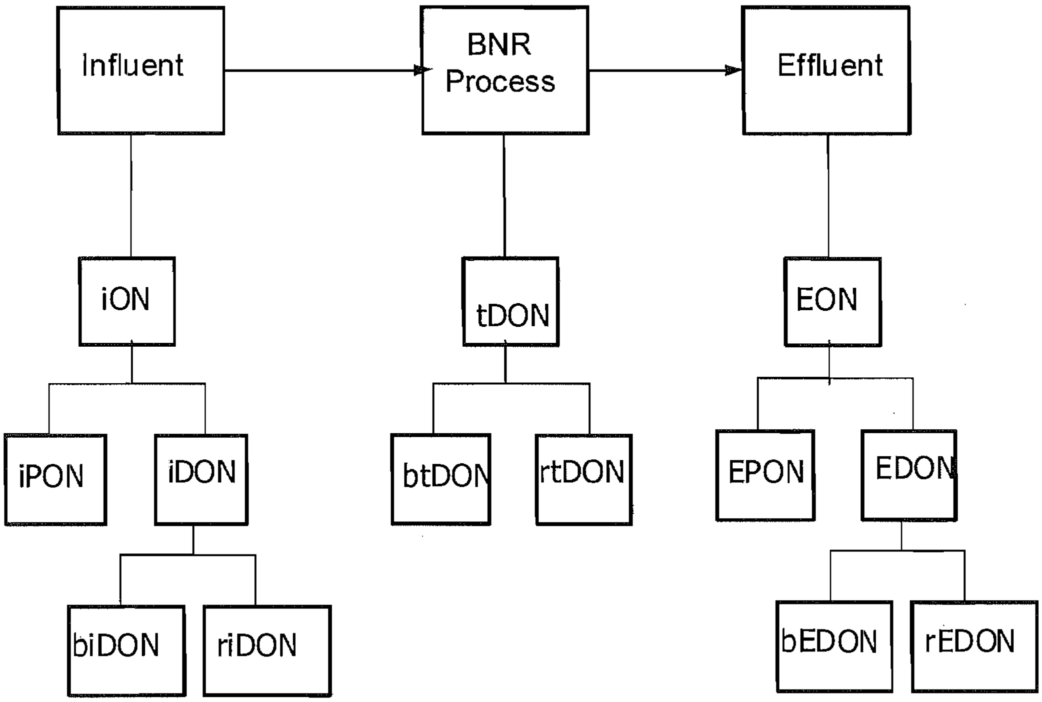


Figure 1. Organic nitrogen components of interest in WWT processes and receiving surface waters.

NH_3-N	Total ammonia-nitrogen: includes both free ammonia (NH_3) and ionized ammonium (NH_4^+)
NO_2-N	Nitrite-nitrogen
NO_3-N	Nitrate-nitrogen
TIN	Total inorganic nitrogen: sum of NO_2-N, NO_3-N, and NH_3-N.
TKN	Total Kjeldhal nitrogen: measures sum of organic nitrogen and NH_3-N
TN	Total nitrogen: Sum of inorganic and organic nitrogen as N
ON	Organic nitrogen; nitrogen contained in organic compounds (i.e. amino acids, peptides, and protein) and can be in dissolved form or contained in particulate material
DON	Dissolved organic nitrogen: organic nitrogen measured in the filtrate of a sample (influent, mixed liquor or effluent) following filtration
PON	Particulate organic nitrogen: organic nitrogen contained in wastewater solids or biomass.
iON	Influent organic nitrogen
iPON	Influent particulate organic nitrogen
iDON	Influent dissolved organic nitrogen
biDON	Biodegradable influent dissolved organic nitrogen
riDON	Non-biodegradable influent dissolved organic nitrogen
tDON	Dissolved organic nitrogen in the BNR treatment system
btDON	Biodegradable dissolved organic nitrogen in the BNR treatment system
rtDON	Non-biodegradable dissolved organic nitrogen in the BNR treatment system

EON	Effluent organic nitrogen: the sum of DON and PON in wastewater treatment plant effluent
EPON	Effluent particulate organic nitrogen
EDON	Effluent dissolved organic nitrogen
bEDON	Bioavailable EDON is effluent dissolved organic nitrogen that can be used in surface waters due to bacteria activity and algae uptake of nitrogen
rEDON	Recalcitrant EDON is effluent dissolved organic nitrogen that is resistant to biological transformation and uptake by microbes (algae and bacteria) in surface waters.
BNR	Biological nutrient removal: includes biological process designs for nitrogen and phosphorus removal.
SRT	Solids retention time: average time in days that solids are in the activated sludge system. It can be based on aerobic volume only or total volume.

II. Fate and Transport of Organic N in Aquatic Systems

The largest pool of fixed nitrogen (N) in most aquatic systems is DON (Bronk 2002). This is true even in oligotrophic environments (i.e. nutrient poor) where primary production is limited by available N. The persistence of DON in areas believed to be N-limited led to the traditional view that DON is largely refractory and therefore unimportant to microbial N nutrition in the environment. It was also widely believed that what DON was used was taken up by bacteria over relatively long scales. More recent research, however, has shown that even highly refractory compounds can be a source of bioavailable N to plankton as well as a vehicle to transport N through estuarine systems. Recent findings with new approaches also indicate that DON fuels a significant amount of autotrophic production (Berman and Bronk 2003; Mulholland and Lomas 2008). There is a wealth of data in the limnology and oceanography literature that can inform the discussion of EON bioavailability. As a broad overview, here we review the composition of DON in marine and aquatic systems, what we have learned about its lability, and conclude with why the issue is so important.

Is organic N Labile in Natural Waters?

Based on research to date it is safe to say that at least some fraction of organic N in marine and aquatic systems is labile. Although most DON in aquatic systems is uncharacterized, some similarities between the components of the naturally occurring DON pool and organic N in effluent suggest that the same could be true for EDON. The important question then becomes – what percentage of EDON is labile (bEDON), or more importantly, refractory (rEDON)?

Organic N Composition in Natural Waters

In the ocean, the DON pool is generally treated like a "black box", the composition of which is unknown but is expected to change over small space and time scales. One approach that has been used to characterize DON is size fractionation (e.g. Benner et al. 1992, Aluwihare et al. 1997, McCarthy et al. 1996, reviewed in Benner, 2002). Using an ultrafilter with a 1000 Dalton cutoff a number of researchers have collected sufficient high molecular weight (HMW) material for analysis. These investigations show that amide-linked N comprises the largest fraction of HMW DON (92%) with the remaining 8% consisting of amines (Aluwihare et al. 2005). In some estuarine and coastal systems, however, humics can contribute a significant fraction of measured DON (e.g. Alberts and Takács 1999). For example, in the Savannah and Altamaha estuaries of coastal Georgia humics contributed an average of 70% of the DON pool over a three-year period (Bronk et al., unpublished data).

Another approach to characterizing DON is based on lability. In this sense, the largest fraction within the DON box likely includes the truly refractory components that persist in the environment for months to hundreds of years (reviewed in Bronk 2002 and Bronk et al. 2007). Using terminology from the dissolved organic carbon (DOC) literature, a second fraction of the pool can be described as semi-labile (Carlson and Ducklow 1995). This fraction likely includes compounds such as proteins, dissolved combined amino acids (DCAA), and amino polysaccharides, which turnover on annual time scales. Mixed in with the refractory background, however, is highly labile DON; highly labile moieties including urea, dissolved free amino acids (DFAA), nucleic acids (reviewed in Bronk 2002), and peptides (Mulholland and Lee, in press). These labile compounds turnover on timescales of minutes to hours for amino acids (Fuhrman 1987) and peptides (Mulholland and Lee, in press), to days for urea (Bronk et al. 1998) and DNA (Jørgensen et al. 1993).

The bulk of research on DON availability has focused on the labile fraction. Recent work, however, has also shown that even HMW compounds such as humic substances, considered to be highly refractory, can be a source of N (i.e. See et al. 2006). Humics are operationally defined as DOM that adheres to a macroporous resin (i.e. XAD-8 or DAX-8; Peuravuori et al. 2002) at a pH of 2 (Aiken 1988). They can be further categorized into: 1) fulvic acids, which tend to be smaller (500-2000 Daltons) and are soluble in water at any pH, 2) humic acids, which are larger (2000-5000 Daltons or larger) and precipitate from solution at pH lower than 2 (Thurman et al. 1982), and 3) humins, which are insoluble at any pH.

Natural humic substances, isolated by XAD extraction, have been shown to contain 0.5 to 6% N (Rashid, 1985; Thurman, 1985; Hedges and Hare, 1987). Amino acids, amino sugars, ammonium (NH_4^+), and nucleic acid bases comprise 46 to 53% of the N associated with humic acids and 45 to 59% of fulvic acids (Schnitzer, 1985) with the remaining approximately 50% of humic-N unidentified (Carlsson and Granéli, 1993). Previous work indicates that the C to N (C:N) ratio of aquatic humic substances, isolated with XAD resin, ranges from 18 to 30:1 for humic acids and 45 to 55:1 for fulvic acids, but can vary considerably (Thurman, 1985; See, 2003; See and Bronk, 2005). The C:N of humic substances isolated with macroporous resins, however, may not reflect the C:N ratios of humic substances *in situ*. During the isolation procedure humic substances are acidified to a pH of 2, thus bombarding the solution with free protons. These free protons can bump off loosely associated amino groups such that humics isolated using resins have a C:N ratio higher than humics in natural waters (See and Bronk, 2005).

Bioavailability of Organic N in Natural Waters

The unknown composition of the bulk aquatic DON pool makes determining its bioavailability difficult. Bulk DON uptake by microorganisms has been examined using a bioassay approach (Berg et al. 2003; Stepanauskas et al. 1999a, b; Wiegner et al. 2006) as well as by synthesizing ^{15}N-labeled DON (Bronk and Glibert 1993, Bronk et al. 2004). Isotopic tracers are currently available for only a small fraction of the pool. As a result, bioassay approaches have been used to monitor the decrease in DON concentrations over time. One difficulty with the bioassay approach is it requires the ability to measure relatively small concentration changes in a large pool. Bioassays only measure net flux within a pool, such that even large DON uptake rates could be immeasurable if rates of DON regeneration or production are also high. Despite these drawbacks, a number of studies have used dark bioassays in aquatic systems to measure heterotrophic bacterial utilization of DON. In general, this work suggests that 12 to 72% of the DON pool is bioavailable on the order of days to weeks (reviewed in Bronk 2002). However, it should be noted that phytoplankton can also take up DON during the dark (see Mulholland and Lomas 2008)

In another study, water samples were collected from rivers and estuaries differentially impacted by anthropogenic modification (Wiegner et al. 2006). Dark bioassays were performed with a single bacterial inoculum to compare DON and DOC lability across a range of systems that varied in their amount of forest cover. As much as 40% of the DON was consumed over a 6 day incubation and up to 80% of the total N utilized by the inoculum was organic in form. These results show that classifying all DON as refractory underestimates the bioavailability of this pool in the marine environment.

The refractory nature of humic substances has also recently been challenged, and accumulating evidence indicates that coastal phytoplankton may have the ability to take up humic-N, either directly or after remineralization (Carlsson et al. 1995, 1999). More recently, the uptake of laboratory-produced ^{15}N-labeled humic compounds by the > 0.7 μm size fraction has been observed in both riverine and coastal ecosystems (Bronk et al., unpubl. data), humic substances have been implicated as a potential source of C and N to the toxic dinoflagellate *Alexandrium catenella* (Doblin et al. 2000), and growth of another toxic dinoflagellate *Alexandrium tamarense* was shown to increase when exposed to humic substances (Gagnon et al. 2005). Uptake of humic-N into phytoplankton biomass was also measured directly using ^{15}N-labeled humic substances produced in the laboratory (See and Bronk 2005). In this study, non-axenic cultures of 17 recently isolated estuarine and coastal phytoplankton strains took up ^{15}N-labeled humic-N (See et al. 2006), however, high rates of humic-N uptake were not sustained over long periods of time, suggesting that only a finite pool of labile N is associated with these compounds (See et al. 2006). No uptake of ^{15}N-labeled humic-N was detected in two axenic cultures suggesting that in at least these two cultures, bacterial remineralization was required to make the humic-N bioavailable.

Factors that impact the fate of organic N

DON bioavailability in estuarine and marine systems has received a lot of attention recently; see reviews in Antia et al. (1991), Bronk (2002), Bronk and Flynn (2006), and Bronk et al. (2007). In contrast, our knowledge of DON bioavailability in freshwaters is still in its infancy (deBruyn and Rasmussen 2002, Pellerin et al. 2006), largely because freshwaters are generally P limited. Overall, the lability of natural dissolved organic matter (DOM) appears to vary across aquatic ecosystems with higher lability in lakes and marine systems and lower lability in river systems (del Giorgio and Davis 2003). Another recent study found that anthropogenically-derived DON was more bioavailable than forest-derived DON (Seitzinger et al. 2002).

Salinity. Changes in salinity are known to alter the bioavailability of DOM and to affect photochemical reactions (McCallister et al. 2005, See 2003, See and Bronk 2005, Minor et al. 2006). In addition, the microbial community (bacteria and phytoplankton) changes along the estuarine gradient (Crump et al. 2004, Marshall et al. 2005), which will affect nutrient processing and ecosystem functions (see below). Salinity can also result in conformational changes that can influence both the abiotic and biotic reactivity of DOM, including humic substances (Baalousha et al. 2006). Salinity effects are important to consider when discussing EON bioavailability because the salinity increases along the length of the estuarine transit of a waste stream, and salt influences the behavior, conformation, and reactivity of DOM as it moves through an estuary (Baalousha et al. 2006).

Salinity may also affect the transport of N associated with organic compounds. Recent studies show that humic substances are capable of adsorbing NH_4^+ from surrounding waters to cation binding sites located on the humic structure (See and Bronk 2005). The adsorption of NH_4^+ to humic substances makes them a potentially important shuttle for transporting N that is produced upriver to the estuary and coastal ocean. As the humic materials move downriver, encountering higher salinities, the salt ions can displace the loosely bound amino groups on the humic structure, releasing them into the environment. In laboratory experiments with humics isolated from three different rivers, concentrations of free NH_4^+ increased in solutions with humics when the salinity of the surrounding water increased; the release of NH_4^+ was rapid and reproducible (See 2003, See and Bronk 2005). The question is whether EON, which contains humic substances, operates in a fashion analogous to the humic shuttle. If NH_4^+ binds to EON within the treatment plant, it may not be removed by the coupled nitrification/ denitrification process. Similarly, when reduced forms of N are released from the plant as EON, ammonified or loosely associated amino groups may dissociate from the EON as it is transported into water with higher salinities; in effect, resulting in an EON shuttle.

Light. Recent findings in freshwater and marine systems indicate that photochemical processes can effect the release of labile nitrogen (N) moieties from DOM (reviewed in Bronk 2002). Bushaw et al. (1996) demonstrate that DON from a freshwater pond is a source of labile N for microbial processes, but only after the DON is irradiated with sunlight and that wavelengths in the ultraviolet (UV) region (280 - 400 nm) produce these compounds from DOM sources most efficiently. This photochemical reactivity can alter the bioavailability of DON. However, photochemical reactions can affect the lability of organic material along estuarine gradients (Bushaw et al. 1996, Minor et al. 2006) and readily convert refractory DON to labile forms. A recent paper shows that biologically recalcitrant DOM can be converted into bioavailable forms via photochemical reactions and subsequently stimulate N-limited microbial food webs (Vähätalo and Järvinen 2007). Additionally, previous work has shown that NO_2^- and NH_4^+ can be released from DON photochemically (e.g. Kieber et al. 1999, Koopmans and Bronk 2002). This release may explain why bacterial growth efficiency, bacterial nutrient demand, and bacterial biomass and respiration rates are influenced by light (McCallister et al. 2005). Previous studies of EON bioavailability confined their work to dark reactions using technology-based assays (Murthy et al. 2006).

Plankton community composition. The microbial community present in a given environment will also likely impact what organic compounds are bioavailable. Various bacteria and phytoplankton species have different transport and enzyme systems that allow them to take up a range of N substrates (see Berges and Mulholland 2008, Mulholland and Lomas 2008). The composition of DOM is known to be affected by bacterial growth and bacteria alter the composition of the DOM (e.g. Hopkinson et al. 1998). In the case of phytoplankton, we now know that algal uptake of components of the DON pool, such as dissolved free amino acids (DFAA), can be significant in aquatic environments (e.g. Bronk and Glibert 1993; Mulholland et al. 2002, 2003; Berman and Bronk 2003; Bronk et al. 2007). In addition, a variety of other identifiable DON forms can be used as N sources by algae including dipeptides (Mulholland and Lee, in press), urea (Bronk et al. 1998, Lomas et al. 2002), dissolved combined AA (DCAA)

(Jørgensen and Jensen 1997), peptidoglycan (Jørgensen et al. 2003), and cyanate (Palenik et al. 2003). Further, humic-bound N, which is also found in effluent, can be used by phytoplankton as an N source (See et al. 2006) and bacterial reactions can degrade other DON compounds making them available for uptake by algae (e.g. Berg and Jørgensen 2006). In addition to direct uptake of specific DON compounds, there are a variety of extracellular enzymatic systems used by microbes (including algae) to convert HMW DON into LMW labile organic forms (e.g. Palenik and Morel 1990; Pantoja and Lee 1994, 1999; Pantoja et al. 1997; Mulholland et al. 1998, 2002, 2003; Berg et al. 2002; Stoecker and Gustafson 2003; Mulholland and Lee, in press).

Importance of Determining the Lability of Organic N and its Ultimate Fate

In a review of DON in rivers, Seitzinger and Sanders (1997) estimate that 14 to 90% of the total N in a suite of rivers around the world is organic. This DON represents a large source of N to the coastal zone that is currently ignored in some N loading budgets. This is especially troubling when one considers that effluent from even the most efficient wastewater treatment plants contain approximately 285 μM N with roughly two thirds of the discharged N being organic in form (Pehlivanoglu and Sedlak 2006). Some individuals argue that EON should not be included in N discharge budgets based on the traditional view that DON is not bioavailable and therefore will not contribute to eutrophication. The brief review of recent studies above suggests that this traditional view is incorrect. Collectively, data from bioassays and tracer approaches suggest that bioavailable DON can be utilized within estuaries with water residence times on the order of weeks to months. In systems where residence times are shorter, riverine DON will pass through the estuary and be a source of bioavailable N to coastal waters. Results from studies with individual organic compounds indicate that some fractions of DON have much quicker turnover times and consequently contribute to plankton nutrition even in systems with very short residence times. It is becoming increasingly evident that a significant fraction of DON is bioavailable and contributes to coastal eutrophication and, as such, should be included in N loading budgets. The challenge will be to determine what fraction is biologically available.

Although research on DIN and DON uptake by phytoplankton and bacteria has been fairly extensive, relatively little is known about how these two groups compete for limiting N resources and the time scales of the competition (see Mulholland and Lomas 2008). This is an important issue because it will ultimately determine the ecological effects of releasing the material into the environment. In estuarine and coastal ecosystems, the relative use of organic N (or EON) by autotrophs versus heterotrophs will potentially affect plankton community composition, energy transfer to higher trophic levels, and benthic-pelagic coupling. If DON (or EON) is primarily used by phytoplankton it is more likely to make it into higher trophic levels, including, for example, commercially important fish. Phytoplankton also generate oxygen during growth and sequester CO_2^-, an important consideration when discussing global change issues. If its ultimate fate is bacterial uptake than the N and C is less likely to make it into higher trophic levels. Bacteria release CO_2^- and take up oxygen, thus potentially generating or exacerbating the environmental problem of hypoxia or anoxia. Finally if the organic compounds are not used by phytoplankton or bacteria in a time period less than the residence time of the water in a given area that the ultimate fate is advection – either down river, down estuary, or out to sea. Clearly, the type of N entering coastal and estuarine waters can play a significant role in altering plankton community structure, but may also affect broader scale processes determining overall ecosystem health.

III. EON Components in Wastewater Treatment Processes

Nitrogen Components in Wastewater Treatment Plant Effluents

The wastewater treatment plants where EON exists as a significant fraction of the total effluent nitrogen are biological nitrogen removal (BNR) facilities. Table 2 shows the effluent nitrogen constituents that contribute to the effluent TN concentration from a BNR treatment process, and the BNR process mechanism and factors that affect the respective effluent concentration. Note that key process design parameters that affect the ability to achieve minimal effluent TN concentrations (LOT performance) from BNR systems are longer solids retention times (SRTs), carbon addition for NO_3-N and NO_2-N removal, and enhanced effluent solids removal by membrane separation or filtration. Other factors may be the impact of variable loadings due to seasonal or wet weather conditions and the impact of in-plant recycle streams such as nitrogen-rich centrate return.

Table 2. BNR effluent nitrogen constituents and process removal mechanisms.

Nitrogen constituent	Process removal mechanisms	Known factors affecting ability to reach minimum concentrations
NH_3-N	Nitrification	Temperature, pH, dissolved oxygen, SRT
NO_2-N	Oxidation to NH_3-N Denitrification	Temperature, pH, dissolved oxygen, SRT Temperature, SRT, carbon source, anoxic detention time
NO_3-N	Denitrification	Temperature, carbon source, anoxic detention time
EDON	Hydrolysis and ammonification	Temperature, SRT
EPON	Clarification, filtration or membrane separation	Liquid-solids separation process design

Filter pore size is used to define EDON, iDON and tDON

The DON concentration measured for influent, treatment process or effluent samples will depend on the filter pore size used to separate particulate and colloidal solids from a sample. The common filter size for "dissolved constituents" is 0.45 μm and has been used to define EDON in many studies. In bioassays aimed at determining the biodegradable DON by bacteria in wastewater treatment processes (btDON) (Khan 2007) and on the bioavailable EDON for freshwater algae consumption (Pehlivanoglu and Sedlak 2004), a 0.20-0.22 μm filter size has been used. A 0.45 μm filter size has also been used to quantify EDON. An unquantified fraction of the total colloidal organic nitrogen passes through 0.45 μm filters and possibly through a 0.20 μm filter and ends up as part of the EDON. The only way to separate this from the truly dissolved fraction is with ultrafiltration, and to date those studies have not been done.

The data in Table 3 were presented by Pagilla (2007) and show the effect of filtration pore size on the organic nitrogen concentration for effluents from a number of wastewater treatment facilities. For some plants the effluent colloidal organic nitrogen contained in the so-called DON fraction can be significant. There is also the possibility of colloidal organic nitrogen in filtrate from 0.10 μm filtration.

Table 3. EDON measurements (mg/L) as a function of filter pore size (Pagilla 2007)

	Filter pore size		
WWTP	1.2 µm	0.45 µm	0.10 µm
Stickney	2.9	1.7	1.6
Hinsdale	4.2	3.6	3.6
Elmhurst	2.1	2.0	2.0
Gdynia	3.4	2.4	1.5
Gdansk	1.9	1.3	0.4
Elblag	5.0	2.7	2.0
Slupsk	1.6	1.6	1.0

What fraction of the effluent TN is EDON?

Figure 2 illustrates effluent TN concentrations possible from a BNR LOT system and the relative contributions of the nitrogen constituents. In this case the EDON concentration is assumed to be 1.0 mg/L. The effluent TN concentration may range from 2.0 to 4.0 mg/L, depending on the ability to minimize the NO_3-N and NH_3-N concentrations and maximize effluent suspended solids removal. For BNR LOT processes filtration or membrane separation would be used, so the EPON contribution would be negligible or minimal. No single minimum TN concentration value can be projected for all facilities as the effluent value is affected by influent flow and strength variations, equipment malfunctions, recycle streams, process design, and plant operations.

The figure shows that the EDON concentration can account for 25 to 50% of the effluent TN concentration and thus is very significant for systems needing to reach minimum TN concentrations. For applications with an effluent TN concentration goal of less than 10 mg/L (typical value for water reuse applications), the EDON concentration is not as great of a concern.

Typical EDON concentrations in BNR processes

Table 4 summarizes EDON values from various BNR facilities and shows EDON concentrations ranging from 0.10 to 2.80 mg/L. Figure 3 shows a composite summary of the data. The 50 and 90 percentile values are 1.2 and 2.1 mg/L, respectively. There is a wide range of observed EDON concentrations observed from BNR processes, and it appears that in some cases the EDON can be at a high enough concentration to make it impossible to meet an effluent TN concentration goal of 3.0 mg/L. Furthermore Pagilla (2007) (Table 4) indicated that about 65% of 188 facilities in Maryland and Virginia had EDON concentrations at 1.0 mg/L or less. The reasons for the higher EDON concentrations are not known at this time.

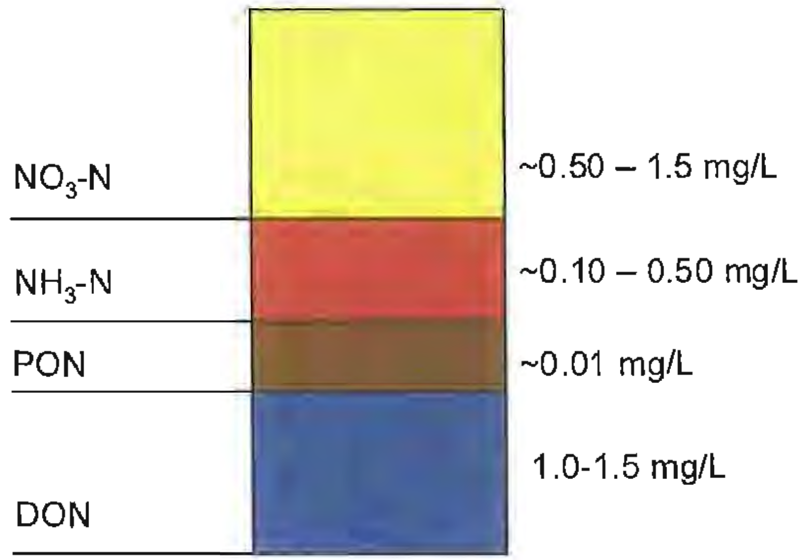


Figure 2. BNR effluent TN concentration possible and amount from nitrogen constituents

What is the composition of EDON?

Sedlak and Pehlivanoglu (2007) evaluated the molecular weight distribution of EDON and hypothesized that the HMW fraction (MW greater than 1 kDa) was not biologically available. The composition of this fraction has not been determined but is expected to be made up of larger molecular weight humic substances. Of the lower molecular weight compounds that may be bioavailable, only about a third have been identified as free and combined amino acids and ethylenediaminetetraacetic acid (EDTA). Other N-containing compounds in BNR effluents may include N-containing pesticides, pharmaceuticals, and other trace organics.

What are possible sources of DON in BNR facility influent or in the treatment process?

DON originates in domestic wastewater influent as urea (60-80% of domestic influent TKN), amino acids, proteins, aliphatic N compounds and synthetic compounds, such as EDTA. DON may also be produced and released or altered during biological wastewater treatment processes, including sludge digestion, due to cell metabolism processes that excrete biomolecules, cell decay and cell lysis. Humic organic substances may be present in some drinking water supplies and therefore contribute to the wastewater DON. Little is known about industrial wastewater compounds that may contribute to DON in combined municipal-industrial wastewater treatment plants. Thus, EDON may consist of influent recalcitrant DON, DON produced through or altered by microbial activity in the BNR process, and biodegradable DON that remains in the effluent.

Table 4. Summary of effluent dissolved organic nitrogen values reported.

Plant Location	EDON mg/L	Percentile %	Reference
Gordonsville, VA	2.80	97	Pagilla (2007)
Daytona Beach, Fl, Bethune	2.46	94	Jimenez et al. (2007a)
Back River WWTP	2.24	91	Parkin and McCarty (1981)
New Smyrna, Fl	2.10	88	Jimenez et al. (2007a)
Daytona Beach, Fl	2.00	85	Jimenez et al. (2007a)
City of Bradenton, Fl	2.00	82	Jimenez et al. (2007a)
JEA Black Fords, Fl	1.88	79	Jimenez et al. (2007a)
City of Palmetto, Fl	1.80	76	Jimenez et al. (2007a)
Stamford, CT	1.70	74	Sharp and Brown (2007)
Orange County, Fl, Eastern	1.55	71	Jimenez et al. (2007a)
Fort Meyers, Fl, Central	1.50	68	Jimenez et al. (2007a)
TMWRF, NV	1.50	65	Pagilla (2007)
Palo Alto, CA (2)	1.50	62	Randtke and Mccarty (1977)
Homestead, Fl	1.40	59	Jimenez et al. (2007a)
Lynn Haven, Fl	1.40	56	Jimenez et al. (2007a)
Bayou Marcus, Fl	1.37	53	Jimenez et al. (2007a)
City of Tarpon Springs, Fl	1.20	50	Jimenez et al. (2007a)
City of Clearwater, Fl	1.20	47	Jimenez et al. (2007a)
City of Largo, Fl	1.20	44	Jimenez et al. (2007a)
Chesapeake Beach, MD	1.20	41	Pagilla (2007)
Blue Plains, D.C.	1.20	38	Pagilla (2007)
City of Dunedin, Fl	1.18	35	Jimenez et al. (2007a)
Truckee Meadows, NV	1.00	32	Sedlak and Pehlivanoglu. (2007)
Titusville, Fl	0.95	29	Jimenez et al. (2007a)
Fort Meyers, Fl, south	0.94	26	Jimenez et al. (2007a)
Piscatway, MD	0.90	24	Pagilla (2007)
Palo Alto, CA	0.90	21	Randtke and McCarty (1977)
Orlando, Fl	0.88	18	Jimenez et al. (2007a)
Tampa, Florida	0.73	15	Jimenez et al. (2007b)
Alexandria, VA	0.70	12	O'Shaughnessy et al. (2006)
Boone WWTP, VA	0.69	9	Wikramanayake et al. (2007)
Fort Meyers, Fl	0.60	6	Jimenez et al. (2007a)
Upper Potomac R., MD	0.10	3	Pagilla (2007)

* DON in Jimenez et al. (2007a) reference estimated from effluent TN and TIN concentrations

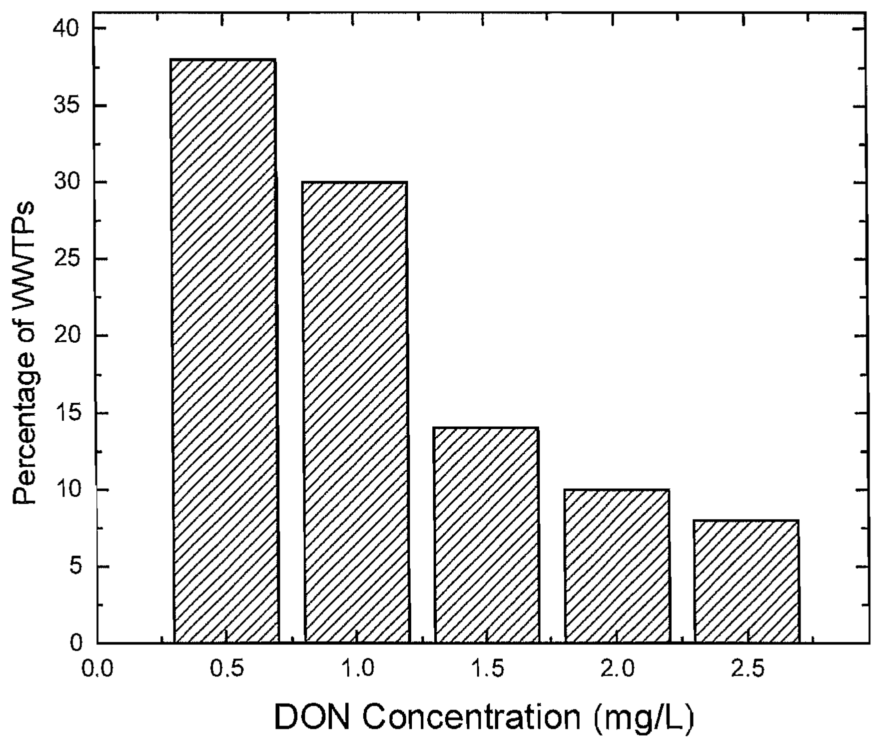


Figure 3. Summary of EDON concentration (0.45 μm filtration) from 188 Maryland and Virginia wastewater treatment plants (Pagilla 2007).

IV FATE OF DON IN BIOLOGICAL WASTEWATER TREATMENT

In early work by Parkin and McCarty (1981), the composition and fate of DON at the Palo Alto, CA wastewater treatment plant was studied. The average EDON concentration was 1.5 mg/L. They claimed that 52% of it was recalcitrant from influent wastewater sources, 20% was produced from biomass endogenous decay in the activated sludge process, 15% was in equilibrium between that sorbed to biomass and the liquid and about 13% could be further degraded. However, they noted that while increasing the activated sludge SRT could further degrade influent DON, DON could also be added via biomass endogenous respiration thereby negating any positive effect. Based on the balance between consumption and production of DON, they claimed that the optimal operating point leading to a minimal EDON concentration after influent DON biodegradation and microbial DON release was at an SRT of 6-10 days. A number of important concepts regarding the fate of DON in wastewater treatment were revealed in this work: 1) some portion of the influent DON was not bioavailable, 2) increasing the system SRT could minimize the biodegradable DON concentration, and 3) increasing the SRT could increase the non-biodegradable DON concentration due to contributions from biomass endogenous decay.

Determining the fraction of influent DON that is biodegradable is a subject of current research. Work reported by Khan (2007) suggested that 40-60% of influent DON is biodegradable. This is in the range of that given by Parkin and McCarty (1981) above. The relative effectiveness of different biological treatment process technologies on degrading influent or biomass-derived organic nitrogen has not been studied.

V Controlling and Minimizing EDON from BNR Facilities

The design and operating conditions that can minimize EDON concentrations in BNR facilities is also a current research topic. One issue is whether the optimal SRT required to achieve minimal EDON concentration is compatible with the SRT needed to maximize inorganic nitrogen removal efficiency. The impact of DON in recycle streams from aerobic or anaerobic digestion and dewatering needs to be further evaluated.

Of further interest is identifying process technologies that can be used to achieve effective EDON removal from a BNR process effluent. Randtke and McCarty (1977) evaluated physical-chemical processes for EDON removal in the Palo Alto, CA effluent. The EDON concentration in bench scale tests with the Palo Alto facility effluent was 1.3 mg/L. For chemical treatment, the removal efficiencies were 33% with lime, 28% with 200-300 mg/L alum, and 40% with 200-300 mg/L ferric chloride. These are very high coagulant doses that are unlikely to be practical. Removal efficiencies were lower for cation and anion exchange (less than 13%). About 71% of the EDON was removed with activated carbon adsorption.

Generally, HMW EDON constituents are considered to be non-biodegradable or recalcitrant (rEDON). Other removal methods for rEDON constituents would be very expensive, requiring either chemical oxidation processes or reverse osmosis. The chemical oxidation processes would need to be followed by a biological treatment step to biodegrade the oxidation products.

VI Fate and Effect of EDON in Surface Waters

In general, the fate and effect of EDON in surface waters is not currently known. The potential impact of bEDON on surface waters was discussed in section II. Whether EON is more or less reactive than naturally-derived organic nitrogen is not yet known. Based on what we know about EDON, however, the following can be stated. Hydrolysis and deamination of EDON can produce inorganic and organic forms of N that can be taken up by estuarine microbes, including algae (see above). Further, many microbes can hydrolyze large compounds extracellularly prior to their uptake (Pehlivanoglu and Sedlak 2004, Mulholland and Lee in press, see also above). There is less known about the availability of nitrogen in HMW humic substances; however, in general, it is considered less bioavailable by some and has been termed recalcitrant EDON (rEDON), even though some environmental studies suggest that at least portions of this pool are bioavailable (see above).

Key to this debate is defining the fraction of EON that is recalcitrant. rEDON is that portion of effluent DON that is considered not available for algal or bacterial growth over time scales of days to weeks. During this timeframe, discharged EON may move through fresh water or both fresh water and more saline waters, depending upon the residence time in particular segments of an estuary. Salinity may play a key role in the bioavailability of at least a portion of the EON pool. At this time, it is not known if the specific type of humic compounds and possibly other HMW nitrogen compounds present in BNR effluents are bioavailable in saline environments.

VII IMPACT OF rEDON ON MEETING REGULATED EFFLUENT TN CONCENTRATIONS

Just as there is a wide range of EDON concentrations observed at BNR facilities (e.g. Table 3), it is not possible to generalize regarding the fraction of the EDON that is rEDON at all treatment plants. Using a freshwater bioassay procedure that included algae and bacteria, and effluents with low final TN concentrations, the fraction of EDON available for algae growth over a 14-day incubation period was 56% (Pehlivanoglu and Sedlak, 2004) and 18 to 61% (Urgun-Demirtas et al. 2007). Based on these observations, the potential fraction of rEDON in EDON from BNR facilities may be 40-80%. A similar analysis has not been done for treatment plants that discharge into watersheds that are significantly estuarine, which constitutes all of the treatment plants in the Chesapeake Bay region and many others located near coasts.

There is great interest in determining the effect of rEDON on the cost and ability to meet stringent effluent TN concentration permit values. Here, we provide a simple estimate of that cost considering typical values currently available from the research that has been done to date. For eutrophication-impaired surface waters, a common regulated effluent TN concentration value is 3.0 mg/L. Assuming that the EDON concentration is 1.0 mg/L, and that 50% is available for algae growth, the rEDON accounts for 0.50 mg/L of the effluent TN concentration. This is a significant concentration and affects the operational and design challenge for TIN removal. If the rEDON contribution is not included in the permit effluent TN concentration, the plant allowable effluent TIN concentration could be increased to 2.5 mg/L from the 2.0 mg/L concentration in this example; a reduction of 0.50 mg/L in the amount of NO_3-N that must be removed.

The impacts of removing 0.50 mg/L of NO_3-N are increased operating cost for carbon addition and increased carbon dioxide emissions that contribute to greenhouse gases. Therefore, if this nitrate did not need to be removed because 0.5 mg/L of the EDON is found to be recalcitrant, the annual savings can be estimated (see Table 5 for different plant sizes). The calculation assumes a methanol dose of 3.2 mg methanol per mg of NO_3-N removed and a methanol cost of $0.20/lb. For a 100 Mgal/d facility, the methanol cost savings is about $97,000 per year and for a 5 Mgal/d facility it is about $5,000 per year. If a nutrient trading program is in place, the value of selling the rEDON as a credit can increase significantly beyond the estimated values in Table 5.

Table 5. Annual reduction in operating cost if 0.50 mg/L NO_3-N is not removed from the effluent to compensate for an rEDON concentration of 0.50 mg/L for a plant with an effluent TN concentration goal of 3.0 mg/L.

Flowrate, Mgal/d	5	10	20	100
Annual Methanol Cost	$4,900	$9,700	$19,000	$97,000

VIII BIOASSAYS FOR MEASURING DON

At present, there is no consensus as to the appropriate way to determine bEDON or rEDON using bioassays. Two possible approaches are outlined below.

Goals of Different DON Bioassays

Bioassays are done to determine the biodegradability or bioavailability of DON. The recalcitrant DON in the wastewater influent (determined through technology-based assays) and in the rEDON (determined through water quality based assays) is of major interest from both a wastewater treatment perspective and a regulatory perspective. The type of bioassay employed depends on the ultimate goal of the test. For in-plant issues the test goals may include: 1) determining what portion of iDON is not subject to biotreatment or is recalcitrant (riDON), 2) what portion of the EDON from the treatment process may be biodegradable and thus removed with longer treatment time in the BNR process, and 3) what amount of recalcitrant DON may be in recycle streams to the treatment process. All of these goals involve the BNR treatment process and the biodegradability of DON by bacteria within the treatment plant. Therefore, the bioassay procedure should incorporate biomass from the BNR process being assessed. This approach is referred to as a "***technology-based bioassay***" because it assesses the biodegradability of DON during the treatment process **within** the plant (Awobamise et al., 2007).

On the other hand, to evaluate the impact of EDON in wastewater treatment effluents on the environment (the goal of the CBP and regulatory agencies), the bioassay goal is to determine the fraction of the EDON that is recalcitrant (rEDON) in receiving waters and thus will not contribute to eutrophication. In this case, the bioassay needs to account for the independent and combined effects of light, salinity, and microbial (bacteria and algae) community structure on the bioavailability of EDON in the environment. This bioassay is a "***water quality-based bioassay***." The recalcitrant fraction is determined by measuring the EDON that remains in a bioassay after exposure indiginous conditions experienced as effluent is transported from proximate to ultimate receiving waters. The time period of this bioassay has to be long enough and conditions appropriate to allow evaluation of bEDON as EDON transits through the system and experiences natural or simulated changes in the environment. However, bioassays cannot be so long as to allow steady state internal recycling of EDON within the bioassay to mask changes that might occur in the environment.

The Technology-Based DON Bioassay Protocol

Khan (2007) used a technology-based assessment protocol (Table 6) to determine if activated sludge biomass could further biodegrade EDON in wastewater plant effluent samples The outcome from this test can be used to determine if treatment plant biomass can further degrade the EON if given more time than was provided through the treatment process. The test is in its early stages of development and application, so that future modifications to the protocol are possible. The test is done with 300 mL BOD bottles and follows changes in dissolved oxygen (DO) concentration to thus also determine the BOD satisfied in the sample over time. The test also requires DON measurements at time intervals. The bEDON concentration is the difference between the initial EDON concentration and that at time t. Because the method is a technology-based bioassay that looks at the potential for BNR mixed liquor to further biodegrade EDON if the process retention time were to be extended, it is appropriate to conduct the assays in the dark because photosynthetic metabolisms do not routinely occur in activated sludge treatment. This bioassay may be used to evaluate the impact of various BNR process designs on minimizing bEDON, the contribution and impact of recycle flows, and the potential for increasing the system SRT to further reduce the bEDON concentration.

Table 6. Biodegradable (bEDON) bioassay protocol[a] (Awobamise et al. 2007) (300 mL BOD bottles)

Test Components	Procedure	Comments
Sample preparation	Use filtrate from 0.22 μm glass fiber filtration	Effluent filtrate or primary effluent?
	Saturate DO by aeration or shaking	
	Add 2 mL inoculum	Inoculum is mixed liquor from the same treatment plant at 240 mg/L
Seed control	Add 2 mL inoculum to distilled water	
Test bottle incubation	Unmixed and at 20ºC	In the dark
	5-20+days	For ultimate bEDON, the time is not yet known
	Check and adjust DO periodically	Time intervals may be 0, 5, 10, 20 days or more*
DON measurements	Measure DON at sample time intervals	Time intervals may be at 0, 5, 10, 20 days or more[b]

[a] Although this is listed as a bEDON method, unfiltered samples can be used to determine the bEON
[b]- Awobamise et al. (2007) found most bEDON to be gone by 20-30 days

A First-Generation Water Quality-Based DON Bioassay Protocol

A surface water quality-based assessment protocol under consideration is summarized in Table 7 below. It was first applied to measure bEDON by Pehlivanoglu and Sedlak (2004) and later by Urgun-Demirtas et al. (2007) for a number of BNR effluents. In both cases, more EDON was consumed when bacteria were present in the test with algae versus algae alone, indicating a synergistic relationship between algae and bacteria, consistent with Bronk's results regarding humic-N (see above). The test uses a freshwater alga, thereby limiting its application to BNR plants that discharge into exclusively freshwater watersheds. Modifications to the protocol are needed to determine the bEDON (DON lost) or rEDON (DON retained) for treatment plants located in watersheds that discharge into freshwater estuarine end-members or estuarine watersheds (Mulholland et al. 2007). The bEDON consumed by the algae is estimated by measuring the conversion of bEDON into plant (chlorophyll *a*) biomass relative to control incubations. The test protocol is in its early stages of development and application, and future modifications are possible.

The value of this water quality-based assessment method is not presently fully understood due to the use of a single, non-indigenous lab-cultivated freshwater alga and activated sludge biomass that may not be indicative of biomass found in surface waters. Furthermore, application of the method is limited to treatment plants contained entirely in freshwater watersheds. A benefit of this method is that it is relatively easy to standardize and implement. If results from this method are found to correlate in a predictable way with more complex bioassays that use indigenous microbiota, then it could be valuable as an indicator.

Important Factors for a Revised Surface Water Quality-Based DON Bioassay Protocol

Key parameters that appear to affect the bioavailability of EDON by microbes include the salinity and pH of the water receiving EDON. It appears that nitrogen-containing humic substances are more bioavailable in saline water versus fresh water. The sorption of ammonium on humic material is also affected by salinity and ammonium is likely to desorb in higher salinity waters (see above). Further, organic material undergoes conformational changes as a result of exposure to saline waters (Canuel, pers. comm., see above). In addition to physical and chemical interactions of nitrogen species due to water chemistry, it is known that populations of bacteria and algae species present in aquatic systems have particular salinity tolerances. These variations in population dynamics across a receiving stream watershed are not captured in the previously mentioned protocols that employ organisms that are oligohaline or have a limited range of environmental tolerances that do not span the entire estuarine continuum. Therefore, the ideal water quality-based assessment protocol should consider the receiving water physical characteristics and microbial diversity. This complicates the development of a simple protocol as few organisms span the entire estuarine continuum.

Another factor not addressed in the protocols presented above is whether the microbes responsible for the uptake or conversion of EDON to nitrogen forms that may be bioavailable for algae require additional carbon sources or other nutrient elements (e.g. P, trace metals, or vitamins) to maintain their activity during the incubation periods used in the assays. Evidence from previous studies on natural (not effluent) DON bioavailability in surface waters suggests that long assay times may not be necessary and, in fact, may be detrimental to effective interpretation of results. Del Giorgio and Davis (2003) concluded that the only portion of any bioassay that can be compared to *in situ* metabolic rates is the initial stage, when the pool of labile ON and the physiological state of organisms stills reflect *in situ* conditions. Additionally, bacteria can modify DOM, making it resistant to further degradation (Ogawa *et al.* 2001; Keil and Kirchman 1991). The net effect of long bioassays is simply to cycle N among dissolved and particulate pools in a closed system where there is tight coupling of N reactions. Thus, long incubation times under closed-bottle conditions likely reflect steady state N recycling rather than true bioavailability of the initial starting material. Appropriate incubation times that allow EON bioavailability or recalcitrance to be assessed in bioassays needs to be determined and is likely to be system-specific.

Table 7. A water quality-based assessment protocol for determining rEDON using 500-mL sample flasks (Pehlivanoglu and Sedlak 2004)

Test Components	Procedure	Comments
Sample preparation	1. Chlorinated effluent samples dechlorinated with sulfur dioxide 2. Use filtrate from 0.20 µm glass fiber filtration and fractionate with ultrafilters down to 1 kDa MW. 3. Distilled water and EDON samples spiked with 1 mg/L NO_3-N were run in parallel	
Bacteria inocula	1. Filter 3L of surface water first with 1 µm glass fiber filter 2. Filter 1 µm filtrate through 0.20 µm membrane filter 3. Suspend retentate of 0.20 µm membrane filter in 100 mL of 0.20 µm filtered surface water 4. Add 1 mL of bacteria suspension to 400 mL sample	Biomass is obtained from surface water samples
Algae inocula	1. A lab-cultivated freshwater algal species, *Selanastrum Capricornutum*, was used 2. Algae cultured per freshwater algae toxicity test protocol (APHA, 1998), amended with nutrients except nitrate. K_2HPO_4 added to media to give N/P molar ratio of 3.0. 3. 5 mL of algal suspension at logarithmic growth phase added to 400 mL sample	
Test flask incubation	1. In shaker at 20-22°C 2. 12 hr light/dark cycle	
Algal growth	Monitor with vivo chlorophyll- α measurements using fluorometer until stationary growth phase reached	Stationary growth was found in about 14 days
DON measurements	Measure DON at sample time intervals	

The dissolved inorganic nitrogen (DIN) content of the sample may also affect the accuracy of bioassay protocols that involve use of algae and rely upon measuring chlorophyll *a* (plant biomass) production. High ratios of effluent DIN (EDIN) to EDON will result in very high levels of chlorophyll *a* production from DIN relative to DON. It can be difficult to accurately quantify the amount of plant biomass due to EDON versus DIN when there is a high background concentration of DIN. Similarly, assessing changes in bacterial biomass suffer the same limitations as they can also take up DIN and DON to support growth. To overcome this, DIN must be removed from or reduced in samples while retaining the DON, which is not a trivial feat.

IX The Regulating Community

Rich Batiuk, Associate Director for Science, Chesapeake Bay Program Office, U.S. Environmental Protection Agency Region 3, represented the EPA's Chesapeake Bay Program at the workshop. He pointed out that people are proportional to nutrients and that the populations of the Chesapeake Bay and most coastal watersheds are growing rapidly around the world and putting pressure on existing infrastructure and nutrient removal technologies. Nutrient discharge reduction goals in the Chesapeake Bay are based on 1990 levels; however, the population in the watershed has grown substantially and wastewater treatment not only needs to accommodate the initial reductions but also the growth in population pressure that has increased the treatable wastestream. This challenge has been addressed by improving technologies for DIN removal and BNR processes. However, we are at a tipping point because as populations increase, loads increase but allocations decrease. Thus, even current limit of technology (LOT) plants are being challenged.

Mr. Batiuk detailed the approach taken by the Chesapeake Bay 2000 Agreement in setting goals and allocating loads on a watershed specific basis. He pointed out that in 9 VAC 25-820-10 General VA NPDES Watershed Regulation for Total Nitrogen and Phosphorus Discharges and Nutrient Trading in the Chesapeake Bay Watershed in Virginia Effective November 1, 2006, it is stated that, "unless otherwise noted, entire nitrogen and phosphorus waste load allocations assigned to the permitted facilities are considered to be bioavailable to organisms in the receiving stream. On a case-by-case basis, a discharger may demonstrate to the satisfaction of the board that a portion of the nutrient load is not bioavailable; this demonstration shall not be based on the ability of the nutrient to resist degradation at the wastewater treatment plant, but instead, on the ability of the nutrient to resist degradation within a natural environment for the amount of time that it is expected to remain in the Bay watershed. This demonstration shall also be consistent with the assumptions and methods used to derive the allocations through the Chesapeake Bay models. In these cases, the board may limit the permitted discharge to the bioavailable portion of the assigned waste load allocation." Thus, for regulatory purposes, the main driver is an assessment of the bioavailability of N in the environment. Until an appropriate assay is developed, all N must be assumed to be bioavailable and therefore counted as part of the permitted discharge. The state regulatory representative from Virginia also pointed out that some standardization of such an assay would be desirable. He further pointed out that the regulatory goals laid out in the Chesapeake Bay Agreement would require an assay to demonstrate bioavailability in the environment, a water quality-based assay. Technology-based assays are useful if the goal is to change the waste load allocation and the plant is already doing the best that it can.

The regulated community has used LOT technologies to achieve significant N removal. However, as population grows, total volume/mass of treatable N grows and increasingly, final effluents are dominated by organic N, which is difficult to treat using current LOT. Because this N is deemed untreatable based on current LOT processes and unreactive to treatment plant microbes, it has been called recalcitrant. However, the microbial community in a treatment plant is highly selected to promote certain metabolic processes. In nature, the microbial community (including algae) is completely different from that in a treatment plant. So, what is deemed recalcitrant in a plant setting may be entirely bioavailable in the natural environment. Further, after discharge, EON is transported downstream where it may encounter salinity (e.g, the Chesapeake Bay system) where it becomes bioavailable (see above).

Concerns in the regulating community are aimed at failures to achieve water quality goals even after 20 years of targeted efforts. Because of these failures, more stringent regulations will come into effect and a more careful evaluation of nutrient inputs and their bioavailability must be undertaken in order to determine why previous targets for nutrient reduction have failed to improve water quality. The role of the regulatory community is to advise research and the regulated community so that treatment plant technologies are developed that will result in the desired outcome, improvements in water quality in the environment. The needs of the regulatory community are in-plant technologies that remove effluent constituents that negatively affect the proximate and ultimate receiving waters.

There appears to be a major disconnect between the regulated and regulating communities. This may be due to conflicting definitions rather than conflicting goals. The regulated community defines nitrogen pools and bioavailability within the treatment plant and in association with treatment plant microorganisms, while the regulating community defines nitrogen pools and bioavailability in the environment where different biotic and abiotic factors come into play. This is important because the regulatory driver relies on monitoring of receiving waters, and is concerned with biological endpoints measured in the environment. In contrasts, dischargers trying maximize in-plant biological N removal. Conflicting definitions of bioavailability and just what is inert and where, has resulted from studies employing technology-based assays of the ecosystem living inside the plant, versus studies based on the water quality-based assays trying to determine impacts to the environment.

In order to better develop reasonable but effective nutrient removal strategies, environmental biogeochemists specializing in organic nitrogen cycling need to team with process engineers to: 1) develop an effective assay for determining environmental bioavailability of EON that can advise regulators, 2) identify components of the EON pool that are immediately or become bioavailable in the environment, and 3) develop processes that can remove these components from treated effluents. Because the composition of EON varies between wastestreams and the different types of processes they undergo during treatment, we know little about the reactivity, bioavailability and fate of organic nitrogen in the environment. This needs to be the first task so that the resulting information can feed back to advise in-plant removal processes.

X Research Needs

As regulations require further nutrient reductions from dischargers to protect impaired natural waters from eutrophication, the relative importance of EDON in final effluents has increased and represents a new challenge in the area of biological nutrient removal. Initial efforts to measure EDON, its bioavailability to aquatic microbes (including bacteria and algae), and bioavailability to treatment plant microbes in order understand potential impacts of EDON in the environment and the effectiveness of EDON removal during BNR treatment processes, has led a heightened awareness that more research on this topic needs to be done. The research needs identified during this workshop are summarized here by topic area and as identified during the workshop.

1 Bioassay Protocol to Determine Impacts of rEDON in Fresh and Salt Water

It has been suggested that not all of the EDON from BNR treatment facilities may be bioavailable to natural microbial communities in aquatic systems and that the rEDON fraction may vary for different receiving waters. Thus, regulators need a means to monitor plant effluent quality to assure that their goals for limiting the effect of nitrogen N discharges on eutrophication are being met while dischargers need to be able to implement effective nutrient removal at reasonable cost. One possible approach to setting nutrient discharge allowances would be to permit an effluent "effective" TN concentration that is equal to the measured effluent TN concentration minus the measured rEDON concentration. To do this, there must be an effective, accurate, and adaptable assessment of rEDON.

A rEDON bioassay must provide a measurement of recalcitrant EDON that would indeed be inert in the receiving water over exposure conditions during transport that are deemed consistent with the proximate and ultimate receiving waters. Any viable bioassay protocol for rEDON must be accepted by the environmental engineering and aquatic science professions, as well as the utilities and regulators. To achieve the goal of a viable rEDON assay, research is needed to understand factors that influence the outcome of the assay under environmental conditions (e.g. salinity, the microbial community used, etc.), and the variability they introduce into the bioassay results. It may be that protocols need to be specific for the discharge environment and that one set of assay conditions may be appropriate for dischargers who are wholly contained within freshwater watersheds versus another set of conditions would be applied to those dischargers contained within estuarine watersheds (discharges in the latter may discharge locally into a freshwater receiving body that flows to the estuarine; therefore, the estuarine test condition is relevant even though the immediate receiving water condition is freshwater). It is important that we understand how the transport and degradation of EDON in natural waters occurs along a salinity gradient in order to model the effect of point discharged nitrogen on proximate and downstream eutrophication. Research is needed to determine if the bioavailability of EDON and the composition of rEDON changes along salinity gradients to improve models describing the impact of discharged N in the environment. This topic will be investigated under an on-going National Science Foundation-sponsored research grant (PI: D. Bronk; co-PI's: N. G. Love, M. R. Mulholland, E. Canuel, and P. Hatcher).

Table 8 presents research issues that should be addressed in order to develop an acceptable rEDON bioassay or collection of bioassays.

Table 8. Research needs for rEDON bioassay test protocol

Test Parameter	Research Issue	Comment
Definition of filter pore size distributions needed to fractionate DON	Sample filter pore size to define dissolved portion	There may be a significant amount of colloidal organic nitrogen between 0.45 and 1.2 μm filter pore size, and below 0.45 μm.
pH control	Buffer addition and appropriate pH particularly in freshwater	Should the test alkalinity be similar to that of the receiving water?
Incubation time	What is the appropriate time period for bioassays that measure rEDON?	If the test is too long, N cycling will reach steady state within the bottle and will compromise interpretation of the results.
Incubation temperature	Is 20°C test condition satisfactory for predicting rEDON concentrations in receiving water?	Should temperature in receiving waters be simulated.
Light intensity and diurnal variability in rate processes	Should bioassays be conducted in the light, dark, or both to assess rEDON?	Many algal processes are linked with the daily rhythm of photosynthesis.
Bacteria seed source	Can it be from wastewater plant or must it be from receiving water?	To test the fate of rEDON in the environment (freshwater or estuarine), seed would be obtained from receiving waters.
Need for carbon addition	Is a carbon source needed to maintain activity of bacteria needed for effective EDON hydrolysis and transformation? Would carbon addition reduce necessary test incubation time?	This might complicate interpretation of results because of C associated with EDON.
Effect of total inorganic concentration in test sample	A sample preparation method must be developed to reduce the sample TIN concentration so that an acceptable portion of the test sample microbial production is from EDON	Removal of inorganic N has been problematic in the past.
Algae seed type and source	Is *Selenastrum capriconutum* satisfactory for the fresh water rEDON protocol? What is the effect of collecting and using different algal seed sources along the fresh water to saline water gradient? Is there an acceptable standard pure or mixed culture that can be used?	There is currently no euryhaline test organism that could be used at all salinities and most aquatic algae are currently uncultured.
Algae growth condition prior to sample inoculation	Is the exponential growth condition the preferred physiological state for test organisms? What should the N source and N:P ratios be for cultivating or acclimating the algal test organism?	Nutrient prehistory is crucial for determining algal uptake capabilities.
Water quality conditions within bioassay	What is the appropriate solvent to use during the bioassay, and how does it differ for freshwater versus estuarine situations? Should the solvent composition change over time or with different bottles as part of the procedure?	It is expected that a salinity gradient influences amino bioavailability for some organic N compounds.
QA/QC methods	What EDON compound(s) could be used to test and demonstrate the accuracy of the bioassay? What other QA/QC methods should be employed in protocol?	This is crucial for the end goal of protecting the environment from excess N inputs.

2 Bioassay Protocol to Determine Influent Wastewater (IDON) Biodegradability (bIDON)

Protocols for determining the bioavailability of influent and effluent ON are currently unavailable and, until recently, there has been no effort to fill this gap in our ability to effectively regulate this fraction of the total N discharge from wastewater treatment plants. In addition to the need to assess the impact of EDON in the environment, there is a significant need to understand how constituents of influents into treatment plants and their relative reactivity, contribute to the final composition of EDON. It is currently not known how the plant design and operation, recycle streams, and influent organic nitrogen characteristics differentially affect EDON concentrations and composition. A method is needed to characterize the organic nitrogen in wastewater influents as well as effluents. It is particularly important to characterize any riDON and to determine if rEDON concentrations are related to the riDON (especially if it comes from controllable sources, such as industrial wastewater inputs, reject water recycle streams, and/or additives in the water supply). A biDON bioassay would use biomass from the treatment plant being evaluated to assess the capacity of that biomass to transform the organic nitrogen in the plant's influent waste stream. Because bacteria can also produce organic nitrogen, tests assessing organic N concentrations as endpoints can be misinterpreted because while the organic nitrogen in influent ON can be taken up or degraded simultaneous production of organic nitrogen as a consequence of metabolism can confound interpretation of net changes in DON concentrations. Therefore, it is envisioned that any protocol developed would include an assessment technique that differentiates in a general way the nature of the organic matter in the bioassay over time; whether it was produced during the bioassay or was preexisting in the influent ON.

3 Bioassay Protocol to Determine if Further Wastewater Treatment Will Eliminate bEDON

The bEDON bioassay protocol may be less complex and than the rEDON bioassay; however, the methods give extremely different information. The research needs for further development of the bEDON bioassay method and for establishing an accepted protocol are summarized here:

- What is the contribution of colloidal matter to the bEDON? Filter pore sizes should be selected to allow for evaluating the bEDON of colloidal matter versus truly dissolved EDON. Colloidal matter would not necessarily be removed by the treatment facility or by effluent filtration.
- Should bottle conditions be altered to reflect metabolic conditions experienced during the treatment process (in the plant)? If supplemental readily biodegradable carbon is added to shorten the test time, how will that affect the measured bEDON concentration? How much and how often should it be added?
- What known DON standards could be used to gauge the precision of the bEDON test in order to establish a quality assurance protocol?

4 Removal and Production of bEDON and rEDON in a BNR Treatment Process

Research is needed to determine which design and operating conditions in a BNR facility affect the effluent bEDON and rEDON concentrations? Key questions for this research are:

- Is there an optimal SRT for which the bEDON is minimized by balancing degradation of bEDON against bEDON production from in-plant microbes?

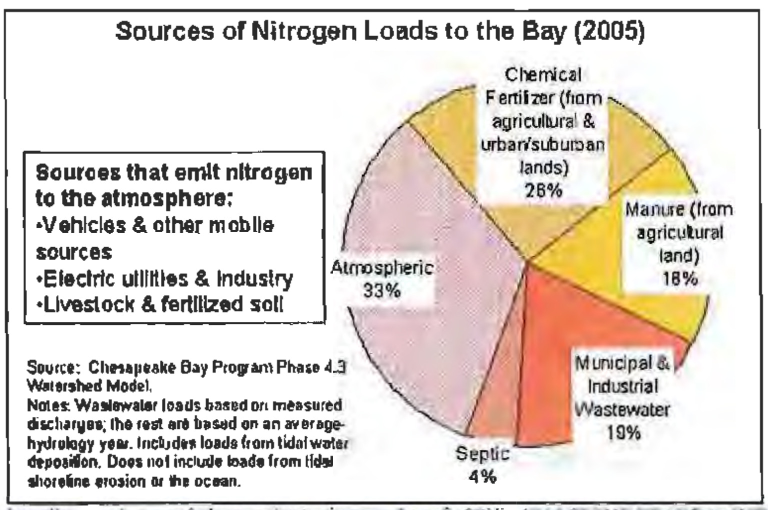
- If SRT is increased to decrease bEDON, will it cause a concomitant increase in rEDON? Can changes in the fraction of bEDON and rEDON be assayed simply as changes in the relative proportion of HMW EDON?
- What is the amount of bEDON and rEDON in recycle streams, including anaerobic sludge digestion and aerobic sludge digestion?
- Is there an effect of the BNR design and configuration (anaerobic and anoxic contact) on concentrations of rEDON and bEDON?
- Is the bEDON and rEDON removal efficiency different for membrane and granular media filtration processes?
- What are promising tertiary processes for bEDON and rEDON removal?

5 Non-Bioassay Methods to Characterize rEDON

Research is needed to characterize the rEDON measured using any bioassay protocol. Previous work suggests that rEDON is primarily HMW humic material that also contains amide compounds and synthetic organics such as EDTA. If suitable progress can be made to characterize rEDON, it may be possible to develop methods to measure key indicator compounds in lieu of conducting complex and time consuming bioassays to assess rEDON.

Treatment Plants to Consider for Partnership in Conducting Future Research

There are more than 300 wastewater treatment facilities discharging over 1.5 billion gallons per day of treated effluent from almost 75% of the approximately 16 million people living in the 64,000 square mile Chesapeake Bay watershed. Wastewater entering treatment plants and treated wastewater leaving the treatment plant contains highly variable nutrient (nitrogen and phosphorus) concentrations resulting in variable loading to aquatic ecosystems. Of the total nutrient load to the Chesapeake Bay watershed, agriculture contributes the largest proportion of the total nitrogen load (42%), followed by atmospheric deposition of N (33%), and finally wastewater facilities (19%).



Reference: http://www.chesapeakebay.net/status/status_dev.cfm?SID 126&SUBJECTAREA=INDICATOR

The largest number of wastewater treatment facilities in the Chesapeake Bay watershed is in Pennsylvania (123), followed by Virginia (81), Maryland (65), New York (22), West Virginia (9), Delaware (3), and the District of Columbia (1) [source: Chesapeake Bay Foundation, October 29, 2003. Sewage Treatment Plants: The Chesapeake Bay Watershed's Second Largest Source of Nitrogen Pollution]. Some of these plants are owned and operated by utilities who are also Subscribers of the Water Environment Research Foundation (WERF). These facilities range in size and effluent load to the Bay area, as well as spatial location and potential impact to water quality (with respect to nitrogen). They include, but are not limited to:

- Alexandria Sanitation Authority, VA
- Arlington County, VA
- DCWASA's (DC Water and Sewer Authority) Blue Plains Advanced Wastewater Treatment Facility, DC
- Howard County, MD
- Fairfax County, VA
- Hampton Roads Sanitation District, VA
- Hanover County, VA
- Henrico County, VA
- Hopewell Regional Wastewater Treatment Facility, VA
- Loudon County Sanitation District, VA
- Lynchburg Regional WWTP, VA
- Prince William County Service Authority, VA
- City of Richmond, VA
- Rivanna Water & Sewer Authority, VA
- Philadelphia Water Department, PA
- Prince William County Service Authority, VA
- WSSC (Washington Suburban Sanitary Commission), MD – with several plants on the DC metropolitan area

Several of these subscribers are actively involved in WERF research and/or have expressed interest in participating in additional water quality research forums. It is suggested that any future research include the following utilities that have different wastewater treatment capacity and configurations and which are also spatially distributed throughout the Bay area:

- Alexandria Sanitation Authority, VA
- DCWASA's Blue Plains Advanced Wastewater Treatment Facility, DC
- Howard County, MD
- Loudon County Sanitation District, VA
- Prince William County Service Authority, VA
- WSSC (Washington Suburban Sanitary Commission), MD
- City of Richmond, VA
- Hampton Roads Sanitation District, VA

WERF's targeted collaborative research (TCR) program provides opportunities for their subscribers and others to share and leverage resources (funding, test sites, laboratory, intellectual, etc.). WERF also has an extensive ongoing research program on their "Nutrient Removal

Challenge" and it is suggested that studies or activities proposed on the dissolved organic nitrogen issue be coordinated with this organization.

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EXHIBIT 6

RE: MEP tech reports

Costa, Joe (EEA)

Sent: Friday, September 04, 2009 3:39 PM
To: Dunn, Dennis (DEP)
Cc: Dudley, Brian (DEP); Ackerman, Michael (DEP); Janik, David (DEP); Callaghan, Todd (EEA); Carlisle, Bruce (EEA)
Attachments: new-bedford-mep-report-bbp~1.pdf (2 MB)

Hi Rick,

Attached for your consideration is the review of MEP's New Bedford Nitrogen TMDL report, that I undertook with Dave and Todd. Although the review is 15 pages long, we simply did not have enough time to evaluate, consider, or address all the issues we wanted to address. We instead undertook a fatal flaws analysis approach on a few major issues as you suggested.

Our conclusion is that the loading analysis includes significant overestimates of both the number of dwellings and the number of septic systems in Fairhaven. There are similar overestimates of septic systems and an underestimate of the extent of sewering in Acushnet. These problems were the result of an inaccurate and non-validated integration of GIS, assessors, and water department databases. Together these errors may have contributed inclusions of thousands of non-existent properties and septic systems into the loading spreadsheet, with possibly an overestimate of nitrogen loading by 20% or more. These overestimates, together with overestimates of nitrogen from agricultural lands (the cranberry bog acreage is off by a factor of three), and corrections needed from roof, lawn, and driveway loads from fictitious dwellings, call into question the veracity of the loading analysis and the meaning and interpretation of the recommendations relating to the restoration scenarios presented.

I am sure these are not the conclusions you wanted to hear at this late stage, but we feel these points should be addressed.

Dave and Todd have did not had time to review the Wareham report. On Tuesday I will give you a briefer assessment of the Wareham report, and I will focus mostly on calculations of cranberry bog area and septic system numbers, since these may be the most important elements in that study where similar issues may be expressed.

Hope this information helps and have a good holiday weekend.

Joe

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Dr. Joe Costa, Executive Director
Buzzards Bay National Estuary Program
Massachusetts Coastal Zone Management
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East Wareham, MA 02538
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From: Dunn, Dennis (DEP)
Sent: Fri 8/28/2009 12:21 PM
To: Costa, Joe (EEA)
Cc: Dudley, Brian (DEP); Ackerman, Michael (DEP)
Subject: Re: MEP tech reports

Thanks Joe

From: Costa, Joe (EEA)
To: Dunn, Dennis (DEP)
Cc: Dudley, Brian (DEP); Ackerman, Michael (DEP)
Sent: Fri Aug 28 11:19:50 2009
Subject: RE: MEP tech reports

Rick,

Sorry for your illness.

I and CZM will adhere to your guidelines.
I will provide Dave and Todd with the documents.
I will be the point person consolidating any additional CZM comments and sending them to you and Brian by the end of next week

"In the future we will try to get it to you as soon as we receive it to allow for the full 30 days."
I am sure I can speak for Todd and Dave, that they will appreciate this. I believe CZM's position is that they just want to help DEP improve the documents to the maximum extent practicable before they are released to the towns and public.

Joe

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From: Dunn, Dennis (DEP)
Sent: Thu 8/27/2009 2:11 PM
To: Costa, Joe (EEA)
Cc: Dudley, Brian (DEP); Ackerman, Michael (DEP)
Subject: RE: MEP tech reports

Hi Joe,

I apologize for not getting back to you sooner on this. I have been out sick and just realized that I never responded.

After speaking with Brian Dudley we both agreed that it is OK for Dave and Todd to review these documents and comment provided the following conditions are met.

a. Since the towns have not yet seen them I ask that the documents do NOT get distrubuted beyond Dave and Todd and that they are instructed not to discuss them with anyone else at least until the SMAST holds there Town workshops. It simply would not be appropriate for the word to get out that CZM got to review these materials before the Towns themselves.

b. DEP does not want to have to review there separate sets of comments by each person at CZM. As such, we ask that you compile all the CZM comments into one document before you submit it to us here at DEP.

c. Our goal at this stage of the process is to review the technicial report for any major issues or show stoppers. As a result we would like you to identify important issues or technical deficiencies that you believe may be appropriate to resolve before the report gets released to the Towns. DEP will review your comments and reserves the right to include the ones that we think are appropriate and applicable at this stage.

Appropriate comments will be included in our response to SMAST on the technical report. I want to be clear that we are not going to entertain any recommendations for an entirely new approach or complete reevaluation. The MEP project has come too far to change approaches now.

d. Timing of the comments is important. We have a detailed schedule that requires DEP to get comments to SMAST within 30 days of receipt. During this time we have also included EPA as well and now we would like to include you because of your work with the Buzzards Bay communities. These documents have already exceeded our timeline so we can only provided limited time for your additional review. As such we would like your joint review by labor day at the latest. In the future we will try to get it to you as soon as we receive it to allow for the full 30 days. Please send your comments to both Brian Dudley and I.

Finally,

I am not sure why the calculations between the New Bedford and Wareham reports are different without speaking to SMAST but this would be a good comment to include as part of your review.

Hope this helps.....Please let me know if you have any additional questions.

Rick

From: Costa, Joe (EEA)
Sent: Tuesday, August 18, 2009 3:17 PM
To: Dunn, Dennis (DEP)
Cc: Dudley, Brian (DEP); Ackerman, Michael (DEP)
Subject: RE: MEP tech reports

Dennis,

I have begun going through these documents and had a general and a technical question.

1) You wrote, "Because these reports have NOT been sent to the Towns yet **we ask that you do NOT distribute them in any way** nor allow others to review them at this stage."

Does that include other CZM staffers? Dave Janik and Todd Callaghan have expressed an interest in seeing and possibly commenting upon these documents.

2) Probably a question for Brian... I have been going through all the formulas in the spreadsheets and in general things look fine (although often inelegant), but one issue I am stuck on is the driveways loading in Wareham, which does not appear to be added in anywhere.

In the New Bedford spreadsheet, the "road loadings" uses the formula:
New Bedford Road N Loadings=(AN[road]+AO[runway]+AR[other]+AP[driveways]+AQ[parking])*AM*(1/12)*28.32*AS

In Wareham spreadsheet the formula is:
Wareham Road Loadings =(AN[road]+AO[runway]+AR[other])*AM*(1/12)*28.32*AS

Why the difference? Am I missing something?

Joe

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Dr. Joe Costa, Executive Director
Buzzards Bay National Estuary Program
Massachusetts Coastal Zone Management

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From: Dunn, Dennis (DEP)
Sent: Tue 8/4/2009 9:40 AM
To: Costa, Joe (EEA)
Cc: Dudley, Brian (DEP); Ackerman, Michael (DEP)
Subject: RE: MEP tech reports

Hi Joe,

Thanks for taking a look at these. I share your concerns about the reports and we will continue to try to solve that problem as well as others that have been raised. Also you should know that I tried to send the Acushnet data files but the file size (over 120 mb) was too big even for yousendit.com so I will have to find another way to get it to you. We will probably have to make a copy and send the disk. Can you send me your address? I will try to get it in the mail today.

Rick

From: Costa, Joe (EEA)
Sent: Monday, August 03, 2009 6:46 PM
To: Dunn, Dennis (DEP)
Cc: Dudley, Brian (DEP); Ackerman, Michael (DEP)
Subject: RE: MEP tech reports

Hi Rick,

I received three emails from yousendit.com, and I was able to download all three files and open them (Wareham and New Bedford reports and the Wareham zipped data files). I especially appreciate that you provided the Wareham data disk files including the GIS shapefiles. If there was a similar email and link for the New Bedford data files, I did not receive it.

I will happy to comment upon the two reports in the order and period suggested.

I wish to pass along one annoyance that I have concerning the pdfs provided, and with other documents made available from OceanScience.net. The pdfs have security features implemented. I understand the intent of the authors to prevent the documents from being altered (actually a pointless endeavor), however, the documents have the additional optional security restriction of preventing "copying of text, images, and other content." This unnecessary hindrance prevents someone from highlighting text and copying it into a comment letter for example. Instead, most users will struggle to quote a passage from the report. I have heard others complain about this annoyance with the MEP reports.

Of course, anyone who knows a bit about computers and pdf files recognize that these security measures are outdated, pointless, and easy to overcome. Pdf structure is no longer proprietary, it is now open source, and there are a number of open source shareware printer drivers where you can just take a secure pdf file and print it to an open source pdf driver, and you have a nearly identical document, but with all security features removed.

Incidentally, by allowing documents to have text copied, you do not remove their accessibility by text readers for the vision impaired, in case there is any confusion on that issue (text reader accessibility is a subset of allowing the copying of text).

I doubt there is a single document on DEP's website where the user is prevented from copying text. Can you image the absurdity of DEP posting regulations in a pdf where the user cannot copy an excerpt from a report or regulations into an enforcement letter or another document? In fact, most state agencies have abandoned security features altogether on posted documents because they are so easy to circumvent and counterproductive.

I would urge DEP to discourage MEP from disabling the copying of text in future MEP submissions because it is more of an impediment for town officials than technical professionals, and it contributes to the perception that the information, data, and models of the MEP are inaccessible.

I will consult with Brian Dudley if I have specific questions on how SMAST handled certain nitrogen loading or modeling issues in past reports.

Joe

==================================

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From: Dunn, Dennis (DEP)
Sent: Mon 8/3/2009 1:57 PM
To: Costa, Joe (EEA)
Cc: Dudley, Brian (DEP); Ackerman, Michael (DEP)
Subject: MEP tech reports

Hi Joe,

Hope all is well. I was speaking to Brian Dudley this AM and he asked that I send you drafts of the Acushnet River/New Bedford Harbor and Wareham MEP Technical Reports for your immediate review and comment. We know you have been working with the Towns on nitrogen issues and we think it is important to get your input.

Because these reports have NOT been sent to the Towns yet **we ask that you do NOT distribute them in any way** nor allow others to review them at this stage. Right now we are looking to identify any glaring problems or inconsistencies that need to be resolved before general public distribution occurs. We would also like your comments sent directly to both Brian Dudley and myself so we can combine them with our comments and any we may receive from EPA in our response to SMAST.

Because the files are too large to send through our DEP firewall I will be sending them to you via an internet site called "yousendit.com". You will receive an email from "yousendit.com" with instructions on how to download each file. You should receive 4 emails. Two of them will have the draft technical report and two of them will be data disks for each report.

In terms of priorities, we would like your comments first on New Bedford followed by Wareham. If possible we would like your comments within the next two to four weeks so we can get comments back to SMAST and keep the process moving.

If you have any questions you can contact me at 508-767-2874. Alternatively you can contact Brian Dudley at 508-771-6047.

Buzzards Bay
National Estuary Program

Dennis Dunn
DEP DWM Program Director
627 Main St, 2nd floor
Worcester, MA 01608

September 4, 2009

Re: MEP TMDL review- Linked Watershed-Embayment Model New Bedford Inner Harbor

Dear Mr. Dunn:

I have reviewed the report titled "Massachusetts Estuaries Project: Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the New Bedford Inner Harbor Embayment System, New Bedford, MA December 2008" that was provided to me on 3 August. In this review, I have incorporated additional recommendations from Dave Janik and Todd Callaghan at CZM, but due to the short time frame for which the report was available to them, you should not consider their comments as comprehensive.

Because of the complexity of issues raised in the report and the establishment of the TMDL, and because the water quality model is not available for review, we have focused our analysis on issues relating to the evaluation of land use and watershed loading. We also paid particular attention as to how MEP characterized nitrogen loading sources in the report, as well as how clearly management options and solutions were articulated. As per your request, we looked for problems and issues that may put the reports conclusions into question, so that DEP can address these issues before they provide the report to the affected watershed communities.

Overall, this report is consistent with previous MEP reports, and provides a good summary of watershed loadings and nitrogen sources. However, the report contains some contradictory statements and many apparent calculation inconsistencies or outright GIS analysis errors that the MEP should correct before they release the report to the affected communities. These errors led to serious over-estimates of loading. Many of our comments and recommended changes relate to the loading coefficients in the spreadsheet to match better the specific characteristics of the watershed, or help address shortcomings in the assessors' data. Some recommendations will be more challenging to address, but could be addressed in future MEP reports. Where possible, we provide solutions to the problems presented.

1. Clarity needed on goal of the TMDL.
Page six of the Executive Summary states, "Threshold nitrogen levels for the embayment systems in this study were developed to restore or maintain SA waters or high habitat quality", but page nine states, "Threshold nitrogen levels for this embayment system were developed to

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restore or maintain SB waters and habitat quality consistent with this systems classification as a working port." We presume the latter sentence is the correct one.

The report further states "The target total nitrogen concentration for restoration of infaunal habitat within the New Bedford Inner Harbor Estuary, is <=0.50 mg TN L-1 (tidally averaged) at the sentinel location", which is now at 0.6 ppm (stated here in the report, but why is no value reported in Table ES-1?). Why is the TMDL proposed as "<="? Other MEP reports do not use "<=" when specifying the TMDL threshold target.

In MEP's support documents (2003 report Site-Specific Nitrogen Thresholds for Southeastern Massachusetts Embayments: Critical Indicators), SB waters to achieve Good/Fair mesotrophic conditions are anticipated range 0.39 to 0.50. If this is the basis of the "<=" threshold target, and there is uncertainty in what precise threshold is necessary to achieve an environment "supportive of diverse benthic animal communities", then this uncertainty should be more explicitly expressed. That is to say, the 0.50 concentration may be an initial concentration target for the sentinel station, and a lower threshold may be needed "to restore the impaired infaunal habitats throughout the Inner Harbor Basins." It is worth noting that the MEP linked watershed loading water quality model is used to predict what level of nitrogen loading is needed to achieve a water quality total nitrogen concentration at the sentinel station. The degree of restoration of infauna habitat is presumed based on achieving that Total Nitrogen concentration, and the TMDL may need to be reduced (or possibly increased?) as more data becomes available about impairments and recovery of benthic habitat.

The Executive Summary seems inconsistent as to the level of nitrogen removal needed in the system. For example, on page nine of the Executive Summary, the authors state that a 49.2% reduction in N load (via closing all CSOs and removing the Fairhaven Treatment Plant outfall) would not meet the goal of 0.5 mg/L TN at the sentinel site. However, in Table ES-1, it is indicated that only 46.6% reduction in loading would achieve that goal. Table 2 states that present watershed load is 310.05 kg day (=113,168 kg year), and that the target load is 165.48 kg day (=60,400 kg/yr), which is the basis of the 46.6% reduction.

We recognize that where you remove nitrogen from the estuary affects how quickly TN is reduced at the sentinel station, so in fact, there is no single watershed nitrogen-loading target, and this might be worth stressing in the executive summary. There are also profound issues that relate to the whether a 0.5 ppm TN standard at the sentinel station is either adequate or appropriate for this TMDL, and whether this report adequately defends that value. We did not address this issue in this review.

In Table ES-1, it is interesting that the observed 7-year average TN concentrations in the "New Bedford System" basin significantly overlap the range of TN concentrations in the upper basin. That is, according to footnote 7, the average value in the upper part of the lower basin (0.67 mg/L TN) is actually higher that the average value in the lower part of the upper basin (0.51 mg/L TN) and approaches the value for the upper part of the upper basin (0.79 mg/L TN). Is this just statistically insignificant variability, or is the lower harbor area more strongly affected by the point sources present?

2. Number of homes on septic in Fairhaven appears grossly erroneous.
The GIS files for Fairhaven show many properties in the sewered center of town to have septic systems, although the areas are sewered, or have buildings on them, when they do not. Some of these errors appear to be due to applying data to merged parcels, or perhaps due to errors or omissions in the water department or assessors records about sewering, and presuming the home has a septic system instead (e.g. town buildings are listed as on septic systems because they are not being billed for sewer systems). Figures 1 and 2 show the great extent of this problem.

Based on the coverage illustrated in Figure 1, the MEP loading spreadsheet indicates there are the 1,045 presumed septic systems (Table 1) in Fairhaven in properties in the three watershed segments between the hurricane barrier to the south and north to route 195. These areas are shown in Figure 3, and MEP estimated septic loading total 6,148 kg N annually in the spreadsheet. We believe this estimate is wholly unrealistic, and after consulting with the Board of Health there is likely less than a few dozen septic systems (but unlikely more than 100) in these three areas of Fairhaven, totaling 275 kg N annually using MEP assumptions (for 45 presumed residences). This means MEP overestimated loading from septic systems in these segments by 5,873 kg annually.

Similarly, the MEP seems to have significantly overestimated the number of residences with septic systems in the north end of Fairhaven to the Acushnet border ("Middle Acushnet River", marine portion of estuary north of 195, shown in Figure 2). In this segment, MEP asserts there are an additional 2,047 residences with septic systems, for a total of 6,455 kilograms annually. Again, these values appear wholly unrealistic, and both the dwelling number is far too high, and more than 90% of the dwellings are sewered. We strongly encourage the MEP to show maps of the sewered and septic areas and number of homes to the Board of Health for comment.

According to the 2000 US Census, the entire Town of Fairhaven has 5273 single family units. A quick visualization of an ortho photograph and the watershed boundaries suggest that 30-50% of these Fairhaven units might occur in the Acushnet River - New Bedford Inner Harbor watershed. However, the MEP's loading spreadsheet indicates that there are 5,162 Single family residential units in the watershed (both sewered and unsewered).

After examining the Fairhaven Assessors data, it is apparent that the MEP did not actually overlay the GIS coverage onto an aerial base map. The MEP did not realize that the building information data was replicated for every parcel where the property owner built a home on 2 to four or more parcels combined (a very common practice in Fairhaven because of original tiny lot subdivision sizes and increasing minimum lot size). The solution to this problem is quite simple; the assessors' database has to be simplified using the Dissolve function on the Prop_ID field. This eliminate perhaps thousands of replicated residential units from the data base. Cumulatively these errors may equal a 15,000 to 20,000 kg over estimate in annual loading, because even if many fictitious residential units were assumed to be sewered, their roofs, driveways, and lawn loadings were added to the nitrogen loading totals. These errors are so significant, they call in to question the conclusions of the report.

Figure 1. A portion of the MEP GIS coverage for Fairhaven. Blue areas are listed as sewered, red areas listed as on septic, and numbers show number of buildings on the parcel. Probably none of the properties shown in this area have septic systems.

Figure 2. Similar MEP GIS coverage for northern Fairhaven along the "Middle Acushnet River". This area is nearly completely sewered, but spurious structure enumerations and incorrect classifications of sewering led the author's to conclude that there were 2047 septic systems in this subwatershed. Numbers show buildings per parcel.

In future MEP reports we strongly encourage that the MEP place a Table showing the number of buildings and septic systems in each subwatershed. They should also give each town a map showing sewered and unsewered parcels. These products would enabled local officials to catch these errors. Septic loadings often represent the majority of loading in most watersheds, and is also the data most easily validated by each town.

3. Extent of Acushnet sewering appears significantly in error.

Based on the sewer coverage field in the MEP GIS database for Acushnet, it appears that a large number of units classified as having septic systems are in fact sewered. We have not obtained an updated sewer coverage from the town, but based on earlier information we have, most of the properties in Acushnet, near the Acushnet River between Tarklin Hill Road and Slocum St (opposite Wood Street in new Bedford). are sewered, but the MEP database shows an odd smattering of sewer connections (Figure 4). We believe this coverage represents a failure to join correctly join the water records, or perhaps imperfect water fee records. The MEP should consult with the town to understand what parts of town are actually sewered. These errors may have incorrectly added thousands of kilograms of septic loadings from this part of the watershed.

Figure 3. Three harbor segments with septic system totals presented in table 1.

Table 1. Presumed septic system in Fairhaven watershed segments in Figure 2.

Lower Acushnet River	761
New Bedford Inner Harbor North	185
New Bedford Inner Harbor South	99

It is worth noting that for the communities in the watershed, the MEP likely expended considerable effort trying to marry town water and sewer records to assessor's records to the GIS coverages. Because of variations on how data is stored in the various databases, "cleaning up" and validating this data can be a monumental task, especially if maps of sewered and unsewered areas are not presented back to the town for review. A more common sense approach would be to classify parcels based on known sewered area maps like those available at: http://www.buzzardsbay.org/wastewat.htm. Using this kind of GIS polygon coverage to clip parcels is quicker and far more accurate that the inadequate and poor implementation of a GIS "parcel analysis" as implemented here. These maps make it immensely easy to classify whether buildout parcels should be in the sewer or septic system column. Anyone with a modicum of understanding as to how towns sewer areas of towns, and how they exert considerable effort to ensure residents tie-in to sewer lines, would immediately recognize that the GIS coverages in

Figure 4. MEP data showing sewered areas (blue crosshatch) and septic systems (red crosshatch) in Acushnet, between Slocum St and Tarklin Hill Road. This areas was reported to us as sewered and should be verified.

Figures 1, 2 and 4 are incorrect. Certainly some properties may have "slipped through the cracks" with tie-ins, but these are best handled based on the judgment of the health agent or other town officials in reviewing sewered area maps. We therefore conclude that MEP's GIS sewer and septic analysis in Fairhaven (addressed in section 2) and Acushnet was poorly implemented and not validated. In short, the loading analysis was very precise but highly inaccurate. The short review time prevented our evaluation of the New Bedford data.

4. Potential impact of dredging projeets not discussed.

When viewing Table ES-1, certain estuary segments are important sinks and generators of nitrogen in the estuary. In the coming years more than half of the area of the upper estuary (above the Coggeshall Bridge) will be dredged as part of the PCB superfund project. In the lower inner harbor, 10-25% of the bottom may be dredged for navigational purposes. It is important that the report acknowledge that these activities will occur and at least speculate how they might or might not affect the loading assessment and ecosystem response.

5. MEP discuss the seasonality flows from the wastewater facility and CSOs.

The MEP loading model is based on annual flows loadings. This works well for groundwater discharges of varying distance from the shoreline, however CSO flows relate to rainfall, which is generally lower in the summer, and higher in the winter. The Fairhaven wastewater facility also shows slightly lower flows in the summer than the winter. It would be helpful if the report authors would discuss the seasonality of discharges and the fact that water quality monitoring is conducted during summer months, and how this affects the conclusions of the report.

We recognize this is a very difficult issue to address, and it is the reason why the MEP attempts to evaluate an average of several years of water data. This is because it is well recognized that water quality in the region is more degraded in wet summers (higher TN and higher chlorophyll) than in dry summers. This is because nitrogen loading is quite simply higher in these wet summers than in dry summers. The MEP watershed loading model represents an average annual assumed loading, although the river model provides useful information on the seasonal nature of loading.

The authors should clarify if their flow data and calculations were for all CSOs, or just the CSOs behind the hurricane barrier.

Given that CSO discharges seem to be so prominent in the analysis and TN reduction alternatives, it is important that this loading value is the best estimate possible and that the readers know its limitations. On page 39 of the report, the MEP describes well how they relied on 1990 CSO TKN data for New Bedford, and presumed a concentration of nitrate plus nitrite based on other CSO studies. In addition, since CDM undertook its study in 2005, the City has closed additional CSOs. It might be worth adding a statement in the executive summary that better characterizes this nitrogen source.

6. Recharge and impervious flow issues should be better justified.
The 60% recharge rate of natural surfaces seems too high for New Bedford, given the soil type for the area and that considerable sheet flow of urbanized "natural surface" areas and may flow to the CSO system. However, this is a relatively small nitrogen contributor making this correction unimportant. Also, based on a read of the report alone, it might appear that the impervious surface stormwater calculations for nitrogen are double counted with CSO discharges, however the loading spreadsheets in CSO areas do in fact have driveway and roof areas removed from the calculations. The authors do not clearly articulate this in the report, and the methodology should be better explained to alleviate any concerns on this issue. Did the authors similarly correct for road areas in the CSO areas? We could not find a GIS coverage of CSO contribution areas in the data disk to validate these calculations. Is this data in a particular shapefile?

7. MEP should use the most up -to-date New Bedford rainfall data.
There is a strong precipitation gradient from southeastern Mass to the outer Cape, so it is appropriate that the MEP is using watershed specific annual precipitation. The MEP report states (page 12), "Based on climate data for the period 1951 to 1980, average annual precipitation ranges from 1.12 to 1.23 m/year (43.9 to 48.6 in./year)." This sentence does not make sense. The average for the period is a single number; otherwise, you delete the word "average" and just state the range for the period.

On page 44, the MEP report notes a 47.8 in/y average based on a CDM 2006 CSO report that reviewed 1961-2000 precipitation records. The report notes that the 90% value of this annual total (=43 in) was used in their precipitation loading calculations.

However, the data used by CDM is now outdated, since the NWS has released climate records for the more recent period of 1971-2000 data for New Bedford, which is available on line at:

http://cdo.ncdc.noaa.gov/climatenormals/clim20/state-pdf/ma.pdf. The recent 30-year average for New Bedford is in fact 50.8 inches. MEP should update page 12 with this more current data and they should use the 90% value (45.7 in) in the loading calculations instead. This change will raise attenuated annual load for the entire estuary by 1% from 118236 to 119357.

Extrapolating this value further to natural landscapes, this value should be 60% of annual precipitation (50.8 inches), which is 30.48.

Cumulatively, the higher rates of precipitation on impervious, ponds, and natural landscapes increases annual nitrogen loading 1.0% from 118236 to 119419 (+1,183 kilograms)

8. Parcel level data provides erroneous characterization of agricultural acreages.
Because of property tax misclassifications, and because the focus of the property tax classification system emphasizes land use by value, not acreage of use, the approach is not well suited for the inland rural areas of the Acushnet River watershed (Figures 5-8). Specifically, MEP has poorly characterized actual agricultural land use (and therefore their loadings) in the watershed. In the future, MEP could supplement its parcel analysis and water use approach for characterizing wastewater, lawn loadings and stormwater loadings, but for larger parcels, use

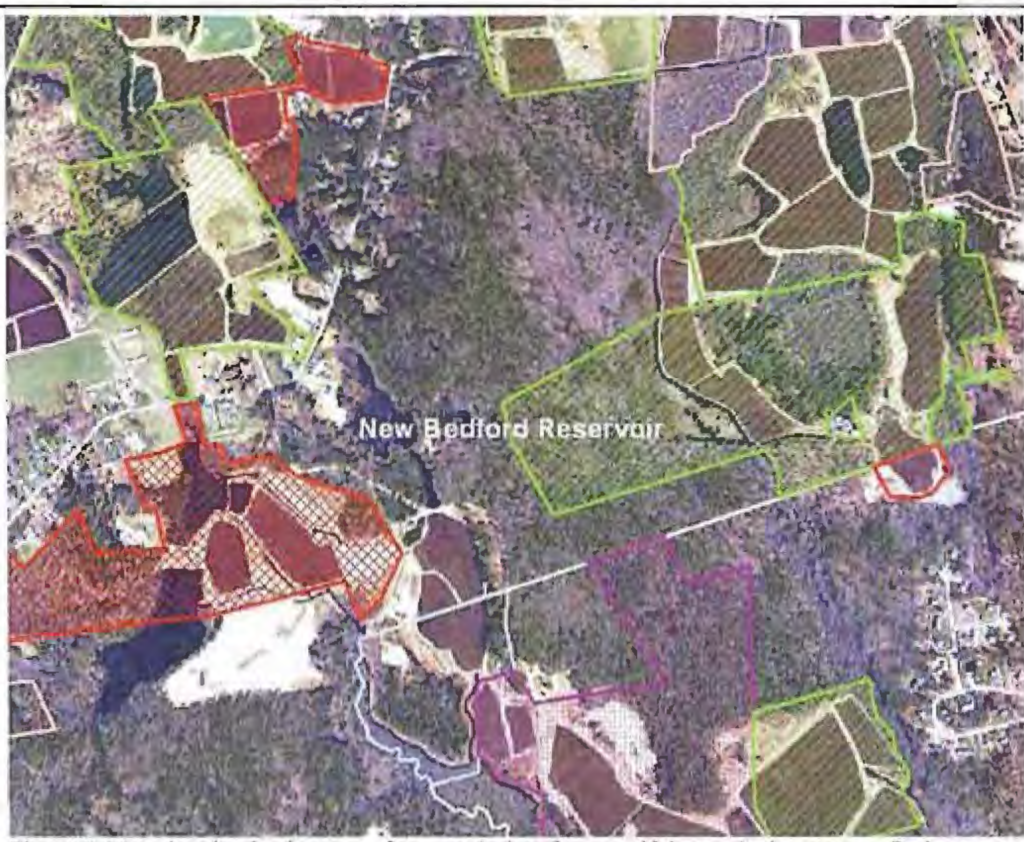

Figure 5. Map showing inadequacy of assessor's data for quantifying agriculture areas. Red areas were classified as principally bogs in assessor's database, green crosshatched areas classified as cropland (a lower rate than bogs). Pink in this figure is potentially developable lands, and purple magenta stippled is mixed-use land, not quantified by MEP in their loading spreadsheet.

MassGIS 2005 land use to obtain a far more realistic assessment of agricultural and natural landscapes for calculating these loadings in the watershed.

To some degree, the MEP already recognized the extreme difficulty of using the assessors parcel data to characterize agricultural land because they abandoned their own approach by creating a separate (and imperfect) parcel-independent coverage for cranberry bogs (described below, Figures 9-11). They then imperfectly adjusted other parcel acreages to preserve the integrity of land areas in the loading spreadsheet. To correct theses issues would take a lot of effort to characterize every large parcel in the database. To preserve the parcel analysis approach MEP should digitize agricultural fields just as they do now for golf courses (even breaking down tee, fairway, and rough areas). MassGIS land use data appears to be a reasonable and more accurate substitute to assess these loadings as compared to the approximations used by MEP. We provide the MassGIS clipped coverages and acreages of agricultural lands in the uppermost two watershed segments (Table 2).

Figure 6. These parcels dominated by bogs were classified in the Lakeville assessor's data base and MEP loadings as single family residences (101).


Figure 7. Another Lakeville parcel of agricultural land classified in assessor's data base and MEP loadings as single family residence (101).


Figure 8. This pink-outlined Lakeville parcel was classified in assessor's data base and MEP loadings as developable land (130).

9. Cranberry Bog acreage is incorrect.
The report states that "In order to determine nitrogen loading from cranberry bogs, MEP staff reviewed aerial photographs of properties classified as cranberry bogs and digitized the areas of the bogs using GIS techniques." In actuality, MEP typically uses a standard assumption that 85% of lands designated as agriculture assessor's records (270, 710 classifications, and others) are in agricultural production. One disadvantage of this approach is that this is an overestimate for some watersheds. An important advantage of this approach is that the MEP can base nitrogen loadings wholly on a manipulation of GIS assessor parcel coverage and watershed acreages remain consistent.

To illustrate the shortcomings of using parcel data alone in characterizing the Pocasset Back River Eel Pond watershed report, MEP estimated bog production area as 55.3 acres (85% of the Chapter 61 A lands), whereas actual bog acreage is 27.1 acres based upon DEP wetland GIS data and (confirmed visually with

MassGIS 2005 aerial photographs, and 2008 Google map photographs). MEP used this 85% estimate despite the fact that cranberry bogs (and other agricultural lands) have been thoroughly mapped on the MassGIS 2005 land use, and older DEP wetlands programs maps (with only the newest bogs missing). This contrasts sharply with their golf course loading estimates, which are based on MEP digitizing golf course rough, fairway, greens, and even tee-off areas.

In the case of the Acushnet River watershed, there are many confounding, erroneous, and contradictory land use classifications in the various town assessors' databases. For example, not all cranberry bog parcels are classified as 270 or 710 series land use. In fact, bogs in the upper watershed some are classified in numerous ways including mixed use, single-family residential, undevelopable lands, and potentially developable land.

Figure 9. New "cranberry bog" polygons created by MEP.

The MEP seems to have recognized the inadequacy of using parcel data to estimate agricultural lands because they created a new parcel-independent GIS coverage called cranberry bogs, and used this new coverage for their nitrogen loading estimates. The areas of the polygons are contained in other spreadsheets and are listed in the "cranberry bog" tab in the loading spreadsheet, and are the basis of the loading calculations. However, when the GIS coverage of this cranberry bog coverage is examined, the basis of the polygon boundaries are often incomprehensible, and coincide neither with land use or parcel boundaries. We illustrate these problems in Figures 9 and 10.

Figure 10. Cranberry bog polygon FIDWARWA(9) and neighboring unaccounted area.

The MEP also does not adjust the polygons by their 85% correction coefficient, and instead multiplies the total area of all these polygons

(755 acres) by the bog loading coefficient (20.46 lbs per acre), for a total of 7,051 kilograms in the spreadsheet. The actual cranberry bog acreage using MassGIS area is 421 acres (Table 2), for a total load of 3,094 kilograms. However, even this value is too high because MassGIS data includes non-growing cranberry bog use areas including berms, sand pits, farm roads, and so forth. The best data set is DEP's wetland Conservancy program coverage, where they digitized the actual bog production area. We show a comparison of the three data sources in Figure 11.

The DEP wetlands data is somewhat out of date, and for this review, we digitized the actual additional bog areas in the Acushnet River watershed based upon the most recent MassGIS aerial coverage (2005) and more recent Google Earth coverages (2007). There are in fact only 252 acres of bog production area in the watershed (Table 2), contributing 2,341 kilograms of nitrogen. This is 4,710 kilograms less than the MEP estimates.

Table 2. MEP estimated cranberry bog acreages versus MassGIS 2005 Land USE and DEP Wetland Conservancy program maps

Category	MassGIS 2005 landuse acreage	MEP acreage	Comments
Cranberry Bog	420.54	754.92	Acreage used in Loading Table based on newly created MEP coverage; MEP did not apply 85% adjustment to created coverage
DEP wetlands Conservancy bog areas (mid 1990s, adjusted for new)	252.23		This is production area only. New bog areas added using MassGIS 2005 orthos.

10. Other agricultural acreages are overestimated.

Other agricultural areas are similarly overestimated by MEP using assessors data and simplified

Figure 11. A comparison of MEP's newly created cranberry bog coverage in the Acushnet River watershed (left), versus MassGIS cranberry bog coverage in their 2005 land use data (middle), versus DEP wetlands conservancy program coverage. The DEP coverage is the most accurate estimate of production area, but needs to be manually updated based on the most recent aerial photographs.

assumption of agricultural area cover. In the 2005 MassGIS landuse data, non-cranberry agriculture totals 771 acres (table 3). This is 30% lower than MEP's estimate of 1,092 acres (after 85% adjustment factor). This alternate value suggests MEP over estimated watershed agricultural loadings by 1,325 kilograms based on their cropland loading rate of 9.1 lbs/acre.

Table 3. MEP estimated cranberry bog acreages versus MassGIS 2005

Category	MassGIS 2005 landuse acreage	MEP acreage	Comments
Other Agriculture			
Cropland	130.10		
Pasture	454.77		
Nursery	184.24		
Orchard	2.24		
Total	771.35	1,092.00	MEP number includes 85% adjustment of agricultural parcels

Most of the overestimate of agriculture acreage (including cranberry bogs) was at the expense of underestimating natural landscapes (Table 4).

Table 4. Natural landscape of MEP versus MassGIS 2005 landuse

Category	MassGIS acreage	MEP acreage	Comments
Open land in uppermost two segments only			Nearly all watershed agriculture is found in these two upper watershed segments
Brushland/Successional	38.93		
Non-Forested Wetland	458.77		
Forest	7,691.73		
Forested Wetland	1,272.79		
Transitional	49.74		
Open Land	249.08		
Total	9,761.03	8,862.00	Overestimates of agricultural areas were taken at the expense of natural areas in the uppermost two watershed segments

11. Other assessor's data is misclassified.

MEP considers the 717 land class (productive woodland) as cropland in the loading spreadsheet. This land class in fact consists of hundreds of acres of Acushnet sawmill property (wetland and upland), that is unfertilized, and rarely has any forestry activities (Figure 12). The authors should treat these areas as undeveloped land.

Moreover, the parcel-independent MEP cranberry bog coverage, none of which is in this land class, is subtracted from this category, apparently in an attempt to preserve the total area integrity of the watershed. The MEP parcel-independent cranberry bog acreage should instead be subtracted from other agricultural parcels in the subwatershed where it is located.

Land use class 720 is now classified under the state code as "Wet land, scrub land, rock land", but in the MEP spreadsheet is called "Necessary Related Farmland" and assigns it the cropland loading rate. An inspection of the 720 classed lands (all in Lakeville) nearly all of the 100 acres in this class are wetlands and natural lands, except a small portion of one parcel converted to cranberry bogs. MEP also shows this wetland and scrublands land type as code 722 (with no acres), but this state class code no longer exists.

Mixed land use codes 017 (mixed use with agriculture secondary in assessed value) occurs mostly in Rochester and is principally agriculture lands (mostly cranberry bogs) but is assigned no loading coefficient in the loading spreadsheet.

12. Buildout methodology description needs additional information.

The buildout approach used by MEP is ambiguous with respect to certain issues. The report states how some land classes (130 and 131) are included, and how they excluded others (e.g., codes 132, 392, and 442), and how commercially developable properties were not subdivided, etc. The report is silent however as to how protected open space coverages, wetland coverages, and agricultural lands were addressed in the buildout analysis (it appears that agricultural lands, and Chapter 61 lands were excluded). It would be helpful for the authors to add a few sentences explicitly defining how they addressed these coverages. This section should stress the tentative or approximate nature of the estimates, and how, if they excluded Chapter 61 agricultural lands in the calculation, these lands could still be

Figure 12. The 378 acre Acushnet sawmill property (class 717, largest yellow polygon, is composed of forest and woodland swamp), is treated as cropland, and has cranberry bog areas (red polygons) subtracted from tits total areas.

Figure 13. These yellow outlined parcels (numbers show buildout unit potential (7+3+6) are located in protected open space (orange crosshatch around a reservoir in Lakeville).

Figure 14. This 22-acre mixed-use upland parcel (class 016) in Acushnet shows zero potential buildable units.

potentially developed after payment of back taxes or conveyance taxes.

Beyond the need for additional clarification of the methodology, there appear errors or lack of validation of the methodology. The report states "Existing developed properties are reviewed for additional development potential; for example, residential lots that are twice the minimum lot size, but have only one residence." However when reviewing the number of potential buildout units for each parcel, anomalous estimates are apparent, and don't seem to account for wetlands or open space, and some buildable parcels, and even some large parcels listed as developable have zero potential units (Figures 12-15). Some of these problems may relate to the ambiguous nature of the assessors land classification, compounded by a lack of review. .

Figure 15. These two parcels in Rochester show a buildout potential of 67 units, despite the fact that wetlands (green crosshatch) and cranberry bogs dominate the parcels. The top parcel is listed as developable land (130), and the bottom parcel is agriculture not in 61A (393).

13. Comments about eelgrass.
"All of the available information on eelgrass relative to New Bedford Inner Harbor indicates that this embayment has not supported eelgrass over the past 2 decades and likely has not supported eelgrass for over a century." Costa (1988, page 82 at www.buzzardsbay.org/eelgrass/costa-1988-epa-eelgrass-report.pdf) reported that eelgrass was present on Palmer's Island in the inner harbor prior to the construction of the hurricane barrier. It is true however, that most of the inner harbor is currently too deep to support eelgrass. It is also worth noting that reductions in dry weather discharges and the upgrade to the New Bedford wastewater facility resulted in a dramatic increase of eelgrass cover in Clarks Cove and Outer New Bedford Harbor, the only areas of Buzzards Bay to show such a recovery as a result of nitrogen reduction (see article at: www.buzzardsbay.org/acushnet-river-shellfish-openings-2008.htm).

14. Roof, driveway, and lawn size seem unrealistically large for these watersheds.
The MEP does not estimate lawn size based on parcel size, nor do they use any assessors data to calculate roof size (although it would be easy to create such algorithms). Instead, they enumerate the number of buildings from the assessor's database and multiply that total by a standard 1500 square feet roof area, 1500 foot driveway area, and for residential SFU and a few other parcel types, assume 5,000 square feet of lawn. These values are the same as they used on Cape Cod but seem unrealistic for this watershed where so many properties are either on 5,000 or 7,500 square foot lots with small lawns and no driveways. If for example the actual average weight parcel values in this watershed were 1000 square feet of roof, 1000 square feet of lawn

and 300 square feet of driveway. Using these numbers as an example, actual watershed loading would drop from 118,086 kilograms annual to 113,956 kilograms. The MEP could generate more realistic values for these features by randomly sampling parcels in each subwatershed and calculating means for these features.

15. Wastewater treatment facility annual loading reported by towns ignored.
We found in the Wareham report that MEPs loading values differ from those reported to EPA. Wastewater facilities must report nitrogen concentrations and loads (as pounds per day) to EPA, and these data are available online, and are even included in the SMAST spreadsheet for Wareham (WWTF![column F and G]). According to the EPA permit for Wareham, the data is based on composite samples which will be "flow based and will consist of at least twenty four (24) grab samples taken over a 24 hour period (e.g. 0700 Monday - 0700 Tuesday). In the Wareham study, SMAST ignores this data and calculates their own loadings based on the town's average flow and average concentration for each of the sampling dates. For Wareham, the MEP report specified wastewater facility loading as 6,761 kg/y, but the MEP reports loading values were mostly lower than the values reported by the town to EPA. In Wareham, using the composite sample daily loading data reported to EPA, and using SMASTs monthly weighted formula approach, the facility's nitrogen loading value should be 7,631 kg/y, or 12.8 percent higher. We did not have time to review the calculations, but SMAST appears to have similarly ignored the values reported to EPA by Fairhaven. It would seem that the MEP should use the daily nitrogen loading values reported to EPA by the town under their permit unless they can justify the data is in error or inadequate.

16. Minor edits and typos.
a) Table VI-6 and VI-8 captions state "The sentinel threshold station is in bold print.", but no station is bolded.

b) The authors use many variations in the name of the estuary, and at times these names sound like the names of the estuary segments. Some examples of text include:

- "Acushnet River (dash or slash) New Bedford Inner Harbor embayment system (or estuary)"
- "New Bedford Inner Harbor System", "The middle reach of the New Bedford Inner Harbor Estuary"
- "Conclusions of the MEP Analysis of New Bedford Inner Harbor"

The authors should make an effort to standardize the terminology to reduce opportunities for confusion. Look especially for consistency and clarity in Table ES-1 and ES-2 since these Tables will be a focal point of interest.

c) In either section VII or VIII, the report would benefit from the inclusion of a list of infaunal and epi-faunal species found and their relative or actual abundances. This would better illuminate terms like "dense accumulations of bivalves," "moderate # individuals," etc (as in Table VIII-1).

17. Main conclusion.
The MEP's loading analysis includes significant overestimates of both the number of dwellings and the number of septic systems in Fairhaven. The MEP made a similar overestimate of septic systems and underestimate of the extent of sewering in Acushnet. Together these errors may have contributed to a significant overestimate of nitrogen loading (possibly 20% or more). These overestimates, together with overestimates of nitrogen from agricultural lands and roof, lawn, and driveway loads, call into question the veracity of the loading analysis and the meaning and interpretation of the recommendations relating to the restoration scenarios presented.

Sincerely,

Joseph E. Costa, Ph.D.
Executive Director

EXHIBIT 7

HydroQual

Environmental
Engineers & Scientists

October 1, 2010

Mr. William E. Taylor
Pierce Atwood, LLC
One Monument Square
Portland, Maine 04101

Dear Mr. Taylor:

HydroQual has conducted a brief review of the Massachusetts Estuaries Project report entitled, "Linked Watershed – Embayment Model to Determine Critical Nitrogen Loading Thresholds for the New Bedford Inner Harbor Embayment System, New Bedford, MA." The following are comments on this report.

- The RMA hydrodynamic and total nitrogen models of Inner New Bedford Harbor were two-dimensional (vertically mixed). If there are vertical gradients in dissolved oxygen and salinity a three-dimensional model is required.

- The calibration of the total nitrogen model was achieved by empirically varying the exchange of total nitrogen between the sediment and water column. This weakens the reliability of the total nitrogen model especially when these water column sediment nitrogen exchange rates are estimated under future nitrogen reduction scenarios.

- A target average total nitrogen concentration of 0.50 mg/L near Popes Island has been established to allow restoration of an impaired benthic habitat. It was assumed that elevated nitrogen levels stimulate algae which consume water column oxygen by respiration and degradation on the bottom sediments. No quantitative link was established between New Bedford Inner Harbor dissolved oxygen and nitrogen levels.

- The target nitrogen concentration of 0.50 mg/L was based on reference to other nearby rivers, ponds, and bays that had healthy to moderately impaired benthic habitats. This extrapolation of the nitrogen-benthic habitat impairment from other waterbodies is inappropriate because the quantitative link between nitrogen and benthic habitat depends on many site specific factors including: flushing time, depth, water clarity, other sources of dissolved and particulate organic carbon, atmospheric reaeration and water column stratification. The only scientifically defensible approach to regulating nitrogen loads to Inner New Bedford harbor is to establish that low dissolved oxygen is the cause of benthic habitat impairment and then to apply a mechanistic model that specifically computes the bottom water dissolved oxygen as a function of BOD and ammonia oxidation, sediment oxygen demand (SOD), algal photosynthesis and respiration, and atmospheric reaeration.

- The potential impact of a nitrogen load to Inner New Bedford Harbor nitrogen and dissolved oxygen levels depends on both location and nitrogen components of the load. For example, the Fairhaven WWTP nitrogen load is close to the hurricane barrier and subject to significant tidal dilution and therefore may have less of an impact than a similar load from the Acushnet River or upper basin. In addition, as the Fairhaven WWTP reduces its effluent nitrogen through denitrification, a greater fraction of the remaining effluent nitrogen is refractory and not readily available to support algal growth. Therefore, any evaluation of the potential impact of nitrogen on Inner New Bedford Harbor nitrogen and dissolved oxygen levels must recognize the bioavailability of the nitrogen from each of the sources.

Very truly yours,

HYDROQUAL, INC.

Thomas W. Gallagher

Thomas W. Gallagher
Principal

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EXHIBIT 8

CAPE COD TIMES

County reverses decision on wastewater study

By Susan Milton
smilton@capecodonline.com
August 21, 2010 2:00 AM

http://www.capecodonline.com/apps/pbcs.dll/article?AID=/20100821/NEWS/8210321/-1/NEWS11

BARNSTABLE — First there was Orleans, the only Cape town to ask for a wastewater study by the prestigious National Academy of Sciences.

Then, this summer selectmen in eight other Cape towns joined the call for an independent review of the science behind the state limits on pollution in coastal waters. Those limits will determine how many billions of dollars Cape taxpayers will need to spend to reverse the pollution of coastal waters, mostly by septic systems.

In an about-face, county leaders now also are interested in an Academy of Sciences study as a way to answer polarizing questions that threaten to stall wastewater treatment on Cape Cod.

"We all know we have a problem," Brian Braginton-Smith, executive director of the Lewis Bay Research Center, a nonprofit group interested in the fate of that coastal bay, said yesterday. "Now the question is, how do we move forward and build consensus?"

Yesterday, Braginton-Smith connected County Commissioner Sheila Lyons, Cape Cod Commission executive director Paul Niedzwiecki and Orleans wastewater leader Augusta McKusick of Orleans with Susan Roberts, director of the Ocean Studies Board at the National Academies based in Washington, D.C. At the end of her Martha's Vineyard vacation, Roberts came over to Barnstable to talk with Braginton-Smith about a variety of ocean issues and to meet with county officials.

For an hour, they talked about how long such studies normally take (several months to several years); how much a study would cost ($400,000 to $700,000); and what issues a wastewater science study could cover.

"I would welcome the National Academy of Sciences to look at the science and some (treatment) implementations," Niedzwiecki told Roberts. "I would love to have that sort of objectivity to be completely confident that we are headed in the right direction, and if we are not, I'd like to know that too."

They talked about how the $4 billion to $8 billion price tag for wastewater treatment Capewide has led to an endless loop of criticism about treatment methods and treatment science.

"We can bring in the experts," Roberts said. "I think, to that extent, we have a role to play. I can't solve your political issues."

The National Academy of Sciences, created by President Lincoln in 1863, uses committees of the nation's top scientists, engineers and other experts to study specific concerns referred to them by government agencies. About 80 percent of the studies are funded by the federal government.

Participants in yesterday's meeting described an Academy of Sciences study that could review the validity of the Massachusetts Estuaries Project's computer models. The models were developed by the University of Massachusetts-Dartmouth under contract with the state Department of Environmental Protection, and they were approved by the U.S. Environmental Protection Agency.

The computer models tell the towns how much nitrogen must be removed from watersheds and water bodies, and they try to predict the effect of various nutrient levels on ecosystems and the effectiveness of remedies. The state uses the models to set standards for bays and estuaries, then communities build collection and treatment systems to meet those standards.

Orleans selectmen sought an Academy of Sciences study to answer critics who believe the computer models aren't accurate. Without the study, a majority of selectmen believe they can't get the votes to pay for sewers or other wastewater facilities.

The Cape needs an objective review of how to meet the state's wastewater requirements, by watershed and across the Cape as a whole, McKusick said yesterday. "If you put in those pieces, then you build consensus," McKusick said.

Two months ago, county leaders rejected the need for such a study. In June, the Barnstable County Commission called Orleans' proposal for an Academy of Sciences study an unnecessary delaying tactic. But that was before the Orleans' proposal drew so much support.

More recently, the commission countered the Orleans proposal by offering to convene a panel of scientists to review the state computer models. Critics said the panel wouldn't be independent or do a thorough review.

"We are all frustrated because we know every day we're losing a little bit more of the Cape that we won't be able to recover," Lyons said yesterday.

EXHIBIT 9

Memorandum of Understanding

WHEREAS, the purpose of the Massachusetts Estuaries Project ("MEP") is to address the coastal embayments throughout the Commonwealth that are becoming nutrient enriched due primarily to increased population along the coast. Most of our coastal embayments, covered under this project, have already been identified as impaired or borderline in terms of water quality. Further delays in this project will negatively affect our coastal waters for the foreseeable future since it will take many years to implement solutions. Without solutions these waters will continue to degrade, leading to the loss of eelgrass beds, fisheries, and healthy benthic communities. These harms to the environment will negatively impact the aesthetic value of these water bodies, the use enjoyment and the livelihoods of the Cape Cod and South Coast communities.

WHEREAS, the MEP is a collaborative effort between the Massachusetts Department of Environmental Protection (the "Department" or "MassDEP") and the University of Massachusetts Dartmouth School for Marine Science and Technology ("UMD SMAST" or "University") to provide a consistent method to evaluate embayment health in 89 embayments in Southeastern Massachusetts, to make recommendations for restoration and nutrient reduction and to develop the tools necessary for communities to evaluate the most cost-effective solutions to this problem.

WHEREAS, the results of these evaluations supply the information necessary for MassDEP to complete, and submit for EPA approval, Total Maximum Daily Load Reports ("TMDL") and Water Quality Standards. In addition, these evaluations supply the project partnering Towns with the data and tools to identify and implement the most cost-effective solutions to ensure water quality goals are met through the development and implementation of their Comprehensive Wastewater Management Plans ("CWMPs").

WHEREAS, MassDEP is responsible for incorporating site-specific thresholds into the state Water Quality Standards and working with the Towns in the development and implementation of their CWMPs. MassDEP's role in the MEP includes working with University and UMD SMAST, through ISAs, on scientific analysis and to develop and submit TMDLs for approval to the US EPA.

WHEREAS, UMD SMAST's role in the MEP is to provide scientific expertise and analysis, including data collection, modeling and development of site-specific nitrogen thresholds needed for the development of TMDLs by MassDEP, and to work with the Towns to collect data, develop and implement modeling tools that can be used to help communities evaluate alternatives.

WHEREAS, MassDEP and UMD SMAST believe that it is important to achieve the purposes of the MEP, which will provide a significant benefit to the public, as well as to MassDEP and UMD SMAST. In order to reach settlement regarding their differences regarding data and model ownership and access, the Parties set forth herein the terms under which they will continue to work together in the MEP.

NOW THEREFORE, notwithstanding any disagreement, it is in the interest of MassDEP and UMD SMAST, and most importantly the citizens of the Commonwealth, that MassDEP and UMD SMAST (hereinafter "the Parties") work together to ensure that the MEP is completed in a timely manner. As such, the Parties agree as follows:

Data Definition

The term "data" or "MEP data" as used in the MEP shall have the meaning provided in the federal regulation located at 40 C.F.R. § 30.36 ("EPA Regulation") [1]. Further, as used in the EPA Regulation, references to "Federal Government" shall mean "MassDEP;" references to "recipient" shall mean "UMD SMAST;" and references to "Federal" shall mean "State."

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1 (i) Research data is defined as the recorded factual material commonly accepted in the scientific community as necessary to validate research findings, but not any of the following: preliminary analyses, drafts of scientific papers, plans for future research, peer reviews, or communications with colleagues. This ``recorded'' material excludes physical objects (e.g., laboratory samples). Research data also do not include:

(A) Trade secrets, commercial information, materials necessary to be held confidential by a researcher until they are published, or similar information which is protected under law; and

(B) Personnel and medical information and similar information the disclosure of which would constitute a clearly unwarranted invasion of personal privacy, such as information that could be used to identify a particular person in a research study.

(ii) Published is defined as either when:

(A) Research findings are published in a peer-reviewed scientific or technical journal; or

(B) A Federal agency publicly and officially cites the research findings in support of an agency action that has the force and effect of law.

(iii) Used by the Federal Government in developing an agency action that has the force and effect of law is defined as when an agency publicly and officially cites the research findings in support of an agency action that has the force and effect of law.

(e) Title to intangible property and debt instruments acquired under an award or sub-award vests upon acquisition in the recipient. The recipient shall use that property for the originally-authorized purpose, and the recipient shall not encumber the property without approval of EPA. When no longer needed for the originally authorized purpose, disposition of the intangible property shall occur in accordance with the provisions of Sec. 30.34(g).

Report Data

The Parties agree that MassDEP has joint ownership and unrestricted access to and use of the MEP data contained in the technical reports and technical memoranda ("Report Data"). Access to additional types of data is addressed in detail below, under the heading "Additional Data Access."

Technical Report Ownership

The Nutrient Threshold Technical Reports ("Reports") produced by UMD SMAST under each ISA for the MEP and the data that are provided in the Reports pursuant to the ISAs are jointly owned by UMD SMAST and MassDEP.

Data Storage

The 2004 and 2006 archiving protocols were prepared to respond to public records requests. Those protocols will be used more broadly to encompass the data identified and collected in accordance with the QAPP. UMD SMAST will store this project data in archive per the July 2004, and June 2006 data archiving protocols and any future protocols developed between the Parties and included in a future ISA.

Additional Data Access

Access to MEP data other than Report Data will be determined by payment source and date of data gathering as follows. UMD SMAST asserts that older data is more difficult to access and as such July 1, 2005 is used herein as a surrogate to distinguish between newer, more accessible data and older, less accessible data. All data requests will be copied to the Joint Management Team who will intervene at the request of either project manager if disagreement arises over the production of documents.

Within 90 days of this MOU, UMD SMAST will inventory all data subject to this MOU and provide the list identifying the type of data, its location and its format for review and use of the Joint Management Team. This inventory will assist in determining the availability of data. MassDEP will provide funding for this effort, to be negotiated in the New ISA, subject to billing protocols to be established by the Joint Management Team.

For MEP data collected under future ISAs, thus funded in whole or in part by MassDEP: MassDEP will have joint ownership and unrestricted access and use of this data. UMD SMAST will attempt to include such provisions in any agreement it negotiates with a third party.

For the raw data listed on Attachment A hereto ("Raw Data List"): MassDEP will be provided unrestricted access and use of this data (and to the degree expressly designated on the Raw Data List, the raw data shall be jointly owned by the Parties) within 60 days in the format expressly designated for each.

For MEP data collected during the last three years (commencing July 1, 2005) and funded in whole or in part by the MassDEP: MassDEP will be provided unrestricted access and use of this data within 60 days unless a prior third party contractual agreement does not provide access to such data or such data sharing can be shown by UMD SMAST to be excluded from MEP data as defined by EPA Regulation. UMD SMAST will provide appropriate documentation to support (1) an assertion that a third party contractual agreement prevents access, or (2) such data is excluded from MEP data as defined by EPA Regulation. In the event of such a prior contractual agreement, UMD SMAST will work in good faith to secure access to this data in a timely manner. If the MassDEP project manager disagrees with the interpretation of the third party agreement or the assertion that data is excluded from the MEP data definition, the issue will be elevated to the Joint Management Team.

For MEP data collected with funding solely from a municipal government over the last three years (commencing July 1, 2005) MassDEP will be provided access within 60 days of receiving written permission by the municipal government(s) that funded the data collection. It will be the responsibility of UMD SMAST to obtain permission to grant MassDEP access to this data in a timely manner. If the MassDEP project manager disagrees with the claim of funding by a municipal government, the issue will be elevated to the Joint Management Team.

For MEP data collected with funding solely from non-government organizations over the last three years (commencing July 1, 2005) MassDEP will be provided access and use of this data upon written permission by the non-government organization(s) that funded the data collection. It will be the responsibility of UMD SMAST to request permission to grant MassDEP access to this data in a timely manner. If the MassDEP project manager disagrees with the claim of non-government organization funding, the issue will be elevated to the Joint Management Team.

For MEP data collected more than three years ago (prior to July 1, 2005), UMD SMAST will make a good faith effort to meet any data request made by MassDEP, taking into consideration prior legal agreements with MassDEP or other parties. This includes consideration of any relevant third party contractual agreement, and funding sources, and any data contained in the definition of MEP data noted in above sections. If UMD SMAST asserts that the requested data can not be provided to MassDEP, the UMD SMAST project manager will document his assertion and the basis for it within 60 days of MassDEP's request if the MassDEP project manager disagrees with UMD SMAST project manager's assertions, the issue will be elevated to the Joint Management Team.

FOIA Requests and Data Exceptions

In the event of a FOIA request, the provisions of the EPA Regulation shall apply. If UMD SMAST asserts that particular data is excluded from "research data" under 40 C.F.R. § 30.36(d), UMD SMAST will provide a statement of its position, a specific identification and description of the data claimed exempt from disclosure. Such statement will include its specific legal support, including which specific exemption the data falls within, and any supporting information that leads UMD SMAST to its stated position. If MassDEP's project manager disagrees with the statement, the issue will be elevated to the Joint Management Team.

Model Access

UMD SMAST will, within 90 days, present to MassDEP a proposal to make the calibrated and validated Linked Watershed Embayment Model approach and relevant model files (the "Model") available to MassDEP. This access shall include all files necessary to run the final calibrated and validated model to be set forth in the New ISA. If the MassDEP project manager disagrees with the proposal, the issue will be elevated to the Joint Management Team.

MassDEP acknowledges that researchers from UMD SMAST and Applied Coastal jointly developed the Model approach utilized by the Massachusetts Estuaries Project, as described in "Nitrogen Modeling to Support Watershed Management: Comparison of Approaches and Sensitivity Analysis - *Project #00-06/104,*" prior to the initiation of the MEP. UMD SMAST asserts that the Model approach is copyrightable and patentable. In the context of the New ISA, the Joint Management Team will consider any proposal by UMD SMAST for an access or license fee to use the Model if UMD SMAST perfects a copyright and/or patent claim, taking into account any such copyright or patent and UMass' current policies (including the University of Massachusetts Intellectual Property Policy DOC. T96-040 (the "IP Policy")) and procedures regarding use of copyrighted and patented materials owned by the University.

This proposal will include, but not be limited to, the following:

1. A description of the qualifications required by a technical team to run the Model.

2. A plan to train and qualify MassDEP personnel to run the Model.

3. Language releasing UMD SMAST from all liability related to implementation of the Model by non-UMD SMAST personnel.

4. A procedure to document all changes made to the original calibrated and validated model.

5. Before any Model scenario run by a third party is accepted by MassDEP for any purpose to be presented to the public, UMD SMAST must quality assure the model results.

Model Access Relative to Towns

UMD SMAST will allow the Towns covered under the MEP to use the calibrated and validated Model to test alternative scenarios. Towns are not required to use UMD SMAST. If Towns use UMD SMAST, UMD SMAST may charge them a reasonable fee to run the alternative scenarios. Alternatively, the Towns may engage a consultant to test alternative scenarios.

In either case, the preconditions for use of the Model will include, but not be limited to, the following:

1. A description of the qualifications required by a technical team to run the Model.

2. A plan to train and qualify the personnel intending to run the Model.

3. Language releasing UMD SMAST from all liability related to implementation of the Model by non-UMD SMAST personnel.

4. A procedure to document all changes made to the original calibrated and validated model.

5. Before any Model scenario run by a third party is accepted by MassDEP for any purpose to be presented to the public, UMD SMAST must quality assure the model results.

6. An access or licensing fee for use of the Model based on current UMass policies (including the IP Policy) and procedures and standard practices for the industry, if UMD SMAST perfects a copyright or patent claim relevant to the Model approach.

Establishment of the Massachusetts Estuaries Project Advisory Group

A MEP advisory group will be established to improve communications with the communities and non-government organizations. The Joint Management Team will jointly determine membership of this group. The group will be co-chaired by members of the Joint Management Team.

Establishment of Joint Management Team

A senior management team will be established to keep the project on track. This senior management team would be the forum for reviewing and resolving disputes relative to data or model access, negotiating the terms of the New ISA, including establishing financial documentation procedures and accountability and other matters as they arise. The team will include the managers with the following functions and expertise from UMD SMAST and MassDEP; the technical project leads, project managers, external relations managers, financial managers, and a senior manager from the Chancellor's Office and a senior manager from MassDEP's Commissioner's Office. This arrangement should serve to free each Party's technical experts to do the important work of the project.

The Municipal Services Center

UMD SMAST will draft a proposal within 90 days to establish a Municipal Services Center at UMD SMAST that it will present to the Joint Management Team for discussion with the MEP Advisory Group. The mission of this center will be to gather and organize existing MEP-related data and non-MEP-related environmental data, and future data, and make this data available to policy makers and scientists to benefit the Commonwealth. The Municipal Services Center will also be the education and training center to qualify individuals to use the Model.

Appropriate Attribution

In every instance, use of MEP data by MassDEP and others in accordance with the terms of this MOU is required to be made with appropriate attribution.

Compensation

UMD SMAST will be reimbursed by MassDEP for reasonable costs related to meeting its obligations under this MOU, to be determined consistent with past payments made under the ISAs, including those related to meetings, data and modeling requests, as documented in accordance with the New ISA.

Execution of New ISA

This MOU shall go into effect immediately upon the execution of a full and comprehensive MEP ISA ("New ISA"), not including the proposed 9-final report mini-ISA being proposed by MassDEP. A new MEP ISA will include specific documentation requirements for billing and financial accountability consistent with the Massachusetts Comptroller regulations and standard accounting practices.

Massachusetts Department of Environmental Protection

By: ______________________

Name: Laurie Burt

Its: Commissioner, MassDEP

Date: August 11, 2008

University of Massachusetts

By: ____________________

Name: Jean F. McCormack

Its: Chancellor, UMass Dartmouth

Date: August 11, 2008

Attachment A

Raw Data List

(1) Bathymetry – Access to GIS shape files of the bathymetry of all estuaries, even if collected prior to the MEP.

(2) Tidal Stage data – Access to data processed for modeling and collected under the MEP ISAs commencing July 1, 2005

(3) ADCP - Access to copies of processed data in tabular form processed for modeling and collected under the MEP ISAs commencing July 1, 2005

(4) Streamflow and Attenuation data - Access and joint ownership of copies of processed Flow data and nitrogen data in tabular form collected under the MEP ISAs commencing July 1, 2005 (Note: this dataset is patchy due to the time windows of ISAs and lack of continuous record of sample collection)

(5) Benthic regeneration data - Access and joint ownership of copies of processed data in tabular form for data collected under the MEP ISAs commencing July 1, 2005 (Note: this dataset is limited due to summertime collection)

(6) Chemical data including Dissolved Oxygen, temperature, salinity, water clarity, nutrients (nitrate-nitrite, ammonium, total and ortho phosphorus, total dissolved nitrogen, particulate carbon and nitrogen) and bacteria - Access and joint ownership of copies of processed data in tabular form for data collected under MEP ISAs and used in the Technical Reports commencing July 1, 2005

(7) DO readings and Chlorophyll readings – Access and joint ownership of copies of processed data in tabular form for data collected under the ISAs commencing July 1, 2005 (Note: this dataset is limited due to summertime collection)

(8) Benthic Infauna - Access and joint ownership of copies of processed data in tabular form for data collected under MEP ISAs commencing July 1, 2005 (Note: this dataset is limited due to summertime collection)