*DEPARTMENT OF PUBLIC WORKS*
*TOWN OF DURHAM*
*100 STONE QUARRY DRIVE*
*DURHAM, NH 03824*
*(603)868-5578*

# Draft Small MS4 Stormwater Permit Public Hearing

## January 28, 2009, Portmouth, NH

### Public Testimony From David Cedarholm, P.E., Town Engineer, Durham, NH

1. *Section 2.1 Water Quality Based Effluent Limitations* - requires the permit to "ensure that discharges from the MS4 do not cause or contribute to exceedance of water quality standards." And, *Section 2.2.2 Discharge to an Impaired water without an approved TMDL* – which requires the permittee to "evaluate discharges to impaired waters." And the later *Section 3.0 Outfall Monitoring Program:*

In the absence of a TMDL (which is typically the case in New Hampshire), these requirements will essentially require the communities to conduct their own TMDLs to comply, and will require municipalities to dramatically expand operation and established Stormwater Divisions if they haven't already done so.

- To what extent is the permittee required to "evaluate" the discharge?
- Are the parameters and acceptable methods defined?
- Will the evaluation need to be performed by a Professional Engineer or Geologist? And will the water quality monitoring need to be conducted by certified technicians? State Statute would appear to dictate so, and Consulting firms simply are not yet set up to do this!
- How is this to be funded if not through something like a Stormwater Utility?

Stormwater Utilities are the only statutory vehicle in New Hampshire that provides the local authority to charge existing private entities to help pay for extensive environmental investigations and rehab of infrastructure. Other available statutory authority exists within local Site Plan or Subdivision regulations, but it only pertains to new proposed development. Similar State Regulations such as Alteration of Terrain rules only applies to larger new developments. The idea of a Stormwater Utility is dramatic paradigm shift for small communities that are already struggling with out-of-control municipal budgets. To do the work needed to investigate how to fairly assess discharges and design a whole new enterprise fund will take considerably more than 1 year.

This puts a tremendous burden on a small community like Durham, New Hampshire with only 10,000 residents where only about half are within the MS4. It will also require the Town to establish a whole new division of engineers, environmental scientists and technicians, additional laborers and heavy equipment to expressly manage and maintain the stormwater system needs. To do so will take much more than and year and will likely increase the annual Department of Public Works budget by at least 25 percent.

- How much guidance and financial assistance are the EPA and NHDES prepared to offer to help small communities respond to these new mandates?

*Section 2.2.3 Discharge to chloride impaired water* - Requires private and public owners of parking lots and roads to annually report deicing salt use applied for each storm. Unless a Stormwater Utility is in place, municipalities don't have the authority to require private entities to provide reporting information.

- What mechanism will be put in place to ensure useful and accurate reporting?
- Will the EPA or NHDES provide criteria for how this information is to be consistently and accurately gathered and reported?
- How will the data be used?
- Has the EPA and NHDES evaluated the State of Minnesota guidance criteria (reference on Page page 12) for appropriateness in New Hampshire?
- Will the EPA and NHDES provide guidance or requirements relative to what chloride impairment corrective measure to implement?

*Section 2.2.4* does not define "Increase in discharge" clearly, but it does defined a "new discharge".

- Is an increased discharge based on a specific rainfall frequency, rate or volume? A stormwater system may that is designed to manage a 25 year storm event will not as easily manage a 100 year or 500 year event.
- Does Section 2.2.4.c also pertain to increased discharges?
- Is the EPA or NHDES prepared to receive and respond to submissions from every proposed development regardless of size? This section essentially requires all developments to provide a design report for review by the EPA.
- Does Section 2.2.4.e require a 401 Water Quality Certificate for all developments?

*Section 2.3* indicates that the "requirements" to reduce pollutants to the Maximum Extent Practicable (MEP) approach is an iterative process.

- This section is vague and lack actual requirements. Without specific requirements an iterative process implies a moving target of regulation.

Respectfully,

David Cedarholm, P.E.
Town Engineer
dcedarholm@ci.durham.nh.us

Exeter, NH

"Phyllis Duffy"
<pduffy@exeternh.org>
01/27/2009 07:14 AM

To Thelma Murphy/R1/USEPA/US@EPA
cc
bcc
Subject Stormwater Phase II Permit

Hi Thelma,

Comments on the QLP and New Stormwater Phase II Permit are as follows:

Exeter would prefer to have the Construction General Permit stay with EPA or at least at state level. We have a good program, but for large contractors it is better to have them know that EPA is the permit authority and that there have been large fines at construction sites that are not implementing the correct erosion control and best management practices. We can and have stepped in with "Stop Work" orders and our inspectors do get contractors to correct problems, but if it is large contractors, i.e. box store, we believe it is better to have them know they are watched by a higher authority.

- 2.1.1. (c) - We do not believe that 60 days is feasible for time allowed between discovering a discharge and correcting. (ex. - there was a intermittent discharge, -not into our system but into a local stream, from a private entity - it took quite some time for them to trace the origins from the discharge - even with the town helping- it is a very large campus with many buildings and facilities.) If the discharge had been into our system it would take even longer to remove.
- 2.2.3 - For chloride impaired waters, we must provide alot of information from private entities. For new contruction, we can require that information, but for existing businesses, what authority do we have to require them to report that information?
- 2.3.4.4. How do we determine if non-stormwater discharges are a significant contributor?
- 2.3.4.6 (d) - Walk all strean miles (walk banks of all waters of US) - This may not be possible as we have had property owners refuse giving us permission (which we must get) to walk on their property. Some areas are not accessible by boat, canoe or kayak, we have tried them all. (including a picture)
- 2.3.7.1 (b) - The Town has no authority over schools. If they discharge to our drainage system we can request certain information and encourage BMPs but it will be very difficult to have them complete all requirements of the Good Housekeeping and Pollution Prevention BMP. They are similar to a private institution.
- 3.0 - If outfalls are not accessible, can we complete our water quality monitoring at the last structure before discharge?
- 2.3.4.6(d ii) Outfalls - for the first permit, we reported 65 outfalls. These outfalls are the end of the storm drainage piping system that picks up stormwater from streets and parking lots by draining into catch basins through a system of structures and pipes and discharges to a local waterway. Is this the correct interpretation of an outfall? Should we report outfalls that drain to a wetland? What about outlets from a detention basin?
- Feedback on what towns appear to be doing right in regards to the Stormwater Permit.

"Phyllis Duffy "
<pduffy@exeternh.org>
01/27/2009 02:32 PM

To Thelma Murphy/R1/USEPA/US@EPA
cc
bcc
Subject

Hi Thelma,

I have some additional comments and I am attaching a plan and a picture to give an idea of what we experience trying to conduct stream surveys. We weren't able to go much further on this section of stream than the kayak in top of picture.

1. Can municipalities take credit for items that the state has completed, such as stream surveys? We actually ran into a situation, where we asked waterfront property owners if they had any objections to us walking along the banks of their property. One owner responded that the state had just been there and done the same investigation that we stated in the letter that we were going to investigate. He refused us permission and questioned our time when the state had already done the same investigation. We have in a couple of cases accompanied the state during investigations.

2. It appears that EPA has or is producing training on "How to Collect Samples", step by step instruction for creating SWPPPs, record keeping templates, and other materials that will be helpful to municipalities. Most of us will have to take on these new responsibilities in-house.

3. 2.3.7 (d ii) Ensure that areas used for snow disposal will not result in discharges to waters. (please clarify EPA/State ... NOTE... NHDES Fact Sheet WMB-3 Snow Disposal states "Disposed snow should be stored near flowing surface waters, but at least 25" from the high water mark of the surface water.)"

4. If we have certification regarding Endangered Species and Historic Properties from the first permit, do we need to request additional documentation?

5. What can municipalities do to determine/document that the impairment is coming from upstream communities? (not Phase II towns)

6. Sweeping sidewalks- currently we only sweep arterial sidewalks with an open broom on a tractor - no pickup capabilities. Sidewalk material is pushed in front of street sweeper for pickup. Sidewalks that are not swept have a grassed median strip between sidewalk and street. These sidewalks are not treated with sand. Do sidewalks with grass strip between them and the street require sweeping? If so, this will require a new piece of equipment at a cost of approx. $40,000, which will have to be programmed. This will not be possible within 6 months of the effective date of permit. littlervr.jpg little river survey 2007.JPG

"Dave Poulson "
<DPoulson@windhamnewhampshire.com>
01/06/2009 12:35 PM

To Thelma Murphy/R1/USEPA/US@EPA
cc
bcc
Subject NEW MS4 PERMIT

Thelma,

Reviewing the draft MS4 permit and your NOI model. How much information or is there carry-over from our existing NOI and Storm Water Management Plan from 2003, i.e., historic properties, maps, general NOI, endangered species, etc? Do we need to re-create the wheel? Need more directions on upcoming NOI.

Thanks,

David Poulson, Windham, NH

Postmark 2/18/09

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February 18, 2009

Thelma Murphy
US EPA – (CIP)
One Congress Street – Suite 1100
Boston, MA 02114

RE: COMMENTS ON DRAFT NPDES PHASE II STORMWATER PERMIT FOR NEW HAMPSHIRE

Dear Ms. Murphy:

The purpose of this letter is to submit comments on the Draft Phase II MS4 Permit for New Hampshire that was published in the Federal Register on December 23, 2008. As you know, Comprehensive Environmental Inc. (CEI) has been involved with the NPDES Phase II Program since its inception and has assisted dozens of MS4s with the development and implementation of their Stormwater Management Programs (SWMP). Additionally, CEI has significant experience and background with stormwater, regulatory/guidance and water quality improvement projects in New England that has served the best interests of the public and the environment. Based on these experiences and our review of the Draft Phase II MS4 Permit for NH, CEI respectfully submits the following comments:

Comment #1:
Part 2.1.1(c) "... eliminate the conditions causing or contributing to an exceedance of water quality (WQ) standards ... within 60 days of learning of situation".

*As the December 2008 Draft NH Small MS4 Permit reads, it is possible that outfall monitoring and sampling under Part 3.1.2-3 will identify flows from an outfall that are "causing or contributing to an exceedance of water quality (WQ) standards". It is likely that many outfalls will not meet WQ standards; however, extensive modeling would be required to determine the impact of specific discharges on receiving waters. Regardless, elimination of such a condition within 60 days of knowledge is impractical.*

*The language under this part needs further clarification as to what constitutes a discharge causing or contributing to an exceedance of a water quality standard, possibly including a list of exemptions/situations that do not apply. This will avoid situations where the MS4 may be in violation due to the 60 day criteria or a determination cannot be made without further analysis, modeling, etc. If this section is attempting to address obviously contaminated discharges from the MS4 it should be stated as so.*


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Comment #2:
Part 2.2.3 "Discharge to a chloride impaired water in New Hampshire"

*This part states that the written plan to reduce chloride in discharges from the permittee's MS4 must include requirements for private owners of parking lots and roads to report their annual deicing usage to the MS4, as well as comply with specific deicing storage and application methods. MS4s in NH do not have the authority to regulate the use of deicing agents on private lands. Additionally, this requirement only addresses deicing usage on private lands that discharge to the MS4 within urbanized areas. Many of the large users of deicing agents may not discharge through the MS4 and these requirements would not address this chloride contribution. A regional permit process administered by EPA may be more effective in the reduction of chlorides from private land owners within the watershed of impaired waters.*

Comment #3:
Part 2.3.6.8(b) "Complete an inventory and priority ranking of MS4-owned property and infrastructure that may be retrofitted".

*The priority ranking evaluation should consider the results of the efforts under Parts 2.3.4.5-6, 2.3.7.1(d) and 3.1.2-3. This may result in a more effective evaluation of the overall drainage system needs and the potential for water quality improvements, which includes retrofit opportunities. For example, the results of drainage system inspections under Part 2.3.7.1(d)(iv) may reveal problem areas that rank higher based on the opportunity for pollutant removal relative to cost.*

Comment #4:
Part 2.3.7.1(d.i) "Clean catch basins once every other year".

*This part needs to include provisions for MS4s to comply with an alternative method for catch basin cleaning that is based on actual field data, for example. The 2003 permit suggested that MS4s clean catch basins at a frequency based on inspection results, which may identify areas that required more frequent cleaning. The MS4 should be allowed to demonstrate the appropriate frequency for catch basin cleaning rather than following a strict requirement to clean every other year.*

Comment #5:
Part 3.3 "Wet Weather Analytical Monitoring"

*The monitoring program outlined under Part 3.3 will require significant resources and may not result in representative or comparable data. If wet weather data is collected for different storm events and during varying conditions (e.g., first flush, end of storm,*

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*time of year) it will not adequately characterize water quality impacts. Under these varying conditions, numerous data points would be required to evaluate problem areas and prioritize improvements. In order to obtain representative and comparable data, a wet weather monitoring program should be developed for each MS4. The program should follow a design similar to that of a Quality Assurance Project Plan (QAPP) and focus on key sampling locations to characterize stormwater quality throughout Town.*

*For example, using land use pollutant load calculations and characteristics for each sub-basin, a range of outfalls could be targeted to represent low, medium and high-density development areas. This will focus the wet weather monitoring and allow for additional data points to be collected during multiple storm events. Similar to the evaluation for "substantially identical outfalls" in the NPDES Multi-Sector General Permit, the data could be used to characterize wet weather water quality at other outfalls in Town. A program of this nature would reduce the overall financial burden of wet weather sampling at each outfall while collecting representative and comparable data to evaluate stormwater impacts, priority improvement areas, etc.*

I hope that these comments are helpful in shaping the final NH Phase II Permit for MS4s. If you have any questions or wish to discuss this information, please feel free to call or email me at 800-725-2550 X 307 or rniles@ceiengineers.com.

Sincerely,

COMPREHENSIVE ENVIRONMENTAL INC.

Rich Niles
Project Manager

cc: Jeff Andrews, NH DES

Postmark - 2/19/09
Received.
FEB 24 2009

New Hampshire
DOT
Department of Transportation

**_THE STATE OF NEW HAMPSHIRE_**
**_DEPARTMENT OF TRANSPORTATION_**


**_GEORGE N. CAMPBELL, JR._**
**_COMMISSIONER_**

**_JEFF BRILLHART, P.E._**
**_ASSISTANT COMMISSIONER_**


February 19, 2009

EPA Region 1,
Attn: Thelma Murphy
Office of Ecosystem Protection (CIP),
1 Congress Street
Boston, Massachusetts, 02114-2023.

Dear Ms. Murphy:

Re: New Hampshire Department of Transportation
Comments to the Draft General Permits for Stormwater Discharges for
Small Municipal Separated Storm Sewer Systems

Managing the highway system in New Hampshire is a team effort involving many State and Local agencies including the Departments of: Safety, Environmental Services and others. It is difficult to understand how the NH Department of Transportation became the lead agency in this "Municipal" Permit. We are not a town, city or village. Nobody physically lives in a house or operates a business on the State Right-of-Way. We are designers and maintainers, not regulators, policemen or investigators. Those powers reside elsewhere in state and local government. The Department of Transportation only controls the physical makeup of the road (pavement, guardrail, drainage etc.) Our system is also vast. The Department maintains 627 miles of highways, has over 8,000 catch basins and over 3,600 outfalls within the urbanized areas in southern New Hampshire. What may seem like small inconsequential logical activities at a small scale quickly become overly burdensome and wasteful when multiplied thousands of times. There are a number of activities prescribed in this permit that we think do little to protect water quality.

Non - Numeric Effluent Limitations

The Department's roadway system is very static. Many of our roads have been in the same location since the 1930's with little change and as result the discharges from those pavement surfaces have not changed in a very long time. When a change is made it usually requires coordination with the State Legislature, the General Public and State and Federal Regulators to ensure that all issues are identified and possible consequences are addressed. A Total Maximum Daily Load (TMDL) serves a similar function involving all parties and investigates the root cause and specific conditions that caused impairment of a waterbody. As a result, the implementation of the TMDL load reductions is usually well vetted through the contributors and takes into account the social, and economic consequences. However, it seems this permit has skipped over the TMDL process and prescribed an implementation plan for chloride impaired waters with little or no public input, and little regard for social and economic consequences and public safety. EPA is also trying to apply a single winter maintenance standard to all paved surfaces in the urbanized areas, which is completely inappropriate when considering the wide spectrum of uses, from residential streets to interstate highways. Chloride impairments should not be treated outside the 303(d) process. Each impaired watershed should have a TMDL completed to determine the responsible parties, sources of the loads and required load reductions. Each chloride-impaired watershed should have a well thought out Implementation Plan based on a TMDL; not based on untested guidance from another state with unknown consequences.

It is unclear how the Section 401 process works with this 402 permit. If a project has a 401 Water Quality Certification does the permittee need to apply to EPA for the same discharge? The process for new discharges that do not require 401 Certification is very vague, open to interpretation and open to legal challenges. In addition, Antidegradation provisions are not defined in the regulation.

Illicit Discharge Detection and Elimination (IDDE) Program and Outfall Monitoring Program

The Department sees the need to better integrate the Outfall Monitoring Program and the IDDE Program. First and foremost we need a better definition of outfall. The Department has thousands of "cross road culverts" in which water just passes under the roadway. We also have thousands of "Drop inlets" in which water is collected curbside in a single sumpless catch basin and immediately discharged at the toe of slope. It does not seem useful to investigate these locations. But are they outfalls?

The permit appears heavily oriented on detection of sewer interconnections. The majority of the Department's system is located within the Limited Access Right-of-Way of I-95, I-93, the Spuaulding Turnpike and the FE Everett Turnpike where there are no sewer systems. In addition, much of the highway system is in more rural areas, where again, there are no sewer systems. The Department failed to find any sewer connections in an extensive review and testing program initiated in the summer of 2006 within the urbanized area. It does not seem prudent to investigate the same outfalls especially in areas where bacterial impairments have not been identified. The permit also describes in length the methods to prioritize the testing and screening procedure but in the end requires testing of all outfalls, twice! The suite of tests required is quite expensive at approximately $250 per outfall, without labor. Under this proposed regulation the Department would be required to test approximately 1,800 outfalls per year at an annual coast of over $450,000 for testing alone. Many of the locations have little or no chance of being contaminated by sewer effluent because there are no sewer systems near the storm drain systems. Testing this many outfalls would be an extremely wasteful expenditure of taxpayer funds with little or no benefit to water quality.

Post Construction Stormwater Management

The Department has major concerns with the requirements to inventory Directly Connected Impervious Area and subsequent reporting. We lack the legal authority to comply with this requirement. State regulations only allow the Department to enter private property to evaluate the need to condemn for highway purposes or to determine the highway boundary. The activity described by the permit would not be allowed under state law.

The potential stormwater treatment structure retrofit inventory described in the permit would be an immense undertaking. All items to be included are typical of a fully designed project and require survey, subsurface investigation and coordination with outside entities. This fully designed project would then stretch over 627 miles, and would be extremely costly. In addition we may be investigating and possibly investing in areas where there are no identified impairments, and in areas where there are identified impairments, the NHDOT highway may not be the root cause. Again, the EPA has left out the critical step of a TMDL to identify loads, responsible parties and potential load reductions. The retrofit plan is essentially the first step of a TMDL implementation plan for which there is no TMDL study to support it. The permit should reflect the established TMDL process.

Pollution Prevention / Good Housekeeping

The catch basin cleaning requirement is unclear and overly simplistic. There are many variables to determine when a catch basin should be cleaned that are not accounted for in this regulation. The Department agrees that catch basin inspection in important. However, not all catch basins are the same. Many of our catch basins do not have sumps and therefore have no ability to collect sediment. Many are located in ditches well off the travel way where inductor trucks cannot reach. Many do not accumulate sediments as the Department has mostly eliminated sand from its winter maintenance practices. The regulation clearly states "catch basins shall be cleaned a minimum of once ever other year". It would be unreasonable to clean a catch basin with no sump, tear up a well-vegetated swale trying to reach a basin off the pavement or clean an inch of sediment out of a three-foot sump. The EPA needs to give the Department flexibility to assess its catch basins and develop a cleaning program. Cleaning a catch basin is not cheap. Each cleaning costs approximately $50 per location. Currently, the Department has approximately 8,000 catch basins in the urbanized areas and to clean 4,000 basins a year, especially if they do not need to be cleaned, would be wasteful and would not be any more protective of water quality than just monitoring them until they need to be cleaned.

The street sweeping requirement is also overly simplistic and wasteful. The twice a year sweeping of a low speed, curbed, urbanized street may be warranted. However, the same standard makes little sense for a high speed uncurbed interstate highway. We are assuming EPA is targeting accumulation of sand on the shoulder of the roadway for the spring sweeping. The Department uses very little sand during the winter. The sand that is applied during very cold weather is usually pulverized by high-speed traffic, lifted into the air and blown off the side of the roadway. We assume the fall sweeping would address leaves, which are even more easily swept off the roadway by high-speed traffic. Street sweeping is expensive, costing the Department approximately $10 per mile. The Department should have the ability to inspect the 1,250 miles of roadway shoulders to determine the need, and document where sweeping would be appropriate.

Stormwater Pollution Prevention Plans for maintenance garages

The Department fails to see the connection between the daily operations at our maintenance garages and a Small Municipal Separated Storm Sewer System. Clearly the stormwater pollution prevention plan (SWPPP) requirements are essentially identical to those found and enforced through the Multi-Sector General Permit. EPA through its own admission in a letter dated February 19, 2003 to the Maine Turnpike Authority does not have jurisdiction to enforce. In addition, Section 1.2.1 of this regulation clearly states

> *" The term include systems similar to separated storm sewer systems in municipalities such as systems in military bases, large hospitals or prison complexes and highway and other thoroughfares. The term does not include storm sewers in very discrete areas, such as individual buildings".* (Emphasis added)

We contend sections 2.3.7.1.b Buildings and Facilities, 2.3.7.1.c Vehicles and Equipment, and 2.3.7.2 Stormwater Pollution Prevention Plans for maintenance garages etc. are not eligible for coverage under the Small MS4 permit.

These are the major concerns the Department has with the proposed changes to the regulation. In addition, we are also very concerned that as EPA becomes more proscriptive with the MS4 regulation and becomes more focused on the municipalities; it becomes more burdensome and less relevant to departments of transportation. Even though we collect and discharge stormwater from our highways in a similar manner, our systems, responsibilities and powers are very different from a municipality. There are requirements in this proposed regulation the Department cannot legally accomplish, have nothing to do with "state" highways or wastes taxpayer's funds. We (NHDOT and EPA) need to review these compliance items outlined above and come to an agreement on EPA's intentions that are more compatible with our systems, responsibilities and powers. We may also want to invite the Massachusetts Department of Transportation to participate in these discussions as they will likely have similar issues. I look forward to hearing from you.

Sincerely,

Mark Hemmerlein
Water Quality Program Manager
Bureau of Environment
Ph (603) 271-1550
E-Mail Mhemmerlein@dot.state.nh.us

MTH:mth
cc. Bill Cass
Jeff Andrews NHDES
Henry Barbaro, MassDOT

February 16, 2009

Comments on NH Draft MS4 permit from Roger Frymire:

I appreciate this opportunity to comment on the NH MS4 draft permit. Although I reside in Massachusetts, I have over ten years' experience in multiple watersheds conducting bacterial water quality monitoring. I have taken over 2000 samples for bacterial analysis concentrating on tracing sewage bacteria back to specific outfalls. My comments are mainly on the monitoring requirements in the draft permit, with the intent of both increasing the focus and usefulness of monitoring and reducing some of the burden on permittees of a comprehensive monitoring program.

**WQX**

First, I would suggest that the permit be amended to require that permittees place all monitoring data collected into EPA's WQX database - possibly on a yearly basis. This database is being used by a growing number of states and watershed groups as a permanent repository for water quality data. Further, I suggest that EPANE commit to generating a common spreadsheet for use by all MS4 permittees for initial local storage of required monitoring data. This should allow smooth transfer of all MS4 data into WQX in simple batch operations.

I cannot overstate the usefulness of having all this monitoring data available for query in a single online database along with historical and watershed data.

**Simplification**

While all outfalls need to be GPS located and screened for dry-weather flow, some towns have hundreds of outfalls connected to just one or two catch-basins by a short run of pipe. Country roads can run for miles adjacent to a stream or river, with twenty or more of these tiny drainage systems per mile - almost all bone dry until it rains. Requiring wet-weather sampling of all such outfalls seems an inordinate burden - especially on the less populated towns with more road miles per taxpayer. I suggest removing the wet-weather monitoring requirement for a reasonable majority of such tiny drainage systems. With such a large number of these, at least a few will have dry-weather flow from groundwater and other sources. These few should provide plenty of data for characterizing the majority. A possible cutoff point could be "Four or fewer catchbasins draining under an acre of impervious area connected to a single outfall under 24" diameter - with no dry weather flow or other indication from screening of additional inputs or problems."

## Parameters

**pH** should be dropped from the list of parameters monitored, especially in wet weather when any pH excursions will be buffered by rainwater flows. The few instances of pollution causing pH problems should be easily found by other indicators and especially visual inspection. Even in dry weather, the time-consuming calibration of pH meters will make the time spent noticeably less productive. Also, glass bulbs of pH probes are notoriously prone to breakage and replacement expense. This is simply a large time-sink and expense for basically NO useful data.

**Chlorine** tests should only be required in dry weather and only at outfalls with an ODOR of bleach or swimming pools. Simple field tests by paper strips are available, but the human nose is at least equally sensitive, so testing time and expense should only be required if the screening 'sniff test' indicates chlorine. If instead the intention was to require testing for Chlor**ide**, this can best be accomplished by multimeter testing of Conductivity - which is easily converted to ppt salinity.

**DO** should be monitored along with temperature and conductivity by a field multimeter. Second only to actual bacterial tests, I have found this the most useful parameter in identifying problem outfalls. Besides sewage, low Dissolved Oxygen can be caused by excessive organic material such as leaf litter in catch basins, and may be used to help indicate success of street-cleaning and catch basin maintenance BMPs.

**Bacteria** sampling is the single most expensive parameter in the monitoring requirements - both because of laboratory expense, and the short sample holding time - restricting sampling trip timing and duration. Even though bacterial data is very useful, any way to reduce this requirement could significantly reduce the burden of monitoring programs. While I would like to see wet-weather bacterial sampling at all outfalls, enough other sewage indicators are being required in the dry-weather screening that it might be significantly more cost-effective to skip dry weather bacterial sampling on the first visit. Then if Odor, low DO, Surfactants, Ammonia, Potassium, Outfall size, or Visual indications (or some metric of all these) point to possible problems, a repeat trip to sample JUST for bacteria could be made to many such outfalls in a single trip (and short holding time). Some outfalls might not need the expense of bacterial testing at all, and condensing the remainder into the smallest possible number of laboratory trips should also help reduce the total expense of this testing.

## Screening

Initial screening and cataloging of all outfalls should include two digital photos of each outfall from the front and back when possible to document structure condition as well erosional and depositional features in line with the outfall. These pictures shopuld be taken after labeling the outfall with a unique ID. Larger (>30")and known problematic outfalls may need a sign nearby with the ID and a phone number for public reporting of 'objectionable' flows. When an outfall is not accessible (underwater, etc.) the last accessible manhole before the outfall should be used as the sampling location. For outfalls where safety is an issue for sampling; especially in wet weather, high water, or winter; an upstream manhole should also be designated and documented.

## GPS

GPS positions should be recorded for all outfalls and secondary sampling manholes in decimal degrees to five digits accuracy to the EPA data standard (XX.xxxxx degrees). Handheld GPS units with this accuracy are in widespread use - such as the Garmin 76Cx unit. This is the one datum which will make all other data placed into WQX searchable by location across all variously-sourced data sets.

## Receiving Water Monitoring

For all impaired water bodies with discharges from the MS4, two rounds of monitoring each year should be conducted - once each in wet and dry weather. Each impaired segment should be sampled once upstream of all MS4 discharges to the waterbody, and at one site downstream of all discharges. Alternately, sampling may occur at city boundaries and at ends of impaired segments within the MS4. Samples will be analyzed only for constituents listed as contributing to the impairment.

## Public Involvement Process

Require all SWMPs and Annual Reports be online. In additional to Public Notice requirements for stormwater meetings, require notification by e-mail to all active watershed associations with concerns in the MS4 of all public meetings and opportunities for public comment.

Again, Thank You for this opportunity to comment. I hope these ideas can also be taken into consideration for other draft MS4 permits coming soon from EPANE. And I hope the changes I suggest are not so large as to require complete re-release of a new draft permit - although I believe the WQX provision would be worth even that additional hassle - for the sheer gain in availability and useability of the monitoring data collected. One last comment - I very much appreciate and approve of the SSO provisions contained in this permit.

Sincerely,
Roger Frymire
22 Fairmont Avenue
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Received 2-26-09
Postmark 2-20-09

**TOWN OF LONDONDERRY**
**PUBLIC WORKS DEPARTMENT**
**268B MAMMOTH ROAD**
**LONDONDERRY, NH 03053**
**TEL (603)432-1100 EXT 130**
**FAX (603)432-1128**

February 20, 2009

Ms Thelma Murphy
USEPA - CIP
I Congress Street – Suite 1100
Boston, MA 02114

RE: Comments to Draft Municipal Separate Storm Sewer (MS4) General Permit

Dear Ms. Murphy,

The Town of Londonderry would like to take this opportunity to offer the following comments to the Draft Municipal Separate Storm Sewer (MS4) General Permit.

1.10.2 Contents of the Stormwater Management Program

- Listing of all receiving waters, their classification, any impairments, and number of outfalls that discharge to each water. It is unclear if private outfalls should be included in the list, access to private outfalls may not be possible. NHDES, USEPA and the permittee should work together to identify impaired waters and concentrate on identifying and possibly eliminating the source of those impairments.
- Permittee is encouraged to document all public drinking surface water and groundwater that may be impacted by the discharge. There are many types of discharges that can potentially impact public drinking surface and groundwater. It is unclear what the intent of documenting these items is. It appears that the water supplies should have been identified; well head protection areas determined and regulations currently in place to regulate discharges.

2.1.1 Requirements to Meet Water Quality Standards

- Elimination of a condition causing or contributing to an exceedance of water quality standards within 60-days of its discovery seems unachievable. Elimination and fixing of such a problem may be time consuming and costly and not able to be accomplished within 60-days. The regulators should be flexible and willing to work with the permittees in determining a solution and proceeding in such a manner.

2.2.3 Discharge to a Chloride Impaired Water in New Hampshire

- Requiring that public and private owners of parking lots and roads to report to the permittee the amount of chlorine-based deicing chemicals applied for each storm event is unrealistic. We, as the permittee, can document amounts applied for each storm event, however we have no mechanism to have the private sector report their usage. It is suggested that NHDES and USEPA develop regulations for the usage of chlorine–based deicing chemicals. Regulations should include training, certification and reporting requirements.

2.2.4 New or Increased Discharges to Impaired Waters

- Requiring the permittee to notify USEPA and the state prior to commencing a new discharge should also apply to private entities that have the same potential to discharge to impaired waters. As indicated under 1.10.2 the NHDES, USEPA and the permittee should work together to identify impaired waters and concentrate on identifying and possibly eliminating the source of those impairments and future potential impairments.

2.3.2 Public Education and Outreach and 2.3.3 Public Involvement and Participation

- Evaluating the effectiveness of the program will be difficult; typically people do not attend public or informational meetings unless it directly affects them. We have found success educating persons by attending such events as elections and leadership meetings. Those that attend, such an event, typically are willing to listen and partake.

2.3.4 Illicit Discharge Detection and Elimination (IDDE) Program

- Elimination of sources of non-stormwater from the separate storm sewer system may include the elimination of under drains that were constructed to ensure longevity of the roadways. Please clarify that such under drains would be permitted within the separate storm sewer system.

2.3.6 Stormwater Management in New Development and Redevelopment (Post Construction Stormwater Management)

- Construction of low impact development features and maintenance of the systems will be costly and ultimately not function as intended. Is it practical to think that such LID will function as designed in such a cold climate as what we experience in New Hampshire? Maintenance of LID features by the permittee is unrealistic.

2.3.7 Good Housekeeping and Pollution Prevention for Permittee Owned Operations

- Municipalities and School Districts typically are separate political entities who do not work under the same control.

3.0 Outfall Monitoring Program

- The required monitoring of the outfalls will be very costly.

Thank you for having been given the opportunity to comment to this draft permit. Should you have any questions please feel free to contact me at 603-432-1100 (x-146).

Sincerely,

John R. Trottier, PE
Assistant Director of Public Works
& Engineering

L:\Stormwater Phase II\EPA022009ltr.doc

email received - 2/18/09

Received
FEB 24 2009

**DEPARTMENT OF PUBLIC WORKS**
22 Dodge Road
Amherst, NH 03031
Tel. (603) 673-2317 Fax (603) 249-8857

bberry@amherstnh.gov

February 18, 2009

Ms. Thelma Murphy
Office of Ecosystem Protection
Office of Environmental Protection Agency
One Congress Street – Suite 1100
Boston, Massachusetts 02114

Ms. Murphy,

Thank you for the opportunity to address concerns regarding the proposed next phase of the MS-4 permit. I offer the following,

This permit seems to be written as a one size fits all format. Urban cities with miles of connected drain pipes feeding stormwater and wastewater treatment facilities are grouped in the same class with smaller communities having only individual residential septic systems and simple road crossing culverts because they share similar population density. This is not fair to the smaller communities as it places much too great a burden on their staff and budgets with no federal funding for some of the mandates being placed upon the MS-4 communities. The Town of Amherst has been annually budgeting $15,000 for our stormwater program since the programs inception in 2003. Until this time this budget has been sufficient to support the program and the requirements of the NPDES MS-4 permit. Under the new permit requirements and in these difficult economic times, this budget will need to be tripled or quadrupled to meet the requirements of the new program with no federal assistance to help support the cost increase. The municipal budgets are currently very lean with little to no room for line item increases and at this time the proposed permit will be unfeasible with the money that we have to work with. Where will the funds to support this revised stormwater permit come from?

Section 2.2.3 **Discharge to a Chloride Impaired Water in New Hampshire**

1. New Hampshire is not a "home rule" state, municipalities lack the ability to create rules or penalties not supported by State law. The Town of Amherst's Stormwater Ordinance created in our first permit is tied by State law to the only enforcement available, "Board of Health". Will this permit, hold each town in the State of New Hampshire accountable for the failures of the NH State Legislature?

2. This is more of a question then a statement, what authority do you perceive a municipality has to request an existing business to supply data to the municipality on their chloride usage. We have private subdivisions which hire contractors to do their winter road maintenance. The Town has no way of recording who these contractors are or who they report to. How would you anticipate we verify the factual information we are receiving?

3. Did EPA take into consideration, the increased workload this will place on an already overburdened office staff? I realize this is not EPA's problem, but you are requiring us to produce something we may not be able to deliver, and then fining us if we do not deliver.

Section 2.3.2 **Public Education and Outreach**

Will EPA be offering sample education material? I have an extremely limited staff, and in these difficult economic times, I am on a very tight budget. The timing of the draft release and the Towns budget cycle (July –June and already set to the middle of 2010) makes it impossible to get funding to meet these needs for another eighteen months.

2.3.2.2 Again, more of a question, parts ii & iv. If private industry turns a deaf ear on my education attempts, what will EPA's expectation be as far as goal achievement?

Section 2.3.4.6-d Has the State of New Hampshire granted municipalities some sort of authority to walk private property as it seeks to meet the goal of walking all stream miles?

Section 2.3.5.3.-e Many public and private subdivisions have existing drainage easements, these are necessary but difficult to maintain with a small Public Works crew. Is it EPA's recommendation, by encouraging Low Impact Design (LID), that the burden of maintenance falls on the municipality through easements or some sort of restrictions placed on the homeowner? And under what authority would that be enforced? Who ultimately decides if LID is practicable?

Without legal support by the State of New Hampshire through new legislation, enforcement and penalties by a municipality directed towards the private sector for Sections 2.3.5 **Construction Site Stormwater Runoff Control** through section 2.3.6 **Stormwater management in New Development and Redevelopment (Post Construction Stormwater Management)** will be laborious and difficult to process through the NH Court system.

Portions of the new MS4 permit require additional GIS capabilities that the Town of Amherst currently does not have. The new permit is requiring accurate mapping of all drainage structures. The new permit is also requiring analysis of sub-catchment areas and impervious areas. Without additional modern GIS software and aerial photography as well as more accurate GPS survey grade mapping equipment, these analyses are nearly impossible to perform. This new equipment and software would require additional training and staffing. Again I ask where will the funding be coming from to fund these capital purchases to support the requirements of the new program?

In closing, it was our understanding that through the first permit cycle this was to be a grassroots campaign with town volunteers. This new permit is heavily into the technical side of Stormwater. Is it EPA's intent for this permit to be managed by towns but done by engineering firms?

Respectfully submitted,

Bruce W. Berry
Director of Public Works

John St. Pierre E.I.T.
Planning, Zoning, & Public Works

Received via email
2/19/09 - Hard copy to follow


# DEPARTMENT OF PUBLIC WORKS
22 Dodge Road
Amherst, NH 03031
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bberry@amherstnh.gov


February 18, 2009

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John St. Pierre E.I.T.
Planning, Zoning, & Public Works

Received
FEB 2 4 2009
Postmark 2/20/09


**TOWN OF SEABROOK, NEW HAMPSHIRE**
**DEPARTMENT OF PUBLIC WORKS**
**P.O. BOX 456**
**SEABROOK, NH 03874**




February 19, 2009

**M032-09**

***ALSO SUBMITTED VIA E-MAIL***

Thelma Murphy
United States Environmental Protection Agency
Office of Ecosystem Protection
One Congress Street- Suite 1100
Boston, MA 02114

Subject: Comments on the Draft 2008 MS4 General Permit
Seabrook, NH

Dear Ms. Murphy,
The purpose of this letter is to provide formal comments on behalf of the Town of Seabrook, New Hampshire, on the Draft NPDES 2008 Small Municipal Separate Storm Sewer System (MS4) General Permit. The Notice of Availability of the General Permit for Discharges from Small MS4 communities in New Hampshire was published by the United States Environmental Protection Agency (USEPA) in the Federal Register on December 23, 2008.

Seabrook has carefully reviewed the proposed requirements and control measures proposed in this Draft MS4 Permit from the perspective of overall impact to the Town of Seabrook. Our primary comments and concerns are respectfully submitted and are as follows:

1. The expanded public education (i.e., residential, business/commercial, developer/construction and industrial) and involvement components included in Section 2.3.2 will place a large burden on Seabrook. We request that USEPA develop a national educational program on stormwater pollution prevention that includes information pertinent to these sectors. A USEPA educational Program would be far more effective in New Hampshire's multiple MS4 communities than many individual small programs. Finally, the USEPA should continue to allow joint efforts- such as materials and programs developed by the Seacoast Stormwater Coalition- to count toward education goals.
2. The definition of "screening" that is applied to dry weather outfall inspections is extensive and would be extremely costly. Seabrook requests that USEPA consider outfall inspections to include the visual and sensory evaluation (as described by USEPA in 2.3.4.6.d.ii) but more limited screening sampling, such as using field test kits for detergent in lieu of the nine-parameter analytical collection proposed in Section 3.2.2.

3. Many components in the Draft MS4 Permit include timelines that are very aggressive in the context of limited municipal budgets. Unfortunately, as of the date of this writing, Seabrook residents have not endorsed or passed a Municipal Budget since 2007! Seabrook proposes the following timelines for these components:

- Develop illicit discharge responsibilities, methods, verification, and progress protocol (Section 2.3.4.6.c) by end of third Permit year (not the first);
- Walking all stream miles (Section 2.3.4.6.d) by end of the fifth Permit year (not the second);
- Evaluation of street- and parking lot-design guidelines to address impervious area (Section 2.3.6.6) by the end of the fourth Permit year (not the second);
- Complete MS4 catchment area assessment and prioritization and impervious area (Section 2.3.6.8.a) evaluation by the end of the third Permit year (not the first);
- Complete an inventory of Town-owned properties (Section 2.3.7.1) within two years (not six months) of Permit issuance and development of a written Operations and Maintenance plan for these Town-owned properties by the end of the third Permit year (not the first); and
- Begin outfall monitoring program (Section 3.0) no later than the end of the second Permit year (not the first).

Seabrook is active in the Seacoast Stormwater Coalition, and also participated in the development of the formal comments on the 2008 Draft MS4 Permit submitted to the USEPA from that organization. We look forward to reviewing the USEPA's Response to Comments later this year.

Please do not hesitate to contact me at (603) 474-9771 if you have any questions about the Town of Seabrook's comments.

Very truly yours,

John M Starkey

Mr. John M. Starkey
Manager, Department of Public Works

cc: Barry Brenner, Town Manager
Board of Selectmen
Sue Foote, Chairman – Planning Board and Conservation Commission
Mr. Joseph Boccadoro, P.E. (AECOM)

Received
email - 2/19/09

**TOWN OF SEABROOK, NEW HAMPSHIRE**
**DEPARTMENT OF PUBLIC WORKS**
**P.O. BOX 456**
**SEABROOK, NH 03874**



February 19, 2009

M032-09

***ALSO SUBMITTED VIA E-MAIL***

Thelma Murphy
United States Environmental Protection Agency
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One Congress Street- Suite 1100
Boston, MA 02114

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John M Starkey

Mr. John M. Starkey
Manager, Department of Public Works

cc: Barry Brenner, Town Manager
Board of Selectmen
Sue Foote, Chairman – Planning Board and Conservation Commission
Mr. Joseph Boccadoro, P.E. (AECOM)

**Conservation Law Foundation**
**New Hampshire Rivers Council**
**Cobbetts Pond Improvement Association**

February 20, 2009

Ms. Thelma Murphy (murphy.thelma@epa.gov)
Office of Ecosystem Protection (CIP)
U.S. Environmental Protection Agency
One Congress Street
Boston, MA 02114-2023

**Re: Draft NPDES General Permit for Discharges From Small Municipal Separate Storm Sewer Systems Located in the State of New Hampshire (NHR040000)**

Dear Ms. Murphy:

The Conservation Law Foundation, the New Hampshire Rivers Council, and the Cobbetts Pond Improvement Association appreciate the opportunity to comment on the Draft NPDES General Permit for Discharges From Small Municipal Separate Storm Sewer Systems Located in the State of New Hampshire (NHR040000) ("draft permit").

Founded in 1966, the Conservation Law Foundation ("CLF") is a member-supported environmental advocacy organization that works to solve the problems threatening our natural resources and communities in New Hampshire and throughout New England. Among those problems, CLF has worked, and continues to work, to promote effective regulations and strategies to reduce and minimize the significant impacts of stormwater pollution.

Incorporated as a non-profit organization in 1993, the New Hampshire Rivers Council ("Rivers Council") is New Hampshire's only statewide conservation organization wholly dedicated to the protection and conservation of New Hampshire rivers. The Rivers Council works to educate the public about the value of the state's rivers, designate rivers in the state's protection program, advocate for strong public policies and wise management of New Hampshire's river resources, and strengthen local voices for river protection.

Founded in 1949, the Cobbetts Pond Improvement Association ("CPIA") is a non-profit corporation whose members either live on or have deeded access to Cobbetts Pond. CPIA members are committed to the protection and preservation of Cobbetts Pond and its watershed. Cobbetts Pond is a 302-acre spring fed water body located in Windham. Route 111, 111A and I-93 are located in close proximity to the lake. *See* Attachment 1. For the past 19 years, the CPIA has participated in the NH Volunteer Lake Assessment Program which has assisted in monitoring the lake's water quality. Over this period of time, the lake has shifted from oligotrophic to eutrophic, from the best classification to the worst. As a result, the EPA has classified Cobbetts Pond as an impaired water body. The CPIA recently received an EPA Section 319 Restoration Grant to develop a lake restoration plan.

## I. General Comments

"Stormwater runoff is one of the most significant sources of pollution in the nation, 'at times comparable to, if not greater than, contamination from industrial and sewage sources.'"[1] As the Environmental Protection Agency (EPA) acknowledged in 1999, "[s]torm water runoff from lands modified by human activity can harm surface water resources and, in turn, cause or contribute to an exceedance of water quality standards by changing natural hydrologic patterns, accelerating stream flows, destroying aquatic habitat, and elevating pollutant concentrations and loading." 64 Fed. Reg. 68,724 (Dec. 8, 1999). A 2000 EPA report to Congress attributed pollution, erosion and siltation – three of the four leading causes of degradation of U.S. waterbodies – to stormwater runoff.

In New Hampshire, stormwater has emerged as a major cause of water quality violations, serving as the source of impairment for 63 percent of all waters listed on the state's Section 305(b)/303(d) list and, in combination with "other sources," contributing to the impairment of an additional 20 percent of listed waters.[2] Thus, of all the waters appearing on New Hampshire's 305(b)/303(d) list, only 17 percent are not in some way related to stormwater. Proper implementation of the Phase II stormwater regulations, including those addressing Small MS4s, is essential to protecting valuable surface water resources in New Hampshire from the proven adverse impacts of stormwater. This is especially the case in light of the growing body of evidence of stormwater pollution in the state, including but not limited to (1) significant chlorides impairments in southern New Hampshire, and (2) major eelgrass- and nitrogen-related impairments in numerous water bodies that are part of the Great Bay estuary (both discussed in further detail below).

The draft permit represents a significant improvement over the 2003 Small MS4 General Permit applicable to New Hampshire ("2003 permit") in many ways, including its more detailed requirements relative to minimum control measures. However, to meet the objectives of, and ensure compliance with, the Clean Water Act – and thereby reverse the effects of stormwater that have been observed throughout the state and in such places as the above-referenced chlorides-impaired and Great Bay estuarine waters – it is essential that the draft permit be further strengthened. Although achieving these objectives, and compliance with the Clean Water Act, will require a sustained commitment of resources, EPA and the entities regulated under the Phase II program must not lose sight of the fact

[1] *Environmental Defense Center v. Browner*, 344 F.3d 832, 840 (9th Cir. 2003), *cert. denied*, 124 S.Ct. 2811 (2004) (*citing* Richard G. Cohn-Lee and Diane M. Cameron, *Urban Stormwater Runoff Contamination of the Chesapeake Bay: Sources and Mitigation,* THE ENVIRONMENTAL PROFESSIONAL, Vol. 14, p. 10, at 10 (1992) and *Natural Res. Def. Council v. EPA*, 966 F.2d 1292, 1295 (9th Cir. 1992)).

[2] "The 2008 Surface Water Assessment – Impaired Waters in New Hampshire," Paul M. Currier, NHDES (presented at Nov. 18, 2008 Business & Industry Association/NHDES Water Symposium).

that there are significant costs associated with continued stormwater pollution – such as ongoing and increasing degradation of water quality, loss of recreational value, adverse impacts on water supplies, and declining property values – that can only be reduced and avoided by improved stormwater regulation and management.[3] EPA and the regulated entities also must not lose sight of the fact that Low Impact Development ("LID") practices that restore the natural hydrological cycle and reduce the demand on piped infrastructure can be, in the long run, more cost-effective to implement and maintain than conventional stormwater infrastructure.[4] Thus, in addition to improving and protecting water quality, the increased use of LID has the potential to generate financial benefits and more livable communities.

## II. Water Quality: Ensuring Compliance With, and Maintenance of, Water Quality Standards

A central tenet of the Clean Water Act (CWA) as well as the small MS4 program is the requirement that NPDES permits ensure compliance with water quality standards. This requirement is reiterated in the CWA, its regulations, case law, and the Small-MS4 General Permit.

In enacting the CWA, one of Congress' principal goals was to "recognize, preserve, and protect the primary responsibilities and rights of States to prevent, reduce, and eliminate pollution, [and] to plan the development and use (including restoration, preservation, and enhancement) of land and water resources."[5] In accordance with this goal, the CWA is clear that all provisions in a NPDES permit must comply with state water quality standards.[6] This requirement is reiterated in regulations promulgated pursuant to the

[3] *See, e.g.*, "How Much Value Does the City of Philadelphia Receive from its Park and Recreation System? A Report by The Trust for Public Land's Center for City Park Excellence for the Philadelphia Parks Alliance," June 2008 at 3-4 (estimating that Philadelphia's 10,000 acres of parks save $5.9 million annually in stormwater management costs).

[4] Reducing Stormwater Costs through Low Impact Development (LID) Strategies and Practices, U.S. EPA, Nonpoint Source Control Branch (4503T), Washington, D.C., Dec. 2007 (EPA 841-F-07-006). This EPA report on seventeen LID case studies found that in the majority of the LID projects "significant savings were realized due to reduced costs for site grading and preparation, stormwater infrastructure, site paving, and landscaping." LID projects resulted in up to 80% total capital cost savings. Furthermore, additional benefits, such as improved aesthetics and faster sales, were not factored into these savings figures. The case studies included redevelopment projects (for example, green roofs in Toronto) as well as new development.

[5] 33 U.S.C. § 1251(b).

[6] *See* 33 U.S.C. § 1370 (allowing state water quality standards to be more stringent than federal technology-based standards); 33 U.S.C. § 1341(a) (requiring compliance with water quality standards of both the state where the discharge originates and of any state affected by the discharge). The requirement that permits comply with state water quality standards allows no exceptions for cost or technological feasibility. *In re City of Fayetteville, Ark.*, 2 E.A.D. 594, 600-01 (CJO 1988) (interpreting the language of section 301(b)(1)(C) to require "unequivocal compliance with applicable water quality standards," and prohibit "exceptions for cost or technological feasibility"), *aff'd sub nom.* Arkansas v. Oklahoma, 503 U.S. 91 (1992).

CWA,[7] including the Phase II stormwater regulations pertaining to small MS4s, which explicitly state that an NPDES MS4 permit:

> will require *at a minimum* that [an operator of a Small MS4] develop, implement, and enforce a storm water management program designed to reduce the discharge of pollutants from [its] MS4 to the maximum extent practicable (MEP), *to protect water quality, and to satisfy the appropriate water quality requirements of the Clean Water Act.*[8]

The final permit, and implementation of the small MS4 program under that permit, must in all respects ensure that discharges attain and maintain water quality standards and do not cause or contribute to water quality violations.

### A. Section 1.3 – Eligibility for Coverage

Section 1.3 of the draft permit provides that certain stormwater discharges are not authorized for permit coverage. Among those limitations, it properly does not extend permit coverage to "[d]ischarges prohibited under 40 CFR 122.4," or to "[d]ischarges that cause or contribute to an instream exceedance of a water quality standard . . . ." Draft Permit § 1.3(i), (k). These provisions are essential to enforcing the Clean Water Act's central tenet that permitted discharges not cause or contribute to water quality violations.

The above provisions, however, must be further strengthened to ensure their proper implementation – i.e., to ensure that the permit not authorize discharges that will, in actuality, cause or contribute to water quality violations. Specifically, it is worth noting that the draft permit requires applicants to (1) follow specific procedures to assess the impacts of their stormwater discharges and associated activities on federally listed endangered and threatened species and designated critical habitat, and (2) certify compliance with this procedure in their submitted Notice of Intent ("NOI"). Draft Permit § 1.3(e), App. C. To ensure program implementation in a way that ensures compliance with water quality standards, and that does not unlawfully authorize discharges that cause or contribute to water quality violations, the permit must use a similar model for impaired waters. More particularly, we urge EPA to adopt provisions requiring applicants to specifically assess their proposed discharges as they relate to waters that are impaired as a result of pollution that can be attributed to stormwater, to specifically demonstrate that their proposed discharges will not cause or contribute to such impairments, and to certify that they have undertaken such an analysis.

### B. Section 2.1.1 – Requirements to Meet Water Quality Standards

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[7] *See* 40 C.F.R § 122.4(d) ("No permit may be issued: . . . (d) When the imposition of conditions cannot ensure compliance with the applicable water quality requirements of all affected States"); 40 C.F.R § 122.44(d)(1), (d)(4) ("[E]ach NPDES permit shall include conditions meeting the following requirements when applicable: . . . (d) any requirements in addition to or more stringent than promulgated effluent limitations guidelines or standards under sections 301, 304, 306, 307, 318, and 404 of CWA necessary to: . . . (1) [a]chieve water quality standards established under section 303 of the CWA, including State narrative criteria for water quality . . . .").

[8] 40 CFR § 122.34(a) (emphasis added).

Section 2.1.1 contains important provisions prohibiting discharges from causing or contributing to water quality violations, including the requirement that "[i]f at any time the permittee becomes aware or EPA or NHDES determines that a discharge causes or contributes to an exceedance of applicable water quality standards, the permittee must within 60 days of becoming aware of the situation eliminate the conditions causing or contributing to an exceedance of water quality standards." Draft Permit § 2.1.1(c). We strongly support these provisions.

Section 2.1.1(a) of the draft permit limits the "applicable water quality standards" for purposes of the permit to "the State standards that are in place upon the effective date of this permit." Draft Permit § 2.1.1(a). We strongly object to this limitation and urge EPA to make clear in the final permit that water quality standards include those additional standards adopted by the State after the effective date of the permit but during its five-year term. The significant challenges facing the Great Bay estuary – as evidenced by existing nitrogen and eelgrass-related impairments, and the imminent 303(d) listing of many of its waters for those impairments (*see* Part VI, *infra*) – highlight the need for this amendment. Specifically, NHDES is in the process of developing nitrogen criteria that will be adopted as part of the state's water quality standards. It is essential that MS4s discharging to estuarine and associated waters be subject to these criteria during the term of this permit.

Section 2.1.1(a) contains a provision which we urge EPA to strike from the permit. Specifically, it states: "in the absence of information suggesting otherwise, discharges will be presumed to meet the applicable water quality standards if the permittee fully satisfies the provisions of this permit." Draft Permit § 2.1.1(a). This presumption directly contradicts the statutory burden imposed on dischargers, under the Clean Water Act, to demonstrate that water quality standards will be met. It also undermines other requirements in the permit specifically pertaining to impaired waters and, we fear, may cause regulated entities to not address those requirements. Additionally, it undermines and its contrary to the right and ability of citizens under the Section 505 of the Clean Water Act, 33 U.S.C. § 1605, to enforce the provisions of the permit.

### C. Section 2.2 – Discharges to Impaired Waters

Section 2.2 of the draft permit states: "Impaired waters are those waters that the State agency has identified pursuant to Section 303(d) of the Clean Water Act as not meeting applicable state water quality standards." Draft Permit § 2.2. Given the five-year duration of the permit, it is essential that the term "impaired waters" include not only waters already appearing on the state's 303(d) list at the time the final permit is issued, but also waters that are otherwise known to be violating water quality standards, and waters added to the 303(d) list *after* issuance of the final permit. For example, as further discussed in Part VI of these comments, below, NHDES has identified numerous waters in the Great Bay estuary as being impaired as a result of significant eelgrass declines and excessive nitrogen. Although known to be impaired, these waters have not yet been added to New Hampshire's Section 303(d) list. The addition of these impairments to the

Section 303(d) list, a process in which EPA is currently engaged, is believed to be imminent. If, however, the actual Section 303(d) listing does not occur until after the effective date of the final permit, these waters must nonetheless be treated as impaired waters under the permit. Should the waters not be added to the list in advance of the final permit's issuance, it will be essential to provide notice to all regulated entities discharging directly or indirectly to these waters of their impaired status. We urge EPA to address this issue – should the 303(d) listing process not be complete upon issuance of permit – by adding a new appendix to the permit that (1) identifies these waters as impaired; (2) states that such waters must be treated as impaired for purposes of implementing and complying with the permit's requirements pertaining to impaired waters; and (3) notes that the waters will be added to the 303(d) list at some time in the future. These impaired waters, and other waters added to the Section 303(d) list in upcoming listing cycles, must be treated as impaired waters under the permit.

### D. Section 2.2.1 – Discharge to an Impaired Water with an Approved TMDL

Section 2.2.1(a) of the draft permit references Appendix F of the permit, which identifies and describes certain specific TMDLs already in place in New Hampshire. Appendix F should be amended to include the TMDLs approved by EPA on January 14, 2009 relative to chlorides impairments in Dinsmore, Beaver and Policy/Porcupine Brooks and the North Tributary to Canobie Lake.[9] Also, rather than relying exclusively on provisions pertaining to specific TMDLs to be described in Appendix F, Section 2.2.1(a) should be amended to include general requirements pertaining to discharges to impaired waters with TMDLs. Specifically, we urge the inclusion of language requiring MS4s with such discharges to (1) affirmatively demonstrate controls being implemented to control the pollutants identified in approved TMDLs; (2) evaluate whether additional controls are necessary to satisfy TMDL requirements; (3) implement all controls necessary to satisfy TMDL requirements; and (4) document the foregoing analyses and implementation in the NOI, SWMP and annual reports. These general requirements will be crucial to ensuring both that TMDLs are met (as required by the CWA and regulations), and that the public has an active role in understanding and supporting the achievement of the needed pollutant load reductions.

Section 2.2.1(c) of the draft permit states, with respect to TMDLs that do not specify a wasteload allocation ("WLA") individually or categorically for discharges from small MS4s, that compliance with certain conditions in the permit "will be presumed adequate to meet the requirements of the TMDL, unless otherwise notified by EPA." For the reasons discussed above relative to Section 2.1.1, the final permit should eliminate any *presumption* of adequacy, and EPA should affirmatively and specifically assess whether the discharger has met all applicable requirements, including those contained in

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[9] We acknowledge and support the following statement of intent in EPA's Fact Sheet: "If the draft TMDLs [for the chloride-impaired waters] are finalized and approved prior to the issuance of the final permit, and the TMDLs include a WLA applicable to a regulated small MS4's discharge, EPA will incorporate additional BMPs necessary to support the achievement of the WLA into the final permit." Fact Sheet at 36.

applicable TMDLs, to ensure that discharges do not cause or contribute to water quality violations.

Section 2.2.1(d) of the draft permit states: "'Applicable TMDLs' for discharges from the permittee's MS4 are those that have been approved by EPA as of the effective date of this permit." We urge EPA to amend this language to allow for the possibility that additional, relevant TMDLs may be finalized during the five-year term of the permit, and to ensure that those TMDLs are taken into consideration for purposes of determining, at a minimum, (1) whether specific discharges can continue as authorized under the permit, and (2) whether SWMPs, BMPs and other conditions must be modified for discharges into waters that are the subject of those TMDLs. Regulatory developments pertaining to the Great Bay estuary – i.e., the imminent listing of numerous impairments which, in turn, will require the development of TMDLs – illustrate the importance of including future TMDLs in the permit.

### E. Section 2.2.3 – Discharges to Chlorides-Impaired Waters in New Hampshire

Section 2.2.3 of the draft permit must be amended to make clear that all discharges to chlorides-impaired waters – including those for which EPA has recently approved TMDLs – must comply with the provisions of Section 2.1 and must not cause or contribute to the violation of water quality standards pertaining to chlorides. In other words, this section must be amended to make clear that the more specific provisions pertaining to chlorides-impaired waters to do not supplant more general provisions pertaining to impaired waters, including the provisions of Section 2.1 and the general, yet critically important, prohibition against causing or contributing to water quality violations. These amendments will ensure consistency between Sections 2.2.1 and 2.2.3.

The provisions set forth in Section 2.2.3(a) appear to be tailored more specifically for traditional MS4s (i.e., the municipalities affected by the recently approved chlorides TMDLs), as opposed to the N.H. Department of Transportation. To ensure that discharges do not cause or contribute to water quality violations, these provisions must be amended to require affected MS4s to specifically address the manner in which they are addressing chlorides discharges associated with new or anticipated future development. In doing so, entities seeking coverage under the permit must assess new or increased chlorides loads associated with new private development which will discharge chlorides to chlorides-impaired waters by means *other than* through the regulated entities' MS4.[10] This requirement is essential – and requires detailed analysis by the MS4 entities and EPA – in light of the fact that the chlorides TMDLs allocate *no* chlorides pollutant loading to future development. In addressing this issue, MS4s must be required to establish, describe in detail, and implement a program to themselves further reduce

[10] We interpret Section 2.2.4 of the draft permit, pertaining to "New or Increased Discharges to Impaired Waters," as incorporating chlorides pollution from new development discharged to impaired waters through a regulated entity's MS4. Accordingly, these specific comments relate to new or increased chlorides pollutants loads to impaired waters by means other than the regulated entity's MS4.

chlorides loads to negate increases caused by new private development, to ensure that TMDLs for the chlorides-impaired waters are satisfied.

To ensure that discharges do not cause or contribute to water quality violations, and that TMDLs are satififsied, Section 2.2.3(a) must be further amended to require dischargers to develop – and affirmatively propose as part of the written plan referenced in the draft permit – a specific schedule for implementation of their TMDL compliance plan, and implementation that adheres to that schedule.

Finally, should discharges from I-93 and other state roads to chlorides-impaired waters be authorized by this permit, as opposed to an individual or alternative permit, this section must be amended to (1) clarify that it also applies to NHDOT, and (2) include provisions pertaining more specifically to the operation of Interstate 93 and state roads.[11] Such provisions must include BMPs and other actions to be taken by NHDOT to satisfy the TMDLs and water quality standards, including a specific implementation schedule.

### F. Section 2.2.4 – New or Increased Discharges to Impaired Waters

We strongly support provisions in the draft permit requiring permittees to provide EPA and NHDES advance notice of a new or increased discharge from MS4s. We are concerned, however, that Section 2.2.4 of the draft permit, as currently drafted, is insufficient for ensuring that new or increased discharges to impaired waters will not cause or contribute to water quality standards.

First, Section 2.2.4(a) should be amended to require permittees to demonstrate – prior to commencement of a new or increased discharge – that a new or increased discharge will not only satisfy antidegradation requirements and an associated alternatives analysis, but also that it will not cause or contribute to the violation of other water quality standards. This amendment is necessary to ensure compliance with the central tenet of the Clean Water Act – that permitted discharges shall not cause or contribute to water quality violations.

Second, we are concerned with automatic-authorization provisions contained in Sections 2.2.4(a), (c), and (e), each of which automatically authorizes a new or increased discharge in the event EPA does not render a determination with respect to such discharges within thirty days of having received information relative thereto. To ensure that new or increased discharges that cause or contribute to water quality violations are not authorized, the draft permit must be amended to eliminate these automatic-authorization provisions and to instead require EPA to review, and render a determination on, proposed new or increased discharges.

Third, Section 2.2.4(d) contains certain notice provisions, requiring permittees to make available to the public the information it submits to EPA relative to new or increased discharges. To ensure that interested parties receive actual notice of such submissions,

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[11] These comments are in no way intended to suggest that the commenters believe the Small MS4 General Permit is the appropriate mechanism for EPA to consider and authorize these discharges.

we request that the permit require regulated entities to provide specific notice – of its submission to EPA of new-or-increased-discharge information – to any persons having requested such notice at any time, and to any persons having commented on a regulated entity's NOI, SWMP or other MS4 submissions.

Finally, Section 2.2.4(e) requires that new or increased discharges receive certification from NHDES that the discharge will not violate water quality standards, including antidegradation, and that prior to commencing the discharge, the permittee must submit such certification to EPA. It further states: "Such discharges will become authorized thirty (30) days after permittee's notification unless EPA notifies the permittee that it has failed to demonstrate compliance with the antidegradation provisions of the surface water quality standards." As stated above, and in light of the prohibition against causing or contributing to water quality violations, we strongly urge EPA to eliminate the "automatic authorization" approach set forth in this provision and, instead, ensure that it will actually review and render a determination on proposed new or increased discharges.[12] We also urge EPA, in reviewing state certifications, to not only assess whether the permittee has complied with antidegradation, but also whether it has complied with other state water quality standards.

We view this section of the draft permit to be critical to ensuring compliance with water quality standards. The proposed widening of Interstate 93 between Salem and Manchester illustrates the importance of this section, and of ensuring a meaningful opportunity for EPA to review and render an informed determination relative to significant new and increased discharges, and for the public to understand and comment on such proposed discharges. Specifically, NHDOT has proposed to widen – from a total of four lanes, to a total of eight lanes – a 19.8 mile segment of highway, portions of which discharge to four water bodies – Beaver Brook; Policy/Porcupine Brook; the Northern Tributary to Canobie Lake; and Dinsmore Brook, which is a tributary to Cobbetts Pond – that are impaired for chlorides-standard violations, and for which chlorides TMDLs have been approved. The wasteload allocations in these TMDLs establish that chloride pollutant load reductions from I-93 and other state roads are necessary to eliminate these impairments and attain water quality standards. The proposed widening project – by more than doubling the amount of impervious surface associated with the highway – will result in a significant increase in stormwater discharges and, likely, new discharges within the meaning of the permit. In light of existing impairments, and to ensure compliance with the Clean Water Act and its implementing regulations, this major proposed widening – to the extent it is subject to this permit, as opposed to an individual or alternative permit process – must be subject to a process that includes: (1) detailed review by EPA of all required submissions, including but not limited to state certification, pertaining to the proposed new or increased discharges associated with the proposed highway widening and whether such discharges will cause or contribute to water quality violations and satisfy antidegradation and TMDL requirements; (2) adequate time for EPA's review, absent an artificial 30-day deadline; (3) the opportunity for public review of all materials submitted to EPA, and for comment for EPA's consideration; and (4) an affirmative decision by EPA whether the proposed widening

[12] In amending these provisions, EPA also should remove the 30-day time limit for its review.

and its associated discharges will meet all water quality requirements, including water quality standards, antidegradation, and TMDL requirements. We urge EPA to amend the permit to ensure that such a process occurs for all significant new or increased discharges.

## III. Monitoring

Monitoring is essential to the successful implementation of the MS4 program. The primary goals of a stormwater monitoring program should be to identify the source and effects of pollutants of concern and to show a trend of pollution reduction over the life of the permit so that MS4 discharges do not continue to cause or contribute to exceedances of water quality standards. Successful monitoring programs not only furnish essential information about water quality in permitted receiving streams; they also provide the basis for establishing prioritized areas and for continually developing and improving BMPs.

We support the increased monitoring requirements of the draft permit. However, we urge EPA to include terms making clear that more frequent monitoring, as well as in-stream monitoring, may be necessary under certain circumstances. For example, continued instream monitoring of the chlorides-impaired waters discussed above will be essential to tracking progress under the TMDLs, as will outfall monitoring under specified conditions (i.e., within a certain time of snow-melt or rain events following the application of road salts) at a frequency greater than that specified in the draft permit. Although the implementation plans for the TMDLs may address these monitoring efforts, the final permit should nonetheless incorporate by reference any additional monitoring requirements established as part of TMDL implementation plans.

The data generated by monitoring will be critical to eliminating discharges determined to be causing or contributing to water quality violations, and identifying and correcting IDDE problems. In addition to the above, we request two specific changes to the monitoring requirements set forth in the draft permit. First, nutrients (nitrogen in estuarine and marine waters, and phosphorous in fresh waters) should be added to the list of parameters to be monitored. Second, the permit should require permittees to place monitoring data into EPA's WQX database. This latter tool will not be burdensome for regulated entities, and will create an accessible repository of data that will aid permittees, EPA, and interested stakeholders alike.

## IV. BMPs and Control Measures

BMPs and control measures must be developed and implemented to satisfy not only the draft permit's "maximum extent practicable", or "MEP," standard, but also to satisfy the Clean Water Act's and permit's water-quality requirements. The draft permit, as compared to the 2003 permit, provides significantly more detail regarding the minimum control measures to be developed and implemented in SWMPs. The draft permit's treatment of post-construction stormwater management for new development and redevelopment is particularly effective in addressing the need to reduce impervious surface cover through LID, better planning, and retrofits.[13] We offer the following specific comments.

### A. Compliance Issues Under the 2003 Permit

The draft permit makes clear that, once finalized, it will not provide additional time for regulated entities to complete requirements such as mapping, and the development of ordinances needed to implement minimum control measures (such as ordinances pertaining to construction activities, and post-construction storwmater management). The draft permit and Fact Sheet describe what – on paper – could be an effective stormwater management program. However, the draft permit and Fact Sheet do not appear to recognize the reality that many aspects of the minimum control measures required under the 2003 permit still have not been completed. For example, according to an EPA analysis of SWMP summaries and various metrics for Year 5 of the 2003 permit period (i.e., 2007-2008):

- of 24 NH traditional MS4s reporting on the status of outfall mapping, only 63 percent had completed such mapping;
- of 24 NH traditional MS4s reporting on the status of developing an IDDE regulatory mechanism, only 50 percent have adopted such a mechanism;
- of 26 NH traditional MS4s reporting on the status of developing a regulatory mechanism for construction site runoff, only 66 percent have adopted such a mechanism; and
- of 25 NH traditional MS4s reporting on the status of developing a regulatory mechanism to address post-development runoff, only 56 percent have adopted such a mechanism.

EPA, NPDES Phase II Small MS4 Permit Program, SWMP Summaries & Select Metrics: Permit Year 5 (2007-2008).

If more regulated entities were starting the next permit period having made more significant progress under the first permit, we would be more encouraged about the prospects for meaningful improvement under the permit currently under development, particularly with the more detailed minimum-control-measure provisions contained therein. Although we understand the challenges inherent in forcing compliance with all the terms of this program, regulated entities have been on notice of this program and its requirements for ten years,[14] and have had more than five years now to develop a solid

[13] We strongly support the draft permit's requirements that permittees affirmatively assess street design and parking lot requirements to assess opportunities to reduce paved areas (Section 2.3.6.6); affirmatively assess local regulations to identify opportunities for LID (Section 2.3.6.7); and affirmatively assess and track acreage of impervious area and directly connected impervious area ("DCIA"), and retrofits to MS4-owned property and infrastructure (Section 2.3.6.8). It is essential, of course, that the permit not be implemented in a manner that generates multiple assessments without subsequent *action* – i.e., the actual adoption of new local regulations and standards, and actual retrofits that reduce DCIA. The permit should make clear that following such assessments, certain substantive requirements must be met, such as the actual adoption of legislation that not only allows, but requires, LID.

[14] 64 Fed. Reg. 68,722 (Dec. 8, 1999).

foundation for their SWMPs. We urge EPA to use the process of developing this permit, the terms of the final permit itself, and enforcement mechanisms if necessary, to achieve better, prompt compliance with the small MS4 program. EPA should strongly consider publicly reporting, in a centralized format on its website, the compliance status of all regulated entities with respect to the many discrete deadlines and requirements of the final permit.

### B. Maintenance and Cleaning of Catch Basins

The draft permit requires permittees to establish procedures for inspecting, cleaning and repairing catch basins, and to clean catch basins a minimum of once every other year. Draft Permit §2.3.7.1(d)(i). We are concerned that this minimum standard for cleaning catch basins is insufficient to protect receiving waters. Studies suggest that at minimum catch basins should be cleaned once or twice per year (Aronson et al., 1983). Furthermore, it has been shown that more frequent cleaning leads to improved effectiveness of catch basins.[15] Naturally, the benefits of such inspections and maintenance must also be cost-effective – but if they are not effective in the first place, they are not "cost-effective," either.[16]

### C. Street Sweeping

The draft permit requires permittees to establish procedures for sweeping streets, sidewalks, and permittee-owned parking lots, and to sweep these areas a minimum of two times per year – once in the spring, once in the fall. Draft Permit § 2.3.7.1(d)(ii). Street sweeping is a critically important BMP. We agree with the requirement that street sweeping occur in the spring, to maximize the collection of winter deicing materials. However, we are concerned that two street sweepings per year will be insufficient.[17] Moreover, we believe high-efficiency vacuum-assist street sweeping, as opposed to conventional street sweeping, should be required. Whereas pollutants such as sediment, sand, debris, salt, pet and wildlife waste, and organic matter may be removed by conventional street sweeping, standard sweeping does not remove the smaller sediment particles that contain greater amounts of phosphorous and metals. Frequent use of high-efficiency vacuums is far more effective at removing these particles than is the use of mechanical models.[18] In fact, the City of Boston recently indicated that it will give

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[15] A 1994 Alameda, California study found that sediment removed per year tripled with monthly versus annual cleanings. Frequent cleanings were found to be particularly important in industrial and commercial areas. http://www.stormwatercenter.net/Pollution_Prevention_Factsheets/CatchBasins.htm

[16] *See* Testimony of Tom Schueler, CLF v. Deval Patrick et. al., Case No. 11295-wgy (D. Mass., May 29, 2008)

[17] The Tulsa, Oklahoma MS4 permit requires that residential streets be swept four times a year.

[18] Robert F. Breault, Residential Street-Dirt Accumulation Rates and Chemical Composition, and Removal Efficiencies by Mechanical- and Vacuum-Type Sweepers, New Bedford, Massachusetts, 2003–04," USGS Scientific Investigations Report 2005-5184 (2005). The 2003-2004 study in New Bedford, Massachusetts compared the efficiencies of a Pelican mechanical sweeper with a Johnston 605 Series vacuum sweeper. The study found that the vacuum sweeper efficiency (60 to 92 percent efficient) was greater than mechanical sweeper efficiency (9 to 40 percent efficient) across the board.

preference to street sweeping contractors using vacuum sweepers.[19] To the extent the permit allows the use of conventional sweepers, permittees should be required to document the curb miles swept, the cubic yards of material collected, and the type of sweeper employed for each cleaning. These data will provide important information regarding the effectiveness of permittees' street-sweeping programs, as well as a strong point of comparison between conventional and vacuum sweepers.

### D. De-Icing Applications

Application of road salts for winter de-icing purposes poses a significant threat to the health and sustainability of freshwater ecosystems throughout the region.[20] As part of its "Good Housekeeping" minimum control measures, the draft permit requires permittees to "establish procedures for winter road maintenance including the use and storage of salt and sand," and to "[m]inimize the use of chloride and other salts, and evaluate opportunities for use of other materials." Draft Permit § 2.3.7.1(d)(iii). These requirements are lacking in needed detail.

The draft permit should be amended to prescribe specific measures to be adopted, including but not limited to reduced application rates and the use of speed-calibrated spreaders, consistent with requirements set forth in Section 2.2.3 pertaining to MS4s discharging to chlorides-impaired waters. Extending such requirements to all permittees is warranted not only by the significant and growing impacts of chlorides pollution, but also the fact that chlorides impairments may be more widespread than currently documented. It also is worth noting that practices that reduce the volume of road salts can reduce winter-maintenance costs.

With specific regard to the storage of salt piles, or piles containing road salts, the draft permit requires enclosure or cover in most circumstances, but only *encourages* enclosing or covering piles "if stormwater runoff from the pile will not be discharged directly or indirectly to the MS4 or if discharges from the piles are authorized under another NPDES permit." Draft Permit §2.3.7.2(b)(iv). In light of the significant problems associated with chlorides, permittees should be required to cover all salt piles.

Finally, while the above comments relate to provisions in the "Good Housekeeping" section of the permit, it is essential that the permit also address chlorides pollution associated with new development and redevelopment. Specifically, all permittees should be subject to the requirements set forth in Section 2.2.3, which requires the owners of private parking lots and roads, and private road-salt applicators, to satisfy certain requirements. In light of significant and growing concerns regarding chlorides pollution, all permittees should be required to adopt and impose similar requirements for new development and re-development that discharges, directly or indirectly, to MS4s. The

[19] Andrew Ryan, "High-tech sweeper could make city streets clean and green," Boston Globe (Feb. 11, 2009).
[20] *See* Sujay S. Kaushal et. al., Publications of the National Academy of Sciences, "Increasing Salinization of Fresh Water in the Northeastern United States" (Aug. 4, 2005) (available at www.pnas.org).

permit should also require permittees to consider – in assessing and adopting LID regulations – the use of porous pavements as a means of reducing the use of road salts.

## V. N.H. Department of Transportation

Section 7 of the draft permit sets forth certain special requirements for transportation agencies which, in the case of New Hampshire, pertain to the N.H. Department of Transportation (NHDOT). We are greatly concerned with two aspects of NHDOT's conduct under the 2003 permit, each of which should influence the development of the final permit.

First, as discussed above, and as recognized in the draft permit and EPA's Fact Sheet, there are significant problems associated with chlorides pollution in the I-93 corridor. Although TMDLs related to these problems were only recently approved, the occurrence of chlorides impairments has been known for years. Despite this fact, NHDOT's SWMP and annual reports under the 2003 permit have failed to comply with that permit's requirement that SWMPs specifically address how pollutants of concern will be controlled and how the permittee's program will ensure that discharges will not cause exceedances of water quality standards. *See,* e.g., 2003 General Permit §I.C.2. To the extent EPA elects to use the Small MS4 General Permit as the vehicle for addressing these continued discharges to chlorides-impaired waters (as opposed to requiring an individual permit), it must take into account NHDOT's past conduct under the 2003 permit when finalizing the permit.

Second, NHDOT construction activities related to Exit 3 on I-93 recently caused a significant discharge of sediment into Cobbetts Pond. Specifically, on December 12, 2008, massive amounts of sediment washed off the construction site at Exit 3 into Castleton Brook and Dinsmore Brook which, in turn, caused a large sediment plume in Cobbetts Pond. *See* Attachment 2 ("I-93 work blamed for sediment in Cobbetts Pond," Eagle-Tribune (Dec. 16, 2008)). *See also* Attachment 3 (photographs taken at approximately 9:00 a.m. on Dec. 12, 2008, Castleton Brook and Cobbetts Pond); Attachment 4 (photographs taken between approximately 12:45 and 1:15 on Dec. 12, 2008, Castleton Brook and Cobbetts Pond); Attachment 5 (photographs taken at approximately 1:15 on Dec. 12, 2008, Dinsmore Brook). We understand and appreciate that NHDOT is taking a more aggressive approach to ensuring that its contractor for the Exit 3 construction project prevents pollution problems in the future.[21] Nonetheless, given the extensive construction work in which NHDOT engages, including but not limited to its proposal to widen 19.6 miles of I-93, this incident is cause for major concern – a concern further amplified by the fact that NHDOT is exempt from the typical process required under the Alterations of Terrain program administered by NHDES. In addition to the above, it is important to note that the draft permit appears to be modeled on the assumption that permittees will play a regulatory role with respect to construction activities. *See*, e.g., Fact Sheet at 51. The fact that transportation agencies are essentially self-regulating entities within the permit's model adds to the importance of addressing

[21] NHDOT has allowed CPIA to attend meetings to address stormwater management measures at the site.

these concerns. We urge EPA to address the above issues and concerns in finalizing the permit.

In addition to the above, we urge EPA to amend the draft permit to require NHDOT to strongly consider LID opportunities wherever and whenever feasible. Section 7.3 of the draft permit states: "The agency must . . . evaluate opportunities to include green infrastructure practices in new development and redevelopment at the facility. The agency must evaluate opportunities to reduce the amount of impervious cover due to parking areas and walkways." It is not clear from this language whether NHDOT is required to consider green infrastructure and LID opportunities in the many projects in which it engages. EPA should amend this language to require such consideration – including the use of porous pavements[22] – in all NHDOT projects where LID and green infrastructure opportunities exist.

Finally, we reiterate our strong concerns with NHDOT's proposal to widen – from a total of four lanes, to eight – the 19.6 mile stretch of I-93 between Salem and Manchester. This project will involve significant increased, and potentially new, discharges into the four chlorides-impaired waters. We ask that EPA address this proposed project and its associated discharges by requiring and specifically outlining a detailed review process – as set forth in Part II.F of these comments, above – to determine whether the proposed project is permissible under the Clean Water Act, including whether it can comply with the TMDLs, water quality standards, and Section 401 water quality certification.

## VI. Great Bay Estuary

The Great Bay estuary is one of New Hampshire's most productive and diverse habitats. Comprised of the Piscataqua River, Little Bay and Great Bay, and receiving freshwater flows from several small creeks and seven major rivers – the Oyster, Bellamy, Lamprey, Squamscott, Winnicutt, Cocheco and Salmon Falls Rivers – the estuary contains a broad diversity of habitat types, and a broad array of wildlife species. Among its dependent wildlife, the Great Bay estuary provides important habitat for numerous fish species.[23] Many of these species, such as Atlantic cod, are important commercial fish. Others, such as a variety of herring, are forage fish that support commercial fisheries by serving as an important building block in the marine food chain. Still other species, such as striped bass and bluefish, are important recreational fisheries. In addition to finfish, the estuary supports shellfish, such as oyster and blue mussels, and other invertebrates.

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[22] NHDOT has employed the use of porous pavement at part of a new park-and-ride facility at Exit 5 of I-93. The permit should ensure that DOT gives serious consideration to porous pavement and other LID practices when it constructs or re-constructs such facilities.

[23] The estuary is designated Essential Fish Habitat (EFH) by the National Marine Fisheries Service for numerous fish species in various life stages, including Atlantic cod, Atlantic herring, Atlantic sea scallop, haddock, pollock, red hake, white hake, window-pane flounder, yellowtail flounder, Atlantic mackerel, and bluefish. The Cocheco River, which flows through Dover into the Piscataqua River, is designated EFH for Atlantic salmon for all of its life stages. In addition to these EFH-designated species, the estuary supports numerous other fish, including striped bass, smooth flounder, rainbow smelt, Atlantic sturgeon, American shad, river herring (blueback herring and alewives), black sea bass, American eel, white perch, sea lamprey and Atlantic silversides.

Eelgrass is a cornerstone of the Great Bay estuary ecosystem, serving an important role for fish, invertebrates and birds alike. Eelgrass meadows in the estuary provide breeding grounds, nurseries, food, and cover for many fish as well as important habitat for invertebrate species. The abundant aquatic life found in eelgrass meadows, in turn, provides an important food source for birds. Eelgrass meadows also serve a critically important water quality function by stabilizing sediments and filtering contaminant. As the N.H. Estuaries Project has noted: eelgrass is "an essential habitat for the estuary, the loss of which would fundamentally alter the ecosystem of the bay." NHEP, *Environmental Indicator Report: Critical Habitats and Species* (March 2006) at 8.

The Great Bay estuary is in jeopardy as a result of increasing nitrogen concentrations. According to the N.H. Estuary Project's 2006 *State of the Estuaries* report, not only have nitrogen concentrations increased in the estuary, they have reached the same levels that have been shown to cause negative effects in other estuaries. Related to the significant problem of nitrogen pollution, the estuary has experienced major declines in eelgrass cover and biomass. As a result of these conditions, numerous waters in the estuary are known to be impaired as a result of substantial eelgrass declines and/or the violation of narrative water quality standards pertaining to nitrogen. Specifically, in August 2009, NHDES submitted to EPA a methodology pursuant to which it determined that several waters associated with the Great Bay estuary are impaired as a result of substantial eelgrass declines, and that four water bodies – the Squamscott, Lamprey, Oyster and Salmon Falls Rivers – are impaired for nitrogen. *See* Attachment 6 (NHDES, "Methodology and Assessment Results related to Eelgrass and Nitrogen in the Great Bay Estuary for Compliance with Water Quality Standards for the New Hampshire 2008 Section 303(d) List," Aug. 11, 2008). Subsequently, on December 30, 2008, NHDES published for public review and comment a document discussing numeric nutrient criteria for the Great Bay estuary, some of which demonstrate numerous additional nitrogen impairments. *See* Attachment 7.

We understand that in Massachusetts, EPA intends to develop separate MS4 general permits for four specific geographic areas, and that it intends to do so based on unique water quality issues (i.e., TMDLs) applicable to those areas. In light of the foregoing, we believe a similar approach makes sense for New Hampshire's Great Bay estuary watershed. In particular, the significant threats facing the Great Bay estuary (which include stormwater-related threats); existing impairments in the estuary relative to nitrogen pollution and eelgrass losses and the imminent Section 303(d) listing of those impairments; the imminent development of numeric nutrient criteria for the estuary; and the need to develop TMDLs to ensure the attainment of those nutrient criteria; all warrant special treatment of this watershed for MS4 permitting purposes. Accordingly, we request that EPA create a general permit for MS4s located within the watershed of the Great Bay estuary which directly and specifically addresses the challenges and needs facing the estuary.

## VII. Endangered/Threatened Species

Section 1.3 of the draft permit, pertaining to limitations on permit coverage, provides that the permit does not authorize discharges that are likely to adversely affect species listed as endangered or threatened under the Endangered Species Act, or adverse impacts on designated critical habitat. Draft Permit § 1.3(e). The draft permit also sets forth procedures applicants must follow to assess these issues and to thereby determine eligibility for permit coverage. We believe this language should be expanded to also require consideration of species listed as endangered or threatened under New Hampshire state law. Such an approach would be consistent with the New Hampshire Coastal Zone Management Enforceable Policies – discussed in EPA's Fact Sheet (pp. 14-19) – which include a number of plant and wildlife considerations that are in no way limited to species listed under the Endangered Species Act. *See* EPA Fact Sheet at 15, 16. It also will be necessary to ensure that discharges do not adversely affect state-listed species – such as Blandings turtle (endangered) and spotted turtle (threatened) – which depend on aquatic resources.[24]

## VIII. Authorization to Discharge

In *Environmental Defense Center v. Browner* ("*EDC*"), the U.S. Court of Appeals for the Ninth Circuit addressed the type of review required for Notices of Intent ("NOIs") submitted by small MS4s seeking coverage under a general permit.[25] Certain petitioners in *EDC* challenged the EPA's small MS4 regulations on the ground that they failed to require EPA to review the substance of NOI submissions to ensure compliance with the Clean Water Act. In addressing this critical issue, the *EDC* Court started with the proposition that the Clean Water Act imposes certain substantive requirements that must, consistent with the clear intent of Congress, be satisfied by small MS4s seeking coverage under a general permit. Specifically, the Court found "the plain language of § 402(p) of the Clean Water Act, 33 U.S.C. § 1342(p), expresses unambiguously Congress's intent that EPA issue no permits to discharge from municipal storm sewers unless those permits 'require controls to reduce the discharge of pollutants to the maximum extent practicable.'"[26] The *EDC* Court concluded that EPA must review the substance of NOIs to ensure compliance.[27]

[24] *See* http://www.wildlife.state.nh.us/Wildlife/Nongame/endangered_list.htm, listing species designated as endangered and threatened under New Hampshire law.

[25] *Environmental Defense Center v. Browner*, 344 F.3d 832 (9th Cir. 2003), *cert. denied*, 124 S.Ct. 2811 (2004).

[26] *EDC*, 344 F.3d at 854. Of course, in addition to the "maximum extent practicable" requirement, the Clean Water Act and its regulations contain other important mandates, including the requirements (1) that discharges not cause or contribute to water quality violations, *see* discussion in Section II, below, and (2) that the Phase II stormwater regulations (of which the Small-MS4 regulations are a part) constitute a comprehensive program designed "to protect water quality." *EDC*, 344 F.3d at 844 (*citing* 33 U.S.C. § 1342(p)(6)).

[27] The *EDC* court stated:

> According to the Phase II Rule, the operator of a small MS4 has complied with the requirement of reducing discharges to the "maximum extent practicable" when it implements its stormwater management program, *i.e.*, when it implements its Minimum Measures. . . . Nothing in the Phase II regulations requires that NPDES permitting authorities review these Minimum Measures to ensure that the measures that any given operator of a small MS4 has decided to undertake will *in fact* reduce discharges to the maximum extent practicable. . . . Therefore, under the Phase II Rule,

As a result of the *EDC* decision (which the U.S. Supreme Court declined to review on *certiorari*), EPA must substantively review NOIs to ensure compliance with the Clean Water Act and applicable standards. Because NOIs include substantive elements of permit applicants' SWMPs (*see* Draft Permit, Appendix E), EPA must engage in a substantive review and approval of these SWMP elements – and, by logical implication, the SWMP as a whole – to ensure compliance with all applicable standards and requirements before granting authorization to discharge.

* * * * *

Again, CLF, the Rivers Council, and CPIA appreciate the opportunity to provide these comments. We look forward to working with EPA to ensure the significant problems caused by stormwater pollution are addressed through the final development and implementation of this permit.

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> nothing prevents the operator of a small MS4 from misunderstanding or misrepresenting its own stormwater situation and proposing a set of minimum measures for itself that would reduce discharges by far less than the maximum extent practicable.
>
> In fact, under the Phase II Rule, in order to receive the protection of a general permit, the operator of a small MS4 needs to do nothing more than decide for itself what reduction in discharges would be the maximum extent practical reduction. No one will review that operator's decision to make sure that it was reasonable, or even good faith. Therefore, as the Phase II Rule stands, EPA would allow permits to issue that would do less than *require* controls to reduce the discharge of pollutants to the maximum extent practicable. . . . We therefore must reject this aspect of the Phase II Rule as contrary to the clear intent of Congress.

*EDC*, 344 F.3d at 855 (citations and parentheticals omitted) (italics in original). *See also id.* at 855, n. 32, stating, in pertinent part:

> That the Rule allows a permitting authority to review an NOI is not enough; *every permit must comply with the standards articulated by the Clean Water Act, and unless every NOI issued under a general permit is reviewed, there is no way to ensure that compliance has been achieved.*
> The regulations do require NPDES permitting authorities to provide operators of small MS4s with "menus" of management practices to assist in implementing their Minimum Measures, *see* 40 C.F.R. § 123.35(g), but again, nothing requires that the combination of items that the operator of a small MS4 selects from this "menu" will have the combined effect of reducing discharges to the maximum extent practicable.
> . . . .
> Absent review on the front end of permitting, the general permitting regulatory program loses meaning even as a procedural exercise.

(Emphasis added).

Respectfully submitted,

CONSERVATION LAW FOUNDATION

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603-225-3060

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CONSERVATION LAW FOUNDATION

February 20, 2009

Ms. Thelma Murphy
Office of Ecosystem Protection (CIP)
U.S. Environmental Protection Agency
One Congress Street
Boston, MA 02114-2023

**Re: Draft NPDES General Permit for Discharges From Small Municipal Separate Storm Sewer Systems Located in the State of New Hampshire (NHR040000)**

Dear Ms. Murphy:

Please find enclosed the attachments (Attachments 1 through 7) referenced in the joint comments of the Conservation Law Foundation, New Hampshire Rivers Council, and Cobbetts Pond Improvement Association, relative to the above-referenced draft permit, submitted to you electronically today.

Should you have any questions, please do not hesitate to contact me. Thank you for your assistance.

Very truly yours,

Thomas F. Irwin,
Senior Attorney

Encls.

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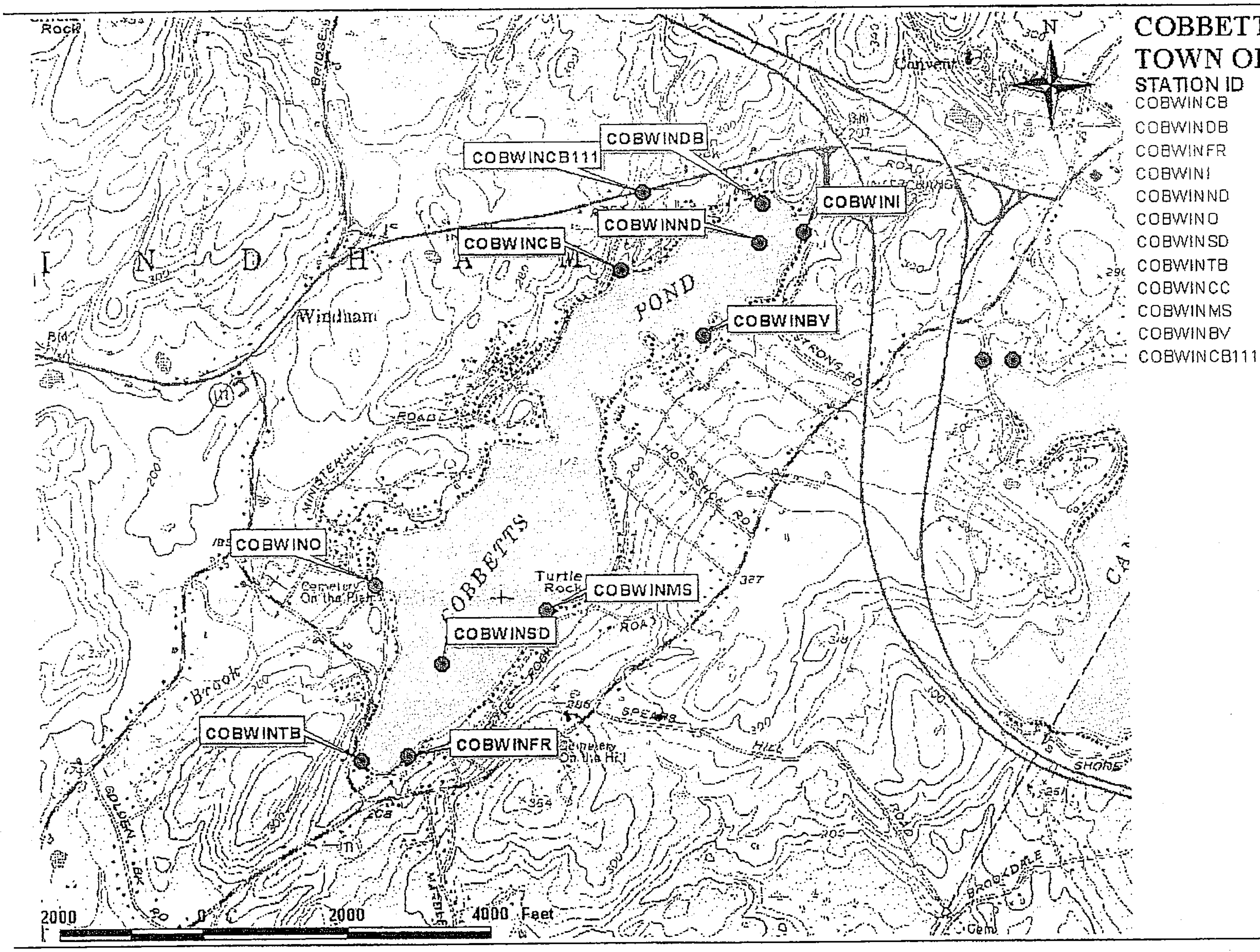
# ATTACHMENT 1



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# ATTACHMENT 2

tdate@eagletribune.com

December 16, 2008 02:44 pm

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WINDHAM — The state project manager for the Cobbetts Pond cleanup plan was alarmed when he saw a huge sediment plume emptying into the pond Friday.

Steve Landry of the Department of Environmental Services suspects the 1,000-foot plume was caused by erosion from the Exit 3 reconstruction project off Interstate 93 due to last week's heavy rain. Landry tested the turbidity of the water Friday morning and estimated the level at 10 times the state surface water standard.

The fine sediment funneled into Castleton Brook and emptied into the pond, adding to its clarity and sedimentation woes, he said. Excess sedimentation on the pond bottom feeds the aquatic plants that are choking oxygen from the pond.

"The timing couldn't be worse," Landry said. "How much more can Cobbetts take?"

The state supervisor for the Interstate 93 widening project acknowledged the state needs to do a better job controlling erosion on this and other I-93 projects in the future.

The department is in discussion with DES on how to prevent a similar incident in the future, said project supervisor Jay Levine.

He said the solution will likely be gravel- and rock-lined detention ponds. Levine expects the water collection area for Exit 3 to be constructed behind the site of the former Dunkin' Donuts on Route 111 in about a month, once the ground freezes enough.

Derek Monson of the Cobbetts Pond Improvement Association said the state was supposed to install erosion protection measures ahead of construction.

"Whatever they are doing was not enough," Monson said.

The state and Northeast Engineering, contracted to monitor water quality, were surprised by the sediment plume. The last water testing done before going home Thursday didn't indicate a problem, Levine said.

Heavy rain overnight Thursday likely washed the sediment into the water, he said.

Levine said testing done later Friday, in the afternoon, did not indicate a problem with turbidity.

Tom Irwin of the Conservation Law Foundation said he has alerted the U.S. Environmental Protection Agency to the incident.

Irwin worries about the influence of project construction on the environment.

"It does not bode well that they are already having problems of this magnitude," he said.

The foundation has challenged the I-93 widening project in court. The foundation maintains that added highway lanes will increase runoff of road salt into the watershed.

Landry said he suspects too much land has been cleared too fast for the Exit 3 work.

"It looks like something went through, like a tornado, and took out every tree for many acres," he said.

The construction work is being done by Middlesex Corp. Middlesex project manager Evan McCormick deferred comment to the DOT because it is sponsoring the work.

Levine said the key focus now needs to be working out a solution.

"Obviously, we are all upset, but the question is how to go forward to try to minimize any kind of discharges," he said.

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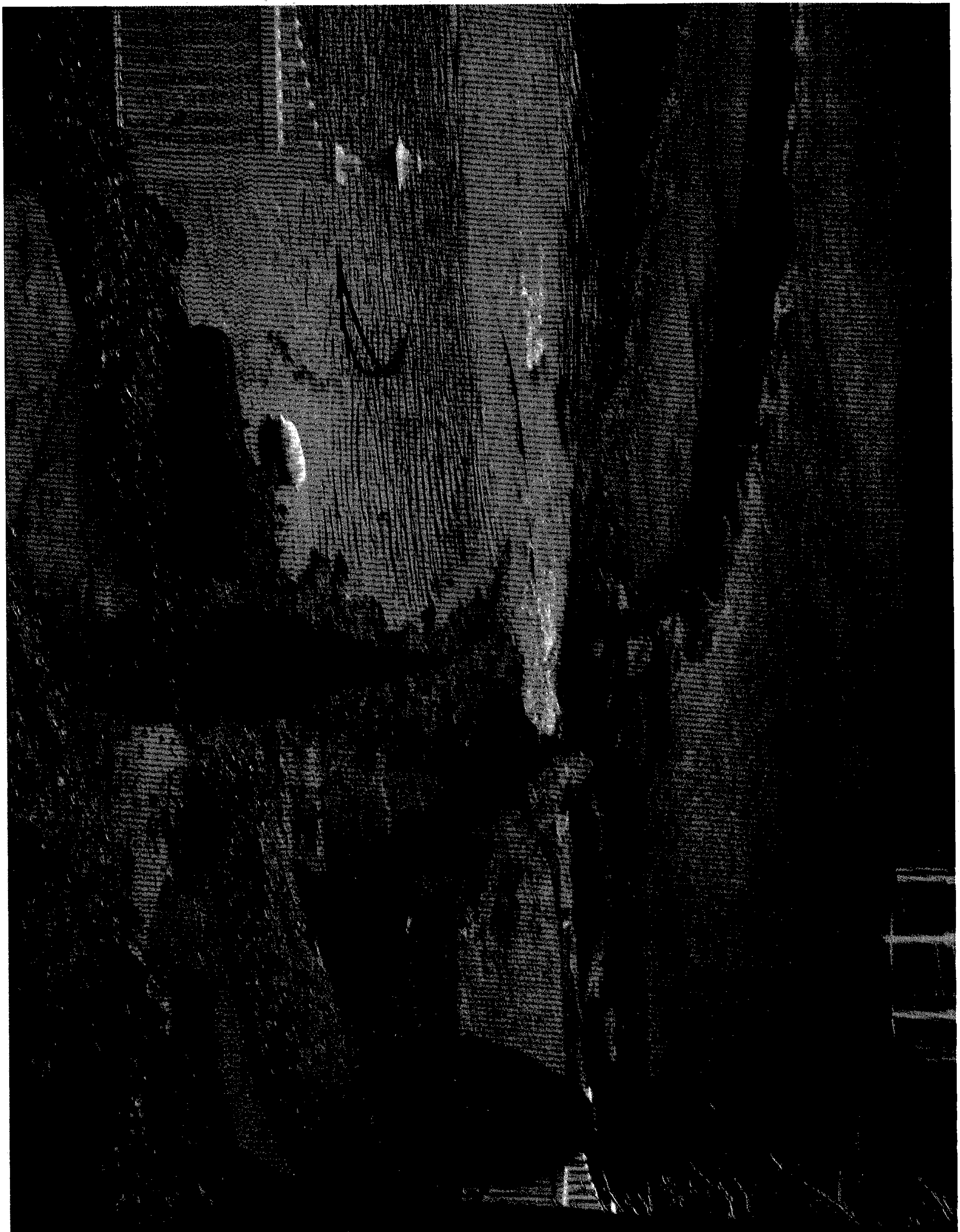
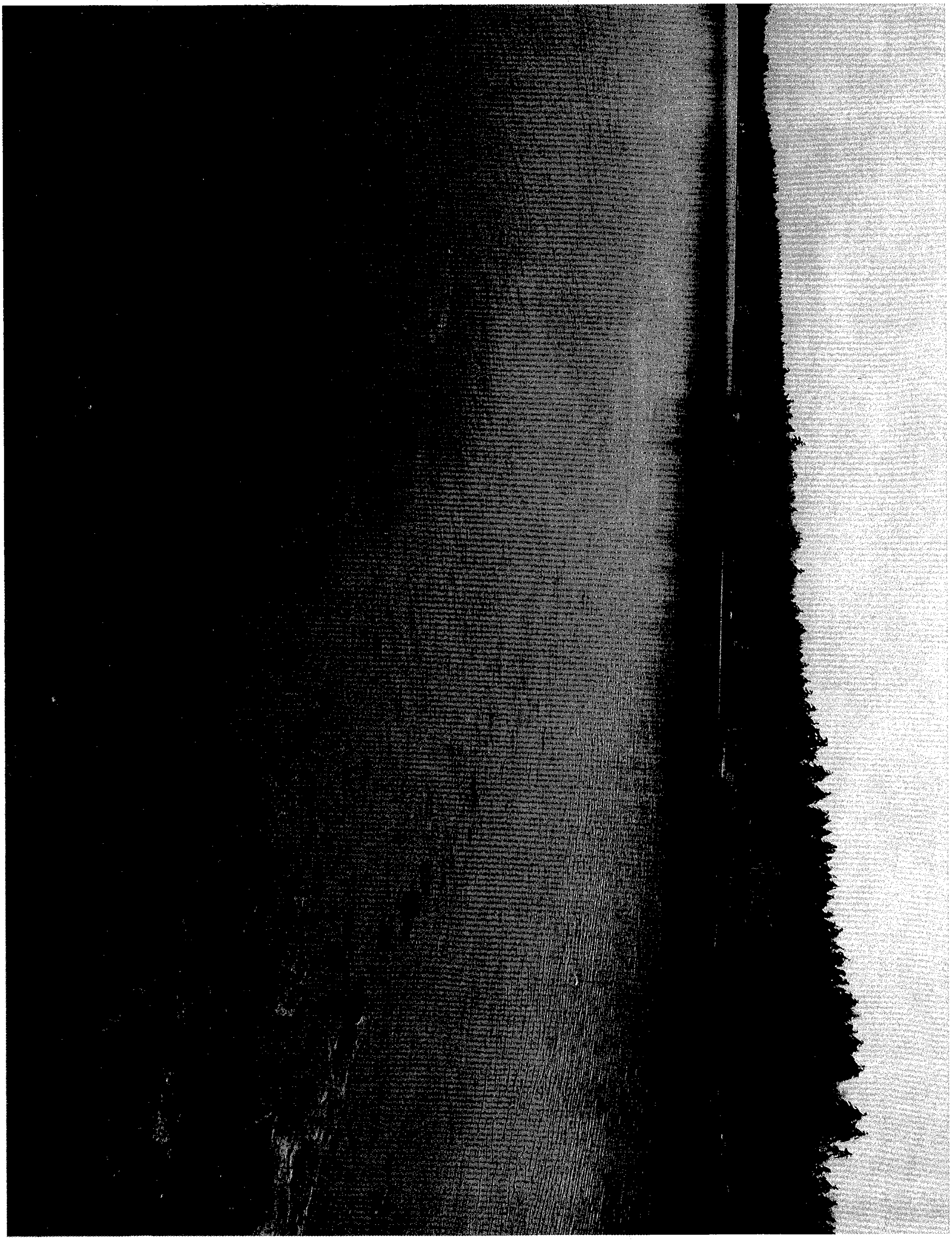
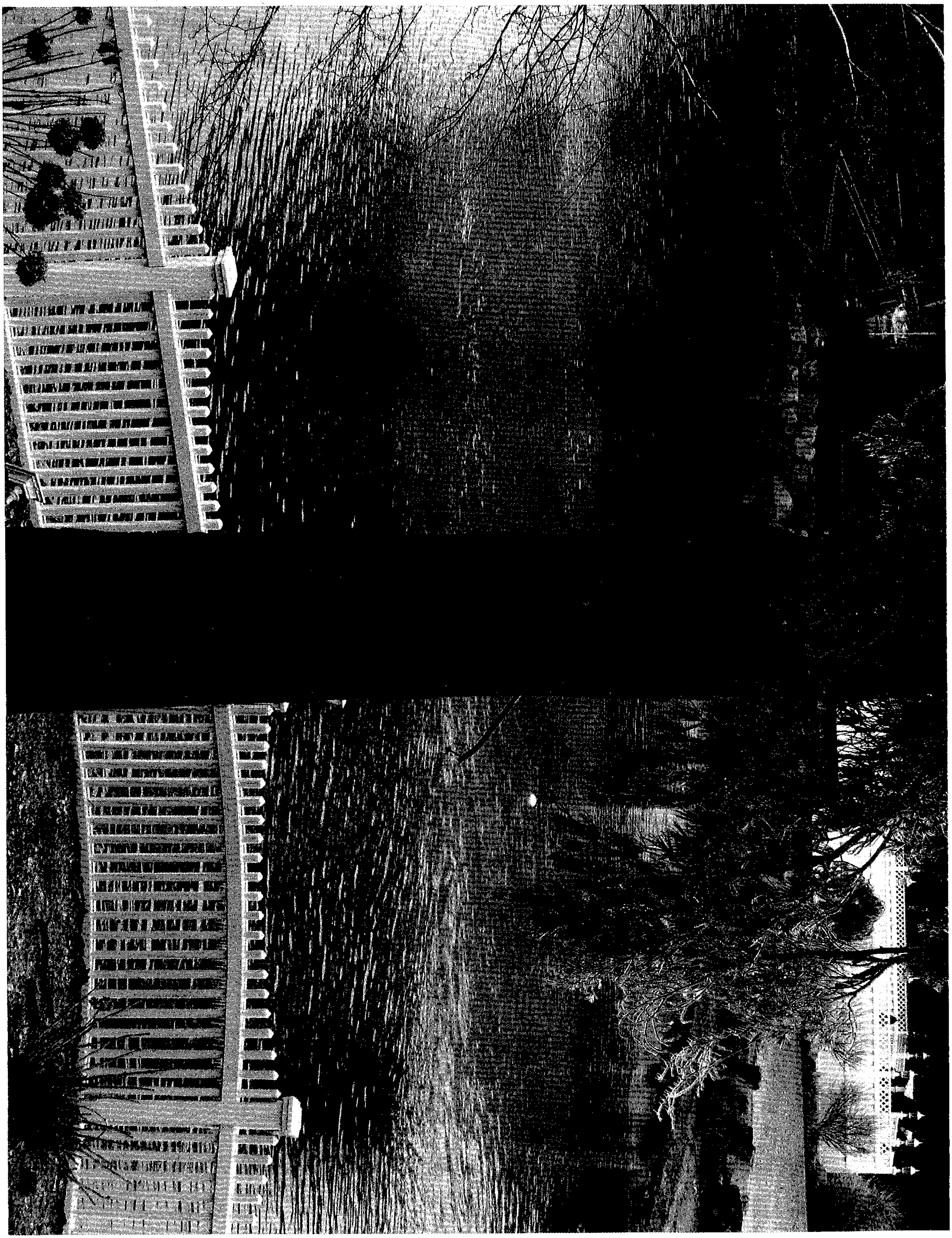
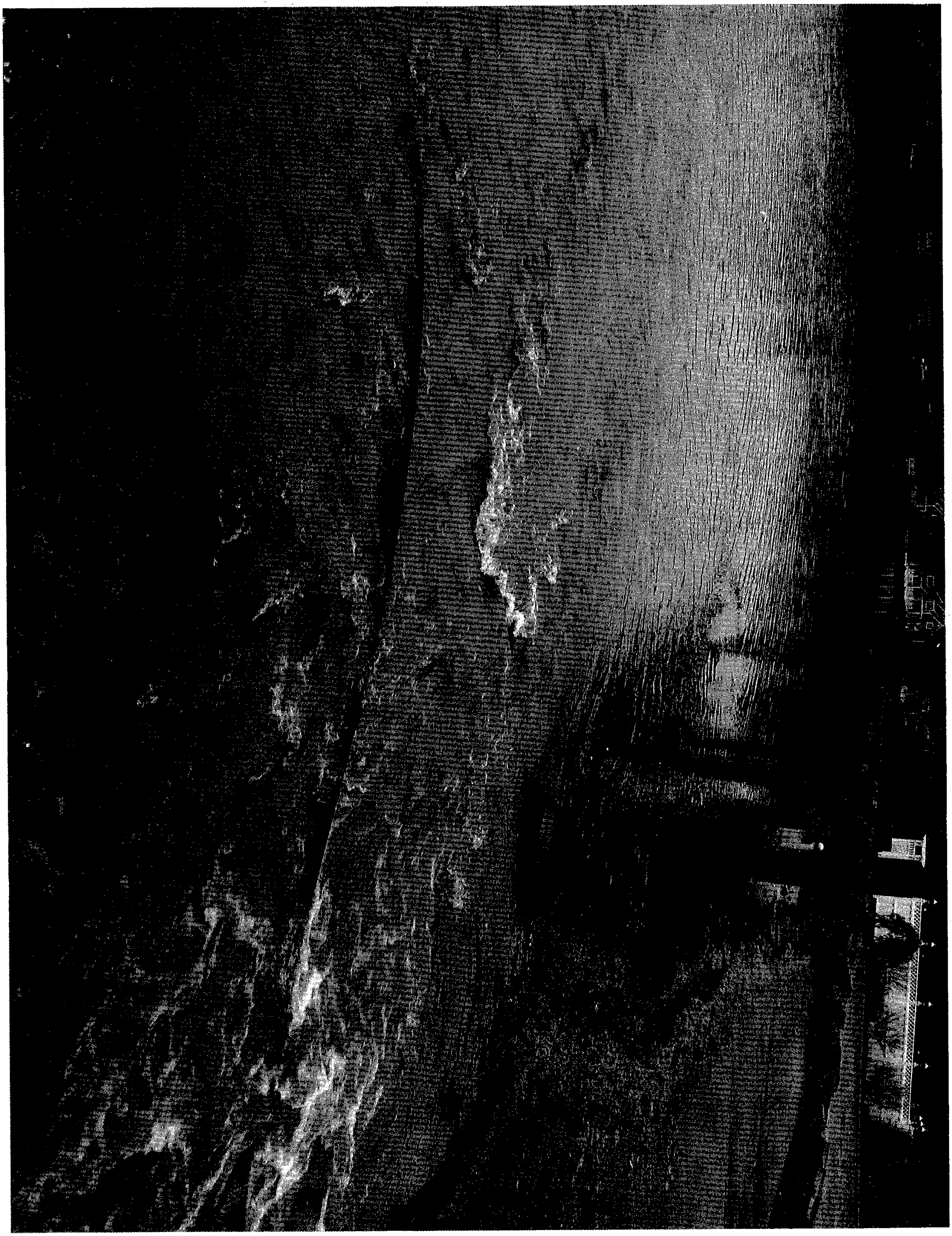
# ATTACHMENT 3









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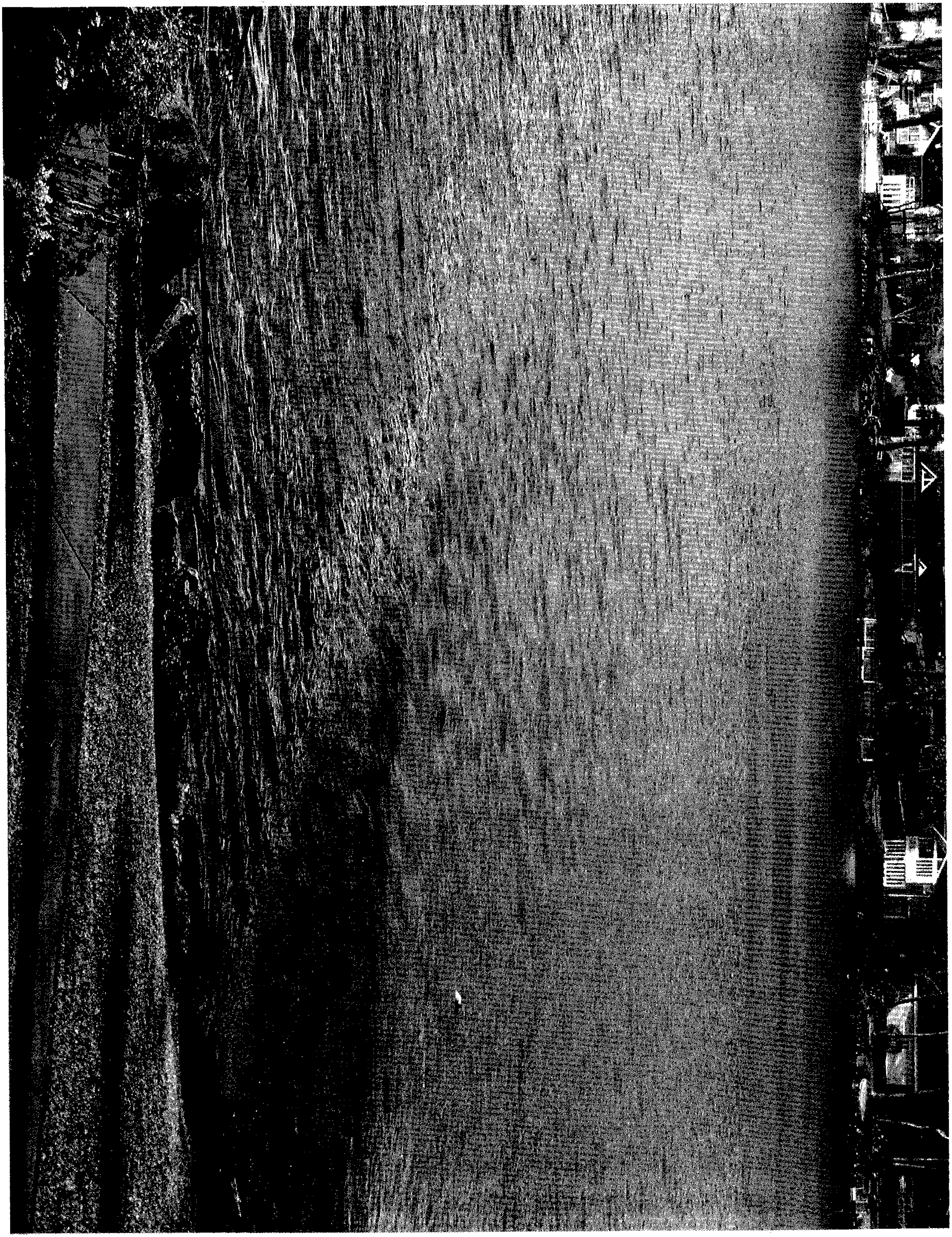

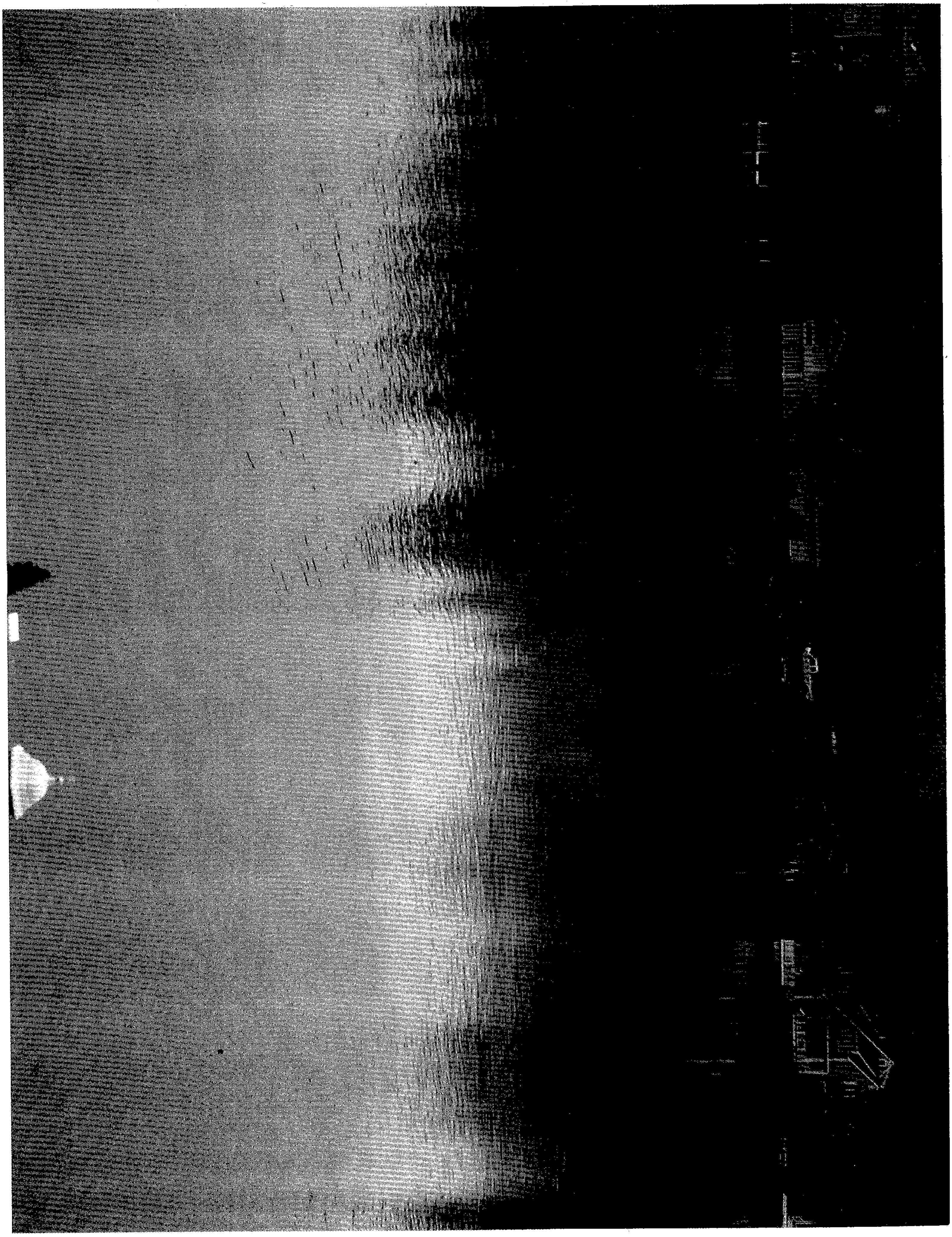

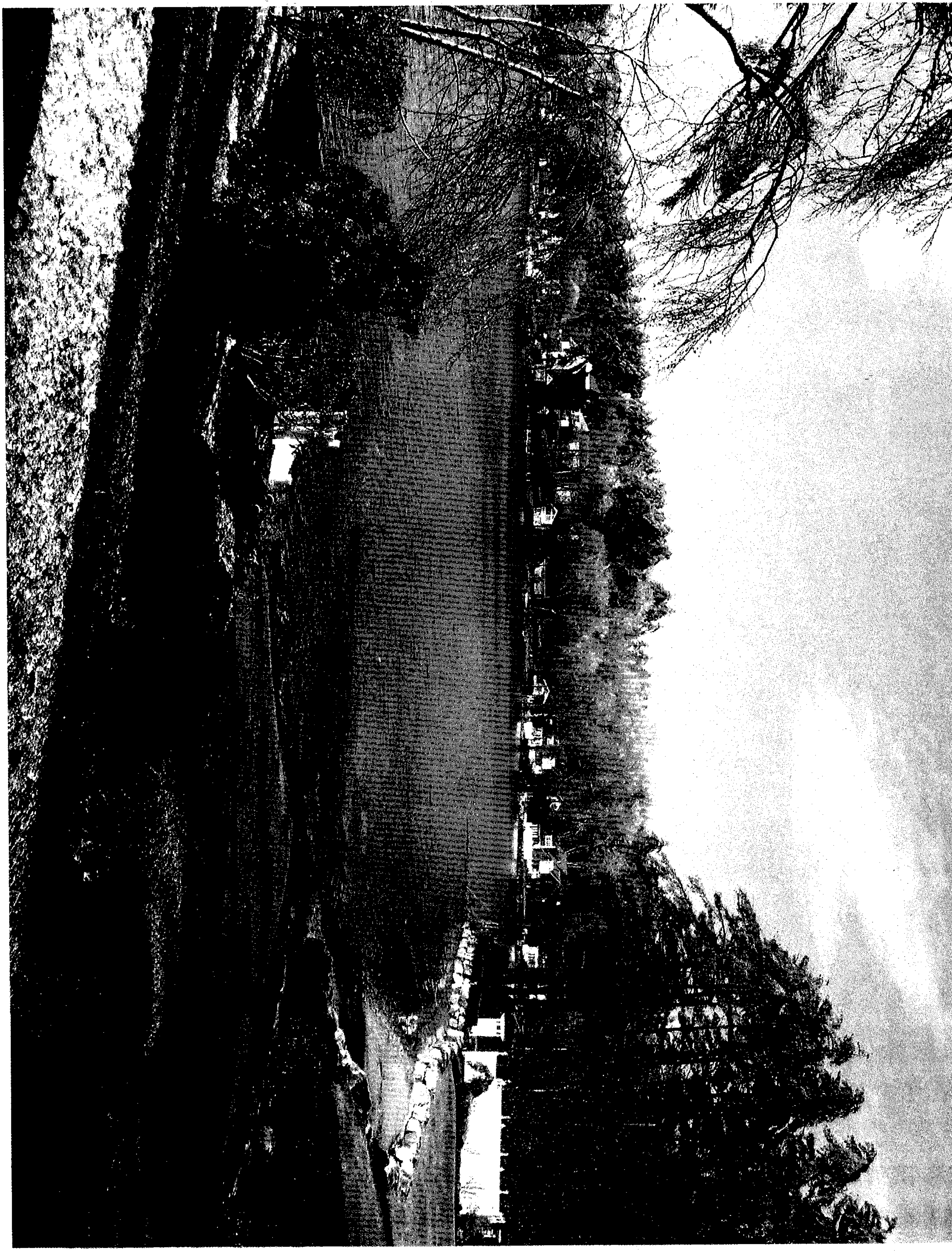

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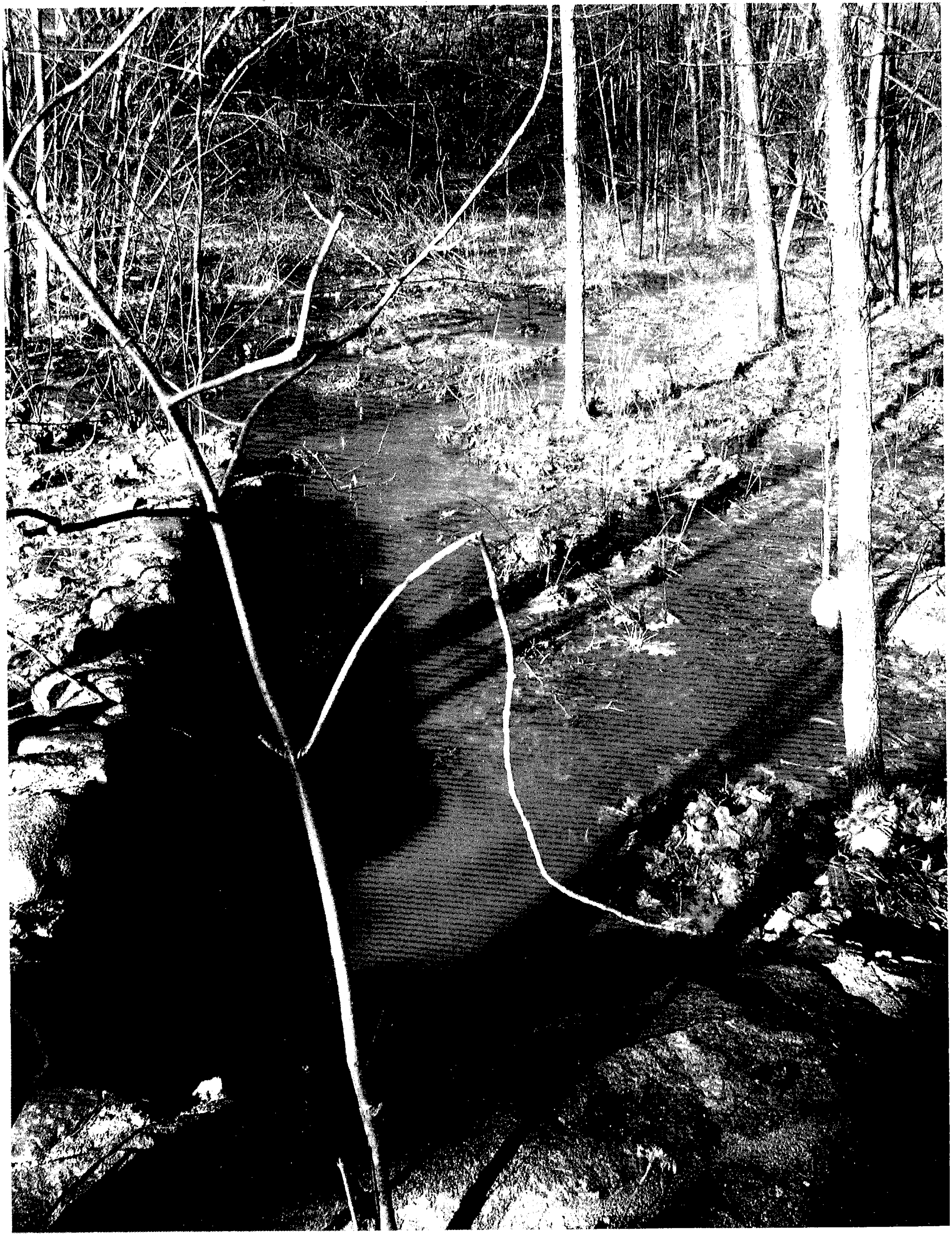

# ATTACHMENT 6

# Table of Contents

**List of Tables**



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# Executive Summary

The New Hampshire Department of Environmental Services (DES) has developed numeric water quality criteria for the Great Bay Estuary. Numeric nutrient criteria were needed because New Hampshire's water quality standards contain only narrative criteria for nutrients to protect designated uses. Narrative standards are difficult to apply for impairment and permitting decisions. DES received considerable assistance with the criteria development from the New Hampshire Estuaries Project (NHEP). The NHEP dedicated staff time to develop methods, formed a technical working group to review approaches and proposed criteria, and funded additional research to fill data gaps.

A variety of data sources were evaluated to provide multiple lines of evidence relative to appropriate thresholds for nutrients in the Great Bay Estuary. Each data source was chosen because of its relevance to the conceptual model for eutrophication in estuaries from the National Estuarine Eutrophication Assessment Update. A weight of evidence approach was used to combine information from the disparate sources. First, water quality measurements from different sections of the estuary were used to develop linear regressions between total nitrogen concentrations and chlorophyll-*a*, dissolved oxygen, and water clarity. Second, continuous monitoring of dissolved oxygen with in-situ sensors provided detailed information related to dissolved oxygen impairments. Finally, relationships between water quality and water clarity were quantified based on light attenuation measurements by in-situ sensors and hyperspectral imagery.

Numeric criteria were developed for the aquatic life use support designated use because this use is the most sensitive to nutrient enrichment. DES considered low dissolved oxygen and loss of eelgrass habitat as the most important impacts to aquatic life from nutrient enrichment for the Great Bay Estuary. For each of these impacts, DES established a threshold for the total nitrogen concentration and a threshold for a response variable. Specifically, in order to maintain dissolved oxygen concentrations greater than 5 mg/L, the median total nitrogen concentration should be less than or equal to 0.45 mg N/L and the $90^{th}$ percentile chlorophyll-a concentration during summer should be less than or equal to 12 ug/L. For the protection of eelgrass habitat, the median total nitrogen concentration should be less than or equal to 0.32 mg N/L and the light attenuation coefficient (a measure of water clarity) should be less than or equal to 0.75 $m^{-1}$. Thresholds were not established for phosphorus because nitrogen is the limiting nutrient in the majority of the estuary.

The numeric criteria will first be used as interpretations of the water quality standards narrative criteria for DES' Consolidated Assessment and Listing Methodology for 305(b) assessments. Later, DES will promulgate these values as water quality criteria in Env-Wq 1700.

# Introduction

In 1998, the U.S. Environmental Protection Agency (EPA) published the Clean Water Action Plan (EPA, 1998) to improve the water quality in the nation's lakes, rivers and estuaries. One component of this plan was the development of numeric criteria for nutrients (i.e., nitrogen and phosphorous) in water bodies. National criteria were not considered appropriate due to the variety of water bodies across the country. Therefore, EPA asked each state to develop numeric nutrient criteria for its own water bodies. EPA provided the states with technical guidance for developing nutrient criteria for lakes, rivers and estuaries (EPA, 2000a; EPA, 2000b; EPA, 2001).

In New Hampshire, the NH Department of Environmental Services (DES) is responsible for developing nutrient criteria for NH's estuaries. The New Hampshire Estuaries Project (NHEP) facilitated the nutrient criteria development process by dedicating significant NHEP staff time to research and develop methods to establish numeric nutrient criteria, forming a technical working group in 2005 to provide input on the methods, and supporting additional research to assist in the development of the criteria. Information from the workgroup meetings is available at www.nhep.unh.edu/programs/nutrient.htm.

New Hampshire's Water Quality Standards currently contain only narrative criteria for nutrients to protect designated uses. Narrative standards are difficult to apply for impairment and permitting decisions. This report contains proposals for numeric nutrient criteria for different designated uses in the Great Bay Estuary, the largest estuary in the State, based on the weight of evidence from the multiple sources of information. The numeric criteria will first be used to implement the narrative criteria as thresholds for impairment determinations in the State of New Hampshire 303(d) list in 2010. Later, the thresholds will be proposed as new water quality criteria in Env-Wq 1700.

The designated uses considered for this analysis were primary contact recreation (swimming use) and aquatic life use support. For aquatic life use support, DES investigated nutrient thresholds for the protection of the benthic invertebrate community, dissolved oxygen, and eelgrass.

# Regulatory Authority

The narrative standard for nutrients, Env-Wq 1703.14, provides DES with the regulatory authority to set thresholds for impairments associated with nutrients and other parameters associated with eutrophication. The narrative standard for estuarine waters, which are Class B, states that: "Class B waters shall contain no phosphorus or nitrogen in such concentrations that would impair any existing or designated uses, unless naturally occurring."

# Precedents from Other States

Numeric nutrient criteria have been established for relatively few estuaries but the criteria that have been set typically fall between 0.35 and 0.49 mg N/L. The criteria have been used as both water quality standards and modeling targets for Total Maximum Daily Load (TMDL) studies. In New England, the Massachusetts Estuaries Project has established water quality thresholds for TMDLs for dozens of estuaries, predominantly on Cape Cod and in Buzzards Bay (reports available at http://www.oceanscience.net/estuaries/index.htm). While the thresholds are site-specific, many of the nitrogen thresholds set for the protection of eelgrass habitat are similar and fall between 0.35 and 0.38 mg N/L for a tidally averaged concentration at a sentinel site. A nitrogen threshold of 0.49 mg N/L has been adopted for Pensacola Bay in Florida. This threshold was derived from current concentrations because eutrophication effects in Pensacola Bay were not apparent at the current concentrations.

## Methods

The overall approach was to divide the estuary into different segments and to develop correlations between median values (or other statistics) for nutrients and response variables in the different segments. States with many different estuaries are able to compare median nutrient concentrations and response variables across estuaries. New Hampshire could not follow this approach because there is only one large estuary in the state, the Great Bay Estuary. However, the Great Bay Estuary is composed of eight tidal rivers and several distinct embayments. The nutrient concentrations in these different segments span a wide range and have differing levels of eutrophic response. Therefore, DES decided to split the estuary into 14 assessment zones of approximately homogeneous water quality and to look for correlations across the assessment zones. The advantage of this approach was that variability in the datasets was muted by taking median values for each assessment zone, which improved the quality of the correlations. Li et al. (2008) also observed an improvement in correlations between nitrogen and chlorophyll-a in Canadian estuaries when data were aggregated over longer time periods. The disadvantage of the approach is that spatial and temporal variability of water quality within an assessment zone was lost. On balance, the advantages of this approach outweighed the disadvantages because the variability of water quality parameters in space and time masked expected relationships.

Several different nutrient concentration thresholds for different designated uses and environmental conditions were developed because different eutrophication indicators occur for different levels of nutrient enrichment. For example, the nutrient concentration threshold to protect against large phytoplankton blooms would be expected to be higher than the threshold to maintain submerged aquatic vegetation. In addition to the thresholds for nutrient concentrations, thresholds for response variables such as chlorophyll-a and water clarity were also developed. These response thresholds provide a means to determine impairments based on measurements of eutrophic effects if nutrient concentration data are missing. The nutrient and response thresholds will be used together to make impairment determinations.

## Conceptual Model

The estuarine eutrophication model used by the National Oceanic and Atmospheric Administration relates external nutrient inputs to primary and secondary symptoms of eutrophication (Bricker et al., 2007). Phytoplankton blooms (as measured by chlorophyll-a concentrations) and proliferation of macroalgae are primary symptoms of eutrophication, while low dissolved oxygen, loss of submerged aquatic vegetation (e.g., eelgrass), and harmful algal blooms are secondary symptoms. Harmful algal blooms, the proliferation of certain species of phytoplankton or cyanobacteria which produce toxins, typically occur offshore in the Gulf of Maine so this indicator was not considered for the Great Bay Estuary (Townsend et al., 2005). Instead, the secondary effects of accumulated organic matter in sediments on benthic infauna were considered. This approach is consistent with the conceptual model of coastal eutrophication presented by Cloern (2001) and the guidance for developing numeric nutrient criteria for estuaries from EPA (2001). DES used a variety of data sources to estimate thresholds for nutrients and response variables for each of the primary and secondary indicators in the conceptual model. The methods used for each indicator are described in the following sections.

## Nutrient Concentrations

All valid data for nitrogen and phosphorus species from the Great Bay Estuary collected between January 1, 2000 and December 31, 2007 were queried from the DES Environmental Monitoring Database. The majority of the data was from the following programs: Great Bay National Estuarine Research Reserve System Wide Monitoring Program (http://nerrs.noaa.gov/Monitoring/), University of New Hampshire (UNH) Tidal Water Quality Monitoring Program, and the National Coastal Assessment (http://www.epa.gov/emap/nca/). Results from the Great Bay National Estuarine Research Reserve Diel Sampling were excluded because of outliers and overlap with the System Wide Monitoring Program samples taken at the same stations.

For each parameter, the minimum, $10^{th}$ percentile, median, $90^{th}$ percentile, and maximum concentrations were calculated from all the measurements between 2000 and 2007 in each assessment area shown on Figure 1 and for each trend station shown in Figure 2. Results reported as less than the method detection level were excluded to avoid assumptions. This approach is justified because for total nitrogen and total phosphorus, less than 1% and 8% of the results were reported as being less than the method detection level. This procedure was considered acceptable because less than 10% of results for each parameter were censored (EPA, 2006). Prior to calculating the summary statistics, all the results from each station on each date were averaged, which merged routine results, quality control, depth duplicate values, and repeat station visits.

If total nitrogen (TN) concentrations were not measured directly, TN was calculated from the sum of total dissolved nitrogen and particulate nitrogen. Dissolved inorganic nitrogen was calculated from the sum of nitrate+nitrite and ammonia or nitrate, nitrite, and ammonia. If total phosphorus (TP) concentrations were not measured directly, TP was calculated from the sum of dissolved phosphorus and particulate phosphorus.

The aggregate statistics for each assessment zone could not illustrate some aspects of nutrient cycling in the estuary because these statistics did not represent the concentrations of nitrogen, phosphorus, and other parameters at the same station at the same time. For example, it is more accurate to calculate the molar ratio of nitrogen to phosphorus in individual grab samples and then average the ratios, than to calculate the molar ratio from average concentrations of nitrogen and phosphorus for an assessment zone. The three topics that required calculations on individual sample data were (1) the percentages of nitrogen and phosphorus in different fraction types (e.g., dissolved, particulate); (2) the molar ratios between nitrogen and phosphorus; and (3) the monthly median concentrations of nitrogen and phosphorus concentrations. For these calculations, the relevant parameters were queried for a trend station. The necessary calculations were performed for each date with complete data for all parameters (using daily averages) and then the median value of the result was computed for each station. Measurements reported as below the method detection limit were included in these calculations and assigned a value of the method detection limit. This assumption was made to increase the sample size for each station. No bias is expected because the results were reported as median values for the stations, which are insensitive to method detection levels. Additional information on the methods used for the three different calculations are presented in the following paragraphs.

The percentage of the total nitrogen in different fractions was calculated in order to determine how much of the nitrogen is bioavailable or associated with phytoplankton. The fractions that were considered were dissolved inorganic nitrogen, dissolved organic nitrogen, nitrogen in phytoplankton, and nitrogen in all other particulate organic matter. Dissolved inorganic nitrogen is the sum of nitrate, nitrite, and ammonia, which were measured directly. Dissolved organic nitrogen was calculated as the difference between total dissolved nitrogen (measured directly) and dissolved inorganic nitrogen. Nitrogen in phytoplankton was calculated from the chlorophyll-a concentration in the sample and assuming that chlorophyll-a, carbon, and nitrogen comprised 5%, 50%, and 6% of biomass by dry weight, respectively. The percentages for chlorophyll-a and carbon were taken from EPA modeling guidance (EPA, 1985). The percentage for nitrogen was calculated from the ratio of particulate carbon to particulate nitrogen an in 110 water samples from the estuary. This calculated percentage is consistent with estimates from the EPA modeling guidance (EPA, 1985). While this percentage can change, the median value should be sufficiently accurate for the purposes of this report. Finally, nitrogen in other particulate organic matter was calculated as the difference between total particulate nitrogen (measured directly) and the estimates of nitrogen in phytoplankton. The percentage of phosphorus in different fractions was calculated using similar methods. The percent of phytoplankton biomass dry weight that is phosphorus was calculated to be 1.3% based on the measured ratio of particulate phosphorus to particulate carbon in 89 water samples. This percentage is consistent with modeling guidance from EPA (EPA, 1985). Otherwise, the assumptions used for the phosphorus fractionation calculations were the same as those used for the nitrogen calculations described above.

The molar ratio of nitrogen to phosphorus is an indicator for which nutrient limits primary productivity in a waterbody (Howarth and Marino, 2006; NRC, 2000).

According to the Redfield Ratio, nitrogen is the limiting nutrient for ratios less than 16 and phosphorus limits for ratios greater than 16. This ratio is best interpreted as an indicator rather than a definitive determination of the limiting nutrient. The ratio can change due to cycling of nitrogen and phosphorus between different fractions (e.g., dissolved, particulate) and media (e.g., water, sediment). Concentrations of nitrogen and phosphorus in units of mg/L were converted to units of mmol/L using the atomic masses of nitrogen (14.0067 g/mol) and phosphorus (30.9738 g/mol). The ratio was calculated for total nitrogen and total phosphorus as well as for dissolved inorganic nitrogen and orthophosphate for each date with complete data. The latter of these two ratios is more representative of bioavailable fractions. The median value of the ratios was computed for each station and plotted against the median salinity for the station.

The concentrations of nitrogen and phosphorus vary over the course of the year. The seasonal patterns in the concentrations of these parameters provide information about critical periods and which nutrient is limiting growth. To illustrate the seasonal patterns, the median monthly concentrations for total nitrogen, dissolved inorganic nitrogen, and orthophosphate were calculated and graphed versus month.

**Figure 1: Assessment Zones in the Great Bay Estuary**

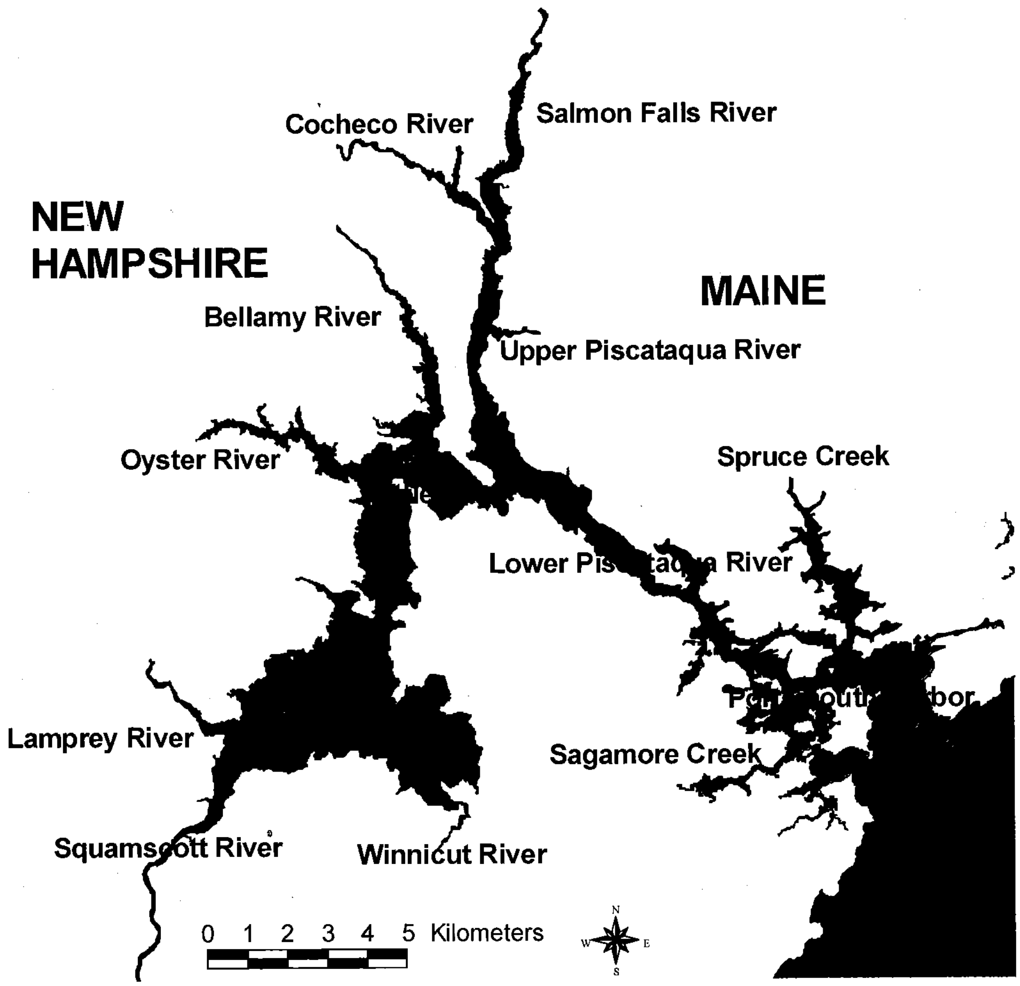


**Figure 2: Trend Monitoring Stations for Water Quality in the Great Bay Estuary**

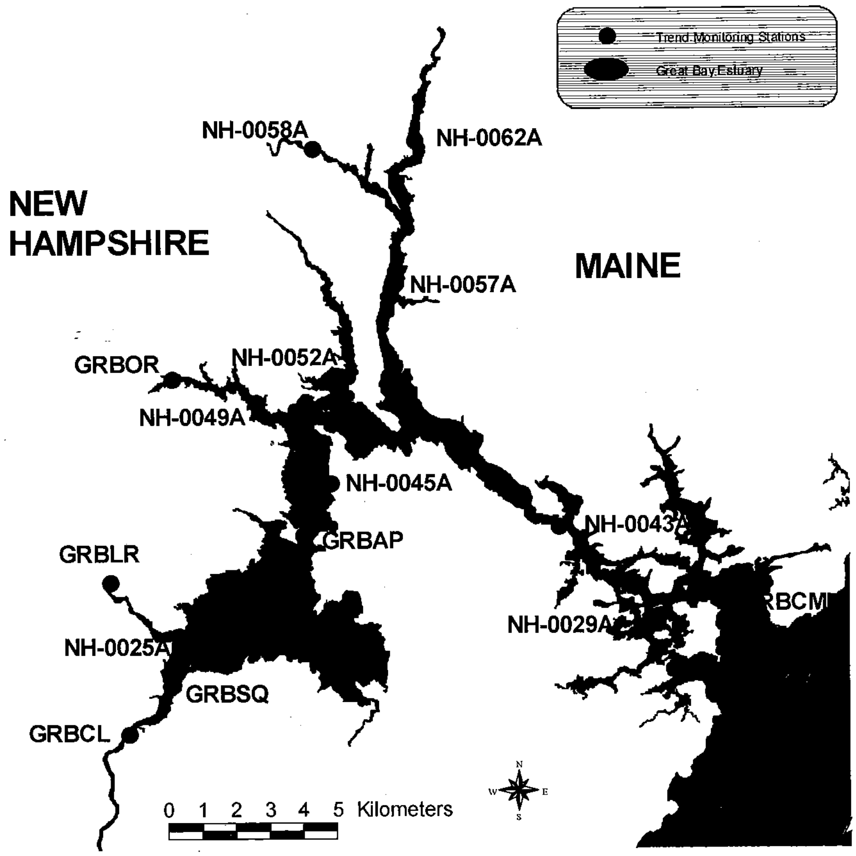



**Table 1: Trend Monitoring Stations for Water Quality**

| Station | Location | Latitude | Longitude |
|---|---|---|---|
| GRBAP | JACKSON ESTUARINE LABORATORY | 43.0922 | -70.8650 |
| GRBCL | CHAPMANS LANDING | 43.0394 | -70.9283 |
| GRBCML | COASTAL MARINE LABORATORY | 43.0724 | -70.7103 |
| GRBGB | GREAT BAY DATASONDE | 43.0722 | -70.8694 |
| GRBLR | LAMPREY RIVER DATASONDE | 43.0800 | -70.9344 |
| GRBOR | OYSTER RIVER DATASONDE | 43.1340 | -70.9110 |
| GRBSQ | SQUAMSCOTT RIVER DATASONDE | 43.0417 | -70.9222 |
| NH-0023A | LITTLE HARBOR | 43.0538 | -70.7202 |
| NH-0025A | LAMPREY RIVER | 43.0638 | -70.9096 |
| NH-0029A | BACK CHANNEL | 43.0682 | -70.7366 |
| NH-0043A | LOWER PISCATAQUA RIVER | 43.0933 | -70.7712 |
| NH-0045A | LITTLE BAY | 43.1056 | -70.8542 |
| NH-0049A | OYSTER RIVER | 43.1270 | -70.8805 |
| NH-0052A | BELLAMY RIVER | 43.1340 | -70.8470 |
| NH-0057A | UPPER PISCATAQUA RIVER | 43.1589 | -70.8302 |
| NH-0058A | COCHECO RIVER | 43.1950 | -70.8580 |
| NH-0062A | SALMON FALLS RIVER | 43.1970 | -70.8210 |

## Primary Indicators

### Chlorophyll-a

All valid data for chlorophyll-a from the Great Bay Estuary collected between January 1, 2000 and December 31, 2007 were queried from the DES Environmental Monitoring Database. The majority of the data was from the following programs: Great Bay National Estuarine Research Reserve System Wide Monitoring Program (http://nerrs.noaa.gov/Monitoring/), University of New Hampshire (UNH) Tidal Water Quality Monitoring Program, and the National Coastal Assessment (http://www.epa.gov/emap/nca/). Results from the Great Bay National Estuarine Research Reserve Diel Sampling were excluded because of outliers and overlap with the System Wide Monitoring Program samples taken at the same stations.

The minimum, $10^{th}$ percentile, median, $90^{th}$ percentile, and maximum chlorophyll-a concentrations were calculated from all the measurements between 2000 and 2007 in each assessment area shown on Figure 1 and for each trend station shown in Figure 2. The data reduction methods used for the nitrogen and phosphorus concentrations were also used for the chlorophyll-a results. However, for chlorophyll-a, the same statistics were also calculated for just the summer season (June 1 through September 30) to facilitate comparisons with thresholds used in the DES Comprehensive Assessment and Listing Methodology (NHDES, 2008a). The relationships between nutrient and chlorophyll-a concentrations (typically $90^{th}$ percentile summer concentrations) were explored through univariate regressions using summary statistics for each assessment area and trend station. Regressions with $p<0.05$ were considered statistically significant.

The concentrations of chlorophyll-a vary over the course of the year. The seasonal patterns in the concentrations of these parameters provide information about critical periods and which nutrient is limiting growth. To illustrate the seasonal patterns, the median monthly concentrations for chlorophyll-a were calculated and graphed versus month.

### Macroalgae

The coverage of nuisance macroalgae in the estuary was mapped in 2007 by the NHEP with funding from EPA. On August 29, 2007, hyperspectral imagery was collected by plane with a visible near infrared spectrograph. The imagery was collected during a spring low tide and had a spatial resolution of 2.5 meters for the area of interest. For each pixel, calibrated irradiance from 64 spectral channels with a nominal spectral resolution of 10 nm between 430 nm to 1000 nm was reported. Ground truth data on eelgrass and macroalgae beds were collected in 2007 for a different study. UNH processed the imagery to generate maps of macroalgae cover and eelgrass. In each assessment zone, the percent of shallow areas covered by macroalgae was calculated. Shallow areas were defined as locations were the bottom was not visible in the imagery. The percent cover of macroalgae was related to median nitrogen concentrations in each zone. The 2007 macroalgae cover in Great Bay was also plotted over eelgrass cover in 1996 and 2007 as mapped by UNH for a separate project (Short, 2008) to determine the locations where macroalgae has replaced eelgrass. Additional details on methods used for these analyses are provided in a technical report from UNH (Pe'eri et al., 2008).

## Secondary Indicators

### Benthic Invertebrates and Sediment Quality

Grab samples of sediment have been collected throughout the Great Bay Estuary for the National Coastal Assessment (http://www.epa.gov/emap/nca/). The sediment quality measurements that are relevant to eutrophication are the benthic index of biologic integrity (B-IBI), total organic carbon (TOC) content, and grain size. Elevated TOC in the sediments can result from accumulation of organic matter when phytoplankton and other organisms die and settle to the bottom (Cloern, 2001). Low dissolved oxygen and elevated TOC in the sediments can disrupt the normal community of benthic invertebrates (Diaz and Rosenberg, 2008). To measure the quality of the benthic community, DES used a benthic index for Gulf of Maine sediments developed by the Atlantic Ecology Division of EPA. The index was calculated as follows:

B-IBI = 0.494 * Shannon + 0.670 * MN_ES50.05 – 0.034 * PctCapitellidae
where:
Shannon = Shannon-Wiener H' diversity index
MN_ES50.05 = Station mean of 5th percentile of total abundance frequency distribution of each species in relation to its ES50 value, where ES50 is the expected number of species in a sample of 50 individuals
PctCapitellidae = percent abundance of capitellid polychaetes
The benthic index was considered poor for values less than 4

Median values for B-IBI, TOC, and grain size were calculated from all the sediment samples collected from each assessment zone of the estuary between 2000 and 2005. These average values were compared to statistics for nutrients, chlorophyll-a, and salinity in these assessment zones to identify causal relationships.

### Dissolved Oxygen

Two data sources were used to evaluate the relationship between nutrients and dissolved oxygen: Grab samples of dissolved oxygen and datasonde measurements of dissolved oxygen.

All valid data from grab samples for dissolved oxygen from the Great Bay Estuary collected between January 1, 2000 and December 31, 2007 were queried from the DES Environmental Monitoring Database. The majority of the data was from the following programs: Great Bay National Estuarine Research Reserve System Wide Monitoring Program (http://nerrs.noaa.gov/Monitoring/), University of New Hampshire (UNH) Tidal Water Quality Monitoring Program, and the National Coastal Assessment (http://www.epa.gov/emap/nca/).

The minimum, $10^{th}$ percentile, median, $90^{th}$ percentile, and maximum dissolved oxygen concentrations were calculated from all the measurements between 2000 and 2007 in each assessment area shown on Figure 1 and for each trend station shown in Figure 2. The data reduction methods used for the nitrogen and phosphorus concentrations were also used for the dissolved oxygen results. The relationships between dissolved oxygen, chlorophyll-a, and nitrogen concentrations were explored through univariate regressions using summary statistics for each assessment area and trend station. Regressions with $p<0.05$ were considered statistically significant.

Six datasondes are deployed in the Great Bay Estuary each year as part of the Great Bay National Estuarine Research Reserve System Wide Monitoring Program and the UNH Datasonde Program (http://nerrs.noaa.gov/Monitoring/, Pennock, 2008). These instruments record near continuous measurements (typically 30 minute intervals) of water temperature, salinity, dissolved oxygen, pH, and turbidity. The datasondes are the only source of information on daily swings in dissolved oxygen, both the daily minimum concentration and the daily average saturation. Datasondes are located at stations GRBCML, GRBGB, GRBSF, GRBOR, GRBLR, and GRBSQ as shown on Figure 2. At the river stations and in Portsmouth Harbor, the datasondes have been deployed at fixed locations less than 1 meter from the bottom. The datasonde in Great Bay was deployed in the same manner through 2004, after which it was suspended 1 meter below the surface from a buoy.

The valid dissolved oxygen data for each datasonde station between 2000 and 2007 were compiled. Daily minimum dissolved oxygen (in mg/L) and daily average percent saturation were computed for all dates in June through September. For the daily average percent saturation calculation, only dates with at least 36 half-hour readings or 72 quarter-hour readings were included (i.e. 75% complete). The daily minimum values during the summer months were plotted together to illustrate typical conditions over multiple years for each station. With only six stations, it was not possible to obtain statistically significant regressions between the minimum dissolved oxygen and median nitrogen at each datasonde station. Instead, the nitrogen concentrations at stations where the minimum dissolved oxygen concentrations fell below the water quality standard were compared to nitrogen concentrations at stations without violations to bracket the range of possible nitrogen thresholds.

The results from the analyses of the grab samples and the datasondes were combined using a weight of evidence approach to determine appropriate nitrogen thresholds for this indicator.

## Eelgrass

Multiple lines of evidence were evaluated to determine a nitrogen threshold for this indicator.

Eelgrass is sensitive to water clarity. Therefore, measurements of the light attenuation coefficient ($K_d$) were compiled from across the estuary. All valid data for $K_d$ from the

Great Bay Estuary collected between January 1, 2000 and December 31, 2007 were queried from the DES Environmental Monitoring Database. The majority of the data was from the following programs: Great Bay National Estuarine Research Reserve System Wide Monitoring Program (http://nerrs.noaa.gov/Monitoring/), University of New Hampshire (UNH) Tidal Water Quality Monitoring Program, and the National Coastal Assessment (http://www.epa.gov/emap/nca/).

The minimum, $10^{th}$ percentile, median, $90^{th}$ percentile, and maximum $K_d$ values were calculated from all the measurements between 2000 and 2007 in each assessment area shown on Figure 1 and for each trend station shown in Figure 2. The data reduction methods used for the nitrogen and phosphorus concentrations were also used for the $K_d$ results. The relationships between nutrient and chlorophyll-a concentrations and $K_d$ were explored through univariate regressions using summary statistics for each assessment area and trend station. Regressions with $p<0.05$ were considered statistically significant.

An analytical model from Koch (2001) was used to predict the minimum requirements for $K_d$ in the Great Bay Estuary. The model was ground truthed using the median values of $K_d$ in different assessment zones and the presence or absence of eelgrass as documented by DES (NHDES, 2008b).

The causal linkage of nitrogen to water clarity was explored through multiple methods.

First, UNH equipped a buoy in Great Bay with light and water quality sensors through a grant to the NHEP from EPA. Instantaneous measurements of light attenuation, chlorophyll-a, turbidity, and colored dissolved organic matter (CDOM) were collected between April 4 and December 1, 2007. The measurements were used to develop a multivariate linear regression between $K_d$ and chlorophyll-a, turbidity, and CDOM. This relationship was confirmed to be applicable to all areas of the estuary through analysis of the hyperspectral imagery described in the macroalgae section. UNH processed the imagery to calculate the light attenuation coefficient throughout the estuary. Ground truthing measurements of water quality were made using ship track surveys and grab samples at the same time as the overflights. Additional details on methods used for this analysis are provided in a technical report from UNH (Morrison et al., 2008).

Second, the relationships between particulate organic carbon, turbidity, and nitrogen concentrations in grab samples were explored using univariate regressions. Particulate organic carbon data were queried from the DES Environmental Monitoring Database and processed using the same methods as for the other grab sample data. Median concentrations of particulate organic carbon were compared to expected values based on chlorophyll-a concentrations and regressed against nitrogen concentrations. All valid turbidity measurements by datasondes between 2000 and 2007 were compiled. Daily average turbidity values were computed for all dates in June through September for dates with at least 36 half-hour readings or 72 quarter-hour readings. For each station, the median value was calculated from the daily average turbidity values for all days between June 1 and September 30. The median turbidity for each station was regressed against the median total nitrogen concentration at the six datasonde stations to evaluate the relationship between these two parameters.

The nitrogen threshold for the protection of eelgrass was derived using a weight of evidence approach which included the thresholds for macroalgae proliferation, offshore water background concentrations, reference concentrations in areas of the estuary which still support eelgrass, and the thresholds that have been set for other New England estuaries.

# Results and Discussion

## *Nutrient Concentrations*

In the Great Bay Estuary, nitrogen concentrations are highest in the tidal tributaries and are progressively diluted by ocean water down to Portsmouth Harbor. Table 2 and Figure 3 show the median concentrations of total nitrogen in each assessment zone between 2000 and 2007. The highest total nitrogen concentrations are in the Squamscott and Cocheco Rivers followed by the Salmon Falls River, Oyster River, and the Upper Piscataqua River. The concentrations in these tidal tributaries exceed the nitrogen thresholds that have been set in other states. The distribution of total nitrogen concentrations at stations throughout the estuary are shown in Figure 5.

In estuarine waters, nitrogen occurs in several different fractions. Water quality measurements from three trend stations (GRBCL, GRBAP, and GRBCML) were compiled to estimate the percentage of the total nitrogen in each fraction (Table 4). These stations were selected because they represent a range of salinities and nitrogen concentrations. The results showed that nitrogen associated with organic matter (both dissolved and particulate) accounted for 62-64% of the total. However, nitrogen in phytoplankton was only 1% of the total. Dissolved inorganic nitrogen was 35-37% of the total nitrogen. The percentages were similar at all three stations despite the differences in salinity and total nitrogen concentrations at the stations. The concentrations shown in Table 4 are median values for each station. The concentrations and percentages between the different fractions will change seasonally.

The Great Bay Estuary receives ocean water from the Gulf of Maine. The nitrogen concentration in these offshore waters provides a boundary condition on nutrient criteria because it would be impossible to achieve concentrations lower than the ocean water. The UNH Coastal Ocean Observing Center measured concentrations of dissolved inorganic nitrogen and particulate organic nitrogen in 2005-2007 along a cruise track offshore from Portsmouth Harbor to the Wilkinson Basin (http://www.cooa.unh.edu/index.jsp). The average concentrations of dissolved inorganic nitrogen and particulate organic nitrogen from offshore samples were 0.096 and 0.031 mg N/L, respectively. Total nitrogen is the sum of these two fractions plus dissolved organic nitrogen. The dissolved organic nitrogen fraction was not measured in the Wilkinson Basin samples. However, the dissolved organic nitrogen concentration can be assumed to be the same offshore as at station GRBCML in Portsmouth Harbor (average 0.117 mg N/L). Therefore, the total nitrogen concentration in the Gulf of Maine offshore of the Great Bay Estuary is approximately 0.244 mg N/L. This estimate compares favorably to the median TN concentration at the mouth of the Portsmouth Harbor (0.257 mg N/L at station GRBCML). If this estimate is accurate, the TN concentration in Gulf of Maine offshore from New Hampshire is approximately 0.02 mg N/L higher than the TN concentration for Nantucket Sound (0.267 mg N/L) (Howes et al., 2006). For this report, we will assume that the nitrogen concentration in offshore waters is not changing. However, it is possible that the concentration is slowly increasing due to nitrogen loads from the Gulf of Maine watershed.

The available data show that total phosphorus concentrations are highest in the Squamscott River (Table 3, Figure 4). Elevated TP concentrations have also been measured in the Cocheco and Oyster Rivers and Great Bay. Downstream of Great Bay the total phosphorus concentrations decrease due to dilution from ocean. Fewer measurements are available for total phosphorus than for total nitrogen so some of the median values were calculated from less than 20 samples. Specifically, the median values for the Squamscott River and the Lamprey River are based on only 11 and 5 measurements, respectively.

The percentages of phosphorus in different fractions were calculated from median concentrations of phosphorus species select trend stations (Table 5). The percentage of phosphorus associated with organic matter ranged from 49% to 75%, but phosphorus in phytoplankton only accounted for 1% of the total.

**Figure 3: Median Concentrations of Total Nitrogen in Regions of the Great Bay Estuary**

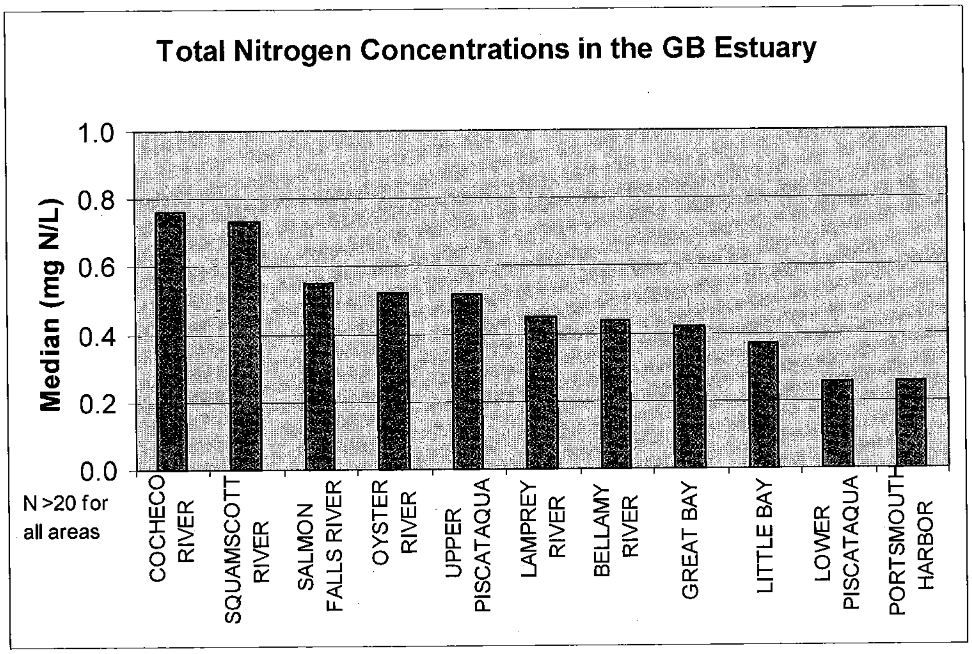



**Figure 4: Median Concentrations of Total Phosphorus in Regions of the Great Bay Estuary**

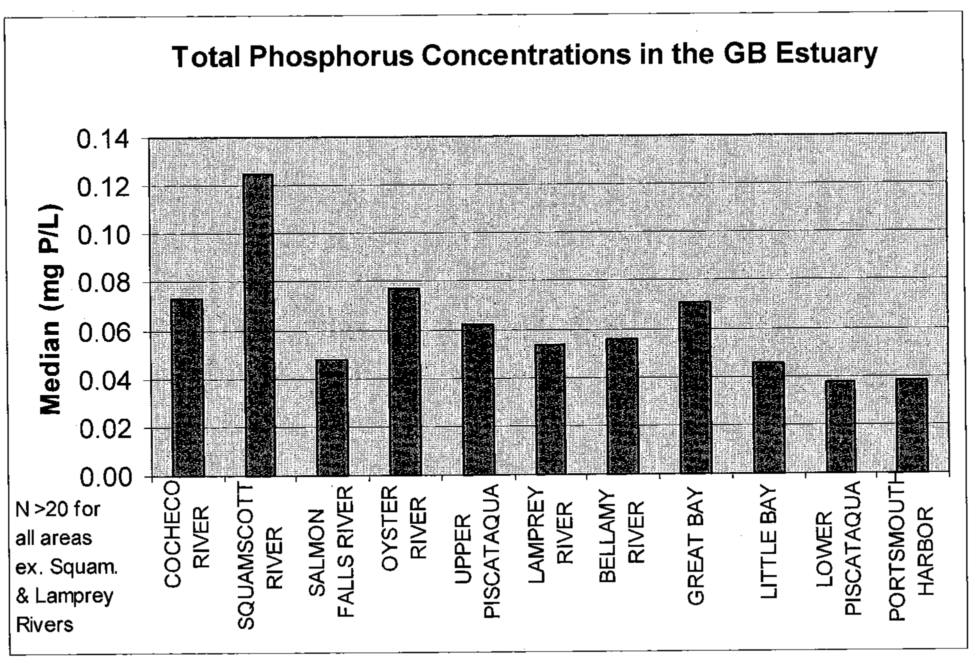
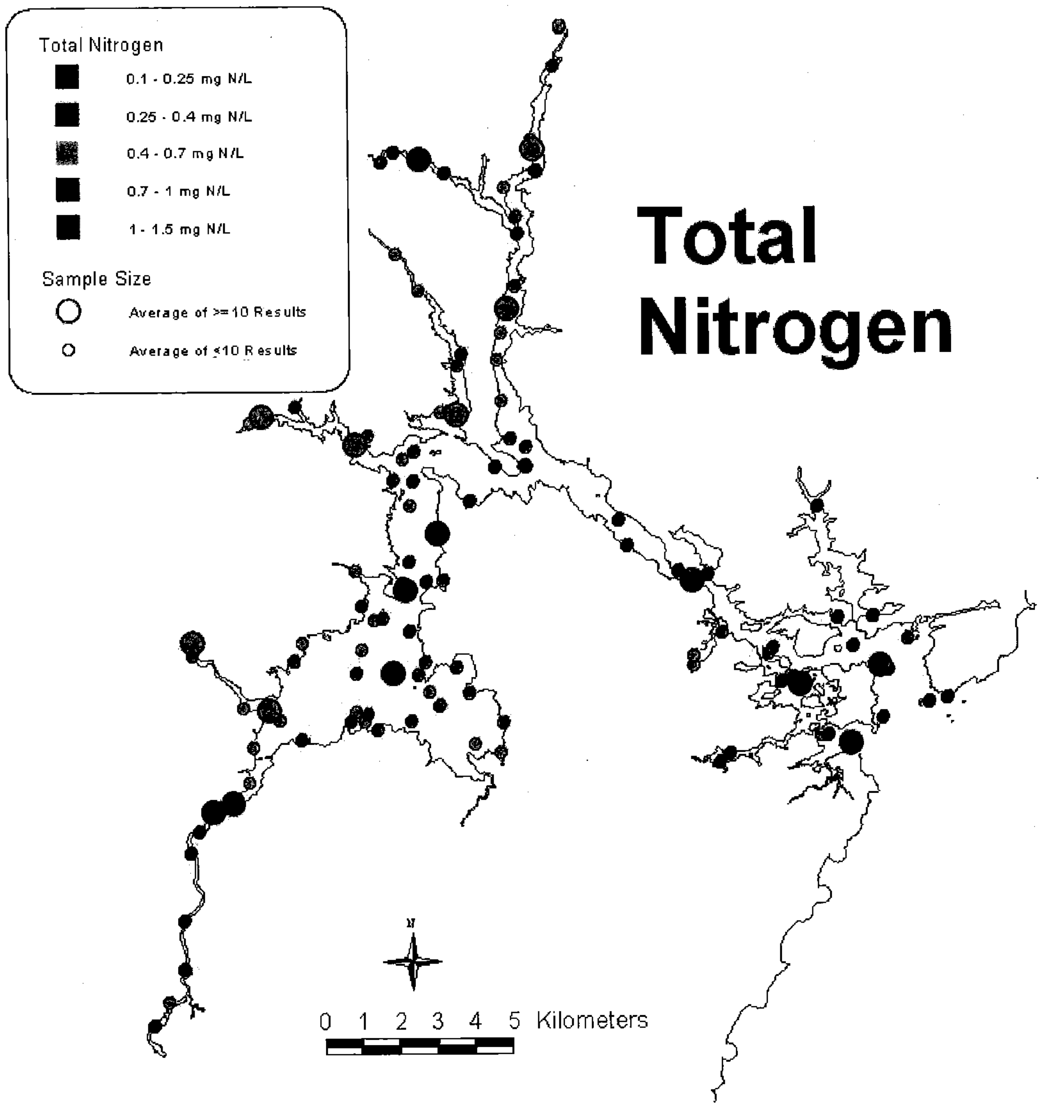


**Figure 5: Average Concentrations of Total Nitrogen at Water Quality Stations**



## Table 2: Summary Statistics for Total Nitrogen (mg N /L) from Grab Samples from 2000-2007

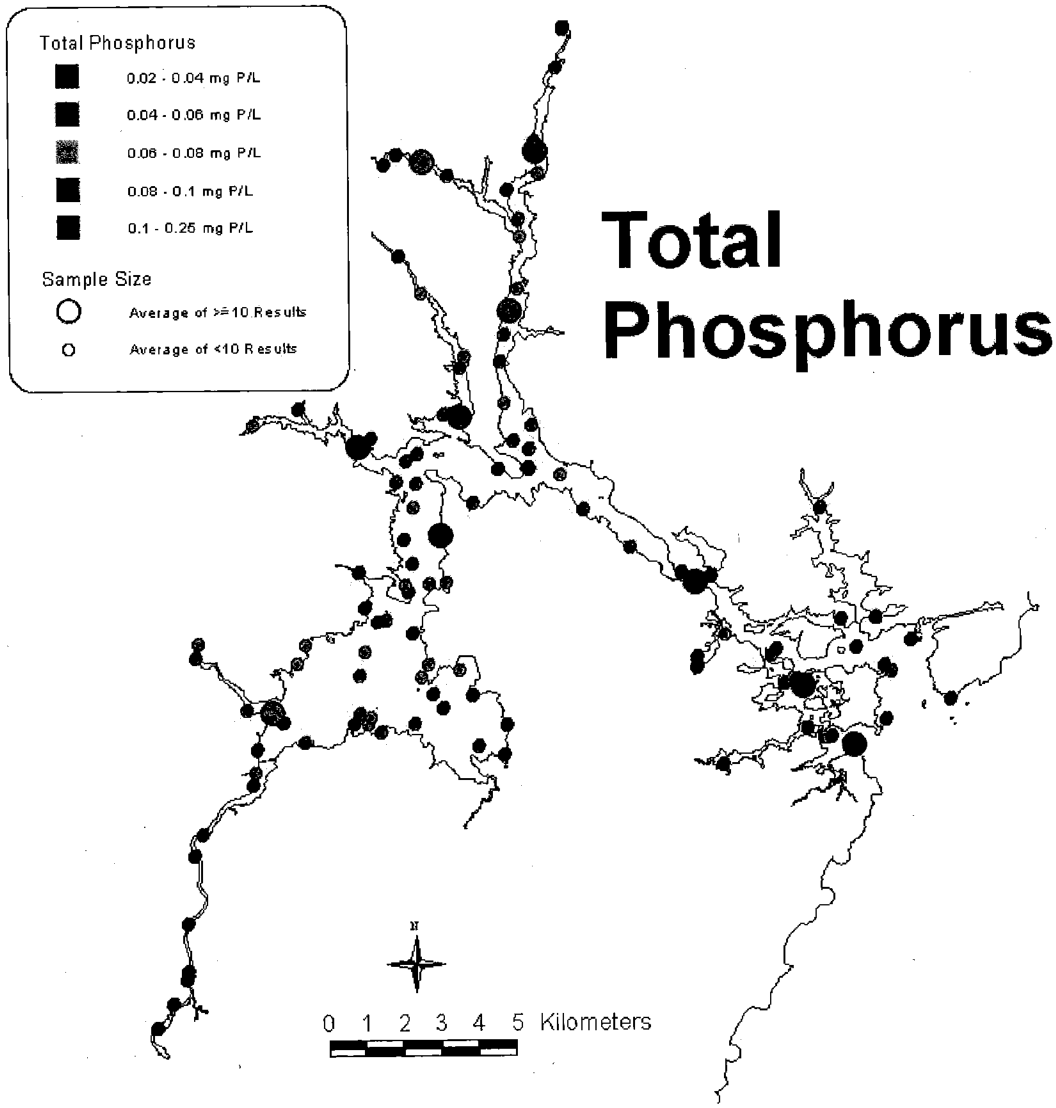
**(A) Assessment Zones**

| Assessment Zone | N | Min | 10th%ile | Median | 90th%ile | Max |
|---|---|---|---|---|---|---|
| BELLAMY RIVER | 37 | 0.200 | 0.264 | 0.436 | 0.585 | 0.670 |
| BERRYS BROOK | 0 | | | | | |
| COCHECO RIVER | 21 | 0.416 | 0.520 | 0.763 | 1.393 | 1.492 |
| GREAT BAY | 77 | 0.200 | 0.278 | 0.423 | 0.600 | 1.056 |
| LAMPREY RIVER | 39 | 0.265 | 0.368 | 0.451 | 0.589 | 0.795 |
| LITTLE BAY | 78 | 0.146 | 0.234 | 0.371 | 0.522 | 0.826 |
| LOWER PISCATAQUA RIVER | 29 | 0.167 | 0.202 | 0.255 | 0.395 | 0.530 |
| NORTH MILL POND | 4 | 0.242 | 0.246 | 0.333 | 0.676 | 0.790 |
| OYSTER RIVER | 40 | 0.266 | 0.310 | 0.526 | 0.677 | 1.669 |
| PORTSMOUTH HARBOR AND LITTLE HARBOR | 84 | 0.146 | 0.192 | 0.257 | 0.376 | 0.935 |
| SAGAMORE CREEK | 2 | 0.174 | 0.176 | 0.186 | 0.196 | 0.198 |
| SALMON FALLS RIVER | 25 | 0.295 | 0.335 | 0.552 | 0.773 | 0.945 |
| SOUTH MILL POND | 0 | | | | | |
| SPRUCE CREEK | 2 | 0.200 | 0.200 | 0.201 | 0.201 | 0.202 |
| SQUAMSCOTT RIVER | 67 | 0.352 | 0.550 | 0.735 | 1.091 | 1.898 |
| UPPER PISCATAQUA RIVER | 35 | 0.290 | 0.396 | 0.519 | 0.773 | 1.093 |

**(B) Trend Monitoring Stations**

| Station | N | Min | 10th%ile | Median | 90th%ile | Max |
|---|---|---|---|---|---|---|
| GRBAP | 50 | 0.174 | 0.260 | 0.384 | 0.517 | 0.642 |
| GRBCL | 31 | 0.431 | 0.609 | 0.728 | 0.916 | 1.165 |
| GRBCML | 37 | 0.167 | 0.209 | 0.291 | 0.370 | 0.489 |
| GRBGB | 29 | 0.200 | 0.264 | 0.390 | 0.487 | 0.590 |
| GRBLR | 34 | 0.265 | 0.361 | 0.448 | 0.538 | 0.785 |
| GRBOR | 21 | 0.311 | 0.450 | 0.567 | 0.646 | 0.870 |
| GRBSQ | 27 | 0.352 | 0.538 | 0.735 | 0.981 | 1.496 |
| NH-0023A | 17 | 0.121 | 0.158 | 0.249 | 0.427 | 0.830 |
| NH-0025A | 16 | 0.382 | 0.404 | 0.526 | 0.688 | 1.056 |
| NH-0029A | 17 | 0.161 | 0.198 | 0.251 | 0.332 | 0.423 |
| NH-0043A | 16 | 0.167 | 0.214 | 0.303 | 0.417 | 0.530 |
| NH-0045A | 15 | 0.146 | 0.198 | 0.364 | 0.520 | 0.671 |
| NH-0049A | 14 | 0.266 | 0.297 | 0.430 | 0.637 | 1.669 |
| NH-0052A | 32 | 0.200 | 0.266 | 0.428 | 0.586 | 0.670 |
| NH-0057A | 28 | 0.382 | 0.418 | 0.537 | 0.775 | 1.093 |
| NH-0058A | 17 | 0.433 | 0.582 | 0.767 | 1.371 | 1.492 |
| NH-0062A | 17 | 0.302 | 0.321 | 0.507 | 0.682 | 0.731 |

**Figure 6: Average Concentrations of Total Phosphorus at Water Quality Stations**



## Table 3: Summary Statistics for Total Phosphorus (mg P /L) from Grab Samples from 2000-2007

**(A) Assessment Zones**

| Assessment Zone | N | Min | 10th%ile | Median | 90th%ile | Max |
|---|---|---|---|---|---|---|
| BELLAMY RIVER | 32 | 0.028 | 0.038 | 0.056 | 0.084 | 0.091 |
| COCHECO RIVER | 27 | 0.025 | 0.040 | 0.073 | 0.109 | 0.132 |
| GREAT BAY | 51 | 0.024 | 0.044 | 0.071 | 0.116 | 0.254 |
| LAMPREY RIVER | 5 | 0.036 | 0.043 | 0.053 | 0.074 | 0.088 |
| LITTLE BAY | 32 | 0.030 | 0.033 | 0.045 | 0.074 | 0.086 |
| LOWER PISCATAQUA RIVER | 29 | 0.025 | 0.029 | 0.037 | 0.057 | 0.074 |
| NORTH MILL POND | 3 | 0.036 | 0.042 | 0.066 | 0.083 | 0.087 |
| OYSTER RIVER | 20 | 0.032 | 0.047 | 0.077 | 0.115 | 0.205 |
| PORTSMOUTH HARBOR AND LITTLE HARBOR | 46 | 0.023 | 0.026 | 0.038 | 0.056 | 0.129 |
| SAGAMORE CREEK | 2 | 0.034 | 0.034 | 0.036 | 0.038 | 0.038 |
| SALMON FALLS RIVER | 21 | 0.028 | 0.034 | 0.048 | 0.066 | 0.102 |
| SOUTH MILL POND | 0 | | | | | |
| SPRUCE CREEK | 2 | 0.046 | 0.046 | 0.047 | 0.048 | 0.048 |
| SQUAMSCOTT RIVER | 11 | 0.044 | 0.067 | 0.125 | 0.168 | 0.248 |
| UPPER PISCATAQUA RIVER | 36 | 0.026 | 0.040 | 0.062 | 0.087 | 0.227 |

**(B) Trend Monitoring Stations**

| Station | N | Min | 10th%ile | Median | 90th%ile | Max |
|---|---|---|---|---|---|---|
| GRBAP | 1 | 0.030 | 0.030 | 0.030 | 0.030 | 0.030 |
| NH-0023A | 17 | 0.023 | 0.024 | 0.037 | 0.050 | 0.129 |
| NH-0025A | 15 | 0.024 | 0.040 | 0.060 | 0.118 | 0.254 |
| NH-0029A | 15 | 0.023 | 0.028 | 0.039 | 0.054 | 0.056 |
| NH-0043A | 16 | 0.025 | 0.029 | 0.037 | 0.057 | 0.072 |
| NH-0045A | 17 | 0.030 | 0.032 | 0.045 | 0.076 | 0.086 |
| NH-0049A | 16 | 0.032 | 0.047 | 0.077 | 0.142 | 0.205 |
| NH-0052A | 27 | 0.028 | 0.038 | 0.056 | 0.087 | 0.091 |
| NH-0057A | 28 | 0.026 | 0.037 | 0.065 | 0.092 | 0.227 |
| NH-0058A | 14 | 0.039 | 0.046 | 0.073 | 0.109 | 0.118 |
| NH-0062A | 14 | 0.028 | 0.035 | 0.047 | 0.063 | 0.102 |

**Table 4: Median Concentrations and Percent of Total for Nitrogen Fractions at Trend Stations**

| Fraction | Species | GRBCL | | GRBAP | | GRBCML | |
|---|---|---|---|---|---|---|---|
| | | mg/L | % | mg/L | % | mg/L | % |
| Dissolved | Ammonia | 0.108 | 16% | 0.048 | 13% | 0.040 | 16% |
| | Nitrate+Nitrite | 0.135 | 19% | 0.092 | 24% | 0.052 | 20% |
| | In Organic Matter | 0.259 | 37% | 0.148 | 39% | 0.104 | 41% |
| Particulate | In Phytoplankton | 0.009 | 1% | 0.005 | 1% | 0.002 | 1% |
| | In Organic Matter | 0.181 | 26% | 0.084 | 22% | 0.056 | 22% |
| Total | | 0.691 | 100% | 0.375 | 100% | 0.253 | 100% |

* The sample size for each station was 48, 31, and 31 for GRBCL, GRBAP, and GRBCML, respectively.
** The values for total nitrogen do not match reported values for these stations on Table 2 because the totals on this table were calculated in a different way (e.g., non-detected samples were included).

**Table 5: Median Concentrations and Percent in Different Phosphorus Fractions at Trend Stations**

| Fraction | Species | GB Tribs* | | UP Tribs* | | LP* | |
|---|---|---|---|---|---|---|---|
| | | mg/L | % | mg/L | % | mg/L | % |
| Dissolved | Orthophosphate | 0.024 | 52% | 0.016 | 25% | 0.024 | 36% |
| | In Organic Matter | 0.011 | 24% | 0.023 | 37% | 0.021 | 31% |
| Particulate | In Phytoplankton | 0.0004 | 1% | 0.0003 | 1% | 0.0002 | 1% |
| | In Organic Matter | 0.011 | 24% | 0.023 | 37% | 0.022 | 32% |
| Total | | 0.046 | 100% | 0.062 | 100% | 0.067 | 100% |

* Data from trend stations with similar concentrations were combined to increase the sample size. "GB Tribs" includes data from NH-0025A, NH-0049A, and NH-0052A (n=33). "UP Tribs" includes data from NH-0057A, NH-0058A, and NH-0062A (n=26). "LP" includes data from NH-0023A, NH-0029A, and NH-0043A (n=24).

Nitrogen is typically the limiting nutrient for primary productivity in estuaries (Howarth and Marino, 2006; NRC, 2000). However, phosphorus can be important in riverine estuaries with low salinities. Data from Great Bay Estuary follow these expected patterns.

The ratio of nitrogen to phosphorus concentrations indicates that nitrogen is the limiting nutrient in the majority of the estuary. The median molar ratios of total nitrogen to total phosphorus and dissolved inorganic nitrogen to orthophosphate (bioavailable fractions) were calculated for the trend monitoring stations in the estuary. According to the Redfield Ratio, nitrogen will be the limiting nutrient if the N:P molar ratio is 16 or less (Howarth and Marino, 2006). Given that kinetics often limit transitions between bioavailable and total fractions, the threshold of 16 is not precise, but is a useful guide. Figure 7 shows that the ratio of total nitrogen to total phosphorus is clustered around 16 and the ratio of bioavailable nitrogen to bioavailable phosphorus is well below 16 for stations with average salinity greater than 20 ppt. Most of the estuary is in this salinity range (88% by volume). However, in the low salinity tidal tributaries the ratio for totals climbs to around 25 and the ratio for bioavailable fractions reaches at high as 60, which indicates phosphorus limitation. This effect is most pronounced in the Cocheco, Salmon Falls, and Upper Piscataqua Rivers. This pattern is probably representative of freshwater inputs to the estuary, with phosphorus being a limiting nutrient when the tidal tributaries are more like freshwater rivers than estuaries. The fact that the ratio for totals does not drop below 16 in more saline areas can probably be explained by the high percentage of nitrogen and phosphorus that is tied up in organic matter in these areas.

**Figure 7: Molar Ratio of Nitrogen to Phosphorus Versus Salinity at Trend Monitoring Stations**

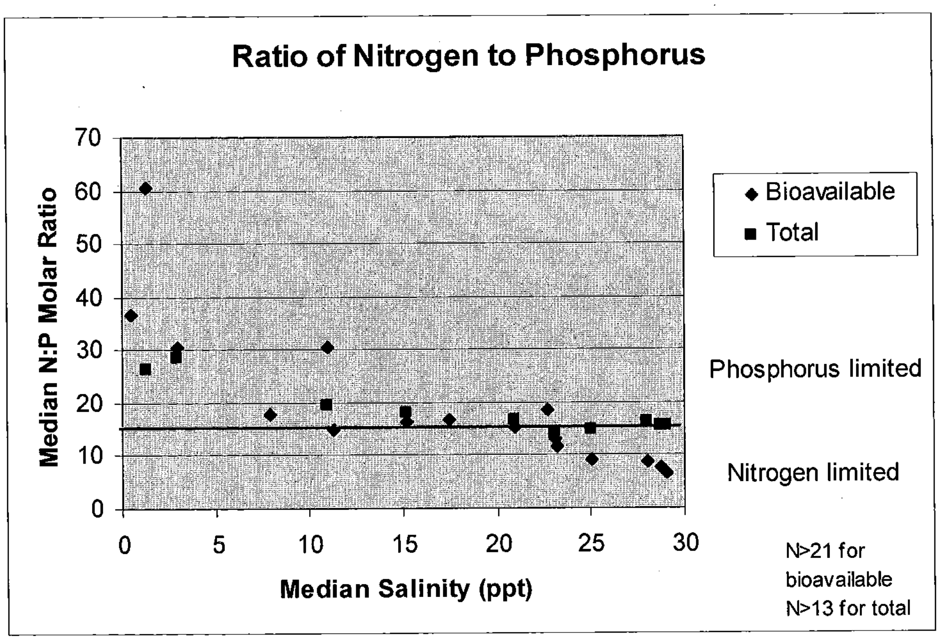


**Figure 8: Seasonal Pattern of Total Nitrogen Concentrations in Great Bay at Adams Point**

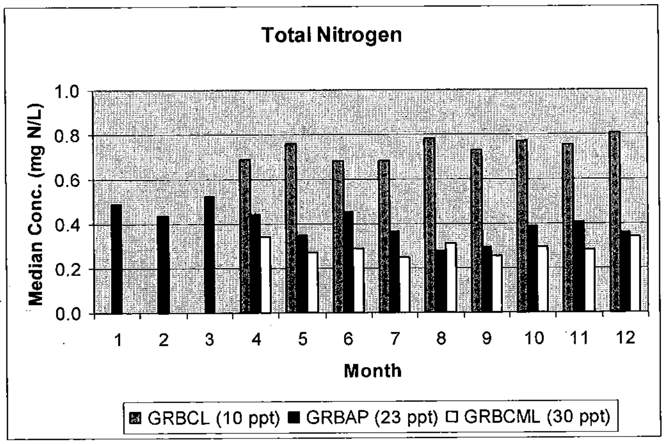



**Figure 9: Seasonal Pattern for Dissolved Inorganic Nitrogen at Trend Stations with Different Salinities**

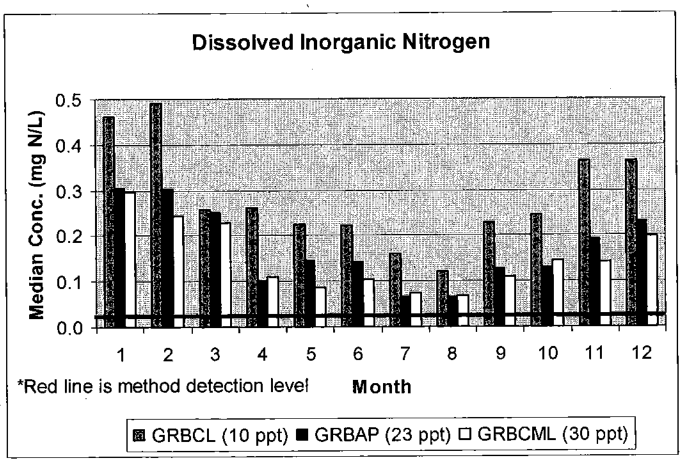
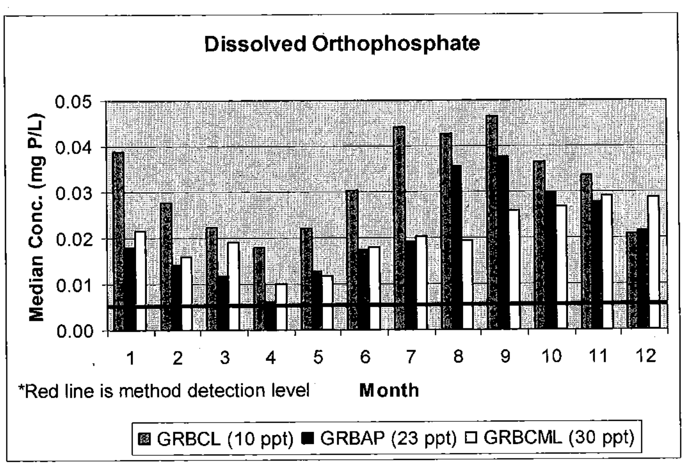



**Figure 10: Seasonal Pattern for Dissolved Orthophosphate at Trend Stations with Different Salinities**



The high N:P ratios in the tributaries reflect the balance of the two nutrients but primary productivity is not actually limited by phosphorus in these areas. Neither phosphorus nor nitrogen concentrations are depleted in the tributaries during any season. Total nitrogen concentrations in the estuary remain relatively constant in the estuary throughout the year (Figure 8). However, the bioavailable forms of dissolved inorganic nitrogen and orthophosphate appear to be depleted in areas with salinities greater than approximately 20 ppt. Figure 9 and Figure 10 indicate phosphorus limitation during the spring bloom and nitrogen limitation in the summer growing season. The concentrations of both nutrients decrease in tributaries during growing periods but are not depleted.

While phosphorus can be the limiting nutrient in tributaries during certain conditions, these conditions represent a relatively small portion of the estuary for short durations. The head of tide on each of the rivers is artificially defined by dams. Above the dam, the river is totally fresh water and below the dam the salinity fluctuates. In high flow periods, the conditions above and below the dam are both essentially riverine and, therefore, phosphorus would be the limiting nutrient because phosphorus typically limits growth in fresh waters. During low flow periods, the salinity below the dam can be higher than 20 ppt and nitrogen is the limiting nutrient. The boundary between 20 ppt salinity in each tidal tributary will move up and down the river during the course of a year depending on the river flows but 88% of the estuary has salinities greater than 20 ppt on average. Therefore, nitrogen will be considered the limiting nutrient for primary productivity in the majority of the estuary during the majority of the year. Impacts of phosphorus on productivity in the estuary during high flows will be controlled by numeric water quality criteria for phosphorus in rivers that are being developed by DES.

## *Primary Indicators*

### Chlorophyll-a

The most common indicator of primary eutrophic response is phytoplankton blooms as measured by chlorophyll-a concentrations (Bricker et al, 2007; Cloern, 2001; NRC, 2000; EPA, 2001). Phytoplankton blooms will occur when there are sufficient amounts of bioavailable nitrogen and phosphorus and adequate water clarity. In nitrogen limited systems, such as estuaries, increasing nitrogen concentrations should result in increased phytoplankton blooms, although the phytoplankton population can be mediated by top-down predation (Heck and Valentine, 2007).

The highest concentrations of chlorophyll-a occur in the Squamscott, Cocheco, Lamprey, and Salmon Falls Rivers, which follows a similar spatial pattern as total nitrogen (Figure 11). Peak concentrations (represented by $90^{th}$ percentiles) are higher in the summer than for the year as a whole. Table 6 and Table 7 contain summary statistics for chlorophyll-a concentrations in different assessment zones and at trend stations during the whole year and during the summer, respectively. The distribution of chlorophyll-a concentrations in the estuary is shown in Figure 12.

Total nitrogen concentrations are the best explanatory variable for peak summer chlorophyll-a concentrations. The magnitude of chlorophyll-a concentrations in each assessment zone and at each trend station during blooms was estimated by calculating the $90^{th}$ percentile concentration using all valid results during summer months in 2000-2007 (Table 6). These values were compared to the median concentrations of TN, total dissolved nitrogen, and dissolved inorganic nitrogen, total phosphorus, and orthophosphate. The best relationship was between chlorophyll-a and total nitrogen (r2=0.78-0.79, Figure 13, Figure 14). It is not surprising that there were inferior relationships between chlorophyll-a and dissolved inorganic nitrogen ($r^2$=0.42-0.54) and total dissolved nitrogen ($r^2$=0.64-0.74) because the concentrations of these species are variable due to biological uptake. For phosphorus species, the relationship between chlorophyll-a and total phosphorus was not as good ($r^2$=0.48-0.65) as the one with total nitrogen. Orthophosphate was poorly correlated with chlorophyll-a concentrations ($r^2$=0-0.11).

One concern about the correlations between total nitrogen and chlorophyll-a is the autocorrelation introduced by the nitrogen included in the organic matter of phytoplankton. In Table 4, the percent of total nitrogen in different fractions has been estimated. The nitrogen in living phytoplankton accounts for approximately 1% of the total. Therefore, there does not appear to be any significant autocorrelation in this relationship.

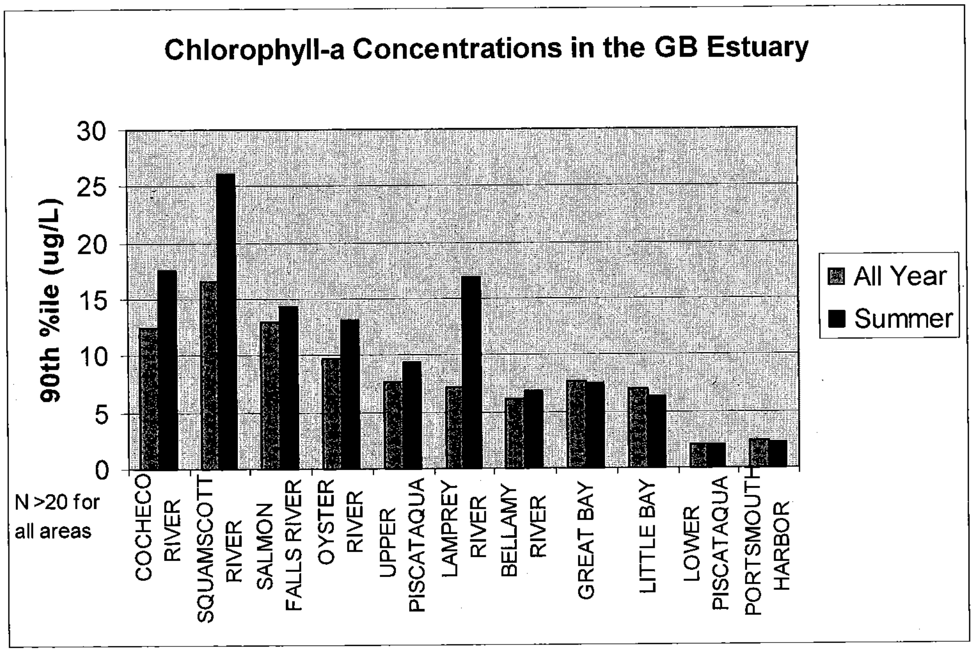
The seasonal patterns of median chlorophyll-a concentrations in three different salinity zones are shown in Figure 15. At a river station (station GRBCL), there is no spring bloom but rather a long summer growing period peaking in June-August. In Great Bay (station GRBAP), there is a distinct spring bloom in April which corresponds to the period of orthophosphate depletion as shown in Figure 10. A longer summer growing period follows during June through September during which dissolved inorganic nitrogen appears to be the limiting nutrient (see Figure 9). At the mouth of the harbor (station GRBCML), chlorophyll-a concentrations remain low the whole year. The patterns in Figure 15 show that summer is the critical period for elevated chlorophyll-a concentrations. The exception is Great Bay which experiences a significant, but short-lived, spring bloom in April.

While large phytoplankton blooms result in many secondary effects (discussed later in this report), the immediate impact of blooms is to impair the primary contact recreation designated use (swimming use). Since 2004, DES has used a threshold of 20 ug/L for chlorophyll-a to determine impairments of this designated use for 305(b) assessments as described in the Consolidated Assessment and Listing Methodology (NHDES, 2008a). DES established this threshold as an interpretation of the narrative standard for nutrients (Env-Wq 1703.14). The threshold was based on the distribution of chlorophyll-a concentrations that had been observed in NH's estuaries and the criteria used in EPA's National Coastal Assessment reports. Specifically, data from NH's estuaries between 1988 and 2003 indicated that only 3% of water samples had chlorophyll-a concentrations greater than 20 ug/L. EPA used a chlorophyll-a concentration of 20 ug/L as the cut-off to designate tidal waters as being of "poor quality" for the National Coastal Condition reports (EPA, 2006a). For the 305(b) reports, the algorithm to determine impairments of the primary contact recreation designated use is primarily based on whether greater than 10% of the chlorophyll-a concentrations exceed the threshold in the summer critical period. This algorithm is roughly equivalent to making assessment using a threshold for the 90$^{th}$ percentile summer concentration.

The nitrogen concentration associated with the chlorophyll-a threshold of 20 ug/L can be determined by regressing median nitrogen concentrations against 90$^{th}$ percentile chlorophyll-a concentrations during summer. In Figure 13 and Figure 14, statistically significant regressions were developed between these two parameters based on aggregate statistics for assessment zones or trend stations, respectively. The regression based on assessment zones (Figure 13) predicts that impairments will occur for median TN concentrations of 0.71 mg N/L. The relationship developed from trend stations (Figure 14) results in a slightly higher estimate of the TN threshold (0.78 mg N/L). The uncertainty in these estimated thresholds was estimated using the methods from Helsel and Hirsch (1992, section 9.4.5) to be +/- 0.20 mg N/L (+/-26-28%) due to the small sample size and the imperfect correlations.

Given the large uncertainty in the nitrogen threshold for this indicator, DES is not proposing to use this threshold as numeric nutrient criteria at this time. The uncertainty in this threshold is too large to use for regulatory purposes. The existing threshold for chlorophyll-a (20 ug/L) will continue to be used to identify impairments due to large phytoplankton blooms. The one reason to include this threshold in the nutrient criteria is to document another tier in the degradation of estuarine systems due to elevated nitrogen concentrations. However, absent a strong regulatory need, the uncertainty associated with this threshold is too great to include it for purely illustrative purposes.

**Figure 11: 90th Percentile Concentrations of Chlorophyll-a in Regions of the Great Bay Estuary**



## Table 6: Summary Statistics for Chlorophyll-a (ug/L) from Grab Samples from 2000-2007

**(A) Assessment Zones**

| Assessment Zone | N | Min | 10th%ile | Median | 90th%ile | Max |
|---|---|---|---|---|---|---|
| BELLAMY RIVER | 65 | 0.1 | 0.4 | 1.9 | 6.1 | 12.8 |
| BERRYS BROOK | 1 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 |
| COCHECO RIVER | 43 | 0.3 | 0.6 | 3.1 | 12.4 | 25.0 |
| GREAT BAY | 148 | 0.2 | 1.2 | 3.4 | 7.6 | 24.7 |
| LAMPREY RIVER | 81 | 0.3 | 0.8 | 2.2 | 7.2 | 145.5 |
| LITTLE BAY | 126 | 0.2 | 1.1 | 2.9 | 6.9 | 11.5 |
| LOWER PISCATAQUA RIVER | 52 | 0.1 | 0.4 | 0.9 | 2.1 | 6.3 |
| NORTH MILL POND | 4 | 0.5 | 0.7 | 1.3 | 1.6 | 1.6 |
| OYSTER RIVER | 96 | 0.2 | 1.0 | 3.1 | 9.7 | 40.1 |
| PORTSMOUTH HARBOR AND LITTLE HARBOR | 154 | 0.1 | 0.5 | 1.1 | 2.4 | 10.0 |
| SAGAMORE CREEK | 5 | 0.6 | 0.7 | 0.8 | 1.0 | 1.1 |
| SALMON FALLS RIVER | 41 | 0.5 | 1.0 | 4.1 | 13.0 | 18.5 |
| SPRUCE CREEK | 2 | 1.3 | 1.6 | 3.0 | 4.3 | 4.7 |
| SQUAMSCOTT RIVER | 133 | 0.6 | 2.7 | 6.1 | 16.5 | 60.9 |
| UPPER PISCATAQUA RIVER | 73 | 0.1 | 0.6 | 2.1 | 7.6 | 78.1 |

**(B) Trend Monitoring Stations**

| Station | N | Min | 10th%ile | Median | 90th%ile | Max |
|---|---|---|---|---|---|---|
| GRBAP | 76 | 0.7 | 1.2 | 3.3 | 7.9 | 11.5 |
| GRBCL | 69 | 0.6 | 2.6 | 6.1 | 14.8 | 58.2 |
| GRBCML | 53 | 0.4 | 0.8 | 1.5 | 2.8 | 4.9 |
| GRBGB | 54 | 0.6 | 1.5 | 4.2 | 9.4 | 18.4 |
| GRBLR | 73 | 0.3 | 0.7 | 2.1 | 6.3 | 145.5 |
| GRBOR | 48 | 0.2 | 1.2 | 4.3 | 13.4 | 40.1 |
| GRBSQ | 45 | 1.1 | 2.8 | 5.1 | 10.4 | 35.0 |
| NH-0023A | 28 | 0.1 | 0.2 | 0.8 | 1.6 | 4.8 |
| NH-0025A | 28 | 0.2 | 0.5 | 1.9 | 4.7 | 12.3 |
| NH-0029A | 29 | 0.3 | 0.4 | 1.0 | 1.8 | 10.0 |
| NH-0043A | 28 | 0.1 | 0.5 | 0.9 | 2.2 | 2.7 |
| NH-0045A | 26 | 0.2 | 1.0 | 1.9 | 5.2 | 6.2 |
| NH-0049A | 28 | 0.2 | 0.9 | 1.8 | 8.5 | 20.3 |
| NH-0052A | 47 | 0.1 | 0.4 | 1.6 | 6.1 | 10.4 |
| NH-0057A | 51 | 0.1 | 0.5 | 1.7 | 7.5 | 78.1 |
| NH-0058A | 27 | 0.3 | 0.5 | 1.6 | 11.3 | 21.9 |
| NH-0062A | 27 | 0.5 | 1.0 | 4.1 | 13.7 | 18.5 |

**Table 7: Summary Statistics for Chlorophyll-a (ug/L) from Grab Samples Collected Between June 1 and September 30 from 2000-2007**

**(A) Assessment Zones**

| Assessment Zone | N | Min | 10th%ile | Median | 90th%ile | Max |
|---|---|---|---|---|---|---|
| BELLAMY RIVER | 37 | 0.4 | 1.1 | 3.0 | 6.9 | 12.8 |
| BERRYS BROOK | 1 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 |
| COCHECO RIVER | 23 | 0.6 | 1.6 | 6.0 | 17.5 | 25.0 |
| GREAT BAY | 98 | 0.3 | 1.6 | 3.7 | 7.6 | 24.7 |
| LAMPREY RIVER | 40 | 0.8 | 1.3 | 3.6 | 16.8 | 145.5 |
| LITTLE BAY | 66 | 0.8 | 1.3 | 3.2 | 6.3 | 11.3 |
| LOWER PISCATAQUA RIVER | 36 | 0.2 | 0.5 | 1.0 | 2.0 | 6.3 |
| NORTH MILL POND | 4 | 0.5 | 0.7 | 1.3 | 1.6 | 1.6 |
| OYSTER RIVER | 51 | 0.7 | 1.2 | 4.3 | 13.2 | 20.3 |
| PORTSMOUTH HARBOR AND LITTLE HARBOR | 83 | 0.1 | 0.6 | 1.1 | 2.2 | 7.1 |
| SAGAMORE CREEK | 5 | 0.6 | 0.7 | 0.8 | 1.0 | 1.1 |
| SALMON FALLS RIVER | 27 | 0.8 | 1.1 | 4.8 | 14.3 | 18.5 |
| SPRUCE CREEK | 2 | 1.3 | 1.6 | 3.0 | 4.3 | 4.7 |
| SQUAMSCOTT RIVER | 70 | 2.7 | 4.1 | 8.2 | 26.1 | 60.9 |
| UPPER PISCATAQUA RIVER | 41 | 0.4 | 1.2 | 3.4 | 9.3 | 78.1 |

**(B) Trend Monitoring Stations**

| Station | N | Min | 10th%ile | Median | 90th%ile | Max |
|---|---|---|---|---|---|---|
| GRBAP | 29 | 1.1 | 2.4 | 4.8 | 5.0 | 7.5 |
| GRBCL | 29 | 2.7 | 6.0 | 9.0 | 12.5 | 22.3 |
| GRBCML | 26 | 0.4 | 1.0 | 1.4 | 1.6 | 2.5 |
| GRBGB | 27 | 1.1 | 2.0 | 5.5 | 5.7 | 9.6 |
| GRBLR | 32 | 0.8 | 1.4 | 3.4 | 9.1 | 8.2 |
| GRBOR | 23 | 2.4 | 3.6 | 8.2 | 8.6 | 17.2 |
| GRBSQ | 23 | 3.3 | 3.5 | 5.6 | 8.8 | 17.5 |
| NH-0023A | 14 | 0.1 | 0.2 | 0.8 | 0.8 | 1.4 |
| NH-0025A | 15 | 0.6 | 1.2 | 3.2 | 3.6 | 6.0 |
| NH-0029A | 14 | 0.4 | 0.7 | 1.1 | 1.2 | 1.8 |
| NH-0043A | 13 | 0.5 | 0.5 | 0.9 | 1.1 | 2.1 |
| NH-0045A | 13 | 1.3 | 1.4 | 2.6 | 2.8 | 4.8 |
| NH-0049A | 14 | 0.7 | 0.8 | 2.5 | 4.8 | 11.4 |
| NH-0052A | 24 | 0.4 | 1.0 | 2.3 | 3.2 | 6.6 |
| NH-0057A | 25 | 0.4 | 1.0 | 3.1 | 6.7 | 9.5 |
| NH-0058A | 14 | 0.6 | 1.4 | 4.0 | 6.4 | 15.2 |
| NH-0062A | 14 | 1.0 | 1.4 | 5.9 | 6.8 | 15.6 |

**Figure 12: Average Concentrations of Chlorophyll-a at Water Quality Stations**

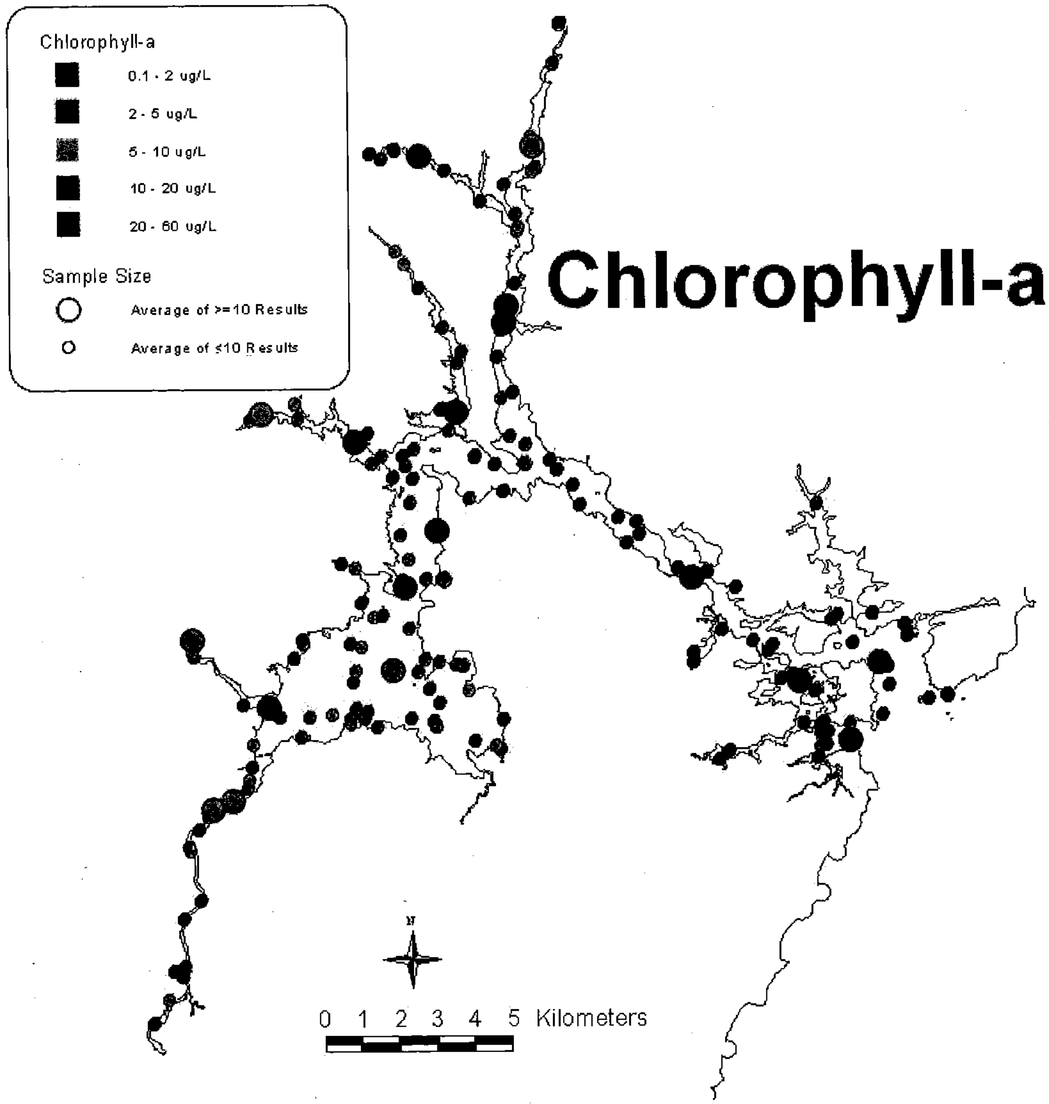


**Figure 13: Relationship between Nitrogen Concentrations and Summer Chlorophyll-a in Assessment Zones**

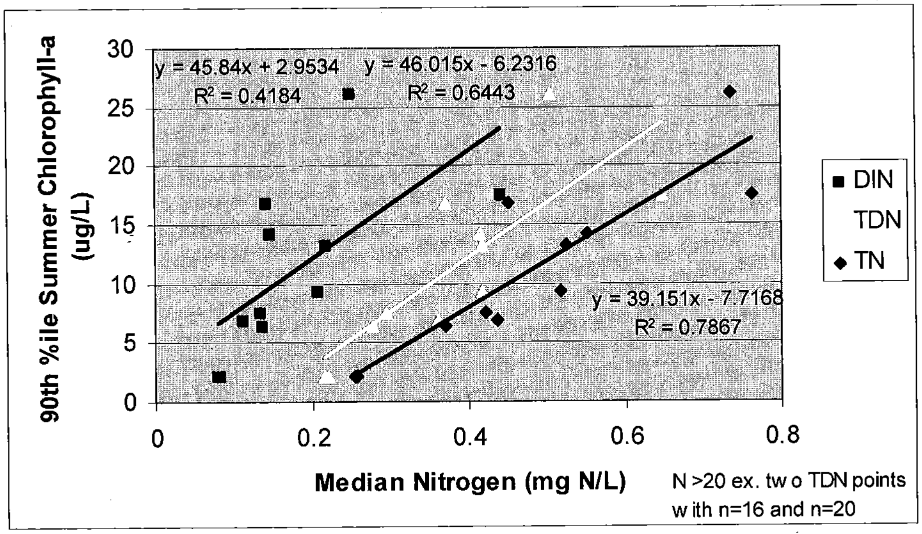



**Figure 14: Relationship between Nitrogen Concentrations and Summer Chlorophyll-a at Trend Stations**

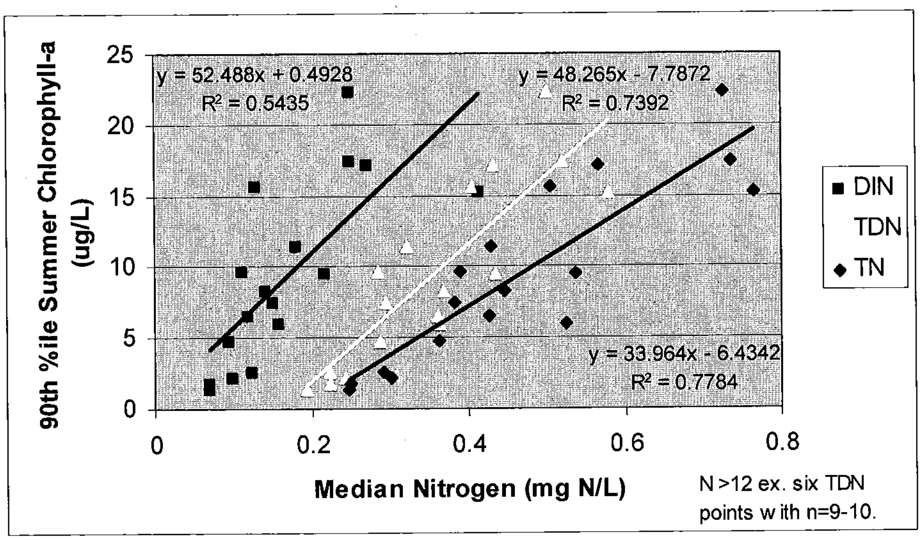
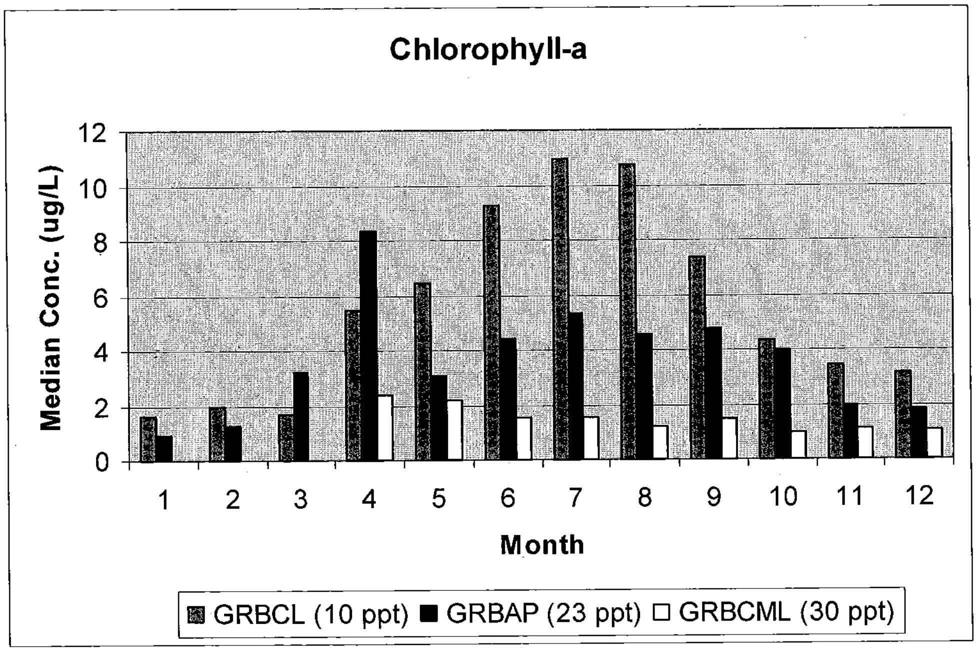


**Figure 15: Seasonal Patterns of Chlorophyll-a at Trend Monitoring Stations with Different Salinities**



## Macroalgae

Increasing nitrogen concentrations in shallow estuaries favor the proliferation of ephemeral macroalgae over seagrasses and other perennial submerged aquatic vegetation (McGlathery et al., 2007; Fox et al., 2008). Macroalgae have lower light requirements for survival than seagrasses and thrive in high nutrient environments (Fox et al. 2008). The proliferation of macroalgae species can be responsible for eelgrass loss due to shading and changes in water chemistry near the sediments (Hauxwell et al., 2001; Hauxwell et al., 2003). When macroalgae forms dense mats on the sediment surface, it can prevent the re-establishment of eelgrass in these areas (Short and Burdick, 1996). The shift to macroalgae dominance is likely to increase the rate of nitrogen export from estuaries to the ocean (McGlathery et al., 2007).

Several studies of macroalgae were completed in the Great Bay Estuary in the 1980s. Mathieson and Hehre (1986) documented the distribution of different macroalgae species throughout the tidal shoreline of New Hampshire, including the Isles of Shoals. Chock and Mathieson (1983) and Hardwick-Witman and Mathieson (1983) studied the species composition at particular locations in the estuary. These studies provide a baseline record of macroalgae species and distribution in the estuary. There have been anecdotal reports of increases in the abundance of different species of nuisance macroalgae by researchers at UNH, but the studies from the 1980s have not been repeated to document the changes.

In 2007, UNH, through a project coordinated by the NHEP with funding from EPA, collected hyperspectral imagery of the Great Bay Estuary. This imagery was used to map eelgrass beds and large macroalgae mats based on unique spectral signatures of the species. The hyperspectral imagery was collected on August 29, 2007 on a spring low tide. Ground truthing data for water quality, but not submerged aquatic vegetation, were collected during the overflight, although ground truth data on macroalgae and eelgrass beds in 2007 were available from another study. The ground truth observations of macroalgae were used to generate a classification training set to classify the spectral signatures of eelgrass and macroalgae species. The nuisance macroalgae species of interest were: multiple *Ulva* species, *Gracilaria* (e.g. *G. tikvahiae*), epiphytic red algae (e.g., ceramialean red algae) and detached/entangled *Chaetomorpha* populations. Additional details about the data collection and analysis methods for this study area available in a technical report (Pe'eri et al., 2008).

The locations of macroalgae in Great Bay in 2007 relative to eelgrass cover in 1996 and 2007 (mapped using aerial photography) are shown in Figure 17. The largest macroalgae mat in 2007 was located in the intertidal region near the Squamscott River. Macroalgae was predominantly found in areas where eelgrass existed in 1996, which was the year with the widest distribution of eelgrass since monitoring began in 1986. Overall, 208 acres of macroalgae and 1,246 acres of eelgrass were identified in Great Bay in 2007. In contrast, the maximum extent of eelgrass in Great Bay in 1996 was 2,421 acres. The macroalgae is predominantly located in areas where eelgrass formerly existed. Therefore, macroalgae mats have now replaced nearly 9% of the area formerly occupied by eelgrass in Great Bay.

The acres of macroalgae in different sections of the estuary are shown in Table 8. In this table, the macroalgae cover has been represented as a percentage of the shallow surface area of each zone. The shallow areas were calculated by subtracting the "optically deep" areas as calculated from the hyperspectral imagery from the total water surface area at high tide. The largest coverage of macroalgae was found in the Great Bay (208 acres). However, the zones with the highest percent cover of macroalgae were the Cocheco River (22%) and the Salmon Falls River (19%). For all the assessment zones, the percent cover by macroalgae is related to the total nitrogen concentration (Figure 16). The precise nature of this relationship (e.g., linear, logarithmic, etc.) is not clear from the graph. However, a median total nitrogen concentration of 0.40 mg N/L appears to be a threshold for proliferation of macroalgae species. This observation is consistent with the fact that significant replacement of eelgrass beds by macroalgae is evident in Great Bay where the median nitrogen concentration is 0.42 mg N/L. Less than an acre of macroalgae was found in Little Bay where the nitrogen concentration is 0.37 mg N/L.

Proliferation of macroalgae is way that nitrogen enrichment can affect eelgrass. The other primary mechanism is loss of water clarity. The relationship between water clarity and nitrogen will be evaluated in later in this report to determine whether a threshold lower than 0.40 mg N/L is needed for the protection of eelgrass.

**Table 8: Macroalgae Cover in Assessment Zones**

| Zone | Macroalgae Cover (ac) | Zone Area (ac) | Deep Water Area (ac) | Shallow Water Area (ac) | Percent Macroalgae Cover (%) | Median TN (mg N/L) |
|---|---|---|---|---|---|---|
| Great Bay | 207.75 | 4,215.48 | 824.57 | 3,390.91 | 6.13% | 0.423 |
| Little Bay | 0.67 | 1,824.77 | 1,170.56 | 654.21 | 0.10% | 0.371 |
| Squamscott River | 0.76 | 306.51 | 58.64 | 247.87 | * | 0.735 |
| Winnicut River | 0.00 | 123.50 | 0.00 | 123.50 | 0.00% | NA |
| Bellamy River | 17.38 | 436.58 | 32.64 | 403.94 | 4.30% | 0.436 |
| Cocheco River | 37.78 | 177.48 | 5.22 | 172.26 | 21.93% | 0.763 |
| Lamprey River | 6.31 | 108.86 | 30.67 | 78.19 | 8.07% | 0.451 |
| Oyster River | 13.31 | 322.29 | 71.60 | 250.69 | 5.31% | 0.526 |
| Upper Piscataqua | 7.66 | 812.71 | 304.08 | 508.63 | 1.51% | 0.519 |
| Lower Piscataqua | 8.90 | 1,573.77 | 0.00 | 1,573.77 | * | 0.255 |
| Salmon Falls River | 60.71 | 365.32 | 52.53 | 312.79 | 19.41% | 0.552 |
| Sturgeon Creek | 0.59 | 35.97 | 0.00 | 35.97 | 1.64% | NA |

* Macroalgae was only mapped in part of this assessment zone. Therefore, the percent cover of macroalgae cannot be calculated.

**Figure 16: Percent Cover of Shallow Water Areas by Nuisance Macroalgae Versus Total Nitrogen in Assessment Zones**

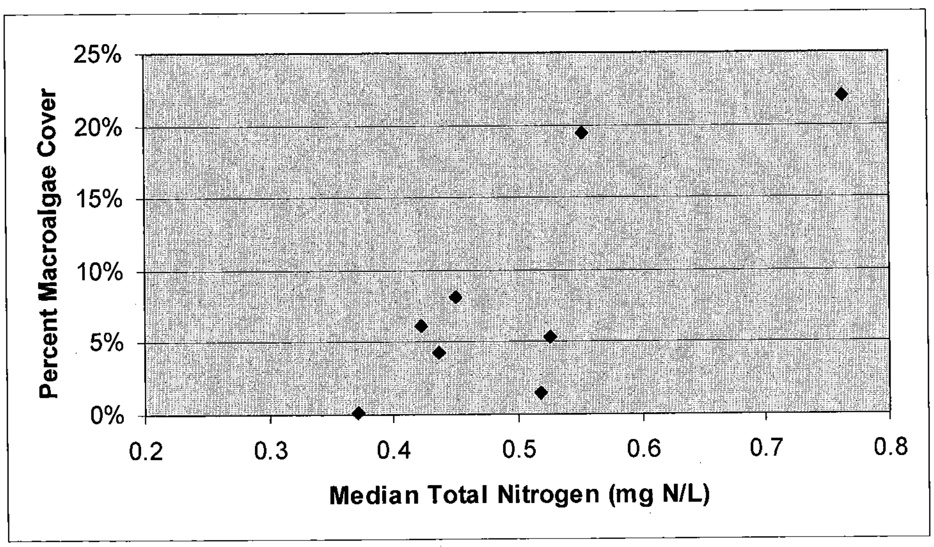
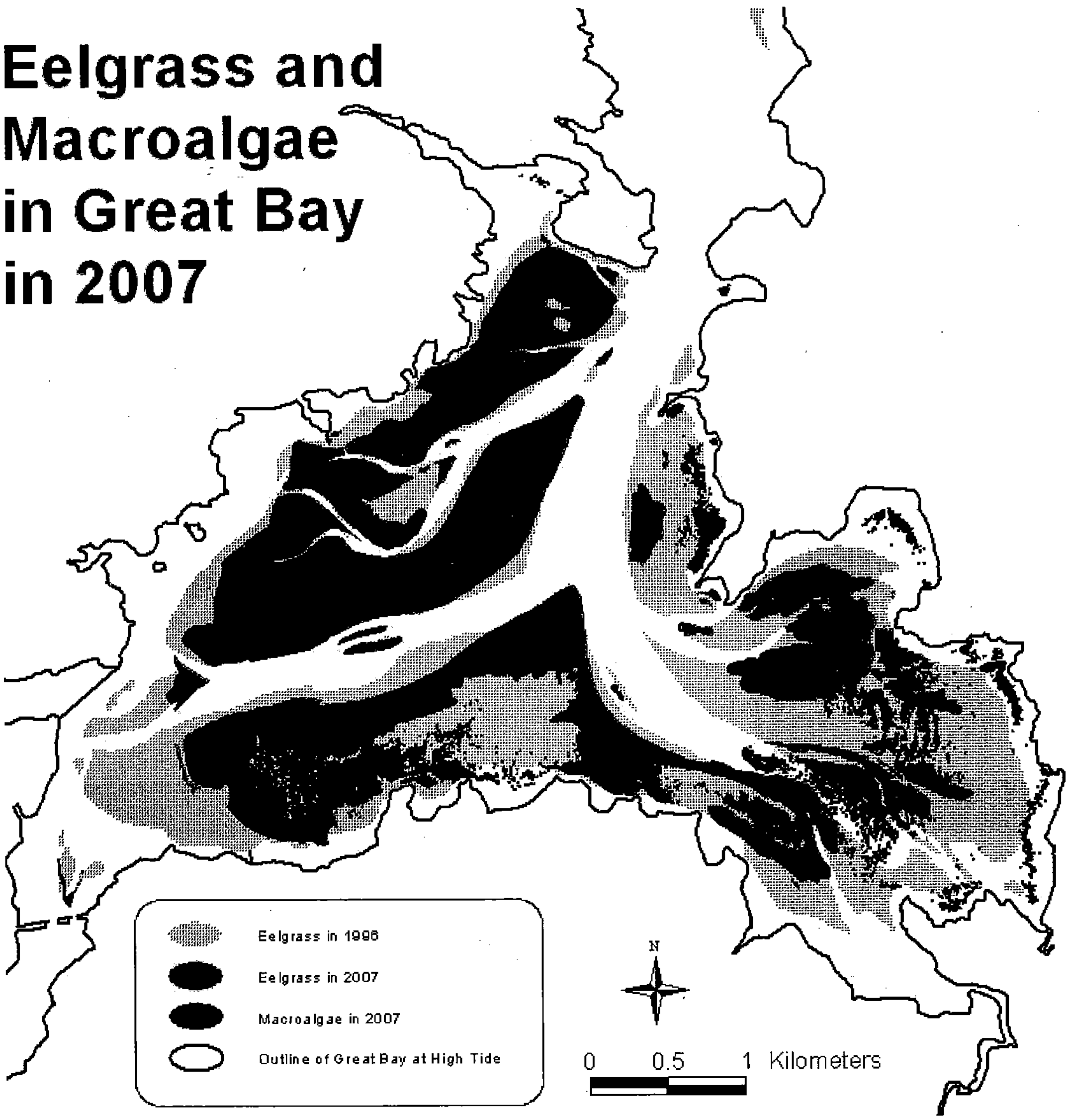


**Figure 17: Eelgrass and Macroalgae in Great Bay Mapped from Hyperspectral Imagery on August 29, 2007**



## *Secondary Indicators*

### Benthic Invertebrates and Sediment Quality

Sediment samples were collected during approximately 130 station visits in the Great Bay Estuary for the National Coastal Assessment (http://www.epa.gov/emap/nca/) during field seasons from 2000 through 2005. The samples were analyzed for toxic contaminant concentrations, grain size, total organic carbon, and benthic invertebrates. The condition of the benthic infaunal community was evaluated with a benthic index of biological integrity (B-IBI) developed by EPA. While the B-IBI was well correlated with nitrogen concentrations (Figure 18), the best explanatory variable for B-IBI was salinity (Figure 19). Diversity and abundance of benthic infauna species are strongly affected by salinity. The B-IBI algorithm developed by EPA does not account for the effect of salinity and is most accurate for higher salinity areas as discussed in Hale and Heltshe (2008). This paper is based on a different B-IBI algorithm than the one used in this report but the caveats regarding salinity are still relevant. Therefore, the relationship between B-IBI and nitrogen concentrations is probably just an apparent correlation caused by the inverse relationship of nitrogen and salinity in the estuary (Figure 20).

The National Coastal Assessment also measured total organic carbon (TOC) content and grain size of the sediments with units of percent of dry weight. TOC is conceptually related to eutrophication. Organic matter from primary producers such as phytoplankton and macroalgae settles through the water column to the sediments. Some of this organic matter is respired in the water column but the rest becomes incorporated in the sediments. Respiration of organic matter in the sediments can consume all of oxygen in the sediments and pore waters, which affects the benthic infaunal community (Cloern, 2001). The relationship between median TOC in the sediments and summer chlorophyll-a concentrations in different areas of the estuary illustrates the linkage between primary productivity and accumulation of organic matter in the sediments (Figure 21). Given that chlorophyll-a concentrations are related to nitrogen concentrations, it is not surprising that TOC in sediments are also correlated to nitrogen concentrations as shown in Figure 22.

Elevated TOC concentrations are scattered across the whole estuary but are predominantly located in the tidal tributaries or creeks. Some of the pattern in TOC can be explained by its association with grain size (Figure 23). The fine grained sediments in tidal creeks lined by salt marsh would be expected to have higher TOC than sandy sediments in higher energy environments. However, there is an apparent threshold at 5% TOC above which TOC does not appear to be controlled by grain size. For the National Coastal Condition Report, EPA also used 5% TOC as a threshold indicative of organic enrichment in sediments (EPA, 2006a).

If 5% is a threshold for TOC in sediments, the relationships between TOC and chlorophyll-a (Figure 21) and TOC and nitrogen (Figure 22) can be used to estimate numeric criteria associated with organic enrichment of the sediments. The $90^{th}$ percentile summer chlorophyll-a concentration and median total nitrogen concentration that correspond to 5% TOC in sediments are 40 ug/L and 1.27 mg N/L, respectively. Using the methods from Helsel and Hirsch (1992), the uncertainty in these estimates was calculated to be +/-12 ug/L (+/-31%) and +/-0.42 mg N/L (+/-33%), respectively. These thresholds have considerable uncertainty for two reasons. First, the relationship between TOC and total nitrogen is statistically significant but weak ($r^2$=0.47). Second, the highest value for TOC in the regression datasets is 3.7% so setting criteria for 5% TOC requires extrapolation.

Given the large uncertainty in the thresholds for this indicator, DES is not proposing to use these thresholds as numeric nutrient criteria at this time. None of the assessment zones in the Great Bay Estuary have $90^{th}$ percentile chlorophyll-a or median nitrogen concentrations greater than 40 ug/L or 1.27 mg N/L, respectively. The one reason to include these thresholds in the nutrient criteria is to document another tier in the degradation of estuarine systems due to elevated nitrogen concentrations. However, absent a strong regulatory need, the uncertainty associated with these thresholds is too great to include them for purely illustrative purposes.

**Figure 18: Relationship between Benthic Infaunal Community B-IBI and Total Nitrogen in Assessment Zones**

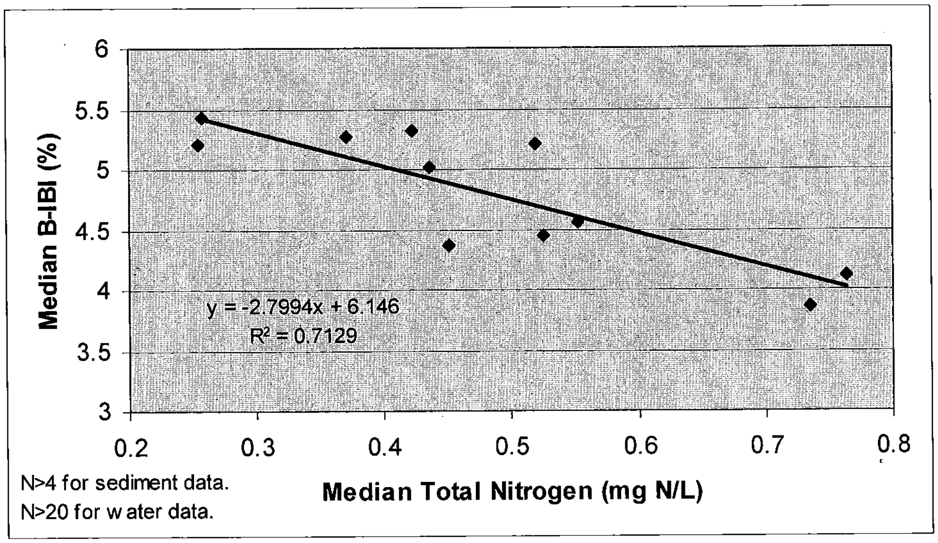



**Figure 19: Relationship between Benthic Infaunal Community B-IBI and Salinity in Assessment Zones**

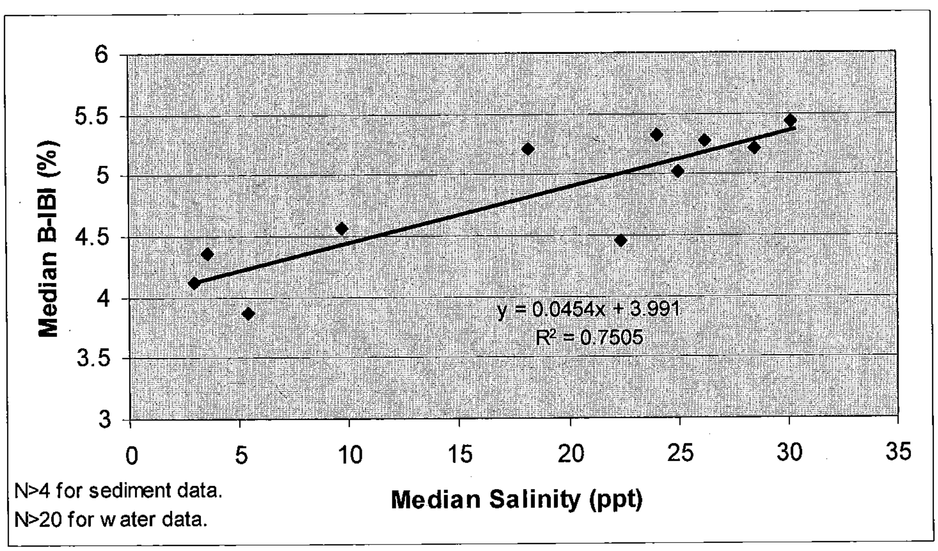


**Figure 20: Relationship between Total Nitrogen and Salinity in Assessment Zones**

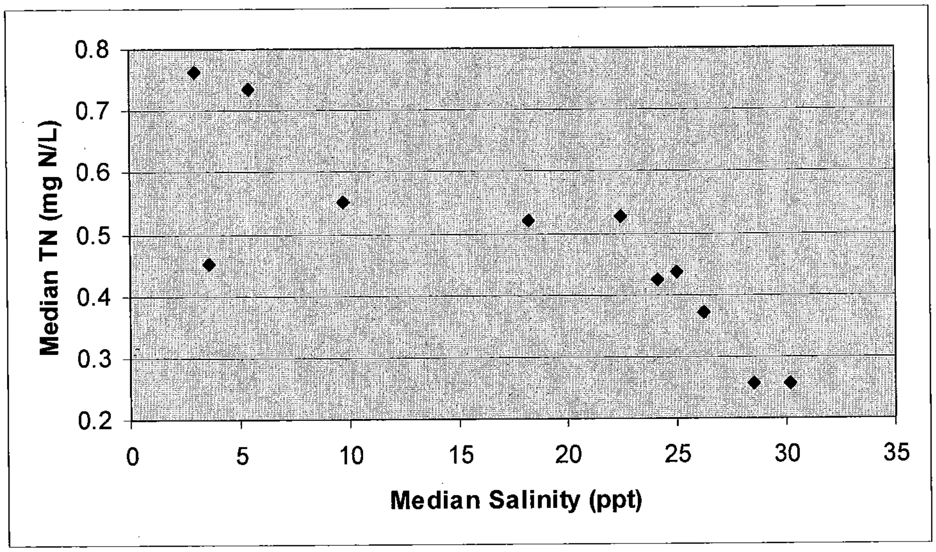



**Figure 21: Relationship between Total Organic Carbon in Sediments and Chlorophyll-a in Assessment Zones**

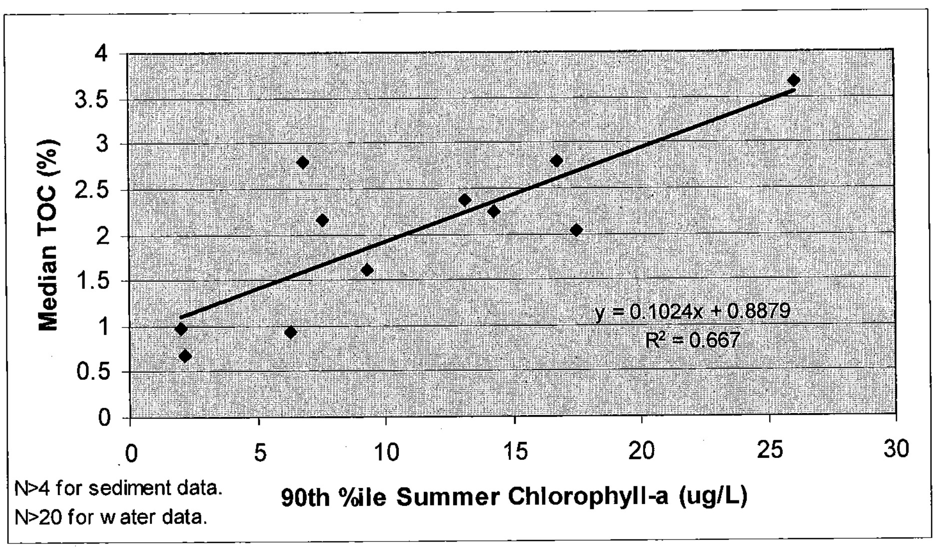


**Figure 22: Relationship between Total Organic Carbon in Sediments and Total Nitrogen in Assessment Zones**

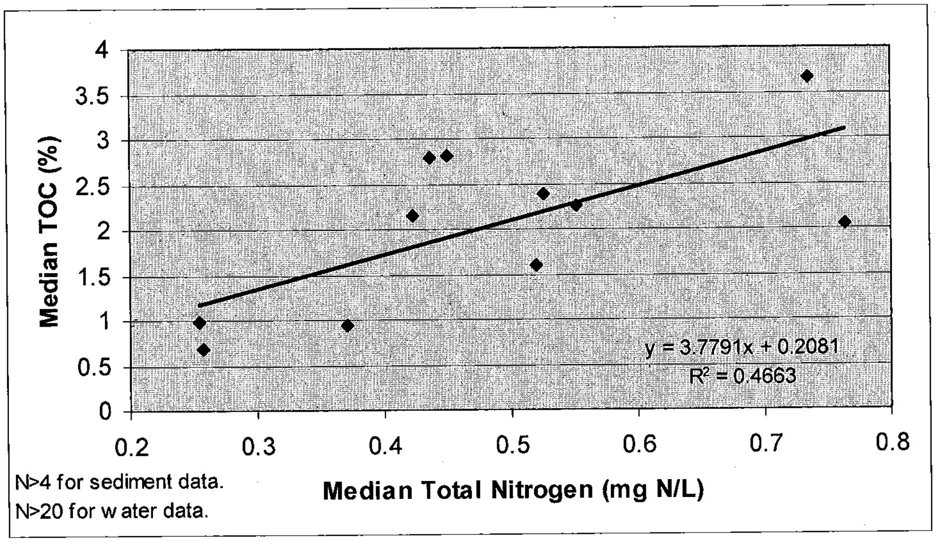
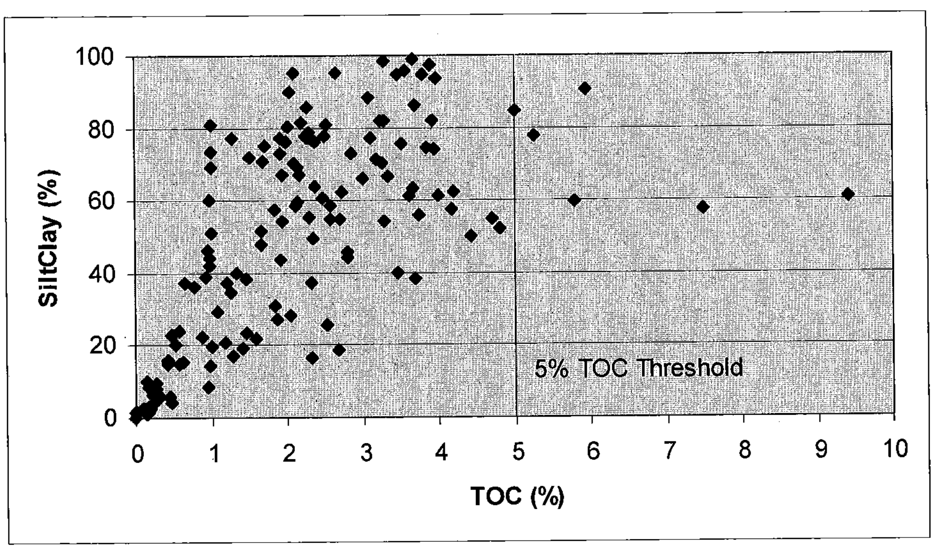



**Figure 23: Relationship between Grain Size and Total Organic Carbon in Sediment Samples**



## Dissolved Oxygen

Low dissolved oxygen is a well established indicator of eutrophication (NRC, 2000; Cloern, 2001; Bricker et al., 2007; EPA, 2001). Respiration of organic matter in the water column and the sediments consumes oxygen. The resulting areas of hypoxia affect fish and benthic communities (Diaz and Rosenberg, 2008; Cloern, 2001; Bricker et al. 2007). New Hampshire already has a water quality standard for dissolved oxygen in tidal waters. For class B waters, which includes estuaries, RSA 485-A:8 and Env-Wq 1703.08 state that dissolved oxygen in units of mg/L must be at least 5 mg/L at all times and that the daily average of dissolved oxygen saturation should be at least 75% (http://www.gencourt.state.nh.us/rsa/html/L/485-A/485-A-8.htm). Hypoxia is typically defined as a dissolved oxygen concentration less than 2 mg/L. Therefore violations of the water quality standard occur before true hypoxia develops.

Summary statistics for dissolved oxygen measured in grab samples at multiple stations in the estuary are provided in Table 9. Figure 24 shows the minimum dissolved oxygen concentrations from stations around the estuary. These measurements show that concentrations of dissolved oxygen below the State standard occur primarily in the tidal tributaries, particularly the Squamscott River.

The minimum dissolved oxygen concentration in surface grab samples collected monthly at trend stations are well correlated with chlorophyll-a, one of the primary indicators of eutrophication (Figure 25). The same relationship is evident when the grab sample data are aggregated by assessment zone (Figure 26). In fact, Figure 26 more clearly shows the corresponding increase in maximum dissolved oxygen concentrations with increasing chlorophyll-a concentrations. This effect would be expected when phytoplankton blooms oxygenate the water during photosynthesis and deplete oxygen during respiration. The minimum dissolved oxygen concentrations are also correlated with nitrogen concentrations as shown in Figure 27 and Figure 28. In these figures, the correlations between dissolved oxygen and the three different forms of nitrogen (dissolved inorganic, total dissolved, and total) are approximately equal. The best relationship was derived from statistics at trend stations and relates median total nitrogen to minimum dissolved oxygen concentrations ($r^2$=0.70, Figure 27).

The correlations between minimum dissolved oxygen and chlorophyll-a and total nitrogen can be used to establish thresholds for chlorophyll-a and nitrogen associated with violations of the dissolved oxygen standard. The regression on Figure 25 predicts that the minimum dissolved oxygen concentration at a station will fall below 5 mg/L for 90$^{th}$ percentile summer chlorophyll-a concentrations greater than 13.4 ug/L. Likewise, a threshold of 0.57 mg N/L can be estimated for total nitrogen based on the regression shown on Figure 27. The uncertainty in these estimated thresholds was estimated, using the methods from Helsel and Hirsch (1992, section 9.4.5), to be +/- 9 ug/L (+/-67%) for chlorophyll-a and 0.24 mg N/L (+/-42%) for total nitrogen due to the small sample size and the imperfect correlations. Therefore, additional information from the datasonde records was sought to improve the accuracy of the thresholds for dissolved oxygen.

## Table 9: Summary Statistics for Dissolved Oxygen (mg/L) from Grab Samples from 2000-2007

**(A) Assessment Zones**

| Assessment Zone | N | Min | 10th%ile | Median | 90th%ile | Max |
|---|---|---|---|---|---|---|
| BELLAMY RIVER | 83 | 5.3 | 6.7 | 8.1 | 10.6 | 14.4 |
| BERRYS BROOK | 2 | 9.3 | 9.3 | 9.3 | 9.4 | 9.4 |
| COCHECO RIVER | 181 | 3.6 | 7.2 | 9.0 | 11.5 | 14.4 |
| GREAT BAY | 253 | 5.2 | 6.9 | 8.5 | 11.0 | 14.1 |
| LAMPREY RIVER | 361 | 4.9 | 6.3 | 8.5 | 11.4 | 17.1 |
| LITTLE BAY | 330 | 5.3 | 7.1 | 8.1 | 10.7 | 14.6 |
| LOWER PISCATAQUA RIVER | 138 | 4.6 | 7.5 | 8.3 | 9.9 | 12.0 |
| NORTH MILL POND | 124 | 6.5 | 7.1 | 9.0 | 11.9 | 15.0 |
| OYSTER RIVER | 159 | 4.2 | 6.3 | 7.7 | 10.1 | 13.9 |
| PORTSMOUTH HARBOR AND LITTLE HARBOR | 298 | 5.9 | 7.4 | 8.8 | 10.6 | 14.1 |
| SAGAMORE CREEK | 9 | 7.6 | 7.7 | 8.4 | 8.6 | 8.6 |
| SALMON FALLS RIVER | 53 | 5.3 | 6.5 | 8.6 | 11.2 | 12.9 |
| SOUTH MILL POND | 150 | 4.0 | 6.7 | 8.1 | 10.6 | 14.8 |
| SPRUCE CREEK | 2 | 7.4 | 7.5 | 7.9 | 8.2 | 8.3 |
| SQUAMSCOTT RIVER | 244 | 3.6 | 5.7 | 8.3 | 11.8 | 17.1 |
| UPPER PISCATAQUA RIVER | 157 | 6.0 | 7.0 | 8.4 | 10.9 | 14.6 |
| WINNICUT RIVER | 64 | 6.0 | 6.7 | 8.0 | 10.1 | 11.1 |

**(B) Trend Monitoring Stations**

| Station | N | Min | 10th%ile | Median | Mean | 90th%ile | Max |
|---|---|---|---|---|---|---|---|
| GRBAP | 68 | 5.3 | 6.9 | 9.1 | 9.6 | 13.5 | 14.6 |
| GRBCL | 61 | 3.9 | 5.9 | 8.3 | 9.1 | 13.4 | 15.4 |
| GRBCML | 39 | 5.9 | 6.9 | 8.2 | 8.5 | 10.1 | 14.1 |
| GRBGB | 47 | 5.2 | 6.7 | 8.6 | 8.8 | 11.4 | 12.1 |
| GRBLR | 63 | 5.1 | 6.7 | 9.6 | 10.2 | 14.9 | 17.1 |
| GRBOR | 35 | 4.2 | 5.1 | 7.0 | 7.6 | 11.4 | 13.2 |
| GRBSQ | 42 | 4.6 | 5.1 | 7.8 | 8.1 | 11.6 | 13.8 |
| NH-0023A | 53 | 7.2 | 8.2 | 9.2 | 9.2 | 10.4 | 11.8 |
| NH-0025A | 29 | 5.9 | 6.6 | 8.0 | 8.9 | 12.0 | 14.1 |
| NH-0029A | 30 | 7.1 | 7.6 | 8.7 | 8.9 | 10.2 | 11.5 |
| NH-0043A | 30 | 6.4 | 7.5 | 8.2 | 8.5 | 9.9 | 11.1 |
| NH-0045A | 30 | 7.2 | 7.3 | 8.5 | 8.8 | 10.2 | 14.6 |
| NH-0049A | 30 | 6.5 | 6.8 | 7.8 | 8.4 | 10.1 | 13.9 |
| NH-0052A | 52 | 5.9 | 6.7 | 8.5 | 8.6 | 10.8 | 14.4 |
| NH-0057A | 60 | 6.0 | 7.2 | 8.7 | 9.3 | 12.0 | 14.6 |
| NH-0058A | 28 | 3.6 | 6.8 | 9.8 | 9.7 | 12.4 | 13.7 |
| NH-0062A | 28 | 5.3 | 6.1 | 9.6 | 9.2 | 11.7 | 12.9 |

**Figure 24: Minimum Concentrations of Dissolved Oxygen at Water Quality Stations**

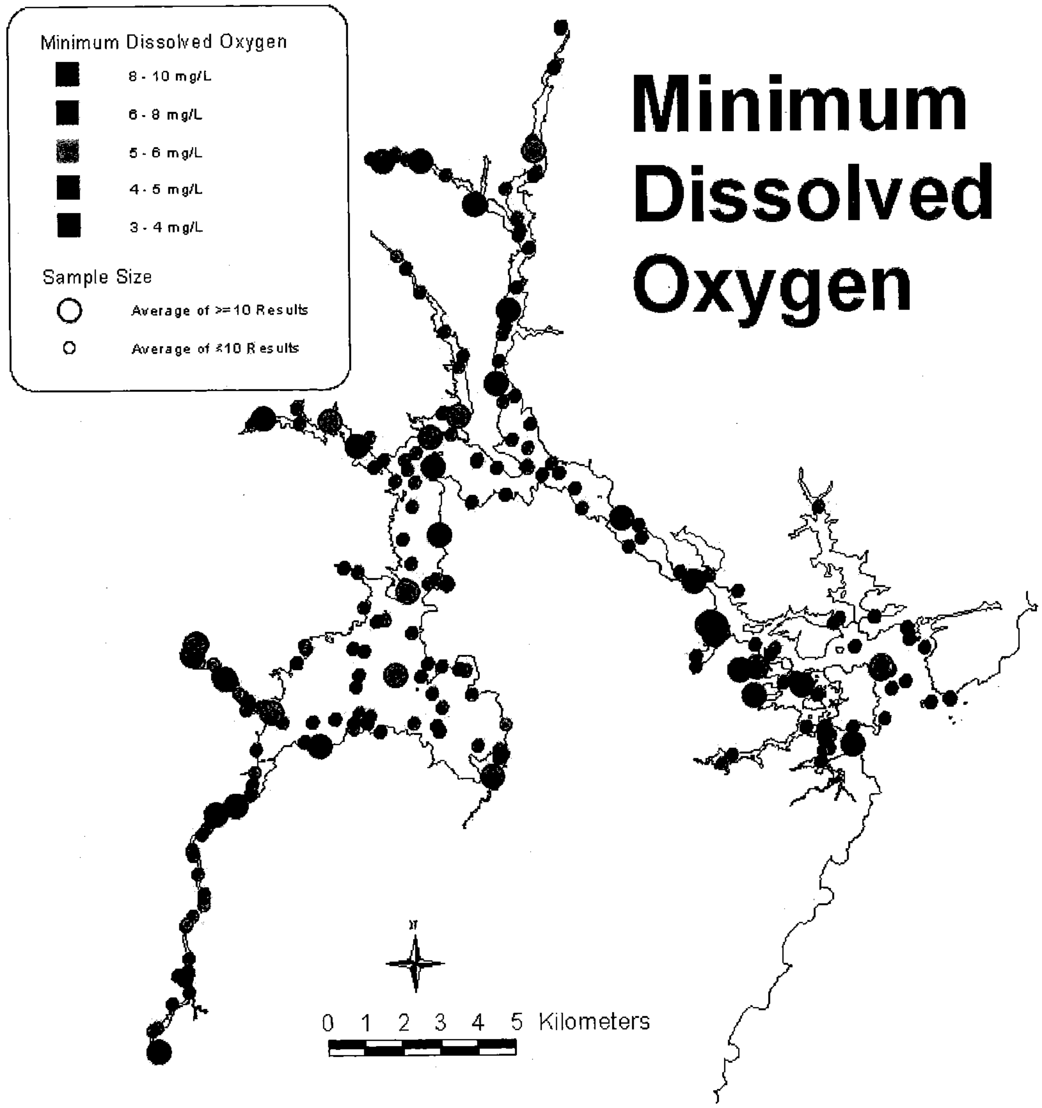


**Figure 25: Relationship between Dissolved Oxygen and Chlorophyll-a at Trend Stations**

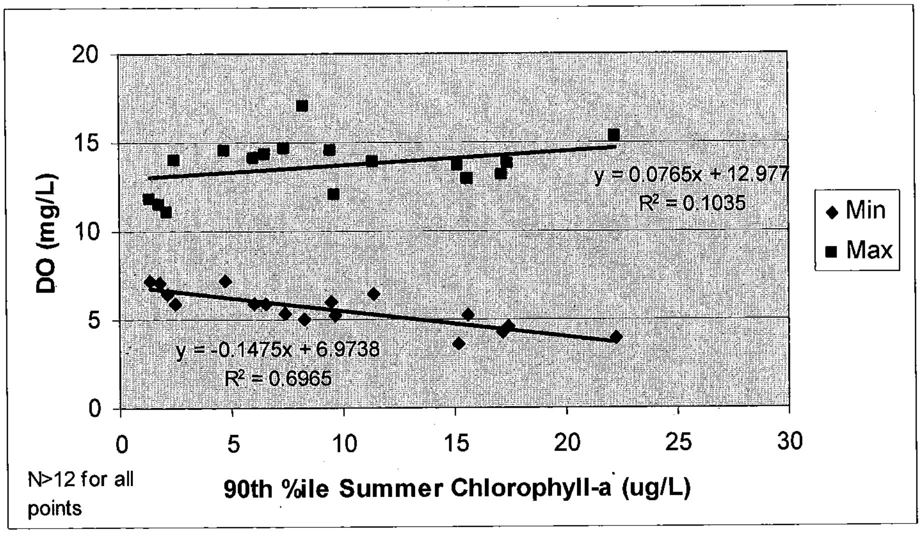



**Figure 26: Relationship between Dissolved Oxygen and Chlorophyll-a in Assessment Zones**

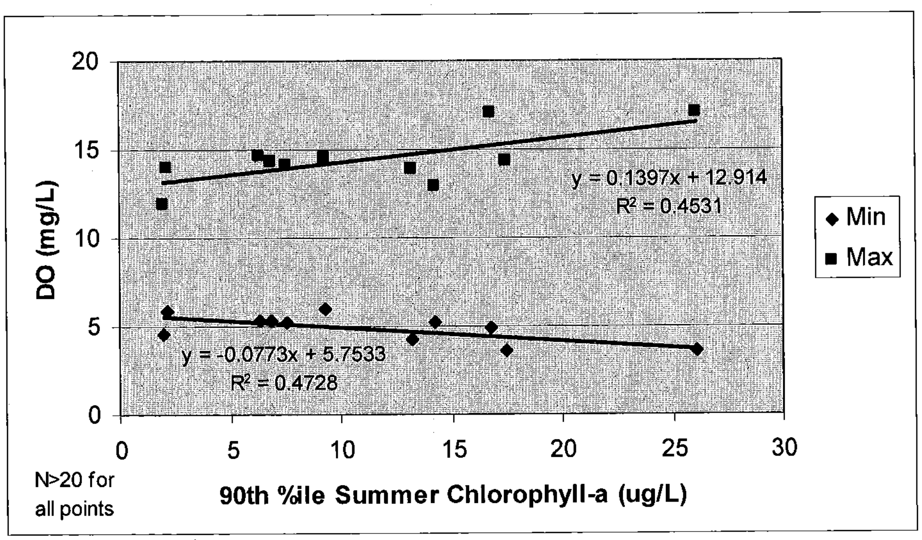


**Figure 27: Relationship between Dissolved Oxygen and Nitrogen at Trend Stations**

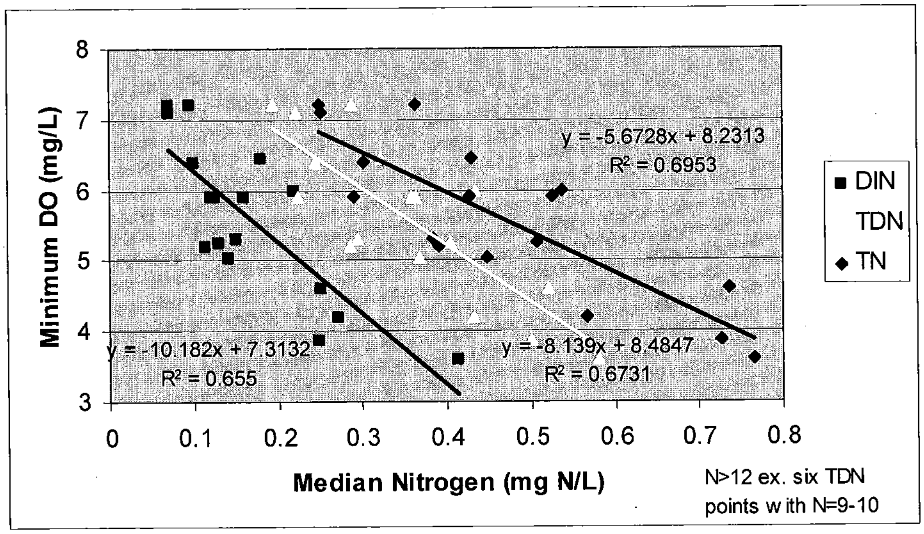
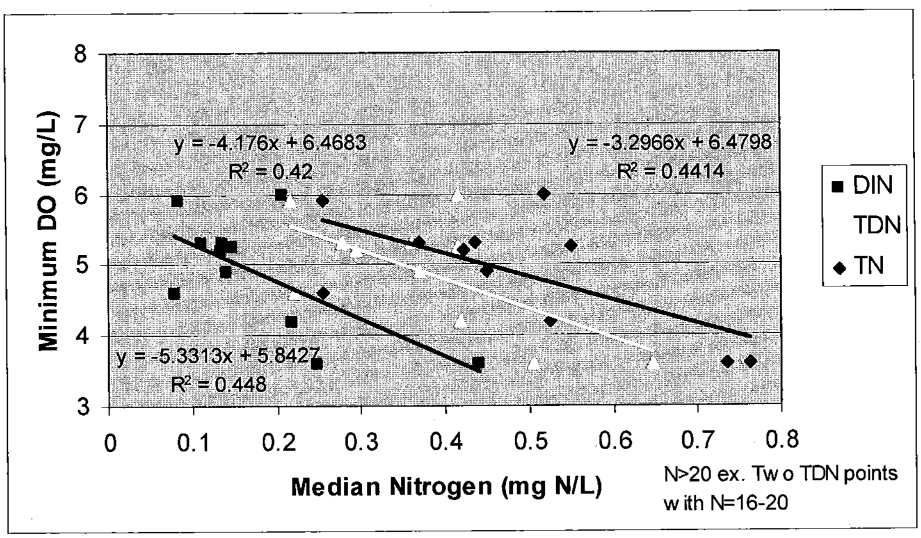



**Figure 28: Relationship between Dissolved Oxygen and Nitrogen in Assessment Zones**



Datasonde measurements provide a richer perspective on dissolved oxygen concentrations because of the large number of measurements and their deployment near the bottom of the water column. The datasondes provide information on seasonal patterns of daily minimum dissolved oxygen and better information on typical concentrations at several key locations.

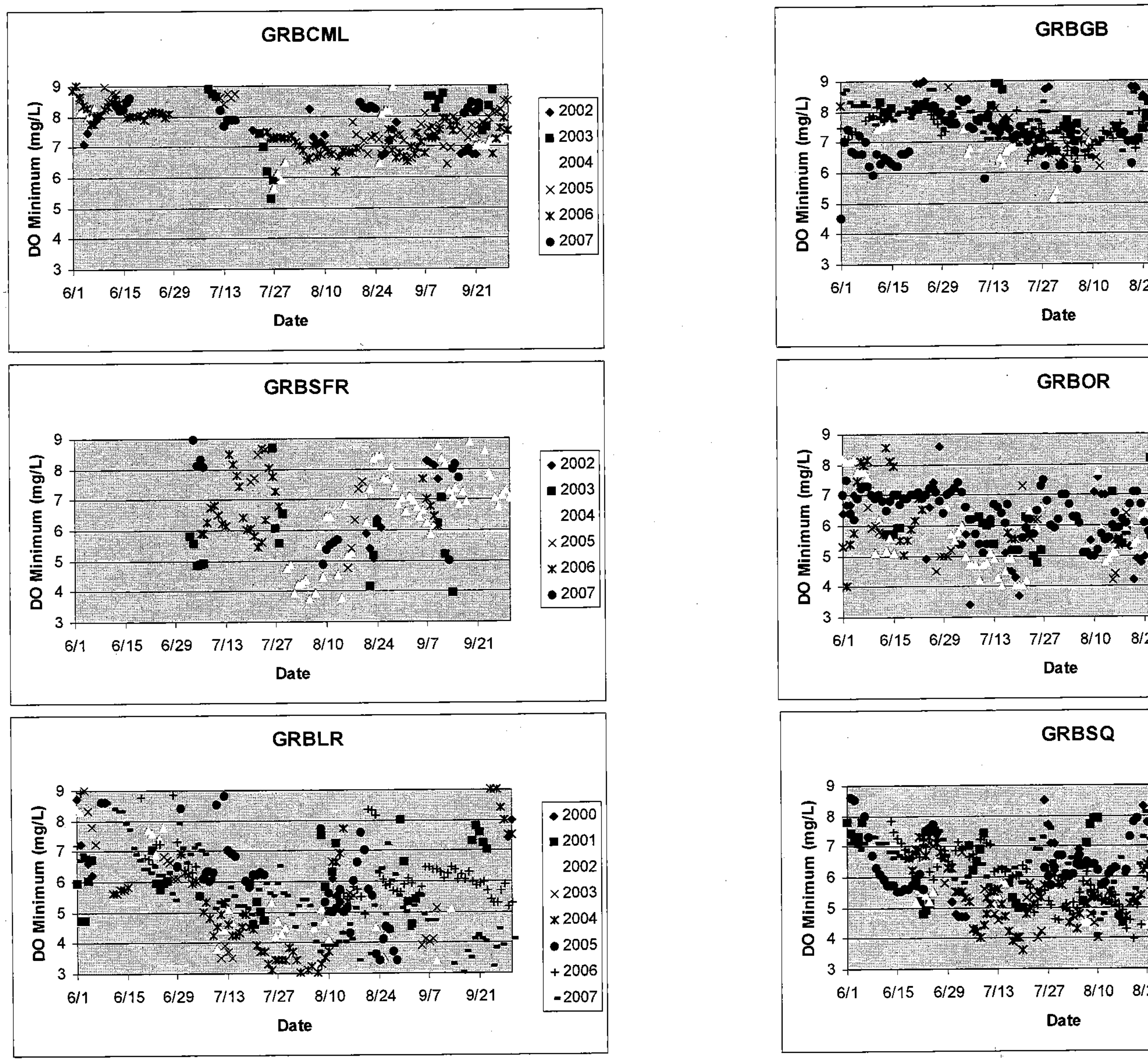
Figure 29 shows the daily minimum concentrations of dissolved oxygen for valid measurements at the datasondes during summer months between 2000 and 2007. Dissolved oxygen concentrations at the mouth of Portsmouth Harbor (GRBCML) never fell below 5 mg/L. In Great Bay (GRBGB), there was a daily minimum DO value below the standard on only one day. By comparison, the datasondes at all of the tributary stations recorded repeated instances of dissolved oxygen less than the state standard. The lowest DO concentrations were recorded in the Lamprey River (GRBLR). A study by UNH in 2004 (Pennock, 2005) determined that the low dissolved oxygen in the river was isolated to a basin that experiences salinity stratification under neap tide conditions. Therefore, the datasonde measurements at GRBLR may not be representative of typical conditions in this tributary and should be interpreted with caution.

The summer chlorophyll-a concentrations (expressed as $90^{th}$ percentiles) and TN concentrations (expressed as medians) were between 2.5 and 9.6 ug/L and between 0.29 and 0.39 mg N/L, respectively, at stations where the sonde measurements rarely if ever indicate violations of the water quality standard for DO (GRBGB, GRBCML). For stations GRBSQ, GRBOR, and GRBSF, where the sonde data clearly demonstrated impairments, the summer chlorophyll-a concentrations and TN concentrations ranged from 15.6 to 17.5 ug/L and from 0.51 to 0.74 mg N/L, respectively. (Note: water quality data from station NH-0062A were used to represent GRBSF.) Finally, the summer chlorophyll-a concentration and TN concentration were 8.2 ug/L and 0.45 mg N/L, respectively, in the Lamprey River where DO impairments were observed but were likely amplified by stratification and possibly sediment oxygen demand (Pennock, 2005). Therefore, the detailed information from the datasondes suggests that the summer chlorophyll-a and TN thresholds associated with the dissolved oxygen standard should be between 9.6 and 15.6 ug/L and 0.39 and 0.51 mg N/L, respectively. Absent additional information, the most appropriate method to balance the decision errors in setting the thresholds is to take the middle values of these ranges: 12.6 ug/L for summer chlorophyll-a and 0.45 mg N/L for total nitrogen. Given the range of possible values, the uncertainty in these thresholds would be +/- 3 ug/L (23%) for chlorophyll-a and +/-0.06 mg N/L (+/-13%) for total nitrogen. DES considers this level of uncertainty to be acceptable.

The thresholds based on the datasonde record are slightly lower than the thresholds that were derived from the grab samples at trend stations (Figure 25, Figure 27) which were 13.4 ug/L and 0.57 mg N/L for summer chlorophyll-a and total nitrogen, respectively. The large volume of data produced by datasondes give this source greater weight than the grab samples. Datasondes collect measurements during early morning hours and other worst-case conditions while grab samples are taken once per month typically in the middle of the day. Most importantly, the uncertainty in the thresholds was much lower for the datasonde records than for the grab samples. Therefore, DES feels that the most appropriate threshold for total nitrogen to prevent violations of the dissolved oxygen standard, in support of the aquatic life support designed use, is 0.45 mg N/L. Also, the threshold for 90th percentile summer chlorophyll-a concentrations corresponding to the dissolved oxygen standard should be 12 ug/L (rounded down from 12.6 ug/L).

The one challenge to using a nitrogen threshold of 0.45 mg N/L is the data from the Lamprey River datasonde. The median total nitrogen concentration at the datasonde (station GRBLR) is 0.45 mg N/L. There have been frequent episodes of low dissolved oxygen measured by this datasonde. However, these episodes appear to be related to more than just ambient nitrogen concentrations. Stratification during neap tides and sediment oxygen demand also play a role (Pennock, 2005). Moreover, the nitrogen concentrations at the datasonde, which is near the tidal dam, are probably not representative of the whole river. At the mouth of the river at station NH-0025A, the median total nitrogen concentration is 0.53 mg N/L. For these reasons, DES feels that it is still appropriate to use 0.45 mg N/L as a threshold despite the observations at station GRBLR.

**Figure 29: Daily Minimum Dissolved Oxygen (mg/L) Measured by Datasondes in Summer (June-September)**



## Eelgrass

Eelgrass (*Zostera marina*) is the base of the estuarine food web in the Great Bay Estuary. Healthy eelgrass beds filter water and stabilize sediments (Short and Short, 1984) and provide habitat for fish and shellfish (Duarte, 2001; Heck et al., 2003). While eelgrass is only one species in the estuarine community, the presence of eelgrass is critical for the survival of many species. Loss of eelgrass habitat would change the species composition of the estuary resulting in a detrimental difference in community structure and function. In particular, if eelgrass habitat is lost, the estuary will likely be colonized by macroalgae species which do not provide the same habitat functions as eelgrass (Short et al., 1995; Hauxwell et al., 2003; McGlathery et al, 2007).

Cultural eutrophication from increased nitrogen loads to estuaries has been shown to be a major cause of seagrass disappearance worldwide (Burkholder et al., 2007; Short and Wyliie-Escheverria, 1996). Excess nitrogen contributes to eelgrass loss by increasing phytoplankton blooms which decrease water clarity and promoting the proliferation of epiphytes and ephemeral macroalgal species on and around seagrasses (Short et al., 1995; Hauxwell et al., 2001; Hauxwell et al., 2003). However, eelgrass can be lost due to other factors such as disease (Short et al., 1986; Muehlstein et al., 1991), sedimentation, and construction of boat moorings, docks or other structures.

A previous section of this report summarized the available information on macroalgae and its effects on eelgrass in the Great Bay Estuary. Proliferation of ephemeral macroalgae, which occupies eelgrass habitat, appears to occur for assessment zones with median total nitrogen concentrations greater than 0.40 mg N/L. Therefore, this value represents an upper bound on the nitrogen threshold for the protection of eelgrass habitat. In the following section, the effects of water clarity on eelgrass survival and the relationship between nitrogen and water clarity will be evaluated to determine whether a lower nitrogen threshold is needed for the protection of eelgrass habitat.

Eelgrass is sensitive to water clarity (Short et al., 1995). Cultural eutrophication from excess nitrogen and suspended sediments in estuaries cause phytoplankton blooms, periphyton growth on eelgrass leaves, and light attenuation from non-algal particles (Short et al., 1995; Hauxwell et al., 2003; McGlathery et al, 2007). Water clarity can be quantified using the light attenuation coefficient ($K_d$) for photosynthetically active radiation. Summary statistics of $K_d$ for different regions of the estuary are shown in Table 10 and Figure 30.

measurements of the light attenuation coefficient and the criteria for minimum light transmission (22%) established by the EPA Chesapeake Bay Program Office (EPA, 2003). This value is supported by Steward et al. (2005) which documented that 20% was the minimum annual light requirement for the maintenance of existing eelgrass beds. Additional light would be needed to restore eelgrass where it has been lost. The difference between $Z_{min}$ and $Z_{max}$ can be used to predict the presence or absence of eelgrass. Koch and Beer (1996) determined that $Z_{max}$ should be at least 1 meter below (less than) $Z_{min}$ for eelgrass survival.

In Table 11, the measured Kd values for each section of the estuary have been paired with tidal amplitudes to estimate $Z_{min}$ and $Z_{max}$ following the procedures in Koch (2001). The depths in this table are relative to mean tidal level (e.g., mid-tide). In the Squamscott, Lamprey, Oyster, Cocheco, and Salmon Falls Rivers, the model predicts that $Z_{max}$ is above (greater than) $Z_{min}$, which matches observations that eelgrass does not currently exist in these areas (NHDES, 2008b). In the Great Bay, Little Bay, and Upper Piscataqua River, the $Z_{max}$ is below (less than) $Z_{min}$ but the difference is less than 1 meter. This result is consistent with observations that eelgrass in these areas is present but has undergone significant losses in recent years (NHDES, 2008b). Only in the Lower Piscataqua River and Portsmouth Harbor was $Z_{max}$ more than one meter below $Z_{min}$. The eelgrass beds in Portsmouth Harbor have been stable in recent years (DES, 2008b) with some losses explained by factors other than water clarity (e.g., grazing by geese)(Short, 2008). In contrast, DES determined that the beds in the Lower Piscataqua River were impaired due to significant changes from historical baseline (NHDES, 2008b). The good water clarity and low nitrogen concentrations (0.26 mg N/L) in this area suggest that the eelgrass loss was due to other factors besides eutrophication.

Given that the model accurately predicts existing conditions in the Great Bay Estuary, the model can also be used to determine the minimum threshold for water clarity to support eelgrass in the Great Bay Estuary. Throughout the estuary, $Z_{min}$ is approximately 1 meter. Consequently, a restoration depth of 2 meters would be needed for $Z_{max}$ to be more than one meter below $Z_{min}$ in shallow rivers and bays. However, in the deep channel of the Lower Piscataqua River and Portsmouth Harbor (average depth >7.5 m), a restoration depth of >2 meters may be more appropriate. Finally, the light transmission criteria of >22% from EPA (2003) will be assumed to be appropriate for the Great Bay Estuary. Based on these assumptions, the model in Koch (2001) predicts that a light attenuation coefficient of 0.75 $m^{-1}$ as a minimum water clarity requirement for the survival of eelgrass in the Great Bay Estuary. In the Lower Piscataqua River and Portsmouth Harbor where the channel is deeper, a lower light attenuation coefficient might be needed. In order to meet these targets, the light attenuation coefficient would need to improve by 56 to 73% in the Squamscott, Lamprey, Oyster, Cocheco, and Salmon Falls Rivers. The Great Bay, Little Bay, and Upper Piscataqua River would need clarity improvements between 22 and 34%. The water clarity in the Lower Piscataqua River and Portsmouth Harbor is already approximately equal to the threshold. However, these thresholds are only for the existence of eelgrass beds. The modeling target of 22% of ambient light is appropriate for the minimum maintenance of existing eelgrass beds, not restoration of beds that have been lost.

**Table 10: Summary Statistics for Light Attenuation Coefficient ($m^{-1}$) from Field Measurements from 2000-2007**

**(A) Assessment Zones**

| Assessment Zone | N | Min | $10^{th}$%ile | Median | 90th%ile | Max |
|---|---|---|---|---|---|---|
| COCHECO RIVER | 2 | 4.59 | 4.39 | 3.60 | 2.81 | 2.61 |
| GREAT BAY | 45 | 6.25 | 2.11 | 1.14 | 0.63 | 0.06 |
| LAMPREY RIVER | 37 | 4.05 | 2.83 | 1.85 | 1.06 | 0.05 |
| LITTLE BAY | 50 | 3.31 | 1.61 | 0.96 | 0.61 | 0.07 |
| LOWER PISCATAQUA RIVER | 12 | 1.31 | 0.94 | 0.50 | 0.08 | 0.04 |
| NORTH MILL POND | 1 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| OYSTER RIVER | 32 | 5.16 | 2.33 | 1.71 | 1.11 | 0.11 |
| PORTSMOUTH HARBOR AND LITTLE HARBOR | 61 | 5.75 | 1.06 | 0.57 | 0.22 | 0.04 |
| SAGAMORE CREEK | 1 | 0.82 | 0.82 | 0.82 | 0.82 | 0.82 |
| SALMON FALLS RIVER | 3 | 5.53 | 4.86 | 2.20 | 1.25 | 1.01 |
| SQUAMSCOTT RIVER | 66 | 7.98 | 4.95 | 2.82 | 1.57 | 0.12 |
| UPPER PISCATAQUA RIVER | 15 | 2.95 | 1.86 | 1.02 | 0.78 | 0.11 |
| SPRUCE CREEK | 1 | 0.41 | 0.41 | 0.41 | 0.41 | 0.41 |

**(B) Trend Monitoring Stations**

| Station | N | Min | 10th%ile | Median | 90th%ile | Max |
|---|---|---|---|---|---|---|
| GRBAP | 41 | 3.31 | 1.52 | 0.97 | 0.72 | 0.07 |
| GRBCL | 30 | 6.02 | 4.50 | 2.97 | 1.72 | 0.12 |
| GRBCML | 28 | 1.42 | 1.11 | 0.60 | 0.42 | 0.22 |
| GRBGB | 37 | 6.25 | 2.13 | 1.10 | 0.65 | 0.36 |
| GRBLR | 36 | 3.79 | 2.63 | 1.79 | 1.01 | 0.05 |
| GRBOR | 31 | 5.16 | 2.33 | 1.74 | 1.18 | 0.42 |
| GRBSQ | 29 | 7.98 | 5.56 | 2.91 | 1.52 | 0.14 |
| NH-0029A | 20 | 1.18 | 1.02 | 0.57 | 0.11 | 0.04 |
| NH-0057A | 7 | 1.70 | 1.66 | 1.10 | 0.81 | 0.72 |

**Figure 30: Average Values of Light Attenuation Coefficient at Water Quality Stations**

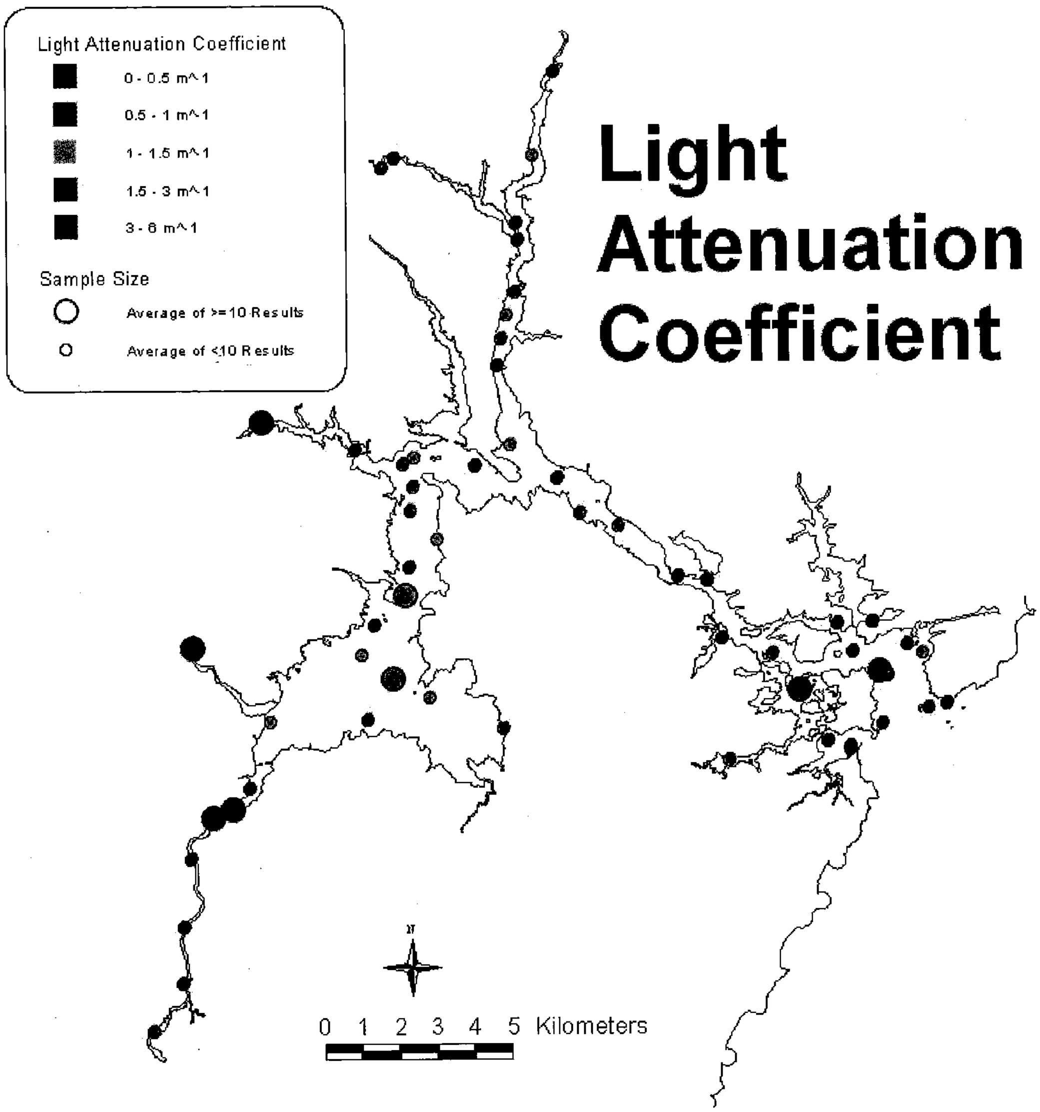


**Table 11: Predicted Eelgrass Depths in Different Regions of the Estuary**

| Assessment Zone | Kd ($m^{-1}$) | | Modeled Depth (m MTL) | | | Eelgrass |
|---|---|---|---|---|---|---|
| | N | Median | $Z_{min}$ | $Z_{max}$ | $Z_{min}$-$Z_{max}$ | Predicted |
| SQUAMSCOTT RIVER | 66 | 2.82 | -1.0 | -0.5 | -0.5 | No |
| LAMPREY RIVER | 37 | 1.85 | -1.0 | -0.8 | -0.2 | No |
| OYSTER RIVER | 32 | 1.71 | -1.0 | -0.9 | -0.1 | No |
| COCHECO RIVER | 2 | 3.60 | -1.0 | -0.4 | -0.6 | No |
| SALMON FALLS RIVER | 3 | 2.20 | -1.0 | -0.7 | -0.3 | No |
| UPPER PISCATAQUA RIVER | 15 | 1.02 | -1.0 | -1.5 | 0.5 | Partial |
| GREAT BAY | 45 | 1.14 | -1.0 | -1.3 | 0.3 | Partial |
| LITTLE BAY | 50 | 0.96 | -1.0 | -1.6 | 0.6 | Partial |
| LOWER PISCATAQUA RIVER | 12 | 0.50 | -1.0 | -3.0 | 2.0 | Yes |
| PORTSMOUTH HARBOR | 61 | 0.57 | -1.0 | -2.7 | 1.7 | Yes |

Water clarity is a function of absorption and scattering by phytoplankton, turbidity, colored dissolved organic matter (CDOM), and water itself. In order to establish a nitrogen threshold associated with the water clarity threshold of 0.75 $m^{-1}$, the causal relationships between nitrogen and these factors were determined through a two-step process. First, the relative importance of each light attenuation factors was measured using high frequency buoy observations in 2007. Second, the relationship of each of the factors to nitrogen was evaluated using evidence from grab samples and other data sources.

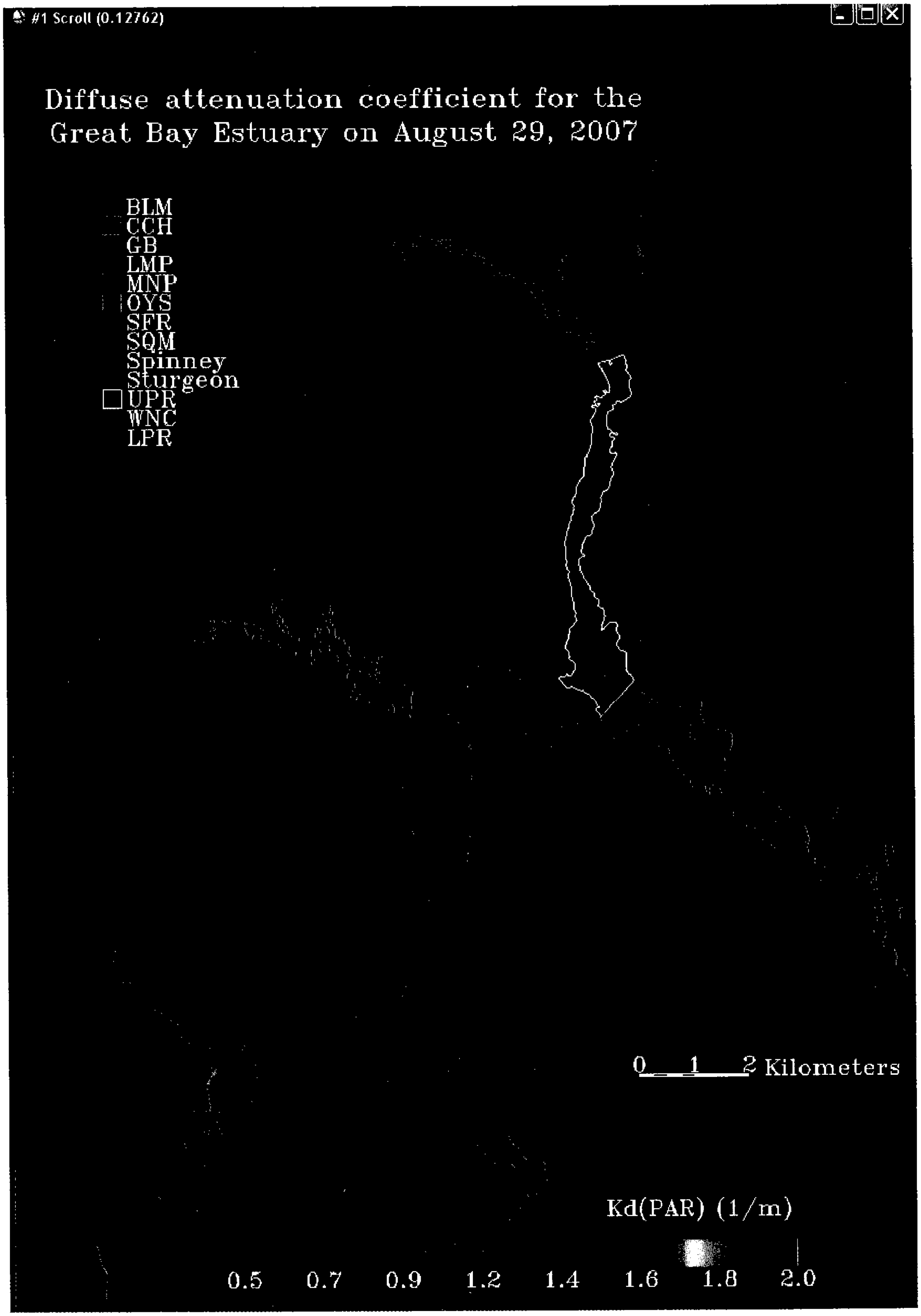
In 2007, the NHEP provided funding from EPA to UNH to collect high frequency observations of light attenuation and water quality in Great Bay. The purpose of the research was to collect enough data points to develop a statistically significant, multivariate regression between the light attenuation coefficient and water quality. Between April 4 and December 1, 2007, light attenuation coefficient, chlorophyll-a, CDOM, and turbidity were measured at the buoy at 15 to 30 minute intervals. The measurements of the light attenuation coefficient were regressed against values of chlorophyll-a, non-algal turbidity, and CDOM using a multivariate linear model. The regression produced a statistically significant relationship which explained 95 percent of the variance in the observed light attenuation measurements (Morrison et al., 2008):

$$\frac{K_d(PAR)}{Do} = 0.2449 + 0.0188.[Chl] + 0.0101.[CDOM] + 0.0784.[NAP] \quad (8.1)$$

with the units of the concentration terms reflecting those used by buoy instrumentations ([Chl] in mg m-3, [CDOM] in ppb QSE, and [NAP] in chlorophyll adjusted turbidity NTUs). Through this regression equation, UNH was able to determine that over the course of the buoy deployment, water accounted for 32%, chlorophyll-a accounted for 12%, CDOM accounted for 27%, and turbidity accounted for 29% of the light attenuation in the middle of Great Bay (Morrison et al., 2008).

The regression relationship established by the buoy observations was confirmed using hyperspectral imagery collected during a spring low tide on August 29, 2007. The imagery was processed to generate a map of light attenuation throughout the bay and in the tributaries on that date (Figure 31). The light attenuation coefficient throughout the estuary was also predicted from ship track measurements of chlorophyll-a, turbidity, and CDOM taken during the overflight and the regression equation listed above. The light attenuation coefficient values from both methods agreed, which indicates that the regression equation from the buoy measurements was valid and applicable throughout the estuary (Morrison et al., 2008). However, the percentage of light attenuation attributable to each factor will not be the same in all areas because the relative concentrations of the different factors are not the same in all areas of the estuary.

**Figure 31: Light Attenuation Coefficient from Hyperspectral Imagery on August 29, 2007**



The relationship of each of the light attenuation factors to nitrogen was evaluated using evidence from grab samples and other data sources. The attenuation by water can be ignored because it is constant. CDOM is important to attenuation in the Great Bay Estuary but is not controllable and does not appear to be related to primary production in the estuary. This parameter is largely based on delivery of dissolved organic carbon from wetlands in the watershed. The delivery process is controlled by rainfall and nutrient cycling in wetlands which occurs over long time periods. However, CDOM should still be correlated with nitrogen concentrations because of the nitrogen bound up in organic matter. Chlorophyll-a concentrations are strongly correlated with nitrogen as has been demonstrated in this report. Therefore, the critical causal relationship to define is the one between turbidity and nitrogen.

Turbidity is a measure of scattering in the water column due to particulate organic matter and inorganic particles. Particulate organic matter is composed of living phytoplankton (as measured by chlorophyll-a), zooplankton and other consumers, and detrital organic matter. Paired measurements of particulate organic carbon and chlorophyll-a at estuary stations show that living phytoplankton constitute less than 5% of the particulate organic matter (Figure 32). For this calculation it was assumed that phytoplankton biomass is 50% carbon and 5% chlorophyll-a based on guidance from EPA (EPA, 1985). Therefore, chlorophyll-a measurements underestimate the amount of organic matter in the water column by a factor of at least 20, on average. Moreover, the concentrations of this particulate organic matter are well correlated with nitrogen concentrations (Figure 32), which suggests that this organic matter was generated by primary productivity within the estuary (autochthonous). For this graph, dissolved nitrogen concentrations were used to avoid spurious correlations due to nitrogen bound in organic matter.

The presence of particulate organic matter in excess of living phytoplankton is important because it accounts for nearly half of the turbidity. Daily average turbidity measurements at datasondes were paired with particulate organic carbon measurements taken at the same station on the same date. Extreme values were trimmed from the dataset. Figure 33 shows that particulate organic carbon accounts for 47% of the daily turbidity variance measured by the datasondes. A perfect correlation between these two variables would not be expected because of the effects of inorganic particles on turbidity.

The relationship between median turbidity and nitrogen at datasonde stations indicates an even better relationship. At each datasonde, daily average turbidity concentrations were calculated for summer days with at least 36 valid turbidity measurements (i.e., 75% complete). Median daily turbidity values were calculated from all of the daily average turbidity values in summer between 2000 and 2007 at each station. Therefore, each median turbidity value on Figure 34 was derived from greater than 15,000 individual measurements of turbidity at each station. These median values were well correlated with the median dissolved and total nitrogen concentrations at these stations. This result suggests that particulate organic matter and nitrogen may be responsible for more than 47% of turbidity.

**Figure 32: Relationship between Particulate Organic Carbon and Dissolved Nitrogen at Trend Stations**

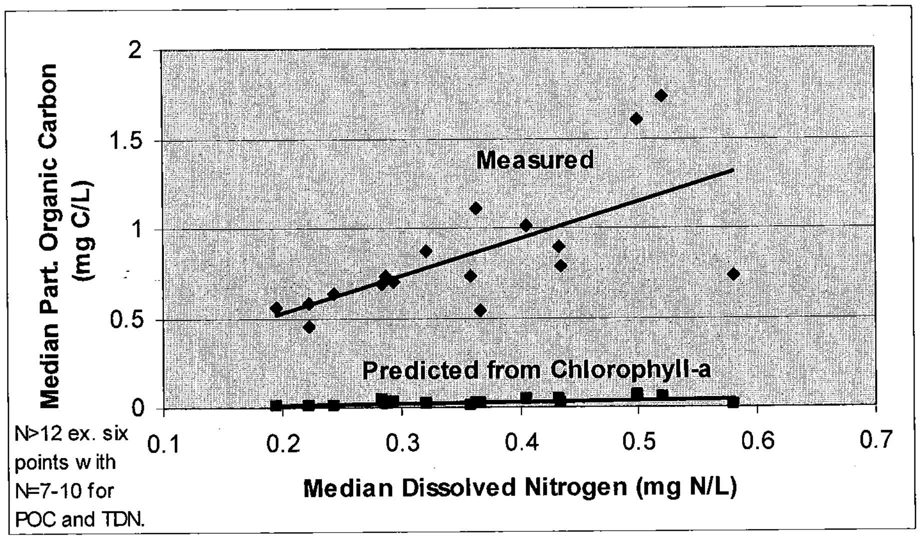


**Figure 33: Relationship between Daily Average Turbidity Measured by Datasondes and Particulate Organic Carbon on the Same Day**

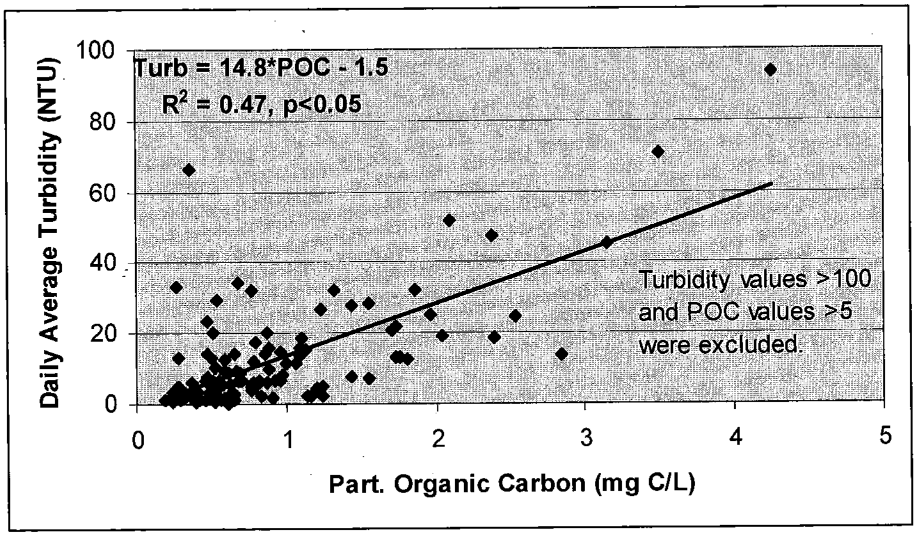
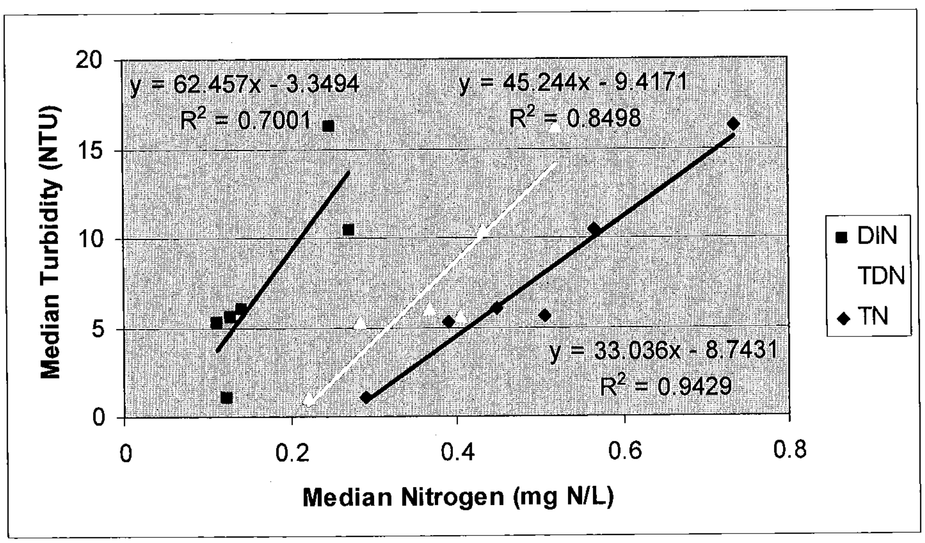



**Figure 34: Relationship between Turbidity in Summer and Nitrogen Concentrations at Datasonde Stations**



Given that chlorophyll-a and at least half of turbidity are causally linked to nitrogen concentrations and CDOM contains nitrogen, light attenuation in the estuary should be a function of nitrogen as well. In Figure 35 and Figure 36, the median light attenuation coefficient at different trend stations is well correlated with both dissolved and total nitrogen concentrations. Based on the relationships between TN and $K_d$ on these figures, a total nitrogen threshold of 0.30 to 0.32 mg N/L would be needed to meet the water clarity threshold for eelgrass habitat of 0.75 $m^{-1}$. The uncertainty in this threshold due to the low samples size and the imperfect correlations is +/-0.13-0.17 mg N/L (+/-44-52%). This uncertainty is too high to set numeric criteria based on this analysis alone, although the results are still useful in conjunction with other information.

While none of the individual data sources provides conclusive thresholds for eelgrass protection, all of the data sources can be combined using a weight of evidence approach to determine a threshold. The range of possible thresholds is bound by the total nitrogen concentration in offshore waters in the Gulf of Maine (0.24 mg N/L) as a minimum and the nitrogen concentration associated with macroalgae proliferation (0.40 mg N/L) as a maximum. Within that range, the best estimate for the threshold based on the analysis of water clarity is 0.30-0.32 mg N/L. However, as discussed above, the uncertainty in this estimate is large. Another source of information is the nitrogen concentrations in areas where eelgrass is still healthy. The only major assessment zone that DES did not determine to be impaired for eelgrass loss was the Portsmouth Harbor/Little Harbor area (NHDES, 2008b). Following EPA guidance for the reference concentration approach, the threshold should be set at the 75$^{th}$ percentile concentration in the reference area (EPA, 2001). For the Portsmouth Harbor/Little Harbor area, this reference concentration is 0.32 mg N/L. Finally, the total nitrogen criteria which have been established for other estuaries in New England predominantly fall between 0.35 and 0.38 mg N/L. These criteria were established for smaller estuaries on Cape Cod with slightly higher nitrogen concentrations in offshore waters, and are based on tidally averaged concentrations, not median values. <u>The combination of these various pieces of information strongly point to 0.32 mg N/L as the most appropriate threshold for the protection of eelgrass in the Great Bay Estuary.</u> Given the range of possible values (0.24 to 0.40 mg N/L), the maximum error in this estimate is +/-0.08 mg N/L (+/-25%). However, error is likely smaller because supporting information narrowed the range of possibilities considerably. In the tidal tributaries, the threshold will only apply for areas where eelgrass has been known to exist. The known historical distribution of eelgrass in the Squamscott, Lamprey, Oyster, and Bellamy Rivers is provided in another report (NHDES, 2008b). The historical upstream extent of eelgrass in the Piscataqua, Cocheco, and Salmon Falls Rivers still needs to be determined.

**Figure 35: Relationship between Light Attenuation Coefficient and Nitrogen at Trend Stations**

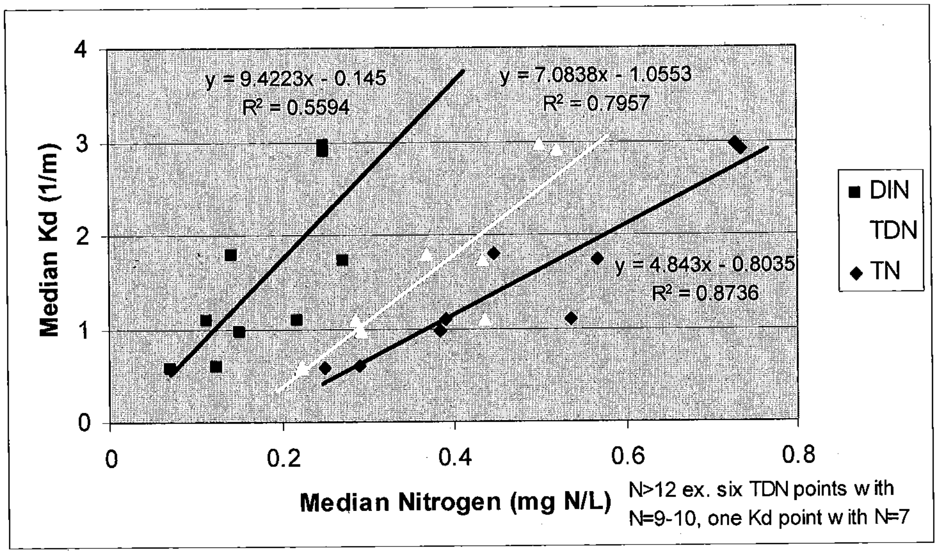
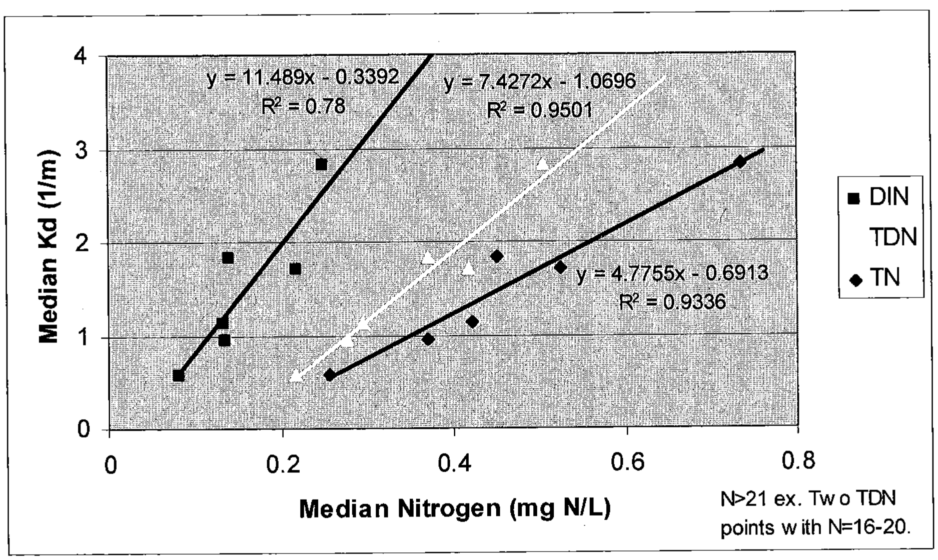



**Figure 36: Relationship between Light Attenuation Coefficient and Nitrogen in Assessment Zones**



# Summary of Proposed Numeric Nutrient Criteria

1. DES is proposing the following numeric nutrient criteria for New Hampshire's estuarine waters. These values will first be used as interpretations of the water quality standards narrative criteria for DES' Consolidated Assessment and Listing Methodology for 305(b) assessments. Later, DES will promulgate these values as water quality criteria in Env-Wq 1700.

| Designated Use / Regulatory Authority | Parameter | Threshold | Statistic | Comments |
|---|---|---|---|---|
| Primary Contact Recreation [1] (Env-Wq 1703.14) | Chlorophyll-a | 20 ug/L | 90th percentile during summer | Applies to all areas of the Great Bay Estuary |
| Aquatic Life Use Support – to protect Dissolved Oxygen [1] (RSA 485-A:8) | Total Nitrogen | 0.45 mg N/L | Median | Applies to all areas of the Great Bay Estuary |
| | Chlorophyll-a | 12 ug/L | 90th percentile during summer | |
| Aquatic Life Use Support – to protect Eelgrass [1,2] (Env-Wq 1703.14) | Total Nitrogen | 0.32 mg N/L | Median | Portsmouth Harbor, Little Harbor, Piscataqua River, Great Bay, Little Bay, and areas of tidal tributaries where eelgrass has existed in the past |
| | Light Attenuation Coefficient (Water Clarity) | 0.75 $m^{-1}$ | Median | |

Notes
1. Maine tidal waters are not covered by these criteria.
2. The thresholds apply to all of Portsmouth Harbor, Little Harbor, Piscataqua River, Great Bay, and Little Bay but only the portions of the tidal tributaries where eelgrass existed historically. Additional research on the extent of historical or potential eelgrass habitat in the tributaries is needed, especially in the Upper Piscataqua, Cocheco, and Salmon Falls Rivers.

2. For impairment determinations for the Section 303(d) List, both the nitrogen threshold and the response threshold (e.g., dissolved oxygen, chlorophyll-a, or light attenuation coefficient) for each designated use will be evaluated and their results combined according to the following decision matrix. The premise for this decision matrix is that evidence of eutrophic response has greater weight than nitrogen concentrations.

| | Nitrogen threshold exceeded | Nitrogen threshold not exceeded | Insufficient information for nitrogen |
|---|---|---|---|
| Response thresholds exceeded | Impaired | Impaired | Impaired |
| Response thresholds not exceeded | Fully Supporting | Fully supporting | Fully supporting |
| Insufficient information for response variable | Impaired | Fully supporting | Insufficient Information |

3. Nitrogen thresholds associated with large phytoplankton blooms and impacts to benthic macroinvertebrates were estimated but the uncertainty in these thresholds was too large for regulatory purposes. The nitrogen concentration associated with the primary contact recreation designated use was determined to be 0.71 +/- 0.20 mg N/L. Impacts to benthic infauna due to the accumulation of organic matter in the sediments were associated with total nitrogen concentrations of 1.27 +/-0.42 mg N/L. The uncertainty in these thresholds was considered too high. In contrast, the uncertainty in the nitrogen thresholds associated with dissolved oxygen and eelgrass were +/-0.06 and +/-0.08 mg N/L, respectively. The estimated thresholds for primary contact recreation and benthic infauna impacts are still useful for tiered aquatic life use assessments.

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# ATTACHMENT 7

WD Doc R-WD-08-18

# Methodology and Assessment Results related to Eelgrass and Nitrogen in the Great Bay Estuary for Compliance with Water Quality Standards for the New Hampshire 2008 Section 303(d) List

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August 11, 2008

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

**Executive Summary**

The New Hampshire Department of Environmental Services (DES) developed an assessment methodology for determining compliance with water quality standards for biological integrity (Env-Ws 1703.19) using eelgrass (*Zostera marina*) cover in the Great Bay Estuary as an indicator. DES reviewed eelgrass cover data from 1948 to 2005. Eight regions of the estuary were found to have significant eelgrass loss based upon the degree of historic loss or recent declining trends accounting for natural variability. One region, Great Bay, was found to be threatened for significant eelgrass loss. Impairments for biological integrity (Env-Ws 1703.19) will be added to the State of New Hampshire 2008 Section 303(d) List for these regions. For four tributaries, DES determined that there should also be impairments for nitrogen per the narrative standard, Env-Ws 1703.14. In these four assessment units, there were impairments for chlorophyll-a, which is a primary symptom of excessive nitrogen in estuarine waters. The assessment methodology and results were peer-reviewed by national and regional experts in this field.

## Introduction

On March 24, 2008, the Department of Environmental Services (DES) received comments from the Conservation Law Foundation (CLF) on the State of New Hampshire's Draft 2008 Section 303(d) List. CLF's comments included the following:

(a) Significant eelgrass declines in the Piscataqua River and Little Bay demonstrate that these waters are impaired (or threatened).

(b) Eelgrass declines within Great Bay, particularly in light of system-wide eelgrass declines and nitrogen loading trends, demonstrate that Great Bay is an impaired (or threatened) water body.

(c) Eelgrass declines within the Squamscott, Lamprey, and Oyster Rivers, particularly in light of system-wide eelgrass declines and nitrogen loading trends, demonstrate that these waters are impaired (or threatened).

CLF contends that the loss of eelgrass constitutes a violation of Env-Ws 1703.19 (Biological and Aquatic Community Integrity) and that the major cause of impairment should be identified as excessive nitrogen loading and that, as such, these assessment units should also be listed as impaired for Env-Ws 1703.14 (narrative nutrient criteria). CLF further requests that because of potential light attenuation impacts, DES should also consider identifying suspended solids as an additional potential cause.

CLF provided a number of sources of data on eelgrass and estuarine water quality to support their comments. The primary data source was the State of the Estuaries Report (NHEP, 2006) from the New Hampshire Estuaries Project (NHEP). CLF also cited reports from Dr. Fred Short from the University of New Hampshire (UNH).

The eelgrass data were not included in the Draft Section 303(d) List because DES had not established a methodology with numeric thresholds for determining attainment of the aquatic life use based on changes in eelgrass habitat. In response to the comments from CLF, DES has researched this question, focusing on four main points.

- The regulatory authority under New Hampshire law by which DES can consider eelgrass habitat loss to be a water quality standard violation.
- Precedents by other states for placing estuaries on 303(d) lists based on eelgrass loss.
- An assessment methodology for eelgrass habitat data that is based on sound scientific principles and is transferable to other biological data.
- A methodology for using the narrative nutrient standard (Env-Ws 1703.14) to determine nitrogen impairments in tidal waters.

## Regulatory Authority

Regulatory authority to consider eelgrass habitat loss to be a water quality violation would be governed by the narrative water quality standard for biological and aquatic community integrity, Env-Ws 1703.19. This regulation states:

> (a) The surface waters shall support and maintain a balanced, integrated, and adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of similar natural habitats of a region.
> (b) Differences from naturally occurring conditions shall be limited to non-detrimental differences in community structure and function.

Eelgrass (*Zostera marina*) is the base of the estuarine food web in the Great Bay Estuary. Healthy eelgrass beds filter water and stabilize sediments (Short and Short, 1984) and provide habitat for fish and shellfish (Duarte, 2001; Heck et al., 2003). While eelgrass is only one species in the estuarine community, the presence of eelgrass is critical for the survival of many species. Maintenance of eelgrass habitat should be considered critical in order to "maintain a balanced, integrated, and adaptive community of organisms". Loss of eelgrass habitat would change the species composition of the estuary resulting in a detrimental difference in community structure and function. In particular, if eelgrass habitat is lost, the estuary will likely be colonized by macroalgae species which do not provide the same habitat functions as eelgrass (Short et al., 1995; Hauxwell et al., 2003; McGlathery et al, 2007). Therefore, DES believes that significant losses of eelgrass habitat would not meet the narrative standard of Env-Ws 1703.19 and create a water quality standard violation for biological integrity.

Eelgrass is sensitive to water clarity (Short et al., 1995). Cultural eutrophication from excess nitrogen, and suspended sediments in estuaries cause phytoplankton blooms, periphyton growth on eelgrass leaves, and light attenuation from non-algal particles (Short et al., 1995; Hauxwell et al., 2003; McGlathery et al, 2007). DES has not developed numeric criteria for the protection of eelgrass for nitrogen or suspended solids. For nitrogen, DES can use the narrative standard for nutrients, Env-Ws 1703.14, to evaluate impairments. The narrative standard for estuarine waters, which are Class B, states:

> (b) Class B waters shall contain no phosphorus or nitrogen in such concentrations that would impair any existing or designated uses, unless naturally occurring.

Until numeric criteria are available, DES must interpret the narrative standard using a weight-of-evidence approach. DES does not have water quality criteria for suspended solids. Therefore, development of impairment assessment methodology for this parameter was not pursued.

The NHEP Technical Advisory Committee is leading an effort to develop numeric nutrient criteria for nitrogen and suspended solids for the protection of eelgrass as the main indicator of aquatic life health in the Great Bay Estuary. The committee hopes to produce recommendations by the end of 2008.

**Precedents from Other States**

DES contacted the other coastal states in New England for their policies on assessing eelgrass loss in terms of water quality standards. One New England state has made impairment decisions for estuaries based on eelgrass habitat loss. The Massachusetts Department of Environmental Protection (MA DEP) considers an estuary to be impaired if there has been a significant eelgrass loss based on the best professional judgment of the assessor (MA DEP, 2007). MA DEP has not established numeric thresholds for significant eelgrass loss. In the Massachusetts approach, eelgrass habitat maps from as far back as 1951 are compared to more recent maps. If the eelgrass habitat loss is easily noticeable to the assessor, MA DEP will consider that estuary to be impaired for eelgrass loss. MA DEP began this practice for the 2006 assessment cycle. Eelgrass assessments are made for estuaries being studied by the Massachusetts Estuaries Project for which there are numeric nutrient criteria as well as for other estuaries for which both historic and current eelgrass data are available but numeric nutrient criteria have not been established. If there is a pattern of loss and there is a weight of evidence that the loss is due to nutrients, the water body segment is listed as impaired by excess nutrients. The weight of evidence approach includes additional data indicating low dissolved oxygen, high phytoplankton chlorophyll *a,* high nitrogen concentrations, and/or organically enriched benthic habitat. If there are no additional data or information available for the "weight of evidence" approach, the assessment staff determine that the water body segment impairment is habitat alteration. Therefore, there is a precedent within New England for states to add assessment units to their 303(d) lists for significant eelgrass loss and to consider the cause of the impairment to be nitrogen without having numeric nutrient criteria.

**New Hampshire Assessment Methodology**

DES uses a standardized approach to assessments to ensure that impairment decisions are made with credible indicators and use support criteria. This standardized approach is described in the DES Comprehensive Assessment and Listing Methodology or CALM (NH DES, 2008). The CALM for the 2008 303(d) list does not contain indicators or use support criteria for eelgrass. Therefore, DES developed a peer-reviewed methodology to use indicators and use support criteria for eelgrass, which is based on sound scientific principles and is equally credible to the indicators already in the CALM.

*Eelgrass Indicator*

There are three indicators of eelgrass habitat in the Great Bay Estuary:

(1) Synoptic surveys of eelgrass cover using aerial imagery. Dr. Fred Short at UNH has completed these surveys for at least portions of the Great Bay Estuary every year from 1986 to 2005. The eelgrass cover maps are ground truthed by annual boat visits to sites in the estuary. The advantage of this data source is that it is collected using standardized procedures that are published in the scientific literature (Short and Burdick, 1996) and an approved Quality Assurance Project Plan. The current survey results can be readily

compared to historic information on eelgrass presence between 1948 and 1981 which was compiled by The Nature Conservancy for the Great Bay Estuarine Restoration Compendium (Odell et al., 2006). The NHEP uses this information as an environmental indicator in its State of the Estuaries Report. The deadline for data submittals for the 2008 Section 303(d) List was December 2007. The most recent data on eelgrass in the Great Bay Estuary that were submitted by the deadline are from 2005. Maps of eelgrass cover in 2006 and 2007 have been or will be generated in 2008. These data will be considered for the 2010 Section 303(d) List.

(2) Estimates of eelgrass biomass throughout the Great Bay Estuary. These estimates are made from the synoptic survey data for cover and estimates of eelgrass density. The advantage of this data source is that it provides information on changes between healthy "dense" eelgrass beds and less healthy "sparse" beds. The disadvantage of this data source is that the error in the biomass estimates is larger than for the eelgrass cover indicator. The magnitude of this error has not yet been quantified. The NHEP uses this information as a supporting variable in its State of the Estuaries Report.

(3) Time series studies of eelgrass cover, biomass, and other metrics at specific locations over multiple years. Dr. Fred Short maintains research sites in the Lower Piscataqua River and Little Bay where he has monitored eelgrass habitat intensively over multiple years. The advantage of this data source is that more detailed and accurate information is available for the sites being studied. The disadvantage of this data source is that the results may only be representative of the areas being studied, not the whole estuary.

Based on the advantages and disadvantages of the various data sources above, DES feels that eelgrass cover (1) is an appropriate indicator for water quality impairment determinations. This indicator is collected using accepted and standardized protocols and is ground truthed annually. Current eelgrass cover data can also be compared to maps of historic eelgrass cover (compiled from various sources from 1948 to 1981) to determine long-term habitat losses. MA DEP has set a precedent for making 303(d) impairments using loss of eelgrass cover. While eelgrass biomass estimates (2) are useful as a supporting variable, DES, at this time, believes that this data source is too uncertain to be appropriate as a water quality criterion. DES has requested information from UNH to determine the magnitude of error associated with the biomass calculations. Should the error be less than expected, DES will reconsider its position on the use of biomass as an indicator in the future. Similarly, the time series studies (3) provide useful information but do not represent a large enough area to be used as a water quality criterion. Loss of eelgrass at one location may be offset by gains in some other location. Therefore, it is more appropriate to use total eelgrass cover as the indicator for the assessment.

*Use Support Criteria for Eelgrass Indicator*

When setting use support criteria in the CALM, DES aims to satisfy several goals: consistency with water quality standards; adherence to sound scientific and statistical principles; and consistency between different indicators and water body types. After a review of the available data and the manner in which it is being assessed by MA DEP, DES considers two methods to be appropriate for assessing eelgrass cover data.

(1) If there are reliable historic and current maps of eelgrass cover for an area, DES will use the percent decline from the historic level to determine impairments. A region will be considered to have significant eelgrass loss if the change from historic levels is >20%. This threshold value was determined from natural variability observed in recent eelgrass cover in Great Bay, which will be discussed in the following section. A higher threshold is not needed to account for error in the maps of historic eelgrass populations, because these maps likely underestimate eelgrass coverage during pristine conditions (see chronology of eelgrass changes in the Results and Discussion section). To avoid spurious impairments from one year of data, the median eelgrass cover from the last three years of data (in this case, 2003-2005) will be compared to the historic eelgrass cover. The historic eelgrass cover will be the maximum cover observed in the assessment zone from any one of the historic maps of eelgrass distribution.

(2) If sufficient data from annual surveys are available, DES will evaluate recent trends in the eelgrass cover indicator. Trends will be evaluated using linear regression of eelgrass cover in a zone versus year. The assessment zone will be considered to have significant eelgrass loss if there is a statistically significant ($p<0.05$), decreasing trend that shows a loss of 20% of the resource with 95% confidence (i.e., the $95^{th}$ percentile upper confidence limit of the regression for the most recent date is less than 20% of the maximum value of the cover over the time series). Statistical procedures for estimating prediction intervals for individual estimates from Helsel and Hirsh (1992) will be used. DES selected 20% as the threshold for "significant loss" based on the natural variability in eelgrass cover that has been observed in Great Bay. For the period between 1990 and 1999, eelgrass cover in Great Bay was relatively healthy and stable. The relative standard deviation of the eelgrass cover during this period was 6.5%. Assuming that the variability in eelgrass cover in Great Bay is representative of other locations, DES chose three relative standard deviations (3 x 6.5 = 20%) as an appropriate threshold for non-random change from reference conditions.

DES will consider a zone to be impaired if either of the two methods indicates significant eelgrass loss. In the EPA Assessment Database, impairments due to significant eelgrass loss will be coded as "Estuarine Bioassessments". For assessment zones with significant eelgrass loss, DES will review available records for dredging and mooring fields to identify potential impacts to eelgrass from these activities.

*Use Support Criteria for Nutrients*

The estuarine eutrophication model used by the National Oceanic and Atmospheric Administration relates external nutrient inputs to primary and secondary symptoms of eutrophication (Bricker et al., 2007). Elevated chlorophyll-a concentrations and proliferation of macroalgae are primary symptoms of eutrophication, while low dissolved oxygen, loss of submerged aquatic vegetation (e.g., eelgrass), and harmful algal blooms are secondary symptoms. This approach is consistent with the conceptual model of coastal eutrophication presented by Cloern (2001). Therefore, the most direct link between nutrient inputs to an estuary and eutrophic effects is for chlorophyll-a concentrations in the water and macroalgae growth.

DES evaluates chlorophyll-a concentrations in the estuary to determine support of the primary contact recreation designated use. More than 1,800 chlorophyll-a results from tidal waters were evaluated for the 2008 Section 303(d) List. Assessment units were considered to be impaired if more than ten percent of the chlorophyll-a samples in the assessment unit had concentrations higher than 20 ug/L, or if any two readings within an assessment unit exceeded 40 ug/L (NH DES, 2008). The tidal portions of four tributaries to the Great Bay Estuary were listed as impaired for chlorophyll-a in the draft 2008 Section 303(d) List for New Hampshire: the Squamscott River, Lamprey River, Oyster River, and the Salmon Falls River.

Several studies of macroalgae were completed in the Great Bay Estuary in the 1980s. Mathieson and Hehre (1986) documented the distribution of different macroalgae species throughout the tidal shoreline of New Hampshire, including the Isles of Shoals. Chock and Mathieson (1983) and Hardwick-Witman and Mathieson (1983) studied the species composition at particular locations in the estuary. These studies provide a baseline macroalgae species in the estuary. There have been reports of increases in the abundance of different species of nuisance macroalgae by researchers at UNH, but the studies from the 1980s have not been repeated to document the changes. It is not possible to determine impairments of designated uses or water quality standards based on the available data. In 2008, the NHEP received a grant from EPA to use hyperspectral imagery to quantify nuisance macroalgal cover (multiple *Ulva* species, *Gracilaria* [e.g. *G. tikvahiae*], epiphytic red algae [e.g., ceramialean red algae] and detached/entangled *Chaetomorpha* populations) using a standard, synoptic method. Once this study is completed, it may be possible to determine trends in macroalgae and to use this as an indicator of impairment in future assessments.

The primary symptoms of eutrophication are useful as a means to detect eutrophication before secondary symptoms develop. Phytoplankton blooms (as measured by chlorophyll-a concentrations) subsequently lead to low dissolved oxygen due to respiration of organic matter (Cloern, 2001). Cultural eutrophication from increased nitrogen loads to estuaries has been shown to be a major cause of seagrass disappearance worldwide (Burkholder et al., 2007; Short and Wyliie-Escheverria, 1996). Excess nitrogen contributes to eelgrass loss by promoting the proliferation of epiphytes and ephemeral macroalgal species on and around seagrasses and by increasing phytoplankton blooms which decrease water clarity (Short et al., 1995; Hauxwell et al., 2001; Hauxwell et al., 2003). However, eelgrass can be lost due to other factors such as disease (Muehlstein et al., 1991), sedimentation, and construction of boat moorings, docks or other structures.

Therefore, for the 2008 Section 303(d) List, DES will consider estuarine assessment units to be impaired for nutrients per Env-Ws 1703.14 if there is an impairment for one of the primary symptoms of eutrophication. A quantitative assessment methodology is only available for chlorophyll-a concentrations in water. The impairments will be specifically for nitrogen because nitrogen is the limiting nutrient in estuaries (Howarth and Marino, 2006).

**Results and Discussion**

DES applied the assessment methodology to the eelgrass cover data for all sections of the Great Bay Estuary. Historical eelgrass cover maps were available from the Great Bay Estuarine Restoration Compendium (Odell et al., 2006) for all areas except the upper reaches of the Piscataqua River, Portsmouth Harbor and Little Harbor. Recent eelgrass cover maps are available for all areas between 1996 and 2005. For the Great Bay, Lamprey River, Squamscott River, and Winnicut River, eelgrass cover has been mapped annually since 1986. Eelgrass is not known to have been present in the Cocheco or Salmon Falls Rivers. These tidal tributaries were only evaluated for nitrogen impairments.

DES has 43 assessment units to cover the Great Bay Estuary that are coincident with the National Shellfish Sanitation Program growing areas. Great Bay itself consists of five different assessment units. In terms of eelgrass habitat it makes sense to evaluate eelgrass cover on aggregates of assessment units covering contiguous areas in order to reduce variability from small shifts in the locations of eelgrass beds. Therefore, DES aggregated the eelgrass cover data into thirteen areas: Winnicut River, Squamscott River, Lamprey River, Oyster River, Bellamy River, Cocheco River, Salmon Falls River, Great Bay, Little Bay, Upper Piscataqua River, Lower Piscataqua River, Portsmouth Harbor/Little Harbor, and Sagamore Creek. The assessment units associated with each of these areas are shown in Table 1. For the Piscataqua River and Portsmouth Harbor zones, the eelgrass cover on both the New Hampshire and Maine sides of the river were included in the totals. Eelgrass in the tidal creeks along the Maine side of the Piscataqua River was not included in the totals. The boundaries of each of the aggregated assessment zones are shown in Figure 1.

Information on the historic distribution of eelgrass cover is available from local maps and the scientific literature. Each of the data sources for the historic distribution of eelgrass are discussed in the following approximate chronology.

> The **pre-colonial distribution** of eelgrass cover in the Great Bay Estuary is unknown. In Buzzards Bay, the coverage of eelgrass in 1600 was estimated to be at least two times greater than the coverage in 1985 (Costa, 2003).
>
> In **1931-1932**, there was a massive die off of eelgrass in both North America and Europe due to 'wasting disease' caused by an infestation of the slime mold, *Labryinthula zostera* (Godet et al., 2008). Nearly all of the eelgrass beds along the east coast of the United States were lost during this outbreak. Beds in low salinity areas (e.g., tributaries) survived and helped to repopulate the coasts (Short et al., 1986). Jackson (1944) reported that the loss of eelgrass in the Great Bay

Estuary released large quantities of silt into the water and affected shellfish, fish, and waterfowl populations.

In **1948**, S. Bradley Krochmal completed a survey of eelgrass in the Great Bay Estuary and its tributaries for a University of New Hampshire M. Sc. thesis on smelt populations (Krochmal, 1949). Aerial photography was not used to map the eelgrass beds. The thesis does not explicitly state the methods used but it is presumed that shore and boat surveys were employed based upon the text.

In 1948, eelgrass populations were just beginning to recover from the 1931 wasting disease outbreak. Costa (2003) reported that the greatest rates of eelgrass recovery in Buzzards Bay occurred in the 1950s and 1960s. Eelgrass beds in France had hardly recovered by the 1950s (Godet et al., 2008). Therefore, the distribution of eelgrass in the Great Bay Estuary in 1948 represents a population in recovery. Much of the eelgrass was concentrated in the low salinity areas in the tidal tributaries, which is expected because the beds in low salinity areas survived the wasting disease. Regarding eelgrass in Great Bay, Krochmal (1949) states, "*Zostera* can be found only on the side sheltered from the prevailing northwesterly winds. The best development is found at the mouths of the Exeter, Lamprey, and Oyster Rivers."

The thesis contains a carefully drawn 1:64,000 scale map of eelgrass presence. Eelgrass presence on the map is denoted by three different density symbols, "P", "S", and "C". The density code "P" is for "isolated patches" of eelgrass. Eelgrass densities of "S" ("scattered") and "C"("common") refer to eelgrass cover greater than or equal to 25 percent of the substrate. The lowest density of eelgrass that is mapped with current methods using aerial photography is 10 to 30 percent cover of substrate. Therefore, to be reasonably consistent with current methods, only the eelgrass beds mapped in the "scattered" or "common" density codes will be used for comparisons to current data.

The boundaries of the eelgrass beds were digitized by The Nature Conservancy by creating polygons that surround groups of the same density symbols on the map. Because the bed boundaries were not actually shown on the map, the polygons created through the digitizing process should be considered approximate. Moreover, with a 1:64,000 map, the width of a line on the page covers approximately 100 feet of actual land surface. Digitizing this scale map introduces additional uncertainty in the area estimates for typical eelgrass beds on the order of 10 to 20 percent.

The map shows the complete extent of eelgrass in the Winnicut, Squamscott, Lamprey, Oyster Rivers, Great Bay and Little Bay. The map also covers the lower part of the Bellamy River and the lower part of the Upper Piscataqua River. In addition to the map, the thesis contains narrative summaries of conditions in the Cocheco River, Salmon Falls River, and Piscataqua River. The author makes frequent references to discharges of raw sewage and industrial wastes to the rivers. Therefore, conditions during this mapping period were far from pristine.

In **1962**, the Maine Geologic Survey mapped eelgrass beds on the Maine side of the Piscataqua River as part of the Coastal Maine Geologic Environment survey (ME DEP, 1962). The beds were mapped from aerial photography and checked by field visits to some sites. This survey covered a relatively small portion of the Great Bay Estuary. However, the eelgrass beds on the Maine side of the river were not mapped by any other sources until 1996. Therefore, this historic dataset provides useful information.

In **1980-1981**, the New Hampshire Fish and Game Department completed an inventory of natural resources in the Great Bay Estuary (NH FGD, 1981). Eelgrass populations in the Great Bay, Little Bay, and portions of the Piscataqua River were assessed using boat and diver surveys. The surveys did not cover any of the tidal tributaries to Great Bay or Little Bay.

The inventory was completed in response to the "T/V New Concord" oil spill in 1979 which released 25,000 gallons of No.6 fuel oil into the estuary. In Buzzards Bay, the eelgrass populations completed their recovery from the 1931 wasting disease outbreak in the 1980s (Costa, 2003). If the trajectory of recovery in Great Bay was similar, the distribution of eelgrass in 1980-1981 is useful for documenting the recolonization of eelgrass in Great Bay, Little Bay, and the Piscataqua River. Eelgrass was largely absent from these areas in the 1948 survey.

The boundaries of the eelgrass beds were drawn on NOAA charts and then represented on a small scale map in the report (1:64,000). As with the 1948 dataset, digitizing from a map of this scale introduces error on the scale of 10-20% in area estimates for typical size eelgrass beds. The uncertainty from transferring eelgrass bed boundaries from the NOAA charts to the report map is unknown.

In **1984**, there was a recurrence of wasting disease in the Great Bay Estuary. The disease virtually eliminated the eelgrass beds in Little Bay and the Piscataqua River (Short et al., 1986). Paradoxically, the distribution of eelgrass in Great Bay increased in 1984 relative to 1981. The 1984 map was created from aerial photography and ground truth surveys by the University of New Hampshire. This map has not been digitized and, therefore, could not be used in this analysis.

In **1988-1989**, eelgrass populations in the Great Bay Estuary were again decimated due to an infestation of wasting disease (Muehlstein et al., 1991). The coverage of eelgrass in the Great Bay fell to 15 percent of normal levels (NHEP, 2006). By 1990, the eelgrass cover in Great Bay had rebounded to pre-infestation levels.

In **1995**, a small wasting disease outbreak decreased the biomass of eelgrass in the Great Bay (NHEP, 2006).

The datasets from 1948, 1962, and 1980-1981 were collected before the current monitoring program using aerial photography began in 1986. Therefore, these datasets are considered to be "historic". However, the preceding chronology shows that none of the historic data sources represent pristine, pre-colonial distribution of eelgrass in the Great Bay Estuary. The eelgrass populations in the estuary have been nearly wiped out by wasting disease on several occasions, most notably in 1931. The historic maps from 1948, 1962, and 1980-1981 illustrate the eelgrass cover in various stages of recovery from the 1931 wasting disease pandemic and impacts due to discharges of untreated sewage, industrial waste, and oil. Therefore, the three maps of historic eelgrass beds should be considered to represent the minimal extent of eelgrass historically.

Figure 2 shows the eelgrass beds mapped by each of the historical data sources. Figure 3 shows the presence of eelgrass from the most recent (2005) survey. The acreage of eelgrass cover in each zone over time is summarized in Table 2. The results for each zone are discussed below.

*Winnicut River*

The historic maps of eelgrass do not show eelgrass cover in the Winnicut River. Linear regression of eelgrass cover from 1990 to 2005 detected a significant decreasing trend at the 0.05 significance level (Figure 4). The trend indicates that at least 48% of the eelgrass cover in this assessment unit was lost as of 2005. The trend was evaluated for the 1990-2005 period because the eelgrass populations in the whole estuary were devastated in 1988-1989 due to an infestation of the slime mold, *Labryinthula zostera*, commonly called "wasting disease" (Muehlstein et al., 1991). Including data from before 1990 would have prevented detection of any trends since the wasting disease episode. Per the assessment methodology, the Winnicut River should be considered impaired for significant eelgrass loss. The cause of the eelgrass loss is unknown. Dredging is not a possible cause as there are no records of major dredging operations in Winnicut River (USACE, 2005). There are no major mooring fields in this assessment zone. There were insufficient data to determine if there were any chlorophyll-a violations in this zone. Since there are no known chlorophyll-a impairments in this zone, an impairment for nutrients per Env 1703.14 is not justified.

*Squamscott River*

The historic maps of eelgrass in the Squamscott River show 42.1 acres of habitat in 1948. Median eelgrass cover for the 2003-2005 period was 0 acres. Therefore, 100% of the eelgrass cover in this area has been lost. The cause of the eelgrass loss is unknown. Dredging is not a possible cause as the last channel dredge occurred in 1911 (USACE, 2005). There are no major mooring fields in this assessment zone. The Squamscott River is also impaired for chlorophyll-a. Seven of the 91 chlorophyll-a samples in this assessment zone were greater than the water quality criterion for primary contact recreation (20 ug/L). Three of these samples had a chlorophyll-a concentration greater than 40 ug/L (Magnitude of Exceedence criterion). Per the assessment methodology, the Squamscott River should be considered impaired for significant eelgrass loss and nutrients (nitrogen).

*Lamprey River*

The historic maps of eelgrass in the Lamprey River show 53.4 acres of habitat in 1948. Median eelgrass cover for the 2003-2005 period was 0 acres. Therefore, 100% of the eelgrass cover in this area has been lost. The cause of the eelgrass loss is unknown. Dredging is not a possible cause as the last channel dredge occurred in 1903 (USACE, 2005). There are no major mooring fields in this assessment zone. The Lamprey River is also impaired for chlorophyll-a. Three of the 110 chlorophyll-a samples in this assessment zone were greater than the water quality criterion for primary contact recreation (20 ug/L). Two of these samples had a chlorophyll-a concentration greater than 40 ug/L (Magnitude of Exceedence criterion). Per the assessment methodology, the Lamprey River should be considered impaired for significant eelgrass loss and nutrients (nitrogen).

*Oyster River*

The historic maps of eelgrass in the Oyster River show 182.5 acres of habitat in 1948. Median eelgrass cover for the 2003-2005 period was 0 acres. Therefore, 100% of the eelgrass cover in this area has been lost. The cause of the eelgrass loss is unknown. Dredging is not a possible cause as the channel has not been dredged (PDA, 2006). There are only a few small mooring fields in this assessment zone. There is also a chlorophyll-a impairment in the Oyster River. Nine of the 98 chlorophyll-a samples in this assessment zone were greater than the water quality criterion for primary contact recreation (20 ug/L). Six of these samples had a chlorophyll-a concentration greater than 40 ug/L (Magnitude of Exceedence criterion). Per the assessment methodology, this assessment unit should be considered impaired for significant eelgrass loss and nutrients (nitrogen).

*Bellamy River*

The historic maps of eelgrass in the Bellamy River show 66.9 acres of habitat in 1948 and 36.0 acres in 1980-1981. Median eelgrass cover for the 2003-2005 period was 0 acres. Therefore, 100% of the eelgrass cover in this area has been lost. The cause of the eelgrass loss is unknown. Dredging is not a possible cause as the last channel dredge occurred in 1896 (USACE, 2005). There are only a few small mooring fields in this assessment zone. Per the assessment methodology, the Bellamy River should be considered impaired for significant eelgrass loss. Available chlorophyll-a data indicate compliance with the chlorophyll-a criterion in this zone. Since there are no chlorophyll-a impairments in this zone, an impairment for nutrients per Env 1703.14 is not justified.

*Great Bay*

The historic maps of eelgrass in the Great Bay show 263.9 acres of habitat in 1948 and 1217.4 acres in 1980-1981. Median eelgrass cover for the 2003-2005 period was 2,043.3 acres. Therefore, the eelgrass cover in this area has expanded relative to the historic data sources; the change relative to the pre-colonial distribution of eelgrass is unknown. Linear regression of eelgrass cover from 1990 to 2005 did not detect a significant trend at the 0.05 significance level. The trend was evaluated for the 1990-2005 period because the eelgrass populations in the whole estuary were devastated in 1988-1989 due to an infestation of the slime mold, *Labryinthula zostera*, commonly called "wasting disease" (Muehlstein et al., 1991). Therefore, per the assessment methodology, Great Bay should not be considered impaired for significant eelgrass loss. Available chlorophyll-a data indicate compliance with the chlorophyll-a criterion in this zone. Since there are no chlorophyll-a impairments in this zone, an impairment for nutrients per Env 1703.14 is not justified.

The Clean Water Act allows for water bodies to be listed as "threatened," which generally means that the listing agency has cause to believe that the water body may well be impaired by the next listing cycle. Preliminary data for eelgrass in 2006 and 2007 in this assessment zone indicate a downward trend since 2005. This trend may be sufficient to result in significant eelgrass loss for the 2010 303(d) List. Therefore, the Great Bay should be listed as "threatened" on the 2008 303(d) List. An additional reason to consider the eelgrass habitat in the Great Bay to be threatened is the absence of eelgrass from the tributaries which served as refuges during past wasting disease outbreaks.

*Little Bay*

The historic maps of eelgrass in the Little Bay show 76.5 acres of habitat in 1948 and 408.7 acres in 1980-1981. Median eelgrass cover for the 2003-2005 period was 14.2 acres. Therefore, 97% of the eelgrass cover from 1980-1981 in this area has been lost. The cause of the eelgrass loss is unknown. Short et al. (1986) attributed the loss of eelgrass in Little Bay between 1981 and 1984 to a wasting disease outbreak. Dredging is not a possible cause as major dredging has not occurred in this assessment zone (USACE, 2005). There are several large mooring fields in this assessment zone. The mooring fields near Dover Point and the Bellamy River seem to overlap with potential and current eelgrass habitat. Per the assessment methodology, Little Bay should be considered impaired for significant eelgrass loss. Available chlorophyll-a data indicate compliance with the chlorophyll-a criterion in this zone. Since there are no chlorophyll-a impairments in this zone, an impairment for nutrients per Env 1703.14 is not justified.

*Upper Piscataqua River*

The historic maps of eelgrass in the Upper Piscataqua River show 62.0 acres of habitat on the New Hampshire side of the river in 1948, 17.7 acres on the Maine side of the river in 1962, and 42.2 acres on the New Hampshire side in 1980-1981. Combining the acreages from the New Hampshire and Maine sides of the river in 1948 and 1962, respectively, the historic coverage of eelgrass in this zone was 79.7 acres. Median eelgrass cover for the 2003-2005 period was 0.7 acres. Therefore, 99% of the eelgrass cover in this area has been lost. The cause of the eelgrass loss is unknown. Short et al. (1986) attributed the loss of eelgrass in the Piscataqua River between 1981 and 1984 to a wasting disease outbreak. Dredging is not a possible cause as major dredging has not occurred in this assessment zone (USACE, 2005). There are several large mooring fields in this assessment zone that seem to overlap with potential eelgrass habitat. Per the assessment methodology, the Upper Piscataqua River should be considered impaired for significant eelgrass loss. Available chlorophyll-a data indicate compliance with the chlorophyll-a criterion. Since there are no chlorophyll-a impairments in this zone, an impairment for nutrients per Env 1703.14 is not justified.

*Lower Piscataqua River*

The historic maps of eelgrass in the Lower Piscataqua River show 41.9 acres of habitat on the Maine side of the river in 1962 and 86.6 acres of habitat on the New Hampshire side in 1980-1981. Combining the acreages from the Maine and New Hampshire sides of the river in 1962 and 1980-1981, respectively, the historic coverage of eelgrass in this zone was 128.4 acres. Median eelgrass cover for the 2003-2005 period was 24.2 acres. Therefore, 81% of the eelgrass cover in this area has been lost. The cause of the eelgrass loss is unknown. Short et al. (1986) attributed the loss of eelgrass in the Piscataqua River between 1981 and 1984 to a wasting disease outbreak. Significant dredging operations have occurred in this assessment zone between 1956 and 2000 (USACE, 2005). This assessment zone is used frequently by large ships. There are several large mooring fields in this assessment zone that seem to overlap with potential and current eelgrass habitat. Per the assessment methodology, the Lower Piscataqua River should be considered impaired for significant eelgrass loss. Available chlorophyll-a data indicate compliance with the chlorophyll-a criterion. Since there are no chlorophyll-a impairments in this zone, an impairment for nutrients per Env 1703.14 is not justified.

*Portsmouth Harbor and Little Harbor*

The historic maps of eelgrass do not cover Portsmouth Harbor and Little Harbor. Comparisons between historic and current eelgrass cover were not possible. Linear regression of eelgrass cover from 1996 to 2005 did not detect a significant decreasing trend at the 0.05 significance level. Per the assessment methodology, this assessment unit should not be considered impaired for significant eelgrass loss. Available chlorophyll-a data indicate compliance with the chlorophyll-a criterion. Since there are no chlorophyll-a impairments in this zone, an impairment for nutrients per Env 1703.14 is not justified.

*Sagamore Creek*

The historic maps of eelgrass do not cover Sagamore Creek. Comparisons between historic and current eelgrass cover were not possible. Linear regression of eelgrass cover from 1996 to 2005 did not detect a significant decreasing trend at the 0.05 significance level. Per the assessment methodology, this assessment unit should not be considered impaired for significant eelgrass loss. There are insufficient data to determine if there are any chlorophyll-a violations in this zone. Since there are no known chlorophyll-a impairments in this zone, an impairment for nutrients per Env 1703.14 is not justified.

*Cocheco River*

Eelgrass is not known to have been present in the Cocheco River. The historic sources did not map and current eelgrass maps do not show eelgrass in this zone. Available chlorophyll-a data indicate compliance with the chlorophyll-a criterion. Since there are no chlorophyll-a impairments in this zone, an impairment for nutrients per Env 1703.14 is not justified.

*Salmon Falls River*

Eelgrass is not known to have been present in the Salmon Falls River. The historic sources did not map and current eelgrass maps do not show eelgrass in this zone. However, the Salmon Falls River is impaired for chlorophyll-a. Six of the 52 chlorophyll-a samples in this assessment zone were greater than the water quality criterion for primary contact recreation (20 ug/L). None of the samples had chlorophyll-a concentrations greater than 40 ug/L (Magnitude of Exceedence criterion). Per the assessment methodology, the Salmon Falls River should be considered impaired for nutrients (nitrogen).

**Peer Review of Methodology**

*Description of the Peer Review Process*

DES organized a two step scientific peer review to validate the science and data used in this assessment methodology. First, on May 30, 2008, DES distributed a draft of the methodology to the Technical Advisory Committee for the New Hampshire Estuaries Project. This group met on June 10, 2008, to discuss the draft methodology (minutes available). DES revised the methodology based on comments received at that meeting. Second, on June 20, 2008, DES distributed the revised methodology to local and regional experts. The peer-review panel consisted of the NHEP Technical Advisory Committee, EPA, NOAA, state governments in New England, National Estuary Programs in New England, National Estuarine Research Reserves in New England, potentially affected municipalities in New Hampshire and Maine, and interested non-governmental organizations. Comments were requested by July 11, 2008. On July 2, 2008, DES staff met with representatives from potentially affected municipalities to review the proposal and answer questions.

*Peer Review Comments and DES Responses*

DES received comments from the following organizations or individuals:

1. Joe Costa, Buzzards Bay National Estuary Program
2. Steve Halterman, Massachusetts Department of Environmental Protection
3. Kathy Mills, Great Bay National Estuarine Research Reserve
4. Jim Latimer, U.S. Environmental Protection Agency
5. Phil Colarusso, U.S. Environmental Protection Agency
6. Pete Richardson, Watershed resident
7. Dave Cedarholm, Town of Durham
8. Tom Irwin, Conservation Law Foundation

9. Russell Dean and Jennifer Perry, Town of Exeter
10. Ray Konisky, The Nature Conservancy
11. Chris Nash, DES Shellfish Program
12. John Bohenko, City of Portsmouth
13. Tim Visel, Sound School Regional Vocational Aquaculture Center

DES paraphrased the comments *that suggested changes to the methodology* from each letter, grouped the comments by subject area, and provided responses in the paragraphs below. Numbers at the end of each comment correspond to the list of people above and denote which person provided the comment. Comments that supported the proposed methodology or suggested editorial changes have not been summarized, although these comments were reviewed and considered by DES staff.

<u>Massachusetts DEP Methodology</u>

- The MA DEP approach to assessing eelgrass loss was incorrectly represented. If there is a pattern of loss and there is a weight of evidence that the loss is due to nutrients, the water body segment is listed as impaired by excess nutrients. The weight of evidence approach includes additional data indicating low dissolved oxygen, high phytoplankton chlorophyll *a,* high nitrogen concentrations, and/or organically enriched benthic habitat. If there are no additional data/information available for the "weight of evidence" approach, the assessment staff determine that the water body segment impairment is habitat alteration. MA DEP has not yet had to set a minimum "significant" loss "threshold" for this impairment category. (2, 8, 10)

Response: The citation to MA DEP method was changed.

<u>Eelgrass Biomass Indicator</u>

- The methodology should include eelgrass biomass declines as an indicator of impairment. The density of eelgrass is a significant factor in determining the health and viability of eelgrass. (5, 8)
- The variability in the eelgrass biomass indicator should be quantified. (5)

Response: DES believes that there is much more variability in the eelgrass biomass indicator than the eelgrass cover indicator. On June 20, 2008, DES requested data from UNH on variability and quality assurance protocols related to this indicator. UNH has not yet provided sufficient data to complete an assessment of the uncertainty for the biomass indicator. If the uncertainty in this indicator is acceptably low, DES will consider this indicator for the assessment methodology for the 2010 303(d) list.

<u>Threshold for Significant Eelgrass Loss</u>

- The 40% threshold for significant eelgrass loss (relative to historical eelgrass coverage) is too high. (4, 5, 8, 10)
- The threshold should be changed to 10% (8) or 20% (5, 10).
- The same threshold for eelgrass cover loss should be used whether the loss is measured relative to historic maps or relative to recent trends. (5, 8)

Response: The threshold for historical losses was changed to 20% assuming that the historical data can be validated. The threshold for significant loss relative to recent trends remained at 20% to be consistent.

Averaging Period/Anomalous Years

- DES should exclude from trend analyses any eelgrass data for years during which there is significant eelgrass loss due to events not associated with water quality conditions (e.g., wasting disease, dredging, storms). (3)
- DES should not to average eelgrass cover data for the most recent four years as a measure of "current conditions". This practice has the potential to mask significant trends, as well as to delay needed action. (8, 10)

Response: For assessing changes from historical datasets to current conditions, the averaging period was shortened to three years. The median value was used instead of the average to discount an anomalous year. For assessing trends using the current monitoring data, the data from all years were weighted equally.

Ruppia

- DES should remove *Ruppia maritima* from its calculations of eelgrass cover and biomass. *Ruppia* (widgeon grass) is an annual plant that may colonize areas of eelgrass loss; counting it as healthy eelgrass habitat is not an appropriate method. (8, 10)

Response: *Ruppia* coverage was removed from all calculations.

Eelgrass Trend Methods

- DES should focus on eelgrass trends and, when a downward trend beyond the natural variation is observed, list the assessment unit as impaired. (8)
- DES should use Great Bay eelgrass cover data for 1996 – the year with the greatest recorded acreage of cover – as the reference point for assessing more recent annual data and trends. (8)

Response: The methodology for assessing current eelgrass data already uses trends with thresholds for impairment set at levels beyond the range of natural variation. The methodology already uses the maximum eelgrass coverage within the period for trend analysis to calculate percent loss.

Data for Report

- DES should include the draft 2006 eelgrass cover data in the analysis for the 2008 303(d) list. (8)

Response: UNH has not provided a final report for the 2006 eelgrass mapping survey. DES has received raw data from 2006. However, there were questions about the polygon attributes which UNH has not answered. DES has quality assurance requirements for data used for 305(b) assessments. Given that the 2006 data would best be characterized as "draft", they do not meet these quality assurance requirements. DES will use eelgrass data from 2006 and subsequent years that are final by December 31, 2009, for the 2010 303(d) List.

Indicators for Nitrogen Impairments

- Nitrogen impairments should be assigned to an assessment unit if any of the primary or secondary eutrophication symptoms are present (e.g., low dissolved oxygen, algal blooms, increasing nitrogen concentrations, and eelgrass loss not explained by other causes). (5, 8)

Response: DES will propose numeric water quality criteria for nutrients in estuarine assessment units by December 31, 2008. This proposal will include a methodology for determining impairments when various primary or secondary symptoms of eutrophication occur. DES expects significant input from the NHEP Technical Advisory Committee and other stakeholders on this proposal. DES believes that determining nitrogen impairments based on phytoplankton blooms (chlorophyll-a) for the 2008 303(d) List is an appropriate first step in this process. The new criteria will be used for the 2010 303(d) List.

Historical Eelgrass Coverage Datasets

- Source citations for historical eelgrass maps should be added. (3, 11)
- The historical eelgrass maps should not have been aggregated. The results from each survey should be presented individually. (9, 12)
- In the summaries for each river, state a time frame for the historic maps to give readers a sense of how far back in time the comparison extends. (3)

Response: The historical maps from 1948, 1962, and 1980 have been presented separately on figures and tables. The methods and applicable area for each historical survey have been described.

"Threatened" Listing for Great Bay

- The Clean Water Act allows for water bodies to be listed as "threatened," which generally means that the listing agency has cause to believe that the water body may well be impaired by the next listing cycle. Given the preliminary eelgrass data for 2006 and 2007, DES should list the Great Bay as threatened for significant eelgrass loss on the 2008 303(d) list. (5, 8)

Response: Preliminary data for eelgrass in 2006 and 2007 indicate a downward trend since 2005. This trend may be sufficient to result in significant eelgrass loss for the 2010 303(d) List. Therefore, DES agrees that Great Bay should be listed as "threatened" on the 2008 303(d) List for Aquatic Life Use Support.

Eelgrass Loss Due to Storms or Dredging or Other Causes

- In areas where significant eelgrass loss has been observed, DES should research non-water quality factors which have the potential to destroy eelgrass beds, such as storms, dredging, erosion, docks, grazing, ice scour, wasting disease, and boat moorings. These factors may account for part or all of eelgrass loss in certain areas of the Great Bay Estuary. (7, 9, 11, 12)

Response: DES has not attributed causes for any of the impairments for significant eelgrass loss. The impairment is merely a reflection that historical eelgrass beds are no longer present or current eelgrass beds are declining faster than natural variability. DES agrees that all relevant factors should be investigated in areas with significant eelgrass loss. DES does not currently have the resources to complete these investigations but can contribute relevant data. Information on dredging and mooring fields has been added to this report to assist with the investigations.

Nitrogen Effects on Eelgrass

- Heck and Valentine (2007) argue that cascading trophic effects from the loss of predator species are equally important to nutrient inputs. (9)
- The cause and effect link between nitrogen concentrations and eelgrass has not clearly been established. (12)

Response: Eelgrass loss is not presumed to be related to nitrogen. Nitrogen impairments for the 2008 cycle are based exclusively on elevated chlorophyll-a concentrations, a primary symptom of cultural eutrophication. DES may develop a relationship between nitrogen and eelgrass as part of the numeric water quality criteria for nutrients in estuarine assessment units.

Chlorophyll-a Impairments

- Details on the chlorophyll-a concentrations in the Squamscott River, Lamprey River, Oyster River, and the Salmon Falls River should be included in the report. (7)

Response: This information has been added to the summaries for each assessment area.

Additional Research

- DES should investigate historical changes in nitrogen loading and eelgrass loss using $^{210}Pb$-dated sediment cores using USGS methods (see http://sofia.usgs.gov/workshops/waterquality/ligninphenol/). (9)

Response: It is not possible complete this research in time for the 2008 303(d) List deadline but DES will consider this idea for future studies.

## Conclusions and Recommendations

1. There has been significant eelgrass loss in several sections of the Great Bay Estuary. Due to the importance of eelgrass for the ecosystem of the estuary, the loss of this habitat constitutes a water quality impairment under Env-Ws1703.19. The specific zones and assessment units that will be considered impaired for Aquatic Life Use Support due to "Estuarine Bioassessments" in the 2008 Section 303(d) List are as follows (Figure 5):

| Assessment Zone | DES Assessment Unit ID |
|---|---|
| WINNICUT RIVER | NHEST600030904-01 |
| SQUAMSCOTT RIVER | NHEST600030806-01 |
| OYSTER RIVER | NHEST600030902-01-01 |
| | NHEST600030902-01-02 |
| | NHEST600030902-01-03 |
| | NHEST600030904-06-17 |
| BELLAMY RIVER | NHEST600030903-01-01 |
| | NHEST600030903-01-02 |
| LAMPREY RIVER | NHEST600030709-01 |
| LITTLE BAY | NHEST600030904-06-10 |
| | NHEST600030904-06-11 |
| | NHEST600030904-06-12 |
| | NHEST600030904-06-13 |
| | NHEST600030904-06-14 |
| | NHEST600030904-06-15 |
| | NHEST600030904-06-16 |
| UPPER PISCATAQUA RIVER | NHEST600031001-01-01 |
| | NHEST600031001-01-02 |
| | NHEST600031001-01-03 |
| LOWER PISCATAQUA RIVER | NHEST600031001-02 |

2. The Great Bay should be listed as threatened for significant eelgrass loss. Preliminary data for eelgrass in 2006 and 2007 in this assessment zone indicate a downward trend since 2005. This trend may be sufficient to result in significant eelgrass loss for the 2010 303(d) List. The specific zones and assessment units that will be considered threatened for Aquatic Life Use Support due to "Estuarine Bioassessments" in the 2008 Section 303(d) List are as follows (Figure 5):

| Assessment Zone | DES Assessment Unit ID |
|---|---|
| GREAT BAY | NHEST600030904-02 |
| | NHEST600030904-03 |
| | NHEST600030904-04-02 |
| | NHEST600030904-04-03 |
| | NHEST600030904-04-04 |
| | NHEST600030904-04-05 |
| | NHEST600030904-04-06 |

3. Violations of the narrative standard for nutrients, Env-Ws 1703.14, were evident in four assessment units. In these four assessment units, there were impairments for chlorophyll-a, which is a primary symptom of excessive nitrogen in estuarine waters. The specific assessment units that will be considered impaired for Aquatic Life Use Support due to nutrients (specifically nitrogen) in the 2008 Section 303(d) List are as follows (Figure 6):

| Assessment Zone | DES Assessment Unit ID |
|---|---|
| LAMPREY RIVER | NHEST600030709-01 |
| SQUAMSCOTT RIVER | NHEST600030806-01 |
| OYSTER RIVER | NHEST600030902-01-03 |
| SALMON FALLS RIVER | NHEST600030406-01 |

4. UNH should provide DES with the requested information to determine the magnitude of error associated with the biomass calculations.

5. Aerial imagery for future eelgrass cover assessments should be georectified. The older imagery should be archived at NH GRANIT to document the source of the 1986 to 2005 eelgrass cover maps.

6. Metadata records for the historic maps of eelgrass cover should be created and these data sources should be archived at NH GRANIT.

7. The NHEP Technical Advisory Committee should continue to develop numeric nutrient criteria for the Great Bay Estuary.

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## Tables

### Table 1: Assessment units in each zone of the estuary

| GROUP NAME | AUID | DESCRIPTION |
|---|---|---|
| BELLAMY RIVER | NHEST600030903-01-01 | BELLAMY RIVER NORTH |
| | NHEST600030903-01-02 | BELLAMY RIVER SOUTH |
| COCHECO RIVER | NHEST600030608-01 | COCHECO RIVER |
| GREAT BAY | NHEST600030904-02 | GREAT BAY PROHIB SZ1 |
| | NHEST600030904-03 | GREAT BAY PROHIB SZ2 |
| | NHEST600030904-04-02 | CROMMENT CREEK |
| | NHEST600030904-04-03 | PICKERING BROOK |
| | NHEST600030904-04-04 | FABYAN POINT |
| | NHEST600030904-04-05 | GREAT BAY |
| | NHEST600030904-04-06 | ADAMS POINT SOUTH |
| LAMPREY RIVER | NHEST600030709-01 | LAMPREY RIVER |
| LITTLE BAY | NHEST600030904-06-10 | ADAMS POINT MOORING FIELD SZ |
| | NHEST600030904-06-11 | ADAMS POINT TRIB |
| | NHEST600030904-06-12 | U LITTLE BAY (SOUTH) |
| | NHEST600030904-06-13 | LOWER LITTLE BAY |
| | NHEST600030904-06-14 | LOWER LITTLE BAY MARINA SZ |
| | NHEST600030904-06-15 | LOWER LITTLE BAY GENERAL SULLIVAN BRIDGE |
| | NHEST600030904-06-16 | ULITTLE BAY (NORTH) |
| LOWER PISCATAQUA RIVER | MEEST600031001-02 | LOWER PISCATAQUA RIVER |
| | NHEST600031001-02 | LOWER PISCATAQUA RIVER |
| OYSTER RIVER | NHEST600030902-01-01 | OYSTER RIVER (JOHNSON CR) |
| | NHEST600030902-01-02 | OYSTER RIVER (BUNKER CR) |
| | NHEST600030902-01-03 | OYSTER RIVER |
| | NHEST600030904-06-17 | OYSTER RIVER MOUTH |
| PORTSMOUTH HARBOR | MEEST600031001-11 | UPPER PORTSMOUTH HARBOR-ME |
| AND LITTLE HARBOR | MEOCN000000000-02-18 | ATLANTIC OCEAN |
| | NHEST600031001-05 | BACK CHANNEL |
| | NHEST600031001-08 | WENTWORTH-BY-THE-SEA |
| | NHEST600031001-11 | UPPER PORTSMOUTH HARBOR-NH |
| | NHEST600031002-02 | LITTLE HARBOR |
| | NHOCN000000000-02-18 | ATLANTIC OCEAN |
| SAGAMORE CREEK | NHEST600031001-03 | UPPER SAGAMORE CREEK |
| | NHEST600031001-04 | LOWER SAGAMORE CREEK |
| SALMON FALLS RIVER | MEEST600030406-01 | SALMON FALLS RIVER |
| | NHEST600030406-01 | SALMON FALLS RIVER |
| SQUAMSCOTT RIVER | NHEST600030806-01 | SQUAMSCOTT RIVER |
| UPPER PISCATAQUA RIVER | MEEST600031001-01-01 | UPPER PISCATAQUA RIVER |
| | MEEST600031001-01-02 | UPPER PISCATAQUA RIVER |
| | MEEST600031001-01-03 | UPPER PISCATAQUA RIVER-SOUTH-ME |
| | NHEST600031001-01-01 | UPPER PISCATAQUA RIVER-NORTH |
| | NHEST600031001-01-02 | DOVER WWTF SZ |
| | NHEST600031001-01-03 | UPPER PISCATAQUA RIVER-SOUTH |
| WINNICUT RIVER | NHEST600030904-01 | WINNICUT RIVER |

**Table 2: Eelgrass cover in different zones of the Great Bay Estuary (acres)**

| Year | Winnicut River | Squamscott River | Lamprey River | Oyster River | Bellamy River | Great Bay | Little Bay | Upper Piscataqua River* | Lower Piscataqua River* | Portsr Harbc Little |
|---|---|---|---|---|---|---|---|---|---|---|
| Pre-Colonial | ?? | ?? | ?? | ?? | ?? | ?? | ?? | ?? | ?? | ? |
| 1931-1932 | Approx. 0 | Approx. 0 | Approx. 0 | Approx. 0 | Approx. 0 | Approx. 0 | Approx. 0 | Approx. 0 | Approx. 0 | Ap |
| 1948 | 0.0 | 42.1 | 53.4 | 182.5 | 66.9 | 263.9 | 76.5 | 62.0 | a | a |
| 1962 | a | a | a | a | a | a | a | 17.7 | 41.9 | a |
| 1980-1981 | a | a | a | a | 36.0 | 1217.4 | 408.7 | 42.2 | 86.6 | a |
| 1986 | 2.2 | 0.0 | 0.0 | a | a | 2015.2 | a | a | a | a |
| 1987 | 2.2 | 0.0 | 0.0 | a | a | 1685.7 | a | a | a | a |
| 1988 | 0.0 | 0.0 | 0.0 | a | a | 1187.5 | a | a | a | a |
| 1989 | 0.0 | 0.0 | 0.0 | a | a | 312.6 | a | a | a | a |
| 1990 | 15.9 | 0.0 | 0.0 | a | a | 2024.2 | a | a | a | |
| 1991 | 23.4 | 0.0 | 0.0 | a | a | 2255.8 | a | a | a | |
| 1992 | 7.3 | 0.0 | 0.0 | a | a | 2334.4 | a | a | a | |
| 1993 | 6.9 | 0.0 | 0.0 | a | a | 2444.9 | a | a | a | |
| 1994 | 13.8 | 0.0 | 0.0 | a | a | 2434.3 | a | a | a | |
| 1995 | 7.8 | 0.0 | 0.0 | a | a | 2224.9 | a | a | a | |
| 1996 | 7.6 | 0.0 | 0.0 | 14.0 | 0.0 | 2495.4 | 32.7 | 1.6 | 31.2 | |
| 1997 | 7.5 | 0.0 | 0.0 | a | a | 2297.8 | a | a | a | |
| 1998 | 10.0 | 0.0 | 0.0 | a | a | 2387.8 | a | a | a | |
| 1999 | 10.2 | 0.0 | 0.0 | 0.0 | 0.0 | 2119.5 | 26.2 | 0.5 | 11.4 | |
| 2000 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1944.5 | 7.5 | 1.6 | 11.4 | |
| 2001 | 4.1 | 0.0 | 0.0 | 0.0 | 0.0 | 2388.2 | 10.9 | 2.0 | 20.4 | |
| 2002 | 3.5 | 0.0 | 0.0 | 0.0 | 0.0 | 1791.8 | 4.3 | 0.5 | 17.2 | |
| 2003 | 3.5 | 0.0 | 2.2 | 0.0 | 0.0 | 1620.9 | 14.2 | 2.9 | 32.1 | |
| 2004 | 4.2 | 0.0 | 0.0 | 0.0 | 0.8 | 2043.3 | 12.8 | 0.7 | 20.1 | |
| 2005 | 9.2 | 0.0 | 0.0 | 0.0 | 0.0 | 2201.2 | 25.8 | 0.4 | 24.2 | |
| 2003-2005 median | 4.2 | 0.0 | 0.0 | 0.0 | 0.0 | 2043.3 | 14.2 | 0.7 | 24.2 | |
| Percent Change: Historic to '03-'05 Med | NA | -100% | -100% | -100% | -100% | 68% | -97% | -99% | -81% | N |
| Significant Decrease Since 1990 | Yes (-48%) | NA | NA | NA | NA | No | NA | NA | NA | N |
| Listing | Impaired | Impaired | Impaired | Impaired | Impaired | None | Impaired | Impaired | Impaired | N |

a = not mapped NA = not analyzed * The 1948 and 1980-1981 surveys only covered the NH side of the river. The 1962 survey only covered t

* The acreages for 1996-2005 include beds from both the NH and ME sides of the river but not the tidal creeks along the Maine shore.

## Figures

### Figure 1: Eelgrass assessment zones

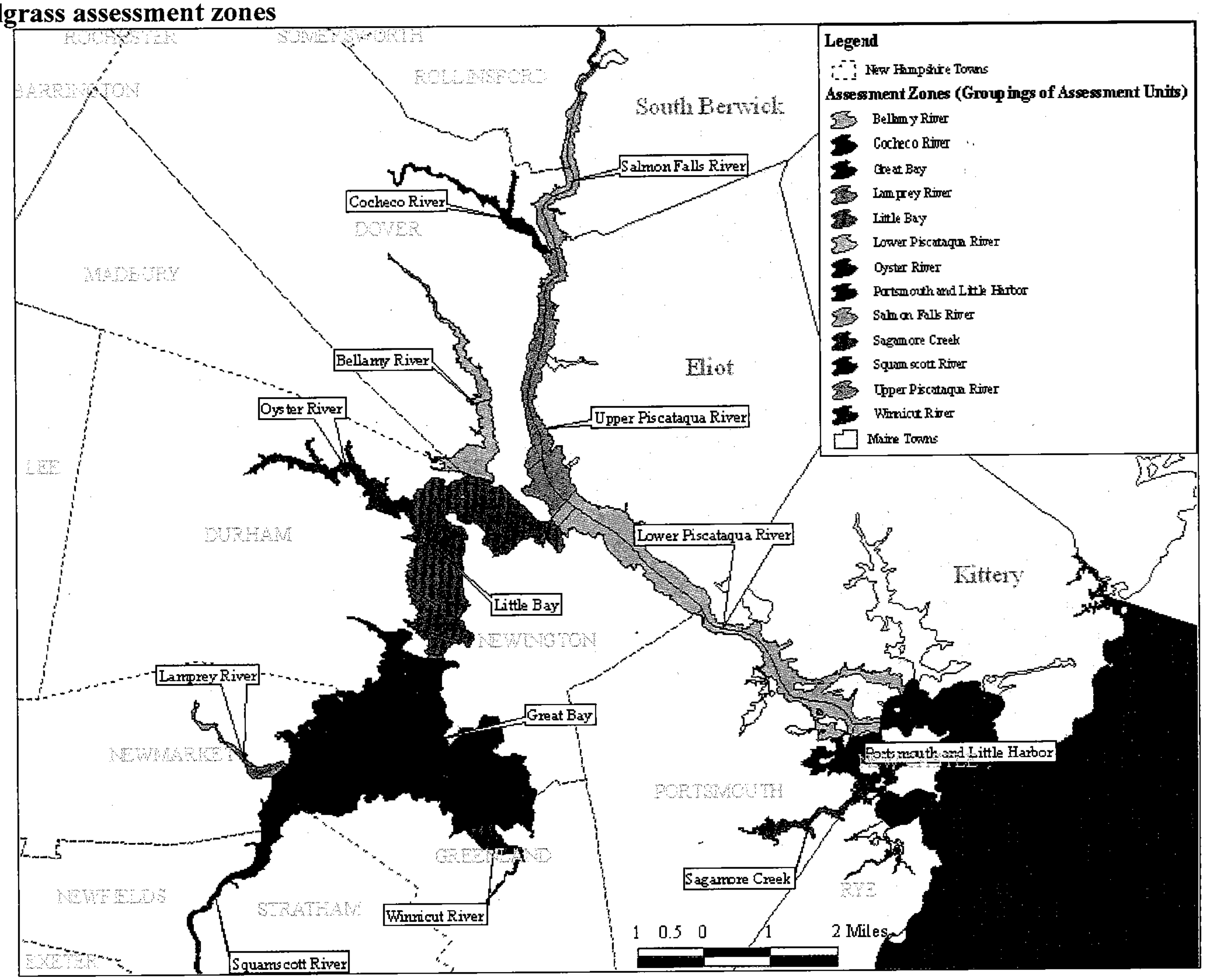

**Figure 2: Historic eelgrass cover from surveys completed between 1948 and 1981**

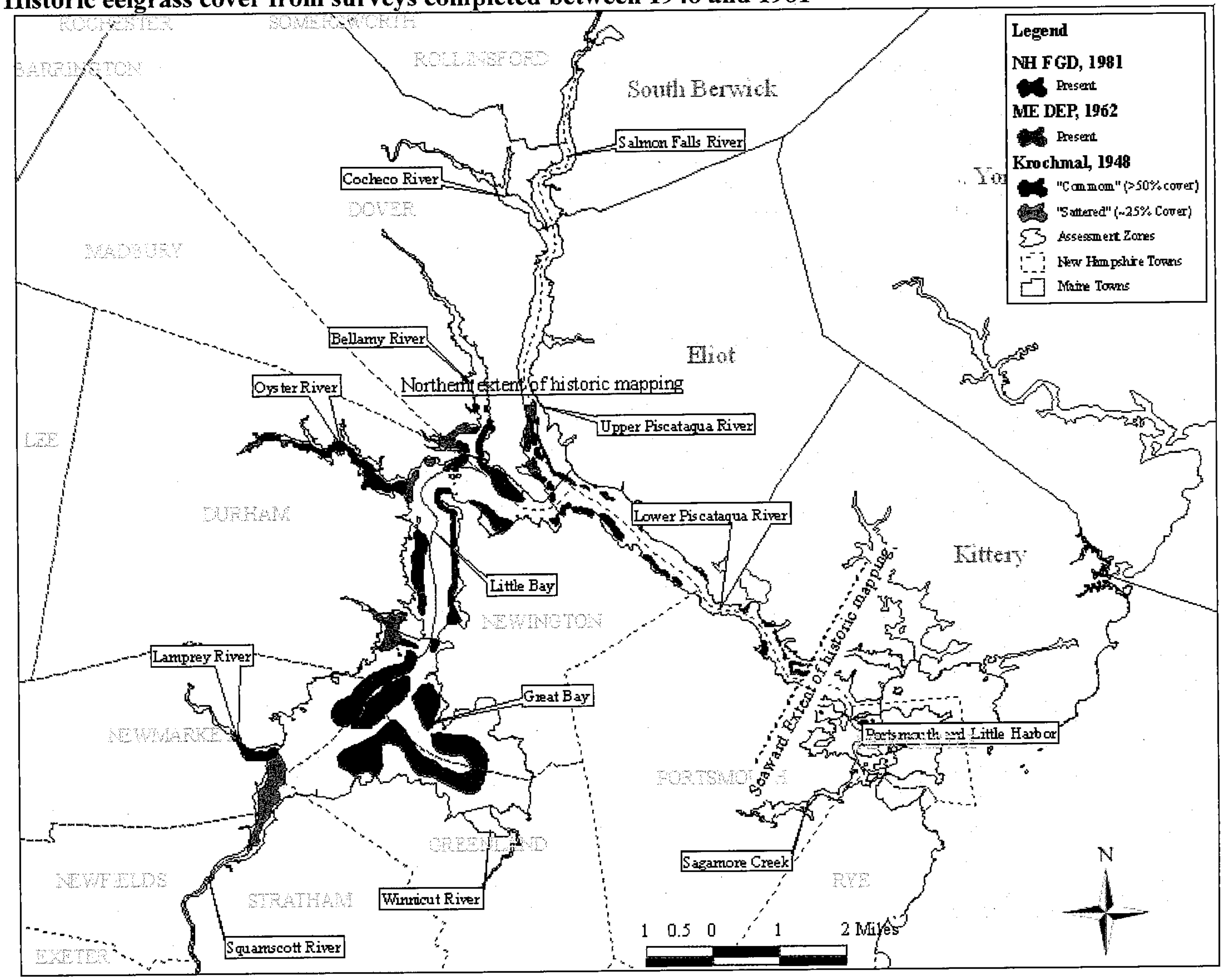

**Figure 3: Eelgrass cover in 2005**

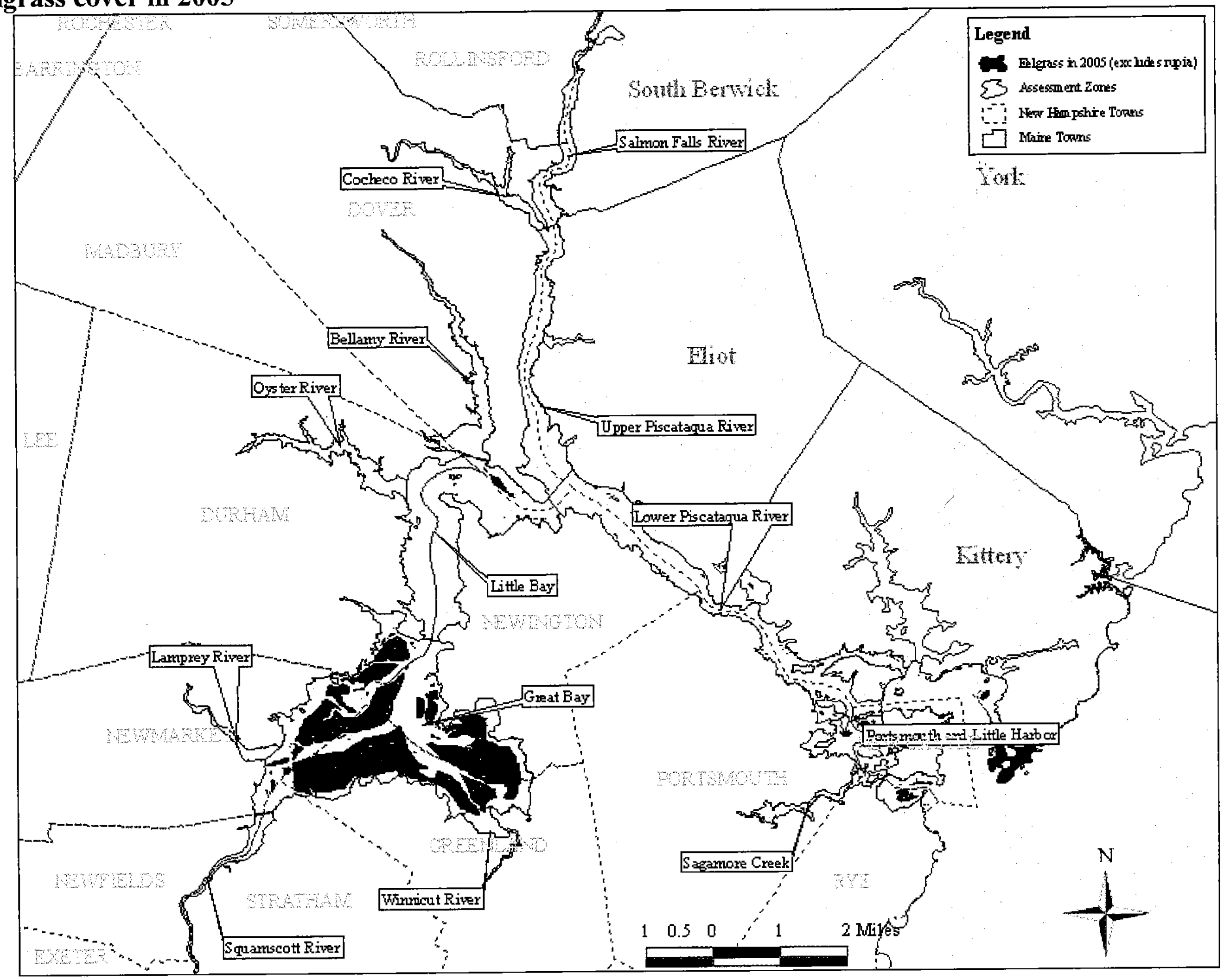

**Figure 4: Trend in eelgrass cover in the Winnicut River**

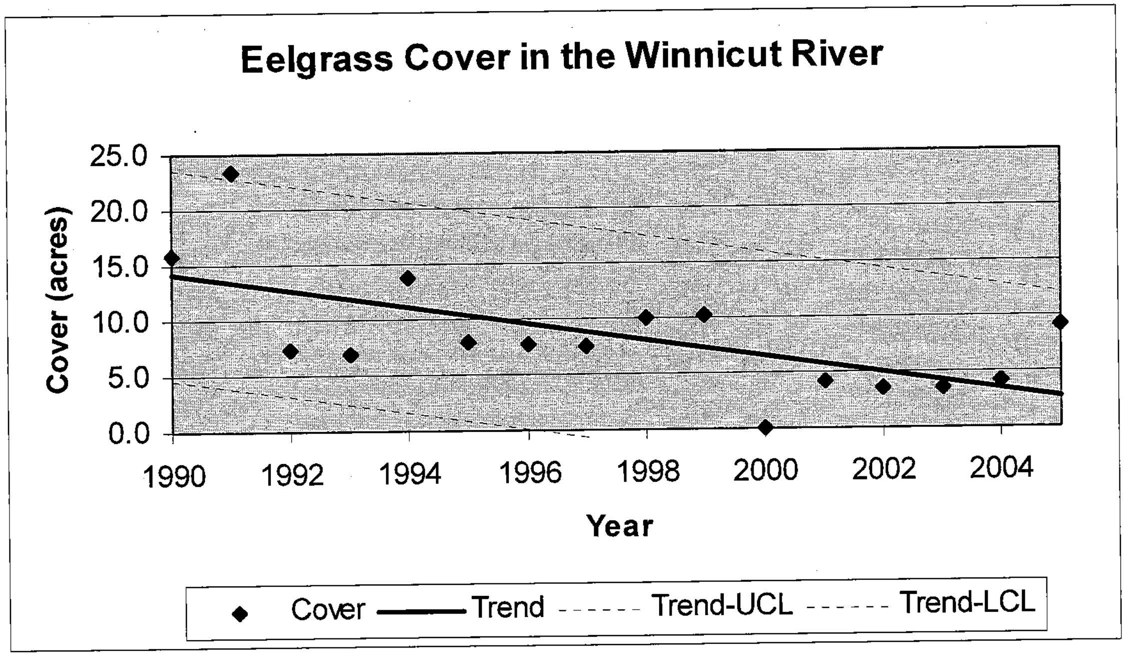

**Figure 5: Final eelgrass assessment for significant eelgrass loss**

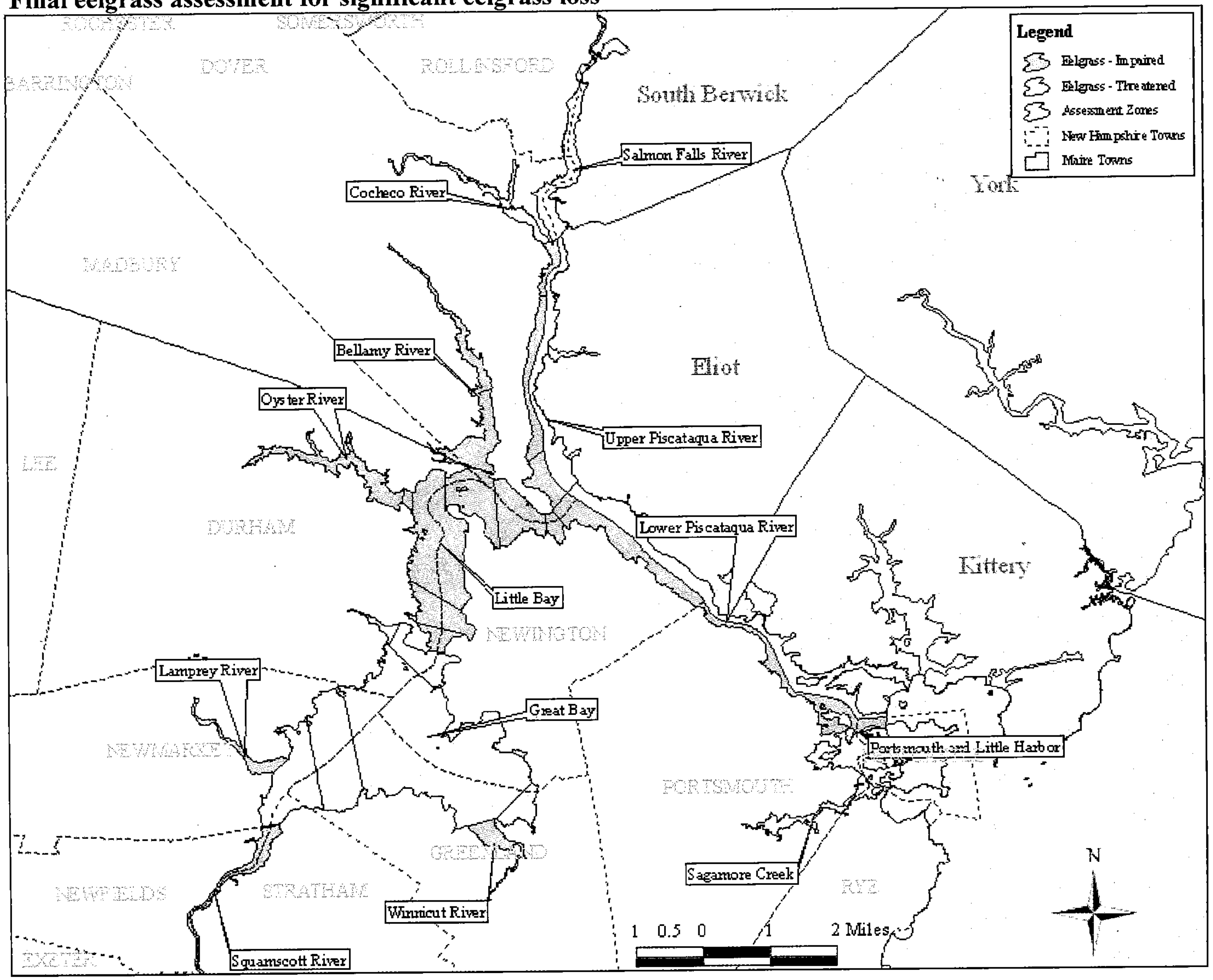

**Figure 6: Impairments for nitrogen**