6-2008

NHEP Monitoring Plan - Version 5, July 2008

Philip Trowbridge
New Hampshire Department of Environmental Services

NewHampshire EstuariesProject

2008

New Hampshire Estuaries Project

Monitoring Plan

Prepared by:

Philip Trowbridge, P.E.
NHEP Coastal Scientist
New Hampshire Department of Environmental Services

June 2008

Table of Contents

1. Introduction

The NHEP Management Plan presents a series of goals, objectives, and specific actions designed to improve, protect, and enhance the environmental quality of the state's estuaries, and outlines a process for implementing the Plan's most critical actions (NHEP, 2000; NHEP, 2005b). Measuring the effectiveness of these actions in achieving NHEP goals is an essential part of implementation that will be achieved through a suite of environmental and administrative indicators. This Monitoring Plan describes the methods and data for the indicators that will be used to answer the following question accurately and unambiguously:

- Are the goals and objectives of the Management Plan being met?

a. Program Tracking Components

The NHEP employs two tiers of program tracking. The first tier is to monitor the cumulative effect of the NHEP projects to answer the question: "Are the goals and objectives of the Management Plan being met?" The second tier is to monitor the success of individual projects to answer the question: "Are the actions in the Management Plan having the desired effect?" The first tier of this tracking is the subject of this Monitoring Plan.

Tier 1: Management Plan Effectiveness
The Management Plan is assessed using the 'measurable' objectives that were developed to evaluate NHEP progress in attaining its programmatic goals. The progress toward the objectives is measured using the environmental and administrative indicators that are the subject of this Monitoring Plan. Environmental indicators are measurements that characterize environmental or ecosystem quality. Administrative indicators describe actions undertaken by the NHEP toward achieving a specific goal or objective. The NHEP Coastal Scientist will be responsible for tracking and reporting on all environmental indicators. The NHEP Director will track all administrative indicators. The Implementation Tracking System outlined below will combine all aspects of program tracking (environmental, administrative) relative to goals and objectives.

To track overall program progress an **Implementation Tracking System** was developed by the NHEP. This includes the following components:

1. Assessments of Environmental and Administrative Indicators - The attainment of program objectives and goals is assessed every three years as part of the National Estuary Program triennial implementation review process. Environmental measurements are calculated for the environmental indicators outlined in this monitoring plan every three years. Progress made towards administrative indicators is compiled by the NHEP Director and staff.
2. A Completion Rating for all Action Plans - A completion rating for each action plan, based on the percentage of each Action Plan completed, is determined on an ongoing basis. This information is available to the public on the NHEP website, and will be presented in written progress reports, such as annual reporting to EPA and the NHEP Management Conference and the Government Performance and Results Act.

Both components are reported by the NHEP in periodic Progress Reports, the most recent completed in 2007 (NHEP 2007).

Tier 2: Specific Project Success
The NHEP funds specific projects in order to implement the Action Plans outlined in the Management Plan. The NHEP requires and tracks a list of specific deliverables for each project. These deliverables will be tracked using the NHEP project database and reported on in quarterly and annual reports. Where appropriate, NHEP requires contractors to conduct environmental monitoring to measure the effectiveness of their projects. Environmental monitoring may not be applicable with all projects; therefore environmental monitoring requirements are negotiated for

each project. The project database and the environmental monitoring are used to identify which projects are, or are not, achieving their intended outcomes. This type of project-specific monitoring is not the subject of this Monitoring Plan.

b. Indicators for the Implementation Tracking System

The NHEP Management Plan sets management goals for a series of major environmental management issues: water quality, shellfish resource, land use and habitat protection, and habitat restoration (NHEP, 2000). For each goal, measurable objectives have been developed. Each goal and objective is then linked to one or more specific actions in the Management Plan. The indicators developed for this Monitoring Plan are all related back to the NHEP management goals and their measurable objectives.

Environmental Indicators
An environmental indicator is a measure, index of measures, or model that characterizes environmental or ecosystem quality (EPA, 1999). NHEP uses environmental indicators for two purposes. First, indicators are used to report on progress toward Management Plan goals and objectives. Second, the indicators are used to report on status and trends in water quality and estuarine resources through periodic "State of the Estuaries" reports to the public. This Monitoring Plan describes how data from ongoing monitoring programs and NHEP-funded monitoring are synthesized into appropriate environmental indicators for these two applications.

The first step toward developing environmental indicators for the NHEP was to translate the goals and objectives from the Management Plan into questions that could be answered by environmental monitoring. For example, the Management Plan objective, "Achieve water quality in Great Bay and Hampton Harbor that meets shellfish harvest standards" was translated to the question, "Do NH tidal waters meet fecal coliform standards of the NSSP for approved shellfish areas?" For some management objectives, multiple monitoring questions were identified due to the complexity of the factors affecting attainment of the goal. For example, the objective related to achieving water quality that meets shellfish harvest standards depends on reducing both dry weather and wet weather pollution sources. Therefore, two additional monitoring questions were developed: "Has wet weather bacterial contamination changed significantly over time?" and "Has dry weather bacterial contamination changed significantly over time?"

The next step was to refine the monitoring questions into a suite of environmental indicators. The difference between environmental indicators and monitoring questions is that indicators have precise definitions of their hypotheses, statistical methods, measurable goals, data sources, data quality objectives, and data analysis methods. Establishing these definitions ensures that the indicators will be interpreted consistently and clearly. As indicators were proposed, they were vetted using the EPA's Office of Research and Development guidelines for ecological indicators (EPA, 1999) to determine their level of development. EPA's four criteria for ecological indicators are listed below:

- Conceptual Relevance – Relevance to both the ecological condition and a management question.
- Feasibility of Implementation – Feasibility of methods, logistics, cost, and other issues of implementation.
- Response Variability – Exhibition of significantly different responses at distinct points along a condition gradient.
- Interpretation and Utility – Ability to define the ecological condition as acceptable, marginal, or unacceptable in relation to the indicator results.

Based on the number of these criteria that were met, the indicators were classified into the following tiers:

- Environmental Indicator – A parameter that meets all the four EPA-ORD criteria for being an indicator. The measurable goals set for these indicators are tied to the management goals and objectives. For cases where "baseline" was the measurable goal, the best available baseline data were used, not just data from 2000 (the start date for NHEP Management Plan implementation).
- Supporting Variable – A parameter that meets the first three of the EPA-ORD criteria but cannot be used to interpret environmental or ecological quality independently. Some of these variables were still considered essential to the NHEP Monitoring Plan because they provided important information for interpreting trends in other indicators. The difference between supporting variables and environmental indicators is that supporting variables lack measurable goals.
- Research Indicator – A parameter that meets the first EPA-ORD criteria for being "conceptually relevant" but lacks clear methods and means of interpretation at the present time. Some research indicators were retained in the Monitoring Plan because they have the potential to address monitoring questions that are not covered by other indicators. NHEP will research these potential indicators in the out-years.

The end result of this indicator development process was a suite of environmental indicators (Environmental Indicators, Supporting Variables, and Research Indicators) to answer the monitoring questions, which in turn report on progress toward the management objectives.

Administrative Indicators

For some NHEP management objectives, it is not possible to establish environmental indicators because the objective is administrative in nature. "Administrative objectives" describe actions that should be taken rather than environmental conditions to be achieved. Therefore, NHEP's progress on these objectives will be tracked by "administrative indicators" that document the activities the NHEP or its partners have undertaken relative to the objective. For example, for the NHEP objective to "allow no new establishment or expansion of existing contamination sources … within the shoreland protection area as tracked by the Department of Environmental Services", the administrative indicator will report any violations tracked by the NHDES Comprehensive Shoreland Protection Act staff. The specific actions or variables that will be tracked for these administrative indicators are described in Chapter 3 of this Monitoring Plan.

Summary of All Indicators

Appendix A contains a comprehensive list of all the NHEP management goals and objectives and their associated monitoring questions, indicators, and measurable goals. This Monitoring Plan will report on 33 unique management objectives. The number of objectives for this plan is less than the 2004 Monitoring Plan because the NHEP will not use indicators to report on four management objectives (LND1-3, LND4-1, LND4-2, LND6-4). The administrative indicators for these objectives were similar, if not identical, to Action Plans from the Management Plan. Progress in implementing the Action Plans will be tracked in the Progress Report.

Nearly all of the management objectives (31 of 33, 94%) have been tied to at least one indicator, with a breakdown as follows: 18 of the 33 (55%) will be tracked using Environmental Indicators and 9 of the 33 (27%) will be tracked using Administrative Indicators. For the remaining 6 management objectives, research indicators or supporting variables have been identified for all but two (LND3-1, LND6-3). In total, Appendix A contains 30 Environmental Indicators, 9 Administrative Indicators, 12 Supporting Variables, and 15 Research Indicators. The reason why there are so many more entries on Appendix A than management objectives (66 vs. 33) is that many objectives have been assigned multiple indicators and supporting variables to answer multiple monitoring questions or to report on different facets of the objective.

c. Scope of This Version of the Monitoring Plan

The previous version of NHEP Monitoring Plan (version 4) was published in 2004. In 2005 and 2006, the NHEP produced a series of indicator reports (NHEP, 2005; NHEP, 2006a,b,c) for the 2006 State of the Estuaries report (NHEP, 2006d). Recommended changes to the Monitoring Plan from the indicator reports were reviewed by the Technical Advisory Committee on September 27, 2006. The NHEP proposed additional changes to the Monitoring Plan at a meeting of the Technical Advisory Committee on June 10, 2008. The major change between version 4 and version 5 of the Monitoring Plan is the elimination of indicators that have not been used for management decisions but require significant staff resources to compile. Also, the methodologies for several indicators were changed to more accurately reflect how these indicators are calculated.

In 2007, the NHEP Management Committee voted to expand the study area for the NHEP into the State of Maine. This version of the Monitoring Plan does not include changes to monitoring program which will be required with expansion to the Maine portion of the watershed.

Monitoring Plan Outline

The elements of the Monitoring Plan required by EPA are as follows (EPA, 1992):

- To define program objectives and performance criteria
- To identify testable hypotheses
- To specify monitoring variables, including sampling locations, monitoring frequency, field and laboratory methods and QA/AC procedures
- To specify data management system and statistical tests to analyze the monitoring data
- To describe the expected performance of the initial sampling design, and
- To provide a timetable for analyzing data and assessing program performance.

To provide this information, each of the **environmental indicators** from Appendix A will be presented with the following details in Chapter 2:

a. Objective
b. Measurable Goals
c. Data Quality Objectives
d. Data Analysis, Statistical Methods and Hypothesis
e. Data Source

The indicators have been grouped into the following categories:

- Water Quality Indicators
- Biological Indicators
- Conservation, Restoration, and Development Indicators

At the end of Chapter 2, the Research Indicators needing additional development are listed.

Chapter 3 summarizes the **administrative indicators** from Appendix A.

In Chapter 4, the monitoring programs in NH's estuaries are listed. The indicator descriptions will refer to these programs in the "data source" section.

Chapters 5, 6, and 7 describe the Data Management and Quality Assurance Plan, Communications Plan, and Implementation Plan, respectively.

2. Environmental Indicators

a. Water Quality Indicators

BAC1. Acre-days of Shellfish Harvest Opportunities in Estuarine Waters

a. Objective

The objective of this indicator is to report on how much of the year the shellfish beds are closed to harvesting due to high bacteria concentrations. The DES Shellfish Program measures the opportunities for shellfish harvesting using "acre-days", which is the product of the acres of shellfish growing waters and the amount of time that these waters are open for harvest. The acre-days indicator is reported as the percentage of the total possible acre-days of harvesting for which the shellfish waters are actually open. In most cases, the reason why a shellfish growing area is closed to harvesting is somehow related to poor bacterial water quality (although closures due to PSP or "red-tide" do occur). Therefore, this acre-day indicator is a good integrative measure of the degree to which water quality in the estuary is meeting fecal coliform standards for shellfish harvesting.

This indicator will answer the following monitoring question:

- Do NH tidal waters meet fecal coliform standards of the National Shellfish Sanitation Program for 'approved' shellfish areas?

This indicator will report on progress toward the following management objective:

- WQ1-1: Achieve water quality in Great Bay and Hampton Harbor that meets shellfish harvest standards by 2010.

b. Measurable Goal

The goal is to have 100% of possible acre-days in estuarine waters open for harvesting.

c. Data Quality Objectives

Shellfishing classifications and closures data should be generated by an agency that has been approved by the National Shellfish Sanitation Program.

d. Data Analysis, Statistical Methods, and Hypothesis

First, the percentage of estuarine waters in each NSSP classification category will be tabulated. The table will show the total acres of estuarine waters in New Hampshire that are managed under the NSSP. Ocean waters will not be included. The table will also show the percentage of the estuarine waters in the "approved" or "conditionally approved", "restricted" or "prohibited", "safety zone", and "unclassified" categories.

Second, the percent of all possible acre-days that are open for harvesting in New Hampshire estuarine waters will be calculated. This calculation excludes the growing areas on the Atlantic Coast because the size of these growing areas would dwarf changes in the estuarine waters. This calculation is limited to areas that are classified as "approved" or "conditionally approved" because these are the only areas that are open to recreational harvesting. The results for this indicator will be reported for five regions: Great Bay, Upper Little Bay, Lower Little Bay, Little Harbor, and Hampton/Seabrook Harbor.

The acre-day calculation by the DES Shellfish Program is a precise number. Statistical methods are not needed to compare the results to the goal. No statistical hypothesis is needed.

e. Data Source

The acre-days of harvesting potential for the estuary will be taken from the DES Shellfish Program annual report. Shellfish growing area classifications and harvest closures are determined by the DES Shellfish Program following protocols from NSSP (2005).

BAC2. Trends in Dry-Weather Bacterial Indicators Concentrations

a. Objective

The objective of this indicator is to identify long-term trends in bacteria concentrations during dry weather periods. Concentrations of the traditional bacteria indicators species (fecal coliforms, enterococci, and *Escherichia coli*) will be measured monthly at fixed stations in the estuary and tributaries. The results from dry weather samples will be analyzed for long-term trends. Trends in wet weather concentrations will be assessed in another indicator.

The trends from this indicator will answer the following monitoring question:

- Has dry-weather bacterial contamination changed significantly over time?

This indicator will be used to report on progress toward the following management objective:

- WQ1-1: Achieve water quality in Great Bay and Hampton Harbor that meets shellfish harvest standards by 2010

b. Measurable Goal and Performance Criteria

The goal is to have statistically significant decreasing trends in bacteria concentrations at stations in the tidal tributaries to the estuary. Significant trends are not expected at the stations located in the middle of Great Bay (e.g., Adams Point).

c. Data Quality Objectives

The monitoring program for this indicator should the ability to detect linear trends of 1 #/100ml/yr after five years with a Type I error of 0.1 and a Type II error of 0.2. NHEP (2002) confirmed that monthly monitoring at estuarine stations satisfies this DQO.

d. Data Analysis, Statistical Methods and Hypothesis

First, samples that were collected at low tide during dry weather will be queried from the dataset. For sites in the middle of Great Bay/Little Bay, “dry weather” samples will be those collected when there has been less than 2 inches of rain in the previous 4 days. For all other sites, a sample will be considered to be dry if there was less than 0.5 inches of rain in the previous 2 days. The two different criteria are used to identify “dry weather” samples because water quality at stations in the middle of the bay responds slower to rainfall runoff than at stations in the tidal tributaries.

Second, trends in low-tide dry weather samples will be assessed using linear regression of natural log transformed concentrations versus year. Trends will be considered significant if the coefficient of the year variable was significant at the $p<0.05$ level. The percent change in concentrations will be calculated following Helsel and Hirsch (1992). Specifically, the coefficient of the year variable, b1, will be converted to a percent change per year by $(e^{b1}-1)*100$. The overall change over the period of record will be determined from the percent change per year and a first order differential equation. Trend analysis will not be completed unless at least 5 years of data are available for a site. The trend results for each parameter at each station will be tabulated and plotted on a map of the estuary to illustrate spatial patterns.

e. Data Source

Data for this indicator will be provided by the UNH Tidal Water Quality Monitoring Program.

BAC4. Tidal Bathing Beach Postings

a. Objective

The objective for this indicator is to track the number of postings at designated tidal bathing beaches in NH waters. The DES Beach Program monitors designated tidal bathing beaches along the Atlantic Coast of NH during the summer months (Memorial Day to Labor Day). If the concentrations of enterococci in the water do not meet state water quality standards for designated tidal beaches (104 Enterococci/100 ml in a single sample), DES recommends that an advisory be posted at the beach. Therefore, the number of postings at tidal beaches should be a good indicator of bacterial water quality at the beaches.

This indicator will answer the following monitoring question:

- Do NH tidal waters, including swimming beaches, meet the state enterococci standards?

This indicator will report on progress toward the following management objective(s):

- WQ1-2: Minimize beach closures due to failure to meet water quality standards for tidal waters

b. Measurable Goal

The goal is to have 0 postings at the tidal bathing beaches over the summer season.

c. Data Quality Objectives

The DES Beach Program reviews the water quality results for each beach and makes a determination whether or not to recommend posting. The data quality objectives for the water quality monitoring are set by the DES Beach Program. So long as these DQO are met, the DQO for this indicator will be considered met.

d. Data Analysis, Statistical Methods, and Hypothesis

The advisories at all tidal beaches managed by the DES Beach Program will be queried from the DES Beach Database. In 2006, there were 16 beaches in the program but this number can change over time. Only advisories for contamination will be included. The number of advisories will be summed for each year and then compared to the goal of zero. The number of postings is an exact measure. Therefore, statistical methods are not needed to compare the indicator to the goal. No hypothesis will be tested.

e. Data Source

Records of beach postings will be obtained from the DES Beach Program.

BAC6. Violations of Enterococci Standard in Estuarine Waters

a. Objective

The objective of this indicator is to track the violations of the state swimming standards for estuarine waters. Every two years, DES assesses the quality of the State's surface waters in the §305(b) Report to Congress. A standardized assessment methodology, based on the state laws and regulations, is used to determine areas of the estuaries that do not meet standards. The state water quality standard for swimming in tidal waters (RSA 485-A:8) is based on the concentrations of enterococci bacteria in the water. Therefore, this indicator will answer the following monitoring question:

- Do NH tidal waters, including swimming beaches, meet the state enterococci standards?

This indicator will report on progress toward the following management objective(s):

- WQ-1-2: Minimize beach closures due to failure to meet water quality standards for tidal waters.

b. Measurable Goal

The goal is to have 0% of the estuarine area in violation of RSA 485-A:8.

c. Data Quality Objectives

The sampling design should be capable of estimating the percentage of the estuary where enterococcus concentrations are greater than state standards with an uncertainty of +/- 10%. The DES Comprehensive Assessment and Listing Methodology (NHDES, 2008, http://www.des.nh.gov/wmb/swqa/calm.html) contains the data quality objectives for data used in the DES assessments. So long as these DQO are met and the DQO for the uncertainty is met, the DQO for this indicator will be considered met.

d. Data Analysis, Statistical Methods, and Hypothesis

This indicator will be calculated from probability-based monitoring data. The statistic will be the proportion of estuarine waters that violate RSA 485-A:8, specifically enterococcus concentrations greater than the single sample maximum criterion (>104 cts/100ml). The proportion will be calculated by adding the weighting factors for stations in violation of the standard and then dividing by the sum of the weighting factors for all the stations in the design (including unsampled stations). Ninety-five percent confidence interval half-widths (CI) on the estimated proportion will be generated using the equation for the error in a mean proportion from a binomial distribution (Triola, 1998),

$$CI = t \cdot \sqrt{\frac{p \cdot (1-p)}{n}}$$

where t is the value of the *t* distribution for the sample size for a 0.05 significance level with a two tailed test, *p* is the proportion of the estuary exceeding a threshold, and *n* is the number of samples in the design. These confidence limits will be used to test the hypothesis that the estimated percentage is significantly different from zero.

If there is more than one value for a parameter from the chosen station visit (e.g., from multiple depths or field duplicates), the result with the maximum value will be used. For results reported as below detection limits, the method detection limit will be substituted as the value prior to making comparisons to water quality standards. For the water quality parameters involved with this assessment, the method detection limits were always less than the water quality standard.

e. Data Source

Data for this indicator will be provided by the National Coastal Assessment Probability Based Monitoring Program and the New Hampshire Estuaries Probability Based Monitoring.

BAC7. Freshwater Bathing Beach Postings

a. Objective

The objective for this indicator is to track the number of postings at designated freshwater bathing beaches in NH's coastal watershed. The DES Beach Program monitors designated freshwater bathing beaches in the coastal watershed during the summer months (Memorial Day to Labor Day). If the concentrations of *E. coli* in the water do not meet state water quality standards for designated freshwater beaches (88 *E.coli*/100ml in a single sample), DES recommends that an advisory be posted at the beach. Therefore, the number of postings at freshwater beaches should be a good indicator of bacterial water quality at the beaches.

This indicator will answer the following monitoring question:

- Do NH designated freshwater beaches in the coastal watershed meet the state *E. coli* standards?

This indicator will report on progress toward the following management objective(s):

- WQ1-3: Increase the water bodies in NH's coastal watershed designated "swimmable" by achieving state water quality standards.

b. Measurable Goal

The goal is to have 0 postings at the freshwater bathing beaches in the coastal watershed over the summer season.

c. Data Quality Objectives

The DES Beach Program reviews the water quality results for each beach and makes a determination whether or not to recommend posting. The data quality objectives for the water quality monitoring are set by the DES Beach Program. So long as these DQO are met, the DQO for this indicator will be considered met.

d. Data Analysis, Statistical Methods, and Hypothesis

The advisories at freshwater beaches managed by the DES Beach Program in the coastal watershed will be queried from the DES Beach Database. Only advisories for contamination will be included. The number of advisories will be summed for each year and then compared to the goal of zero. The number of postings is an exact measure. Therefore, statistical methods are not needed to compare the indicator to the goal. No hypothesis will be tested.

e. Data Source

Records of beach postings will be obtained from the DES Beach Program.

TOX1. Shellfish Tissue Concentrations Relative to FDA Standards

a. Objectives

The objective of this indicator is to determine whether shellfish from the estuaries contain toxic contaminants in their tissues at concentrations greater than FDA guidance values, and, if they do, how much of the estuary is affected by this contamination. For this indicator, the concentrations of toxic contaminants in mussel, oyster, and clam tissue from various locations in the estuary will be measured. The chemicals that will be measured in the tissue are: heavy metals, PCBs, PAHs, and chlorinated pesticides. The results from this indicator will partially answer the following monitoring question:

- Are shellfish, lobsters, finfish, and other seafood species from NH coastal waters fit for human consumption?

The indicator will report on progress toward the following management objective:

- WQ-2-1A: Reduce toxic contaminants levels in indicator species so that no levels persist or accumulate according to FDA guideline levels.

b. Measurable Goal

The goal is for 0% of sampling stations in the estuary to have mean shellfish tissue concentrations greater than the following FDA guidance values (converted to dry-weight assuming 85% of the wet-weight is due to water in the tissue):

Parameter	Threshold (wet-weight)	Threshold (dry-weight)	Units
Mercury	1	6.7	mg/kg
Lead	1.7	11.5	mg/kg
Cadmium	3.7	25	mg/kg
Chromium	13	87	mg/kg
Nickel	80	533	mg/kg
Mirex	100	700	ug/kg
Alpha-Chlordane	300	2000	ug/kg
Dieldrin	300	2000	ug/kg
Heptachlor epoxide	300	2000	ug/kg
Aldrin	300	2000	ug/kg
Heptachlor	300	2000	ug/kg
Sum of PCBs	2000	13000	ug/kg
Sum of DDTs	5000	33000	ug/kg

Source: NSSP (2005)

c. Data Quality Objectives

The monitoring program for this indicator should have 80% power for detecting a difference of 1.0 ug/g between the mean concentration at a station and the FDA guidance value with 0.05 as the level of the test. Lead concentrations will be used to test the results against the performance criteria because historically lead has been the only compound that exceeded guidance values in shellfish tissue. NHEP (2002) demonstrated that the existing monitoring programs meet this DQO.

d. Data Analysis, Statistical Methods and Hypothesis

Each mussel tissue sample consists of four measurements from replicate subsamples. Clam and oyster samples consist of two replicate subsamples. The maximum concentration for each toxic contaminant in each tissue type will be calculated and compared to the FDA guidance values. If the maximum concentration of a contaminant is higher than the screening value, then the results from the subsamples will be averaged and the 95th percentile concentration of the mean will be estimated using a t-value of 2.776 (appropriate for a sample size of 4). Then, the mean value and the 95th percentile of the mean will be compared to the relevant FDA guidance value. Only if the lower confidence limit of the mean is greater than the FDA guidance value will

the result considered to be higher than the FDA guidance values. If a result is found to be above the FDA guidance value, then the database will be checked to determine if the result was from the most recent sample at that station.

Results from PCB, DDT, and PAH congeners will be added together separately to calculate the “Sum PCB”, “Sum DDT”, and “Sum PAH” values. Only detected congeners will be included in the sums.

FDA guidance values will be used as reference values to conform with the NHEP management objective (WQ2-1A) and NSSP guidance.

e. Data Source

The NH Gulfwatch Program will provide the data on blue mussel, oyster, and clam tissue for this indicator.

TOX8. Finfish and Lobster Edible Tissue Concentrations Relative to Risk Based Standards

a. Objectives

The objective of this indicator is to determine whether finfish and lobsters from the estuaries contain toxic contaminants in their tissues at concentrations greater than risk-based consumption limits. For this indicator, the concentrations of toxic contaminants in the edible tissues of winter flounder and lobster from various locations in the estuary will be measured. The chemicals that will be measured in the tissue are: heavy metals, PCBs, PAHs, and chlorinated pesticides. The results from this indicator will partially answer the following monitoring question:

- Are shellfish, lobsters, finfish, and other seafood species from NH coastal waters fit for human consumption?

The indicator will report on progress toward the following management objective:

- WQ-2-1A: Reduce toxic contaminants levels in indicator species so that no levels persist or accumulate according to FDA guideline levels.

b. Measurable Goal

The goal is for the average concentrations of mercury and PCBs in the edible tissues of winter flounder and lobster to be significantly less than risk based consumption limits of 0.8 ug/g dw and 40 ng/g dw, respectively. These limits are the low end of the range of concentrations for which a fish consumption limit of 4 meals per month is recommended in EPA (2000). For concentrations below these values, the recommended fish consumption limit increases to 8 meals per month, which is tantamount to no restrictions for people with a typical diet. This same approach to evaluating fish tissue concentrations was adopted in the National Coastal Condition Report II (EPA, 2005).

c. Data Quality Objectives

The monitoring programs for this indicator should be capable to detecting differences between mean concentrations in edible fish tissue of 0.4 ug/g for mercury and 20 ng/g for PCBs using a signficance level of 0.5 and with a Type II error of <0.2.

d. Data Analysis, Statistical Methods and Hypothesis

Statistical tests will be used to determine whether the mean concentration for each compound among all the fish collected in the estuary is significantly lower than the risk based consumption limits. For each compound, all the samples from the estuary will be used to compute an average and standard deviation. If necessary, the concentrations will be transformed to correct for non-normality. The mean concentration will be tested against the risk based value using a t-test or the Wilcoxon Rank Sum Test (non-parametric) with an significance level of 0.05. The specific hypothesis that will be tested is:

$$Ho: u \leq g; Ha: u > g$$

where u is the mean concentration of the contaminant and g is the risk based value.

Results from PCB congeners will be added together to calculate the “Sum PCB” values. Only detected congeners will be included in the sums.

e. Data Source

The National Coastal Assessment Probability Based Monitoring Program will provide data on winter flounder and lobster edible tissues for this indicator.

TOX3. Trends in Shellfish Tissue Contaminant Concentrations

a. Objectives

The objective of this indicator is to track the trends of concentrations of toxic contaminants in shellfish from New Hampshire's estuaries over time. In order to achieve this objective, the concentrations of toxic contaminants (metals, PCBs, PAHs, pesticides) in mussel tissue will be measured at a benchmark site in consecutive years to assess trends over time. This indicator will answer the following monitoring question:

- Have the concentrations of toxic contaminants in estuarine biota changed over time?

This indicator will report on progress toward the following management objective:

- WQ2-1A: Reduce toxic contaminants levels in indicator species so that no levels persist or accumulate according to FDA guideline levels.

b. Measurable Goal

The goal is to have no increasing trends for any toxic contaminants.

c. Data Quality Objectives

The monitoring program for this indicator should have the ability to detect linear trends over 5 years of 0.05 ug/g/yr for mercury, 1 ng/g/yr for PAHs, and 5 ng/g/yr for PCBs using a significance level of 0.1 and a type II error of 0.2 (NHEP, 2002).

d. Data Analysis, Statistical Methods and Hypothesis

Trends will be evaluated at the three benchmark sites in the estuary: MECC (Portsmouth Harbor), NHDP (Dover Point) and NHHS (Hampton-Seabrook Harbor). At each site, the four replicate results for each parameter will be regressed against the year of collection using a linear model. Linear coefficients with a probability of <0.05 of being different from zero will be considered statistically signficant.

Results from PCB, DDT, and PAH congeners will be added together separately to calculate the "Sum PCB", "Sum DDT", and "Sum PAH" values. Only detected congeners will be included in the sums.

e. Data Source

Data for this indicator will be provided by the NH Gulfwatch Program. A total of three benchmark sites will be tested annually.

TOX5. Sediment Contaminant Concentrations Relative to NOAA Guidelines

a. Objectives

The objective of this indicator is to provide information on the extent and severity of sediment contamination in the estuaries. In order to achieve this objective, the concentrations of toxic contaminants in surface sediment will be measured throughout the two estuaries. The target contaminants will be metals, PCBs, PAHs, and pesticides. This indicator will answer the following monitoring question:

- Do NH tidal sediments contain heavy metals, PCBs, PAHs, chlorinated pesticides, and other toxic contaminants that are harmful to humans, animals, plant, and other aquatic life?

This indicator will report directly on progress toward the following management objective:

- WQ-2-1C: Reduce toxic contaminants levels in sediment so that no levels persist or accumulate according to ER-M levels.

b. Measurable Goals

The goal is for 0% of estuarine area to have sediments containing one or more compounds higher than Probable Effect Concentrations (PEC) or 5 times Threshold Effect Concentrations (TEC) as defined in the DES Sediment Policy. DES uses TEC and PEC values to determine if contaminants in sediment have the potential to impact the benthic community. TEC values are screening thresholds below which adverse effects are unlikely. TECs are typically derived from studies with sensitive species in laboratory exposures. PEC values are screening thresholds above which adverse effects are likely (NHDES, 2005). This indicator had originally used NOAA's Effects Range Low (ER-L) and Effects Range Medium (ER-M) as screening values. The TEC and PEC values were adopted instead because they are a compilation of screening values from many sources, including ER-L/ER-M values. For many parameters, the TEC/PEC values are identical to ER-L/ER-M values. The TEC/PEC values are updated periodically after new studies on species toxicity have been completed.

c. Data Quality Objectives

The data quality objective for the monitoring programs and statistical methods for this indicator is an accuracy of $\pm$ 10% in estimates of the percentage of the estuary with at least one compound greater than its respective PEC value or 5 times its TEC value.

d. Data Analysis, Statistical Methods and Hypothesis

For each station, the total PAHs, total DDT, and total PCB concentrations will be calculated by summing the detected concentrations of the individual congeners. The concentrations of toxic contaminants in the sediment sample from each station will be compared to DES sediment screening values. Results reported as below detection limits will not be compared to screening values to avoid "false positives" for compounds with high method detection limits.

This indicator will be calculated from probability-based monitoring data. The statistic will be the proportion of estuarine waters where the sediment concentration of at least one compound is greater than its PEC or five times its TEC. The proportion will be calculated by adding the weighting factors for stations in violation and then dividing by the sum of the weighting factors for all the stations in the design (including unsampled stations). Ninety-five percent confidence interval half-widths (CI) on the estimated proportion will be generated using the equation for the error in a mean proportion from a binomial distribution (Triola, 1998),

$$CI = t \cdot \sqrt{\frac{p \cdot (1-p)}{n}}$$

where t is the value of the t distribution for the sample size for a 0.05 significance level with a two tailed test, p is the proportion of the estuary exceeding a threshold, and n is the number of samples in the design. These confidence limits will be used to test the hypothesis that the estimated percentage is significantly different from zero.

e. Data Source

Data for this indicator will be obtained from the National Coastal Assessment Probability Based Monitoring Program.

TOX6. Trends in Sediment Contaminant Concentrations

a. Objectives

The objective of this indicator is to track changes in toxic contaminants in sediment over time. The results will answer the following monitoring question:

- Have the concentrations of toxic contaminants in sediment significantly changed over time?

This indicator will provide supporting information on the following management objective:

- WQ2-1C: Reduce toxic contaminants levels in sediment so that no levels persist or accumulate according to ER-M levels.

b. Measurable Goals

The goal is to have no increasing trends for any toxic contaminants.

c. Data Quality Objectives

The dataset used to evaluate TOX5 will also be used for this indicator. Therefore, data quality objectives for this indicator are the same as for TOX5.

d. Data Analysis, Statistical Methods and Hypothesis

The proportion of the estuary above the limits set in TOX5 from 2000-2001 will be compared with proportion from the 2002-2005 period and any subsequent probabilistic survey. The 95 percent confidence interval half-widths (CI) on the estimated proportions from the two periods will be compared. If the confidence intervals of the two proportions overlap, the conclusion will be no trend between the periods. If the confidence intervals do not overlap, the conclusion will be that there has been a statistically significant change in sediment concentrations between the periods.

e. Data Source

Data for this indicator will be provided by the National Coastal Assessment Probability Based Monitoring Program.

TOX7. Benthic Community Impacts due to Sediment Contamination

a. Objective

The objective of this indicator is to provide information on whether the benthic community has been impacted by toxic contaminants in the sediments. In order to achieve this objective, the abundance of benthic species will be enumerated and whole sediment toxicity tests will be performed throughout the estuaries. This indicator will answer the following monitoring question:

- Is there evidence of toxic effects of contaminants in estuarine biota?

This indicator will report directly on progress toward the following management objective:

- WQ-2-1C: Reduce toxic contaminants levels in sediment so that no levels persist or accumulate according to ER-M levels.

b. Measurable Goals

The goal is for 0% of estuarine area to have apparent impacts to the benthic community due to sediment contamination.

c. Data Quality Objectives

The data quality objective for the monitoring programs and statistical methods for this indicator is an accuracy of ± 10% in estimates of the percentage of the estuary with benthic community impacts.

d. Data Analysis, Statistical Methods and Hypothesis

Sediment impairments will be determined using a combination of sediment chemistry, sediment toxicity and benthic community data. Sediment chemistry data will be evaluated using screening values from the DES Sediment Policy (TOX5, NHDES, 2005). Sediment toxicity will be assessed using the test organism *Ampelisca abdita,* a small shrimp-like amphipod. A sediment sample will be considered to have significant toxicity if the percent survival of organisms exposed to the sediment is statistically lower (<80%) compared to an unexposed control group. Benthic community data will be evaluated using a benthic index for Gulf of Maine sediments developed by the Atlantic Ecology Division of EPA. The index will be calculated as follows:

> **Benthic Index** = 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

A sediment sample will be considered impaired if the concentration of a chemical is higher than a Probable Effect Concentration or five times a Threshold Effect Concentration screening value (see indicator TOX5) and either the sediment toxicity test indicates significant toxicity or the benthic index is poor. A sample will be considered to be in fair condition if the sediment contamination is higher than the screening values and the benthic index is fair. The remaining samples will be considered to be in good condition relative to benthic community impacts.

This indicator will be calculated from probability-based monitoring data. The statistic will be the proportion of estuarine waters where impacts to the benthic invertebrate community are indicated. The proportion will be calculated by adding the weighting factors for stations in violation and then dividing by the sum of the weighting factors for all the stations in the design (including unsampled stations). Ninety-five percent confidence interval half-widths (CI) on the estimated proportion will be generated using the equation for the error in a mean proportion from a binomial distribution (Triola, 1998),

$$CI = t \cdot \sqrt{\frac{p \cdot (1-p)}{n}}$$

where t is the value of the *t* distribution for the sample size for a 0.05 significance level with a two tailed test, *p* is the proportion of the estuary exceeding a threshold, and *n* is the number of samples in the design. These confidence limits will be used to test the hypothesis that the estimated percentage is significantly different from zero.

e. Data Source

Data for this indicator will be obtained from the National Coastal Assessment Probability Based Monitoring Program.

NUT1. Annual Load of Nitrogen to Great Bay from WWTF and Watershed Tributaries

a. Monitoring Objectives

The objective of this indicator is to estimate the annual load of nitrogen to the Great Bay Estuary from the major tributaries and the wastewater treatment facilities (WWTF) in the coastal watershed. Concentrations of total nitrogen in freshwater tributaries and the WWTF eflluent will be combined with measurements of flow to estimate the load. Available information on atmospheric and groundwater loading of nitrogen will also be compiled. However, these components of the nitrogen budget will not be measured directly. The decision was taken because groundwater loading rates are expected to change very slowly and are difficult to measure with the precision needed to determine significant differences. Atmospheric loading rates are also difficult to measure with precision. This indicator will answer the following monitoring question:

- Has the total nitrogen load to Great Bay significantly changed over time?

This indicator will report on progress toward the following management objectives:

- WQ3-1: Maintain inorganic nutrients, nitrogen, phosphorous, and chlorophyll-a in Great Bay, Hampton Harbor, and their tributaries at 1998-2000 baseline levels.
- WQ3-2: Maintain organic nutrients in Great Bay, Hampton Harbor, and their tributaries at 1994-1996 baseline levels

b. Measurable Goals

The goal is for annual loads of total nitrogen to the Great Bay Estuary to be less than or equal to the estimated loading from 2002-2004 (1,097 tons/yr) (NHEP, 2006a; NHEP, 2006d).

c. Data Quality Objectives

The tributary loads calculated for this indicator should have an uncertainty of +/-10%. NHEP (2002) documented that a monthly monitoring schedule on each tribuatary is sufficient to meet this DQO.

c. Data Analysis, Statistical Methods and Hypothesis

Five major sources of nitrogen will be estimated for Great Bay: point source discharges from wastewater treatment facilities (WWTFs), discharge from major tributaries, direct discharges from nonpoint sources and small tributaries, atmospheric deposition and groundwater discharge. Nitrogen loads will be calculated for the Great Bay and Upper Piscataqua River portions of the entire Great Bay Estuary system. A complete analysis of nitrogen loads to the lower portion of the Piscataqua River will not be completed, although the loads from WWTFs in this area will be quantified.

Point Source Discharges from WWTFs

The total nitrogen load from each WWTF will be estimated by multiplying the average total nitrogen (TN) concentration by the annual average flow. The TN concentration should be the average of monthly measurements throughout one year. If TN concentrations are not available, total dissolved nitrogen concentrations can be used to estimate TN. TDN values will be increased by 10% for WWTFs with secondary treatment and 40% for the Portsmouth WWTF which uses advanced primary treatment (George Neill, DES, *pers. comm*.). If nitrogen data are missing, then it will be assumed that the TDN concentration is 15 mg/L, the average value for the WWTFs that were monitored in Bolster et al. (2003), or an altenative value from the 2008 NHEP program to monitor WWTF effluent. The average flow from the WWTFs will be the annual average effluent discharge rate reported by the WWTFs in their discharge monitoring reports for the year in which the TN was monitored.

Discharges from Major Tributaries

There are seven major tributaries to Great Bay and the Piscataqua River: the Winnicut, Exeter, Lamprey, Oyster, Bellamy, Cocheco and Salmon Falls rivers. The total nitrogen load from each tributary will be estimated using measurements of TN concentrations in the rivers, measurements of flow and a loading model from the U.S. Geological Survey.

Total nitrogen concentrations will be calculated by adding the results for total Kjeldahl nitrogen to nitrogen as nitrate and nitrite, adding total dissolved nitrogen and particulate nitrogen, or using direct measurements of TN if available. For non-detected samples, one-half of the reporting detection limit will be substituted for the value before addition, if appropriate. Average values will be calculated for the last three years of monitoring data.

Average daily flow in the Lamprey, Exeter, Oyster, and Cocheco rivers will be estimated from USGS stream gages 01073500, 01073587, 01073000, and 01072800, respectively. For these rivers, flow at the tributary monitoring station will be estimated by multiplying the flow at the gage by the ratio of the watershed area upstream of the gage to the watershed area upstream of the station. Flows in the Bellamy River will be estimated using area transpositions from the Oyster and Cocheco river streamgages. Specifically, the average flow per square mile at the Oyster River streamgage will be multiplied by the watershed area for the Bellamy River to obtain one estimate of the flow in the Bellamy. The average flow per square mile at the Cocheco River streamgage will also be multiplied by the Bellamy watershed area to obtain another estimate of the flow. Finally, the two estimates of flow will be averaged. Flows in the Salmon Falls River, Great Works River and Winnicut River will be estimated using area transpositions from the average flow per square mile from the Lamprey River, Cocheco River and Oyster River, respectively. The watershed areas and flow transposition factors are listed in the following table.

The TN concentration and flow measurements will be combined to estimate the TN loads using a USGS computer model: LOADEST (Runkel et al., 2004). The most recent three years of data will be used in the model. LOADEST will be allowed to select the optimal model based on the calibration dataset. Following advice from the USGS, all the parameters in the chosen model will be included, even if the coefficient is not statistically significant.

Tributary Monitoring Station	Watershed Area for Station (sq miles)	USGS Streamgage Number	Watershed Area for Streamgage (sq miles)	Flow Multipier for Transpositions	Comments
Lamprey (05-LMP)	211.56	01073500	183	1.156052	
Exeter (09-EXT)	106.92	01073587	63.5	1.683844	
Oyster River (05-OYS)	19.83	01073000	12.1	1.638450	
Cocheco (07-CCH)	175.23	01072800	85.7	2.044650	
Salmon Falls River (05-SFR)	235.00	01073500		1.284153	Cfsm transposition with Lamprey River streamgage
Bellamy (05-BLM)	27.30	01072800		0.1592940	50% of flow from cfsm transposition with Cocheco River streamgage
		01073000		1.1282227	50% of flow from cfsm transposition with Oyster River streamgage
Winnicut (02-WNC)	14.24	01073000		1.1764778	Cfsm transposition with Oyster River streamgage
Great Works River (02-GWR)	86.70	01072800		1.0116686	Cfsm transposition with Cocheco River streamgage
GB watershed area upstream of tributary monitoring stations	379.85				Lamprey, Exeter, Oyster, Bellamy, and Winnicut rivers
GB watershed area downstream of tributary monitoring stations	61.28				Land immediately surrounding Great Bay and Little Bay
GB watershed area (Total)	441.13				Does not include 11.36 sq miles covered by estuarine waters.
UPR watershed area upstream of tributary monitoring stations	496.93				Cocheco, Salmon Falls and Great Works rivers
UPR watershed area downstream of tributary monitoring stations	26.02				Land immediately surrounding the Upper Piscataqua River
UPR watershed area (Total)	522.95				Does not include 4.65 sq miles covered by estaurine waters.
Great Bay-Piscataqua River Watershed Total Area	**964.07**				Watershed outlet is the confluence of the Piscataqua River and Little Bay at Dover Point

Direct Discharges from Nonpoint Sources and Small Tributaries

The preceding table shows that between 5.0 and 13.9% of the watershed areas draining to the Great Bay and Upper Piscataqua River estuaries are downstream of the tributary monitoring stations. Therefore, non-point source TN loads from these areas will not be captured by the tributary monitoring. The non-point source TN yield (tons N/yr/sq.mile) from these small watersheds will be assumed to be equal to the average yield of the watershed upstream of the tributary monitoring station. The nonpoint source yield will be estimated by subtracting any upstream WWTF loads from the tributary loads estimated in the previous section and then dividing by the watershed area. The nitrogen yield coefficient will be taken to be the average yield observed in the eight larger tributaries (in 2002-2004 it was 0.78 tons N/year/sq. mile) (NHEP, 2006a).

Atmospheric Deposition

Wet and dry deposition of nitrogen from the atmosphere directly to estuarine waters will be estimated using the ClimCalc model from UNH's Complex Systems Research Center (Ollinger et al., 1993, http://www.pnet.sr.unh.edu/climcalc/). The deposition rate will be multiplied by the area of estuarine waters in the preceding table to estimate the annual deposition to the surface of the estuary. Loads due to atmospheric deposition on the land surface of the watershed will be

captured in the tributary loading estimates and in the direct discharges from nonpoint sources/small tributary loading estimates.

Groundwater Discharge (Great Bay only)

Groundwater discharge to the Great Bay Estuary has been estimated by Ballestero et al. (2004). The results from this report will be adopted without alteration into this indicator. The results cannot be extrapolated to any other locations. Therefore, the load from groundwater discharge to the Upper Piscataqua River Estuary will not be quantified.

Nitrogen Load Summary

The total nitrogen loads from each of the sources listed above will be combined to estimate the total load to the Great Bay and the Upper Piscataqua River Estuary. For each estuary, the individual point and non-point sources of nitrogen will be listed. For the tributaries, if there are WWTFs upstream of the monitoring station, the nitrogen loads from the WWTFs will be subtracted from the tributary load and included in the WWTF point source load so that the tributary load only represents nonpoint sources of nitrogen in the watershed. The assumption is that there is no appreciable attenuation of nitrogen loads from WWTFs in the upper watershed.

The seaward boundary for these two estuaries will be the Route 4/16 bridge at Dover Point. The choice of this boundary is somewhat arbitrary, but it is influenced by the strong, tidal currents that occur in the Lower Piscataqua River Estuary downstream of this point. Effluent discharged by WWTFs in the Lower Piscataqua River Estuary can reach the Great Bay and Upper Piscataqua River Estuaries. It will be assumed that 50% of these discharges reach the estuaries. On flood tides, most of the effluent will be carried into the Gulf of Maine.

e. Data Source

For the nitrogen load from WWTFs, flow data will be obtained from NPDES Discharge Monitoring Reports to EPA and nitrogen concentrations in WWTF effluent will be obtained from the NHEP Wastewater Effluent Monitoring Program, Bolster et al. (2003), and other relevant studies.

The loading from the tidal tributaries will be estimated from monthly (March-December) nutrient concentrations collected by the DES Ambient Rivers Monitoring Program (through 2007) and the NHEP Tidal Tributary Monitoring Program (starting in 2008) at the head of tide stations on the Winnicut, Exeter, Lamprey, Oyster, Bellamy, Cocheco, Salmon Falls, and Great Works Rivers. Flow data for the Exeter, Lamprey, Oyster, and Cocheco Rivers will be obtained from the USGS Streamflow Monitoring Program.

Atmospheric deposition of nitrogen to the bay surface will be estimated using the methods from Ollinger et al. (1993) and the most recent data from the National Atmospheric Deposition Program.

Information on groundwater loadings of nitrogen to Great Bay will be taken from Ballestero et al. (2004).

NUT2. Trends in Estuarine Nutrient Concentrations

a. Objectives

The objective of this indicator is to quantify long-term trends in nutrient concentrations (nitrogen and phosphorus) in estuarine waters. This indicator will answer the following monitoring question:

- Have levels of dissolved and particulate nitrogen and phosphorus signficantly changed over time?

This indicator will provide information regarding the following management objectives:

- WQ3-1: Maintain inorganic nutrients, nitrogen, phosphorus, and chlorophyll-a in Great Bay, Hampton Harbor, and their tributaries at 1998-2000 baseline levels.
- WQ3-2: Maintain organic nutrients in Great Bay, Hampton Harbor, and their tributaries at 1994-1996 baseline levels

b. Measurable Goals

The goal is to have no increasing trends for any nitrogen or phosphorus species.

c. Data Quality Objectives

The monitoring program for this indicator should be able to detect at 1 uM/yr change in nitrogen or phosphorus concentrations over a 5 year period using 0.10 as the level of the test with a type II error of 0.20. NHEP (2002) documented that the monthly monitoring frequency is sufficient to meet this DQO.

d. Data Analysis, Statistical Methods and Hypothesis

Trends for nitrogen and phosphorus species will be assessed at long-term trend stations with at least 5 years of monthly measurements. The parameters for trend analysis will be dissolved inorganic nitrogen, total nitrogen, and orthophosphate as well as the individual nitrogen species of nitrite+nitrite and ammonia. Results reported as “below detection level” will be excluded from the trend analysis. For calculated parameters such as dissolved inorganic nitrogen, if any of the input concentrations are “below detection level”, the calculation will not be performed. The results from high and low tides on the same day and any station replicate samples will be averaged prior to trend analysis.

Trends will be assessed using linear regression of un-transformed concentrations versus year. Trends will be considered significant if the coefficient of the year variable is significant at the $p<0.05$ level. The overall change over the period of record will be determined by calculating the value of the regression line for the first and last years of the period of record. The difference between the two values divided by the first value will be assumed to represent the average percent change over the period of record.

Longer-term trends in dissolved inorganic nitrogen and orthophosphate will be tested using historical measurements at Adams Point in Great Bay between 1974 and 1981 (Norall et al, 1982; Loder et al, 1982). The measured concentrations from 1974-1981 will be compared to the most recent 8 years of measured concentrations at this same location. Both datasets will be truncated so that they only cover full calendar years and only contain low tide samples. Non-detected results will be removed. Differences between the two datasets will be analyzed using a parametric t-test and the non-parametric Kruskall-Wallis test with $p<0.05$ as the significance level.

e. Data Source

Data for this indicator will be provided by the UNH Tidal Water Quality Monitoring Programs.

NUT3. Trends in Estuarine Particulate Concentrations

a. Objectives

The objective of this indicator is to quantify long-term trends in particulate concentrations in estuarine waters. This indicator will answer the following monitoring question:

- Have levels of phytoplankton (chlorophyll-a) in NH waters changed significantly over time?
- Have surface tidal or freshwaters shown a significant change in turbidity over time?

This indicator will provide supporting information on the following management objectives:

- WQ3-1: Maintain inorganic nutrients, nitrogen, phosphorous, and chlorophyll-a in Great Bay, Hampton Harbor, and their tributaries at 1998-2000 baseline levels.
- WQ3-2: Maintain organic nutrients in Great Bay, Hampton Harbor, and their tributaries at 1994-1996 baseline levels

b. Measurable Goals

The goal is to have no increasing trends for chlorophyll-a or total suspended solids concentrations.

c. Data Quality Objectives

The monitoring program for this indicator should be able to detect at 1 mg/l/yr change in particulate concentrations over a 5 year period using 0.10 as the level of the test with a type II error of 0.20. NHEP (2002) documented that the monthly monitoring frequency is sufficient to meet this DQO.

d. Data Analysis, Statistical Methods and Hypothesis

The parameters for trend analysis will be total suspended solids and chlorophyll-a. Data analysis for this indicator will be the same as for NUT2.

e. Data Source

Data for this indicator will be provided by the UNH Tidal Water Quality Monitoring Programs.

NUT5. Exceedences of Instantaneous Dissolved Oxygen Standard

a. Objectives

Low dissolved oxygen (DO) concentrations are a common manifestation of eutrophication. In a system as well mixed as the Great Bay, low DO events are not likely to last longer than one tidal cycle. Therefore, DO measurements taken at a high frequency by in-situ sondes deployed near the sediments in the tidal tributaries (where low DO is the most likely) have the best chance of capturing these events in the Great Bay. This indicator will partially answer the following monitoring question:

- Do any surface tidal or freshwaters show less than 75% saturation of dissolved oxygen? For what period of time?

This indicator will report on progress toward the following management objective:

- WQ3-3: Maintain dissolved oxygen levels at: >4 mg/l for tidal rivers, >6 mg/l for bays, >7 mg/l for oceanic areas.

b. Measurable Goals

The State water quality standard for dissolved oxygen (Env-Wq 1703.07) has two components: (1) the *daily average* concentration must remain above 75% saturation, and (2) the *instantaneous* dissolved oxygen concentration must remain above 5 mg/l. This indicator will track the number of exceedences of the instantaneous standard. Another indicator will track exceedences of the daily average standard. The TAC decided that it was more appropriate to use the state water quality standard for this assessment than to use the target levels set in the NHEP management objective (see WQ3-3 above). Using the state standard will maintain consistency between NHEP evaluations of dissolved oxygen and the State's 305b Report.

The goal is to have 0 days with exceedences of the instantaneous standard.

c. Data Quality Objectives

The monitoring programs for this indicator should provide instantaneous readings of dissolved oxygen with an accuracy of +/- 0.2 mg/l.

d. Data Analysis and Statistical Methods

The daily minimum dissolved oxygen concentration will be calculated for each sonde for each date with complete (i.e., 48 valid measurements) dissolved oxygen data. If the minimum value is less than 5 mg/L, then that date will be counted as a having a exceedence of the instantaneous dissolved oxygen standard. For each sonde, the number of days per year with at least one exceedence of the standard will be tabulated and compared to the goal of zero days. Inter-annual trends will be assessed qualitatively using the frequency of days with exceedences relative to the number of days with complete, valid data during July, August, and September.

For each station a graph will show the percent of each day between July 1 and September 30 with dissolved oxygen less than 5 mg/L (only calculated for days with 48 valid dissolved oxygen measurements). A second graph will show a histogram of the durations for "low DO episodes", periods when the dissolved oxygen fell below 5 mg/L. Dissolved oxygen concentrations less than 5 mg/L are not technically hypoxia but will be considered "low DO" for the purposes of discussion.

The data used for this indicator will be quality assured by staff from the Great Bay National Estuarine Research Reserve and DES. For data from 2004 and later, the dissolved oxygen measurements will be validated by pre- and post-deployment checks with an independently calibrated dissolved oxygen sensor. For earlier years, for which quality control data were not available, only measurements from the first 96 hours of the sonde deployment will be used.

e. Data Source

The Great Bay National Estuarine Research Reserve Datasonde Program and the UNH Datasonde Program will provide data for this indicator.

NUT6. Exceedences of the Daily Average Dissolved Oxygen Standard

a. Monitoring Objectives

The objective of this indicator is to estimate the number of exceedences in the estuary each year of the state water quality standard for daily average dissolved oxygen concentrations. This indicator will partially answer the following monitoring question:

- Do any surface tidal or freshwaters show less than 75% saturation of dissolved oxygen? For what period of time?
- SOE question: How often do dissolved oxygen levels in the Great Bay Estuary fall below state standards?
-

This indicator will report on progress toward the following management objective:

- WQ3-3: Maintain dissolved oxygen levels at: >4 mg/l for tidal rivers, >6 mg/l for bays, >7 mg/l for oceanic areas.

b. Measurable Goals and Performance Criteria

The State Water Quality Standard for dissolved oxygen (Env-Wq 1703.07) has two components: (1) the *daily average* concentration must remain above 75% saturation, and (2) the *instantaneous* dissolved oxygen concentration must remain above 5 mg/l. This indicator will track the number of violations of the daily-average standard. The previous indicator will track violations of the instantaneous standard.

The goal is to have 0 days with violations of the daily average standard.

c. Data Quality Objectives

The monitoring programs for this indicator should be able to detect differences of 5 units (%sat) between the daily mean concentration and the state standard (75%) with 0.05 as the level of the test and a type II error of 0.20.

d. Statistical Methods and Data Analysis

The data analysis methods for this indicator will be the same as for Indicator NUT5, except that the measurements of dissolved oxygen saturation will be averaged for each day. The average concentration will be compared to the standard of 75%. If the average concentration is less than the standard, then the day is counted as exceeding the standard.

For each sonde, the number of days per year when the daily average DO fell below the state standard will be tabulated and compared to the goal of zero days with exceedences. Inter-annual trends will be assessed qualitatively using the frequency of days with exceedences relative to the number of full days that the sonde was deployed during July, August, and September.

e. Data Source

The Great Bay National Estuarine Research Reserve Datasonde Program and the UNH Datasonde Program will provide data for this indicator.

NUT7. Trends in Biological Oxygen Demand (BOD) Loading to Great Bay

a. Objectives

One factor that can lead to hypoxia in the estuary is the BOD load from wastewater treatment facilities. This indicator will track the monthly loading from WWTF that discharge directly to the tidal waters to determine if the loads are changing over time. This indicator will answer the following monitoring question:

- Do any surface tidal or freshwaters show a significant change in BOD?

This indicator will report on progress toward the following management objective:

- WQ3-4: Maintain NPDES permit levels for BOD at wastewater facilities in the NH coastal watershed.

b. Measurable Goals

The goal is for no WWTF to have significantly increasing trends in BOD loading. This is a goal for the NHEP but it is not legally binding for WWTF operators. Many WWTF are allowed under their existing permits to discharge more BOD than they currently do. WWTF discharges cannot be required to be less than permitted levels unless the discharge can be shown to cause a water quality impact.

c. Data Quality Objectives

The loads calculated for this indicator should have an uncertainty of +/-10%.

d. Data Analysis, Statistical Methods and Hypothesis

Monthly average flow and BOD loads from WWTFs will be taken from NPDES Discharge Monitoring Reports filed by the facility. The long-term trends in monthly flow and BOD loads will be determined by Seasonal Kendall Test using $p<0.10$ as critical value and two tailed test to determine significance.

e. Data Source

Monthly average monthly BOD discharge from the WWTFs for Exeter, Newfields, Newmarket, Durham, Dover, Portsmouth, Newington, Kittery ME, and South Berwick ME will be obtained from NPDES Discharge Monitoring Reports to EPA.

NUT8. Percent of the Estuary with Chlorophyll-a Concentrations greater than State Criteria

a. Objective

The objective of this indicator is to track the spatial extent of elevated chlorophyll-a concentrations in the estuary. Chlorophyll-a is one symptom of nutrient enrichment and eutrophication. Increasing nutrient loads to the estuary may result in increasing areas of the estuary with elevated chlorophyll-a concentrations. In State §305(b) water quality assessments, chlorophyll-a concentrations greater than 20 ug/L are considered to impair swimming use in estuaries. This indicator will be used to answer the following monitoring question:

- Do any surface waters exhibit chlorophyll-a levels that do not support swimming standards?

This indicator will report on progress toward the following management objectives:

- WQ3-1: Maintain inorganic nutrients, nitrogen, phosphorous, and chlorophyll-a in Great Bay, Hampton Harbor, and their tributaries at 1998-2000 baseline levels.
- WQ3-2: Maintain organic nutrients in Great Bay, Hampton Harbor, and their tributaries at 1994-1996 baseline levels

b. Measurable Goals

The goal for this indicator is for 0% of estuarine waters to be listed in State §305(b) reports as impaired for swimming due to elevated chlorophyll-a concentrations (i.e., >20 ug/L).

c. Data Quality Objectives

The data quality objective for the monitoring programs and statistical methods for this indicator is an accuracy of $\pm$ 10% in estimates of the percentage of the estuary elevated chlorophyll-a concentrations.

d. Data Analysis, Statistical Methods and Hypothesis

This indicator will be calculated from probability-based monitoring data. The statistic will be the proportion of estuarine waters with chlorophyll-a concentrations greater than 20 ug/L. The proportion will be calculated by adding the weighting factors for stations in violation and then dividing by the sum of the weighting factors for all the stations in the design (including unsampled stations). Ninety-five percent confidence interval half-widths (CI) on the estimated proportion will be generated using the equation for the error in a mean proportion from a binomial distribution (Triola, 1998),

$$CI = t \cdot \sqrt{\frac{p \cdot (1-p)}{n}}$$

where t is the value of the *t* distribution for the sample size for a 0.05 significance level with a two tailed test, *p* is the proportion of the estuary exceeding a threshold, and *n* is the number of samples in the design. These confidence limits will be used to test the hypothesis that the estimated percentage is significantly different from zero.

e. Data Source

Data for this indicator will be provided by the National Coastal Assessment Probability Based Monitoring Program and the New Hampshire Estuaries Probability Based Monitoring Program.

b. Biological Indicators

SHL1. Area of Oyster Beds in Great Bay

a. Objective

The objective of this indicator is to track the areas of the six major oyster beds in Great Bay relative to their areas in 1997.

The monitoring question for this indicator is:

- Has the area of oyster beds in Great Bay decreased from the 1997 level?

This is directly relevant to the following management objective:

- SHL1-3: No net decrease in acreage of oyster beds from 1997 amounts for Nannie's Island, Woodman Point, Piscataqua River, Adams Point, Oyster River, Squamscott River, and Bellamy River beds

b. Measurable Goal

The goal is for each bed to at least maintain its 1997 area as reported in Langan (1997):

Oyster Bed	Size in 1997 (acres)
Nannies Island	37.3
Woodman Point	6.6
Piscataqua River	12.8
Adams Point	4.0
Oyster River	1.8
Squamscott River	1.7
Total	64.2 +/- 4

A goal has not been set for the Bellamy River bed because the TAC concluded that it was not worthwhile to monitor the this bed due to its small size.

c. Data Quality Objectives

The monitoring programs for this indicator should have an accuracy of $\pm$ 10% in the area estimate for each bed.

d. Data Analysis, Statistical Methods and Hypothesis

The specific hypothesis to be tested is:

$$Ho: a \geq g; Ha: a < g$$

where a is the sum of the areas of the major oyster beds, and g is the sum of the areas of major oyster beds from 1997. A rigorous statistical test of this hypothesis is not possible. Instead, the error bars for the area estimate will be used to establish an approximate "confidence interval" of possible values for the estimate. To estimate the uncertainty, each bed area estimate will be assumed to be accurate to +/-10%. The error in the total area of oyster beds in the estuary will be calculated by summing the root mean square of the uncertainties in each bed. If the confidence intervals of the current area and the goal do not overlap, the null hypothesis will be rejected in favor of the alternative hypothesis. If the confidence intervals overlap, the null hypothesis will not be rejected.

e. Data Source

Baseline data from 1997 on the six main oyster beds in Great Bay is provided in Langan (1997). Follow-up assessments in 2001 and 2003 were completed by NHF&G and UNH and NHF&G as part of the NHEP Oyster Bed Mapping Program (NHF&G, 2002; Grizzle et al. 2008).

SHL2. Density of Harvestable Oysters at Great Bay Beds

a. Objective

The objective of this indicator is to estimate the average density of harvestable oysters at the six major oyster beds in Great Bay.

The monitoring question for this indicator is:

- Has the density of harvestable-size oysters in Great Bay beds decreased from 1997 levels?

This indicator reports directly on the following management objective:

- SHL1-4a: No net decrease in oysters (>80 mm shell height) per square meter from 1997 amounts at Nannie's Island, Woodman Point, Piscataqua River, Adams Point, and Oyster River.

b. Measurable Goal

The goal is for each bed to maintain its 1997 density (for >80mm) as reported in Langan (1997):

Oyster Bed	1997 Density (#/sq. meter)
Nannies Island	50
Woodman Point	63
Piscataqua River	20
Adams Point	38
Oyster River	29
Squamscott River	9.3

The Squamscott River bed was not included in the management objective (SHL1-4a) but was assigned a goal because it is included in other NHEP management objectives related to oyster beds. Oyster densities were not measured at the Squamscott River bed in 1997. The value for this bed in the table above is from a 1998 survey.

c. Data Quality Objectives

The monitoring program for this indicator should have the ability to detect differences between the mean oyster density and the goal of greater than 10 #/m2 with a significance level of 0.05 and a Type II error of 0.20 (NHEP, 2002).

d. Data Analysis, Statistical Methods and Hypothesis

For each bed, the arithmetic mean and standard deviation of the number of oysters >80mm per quadrat will be calculated. The specific hypothesis that will be tested is:

$$Ho: d \geq g; Ha: d<g$$

where d is the mean density, and g is the goal. A one-sample t-test (two-sided) with an alpha level of 0.05 will be used to determine whether the null hypothesis should be rejected.

e. Data Source

The NHF&G Oyster Resource Monitoring Program will provide data for the six oyster beds. Each of the six beds should be assessed at least once every three years.

SHL3. Density of Harvestable Clams at Hampton Harbor Flats

a. Objective

The objective of this indicator is to estimate the mean density of clams of harvestable size (>50mm) from the NH's major clam flats in Hampton Harbor.

The monitoring question for this indicator is:

- Has the density of harvestable-size clams in Hampton Harbor decreased from the historical average?

This indicator will report directly on the following management objective:

- SHL1-4b: No net decrease in adult clams (>50 mm shell length) per square meter from the 1989-1999 10-year average at Common Island, Middle Ground, and Confluence flats.

b. Measurable Goal

The goal is for each flat to at least maintain the 10-year average density for clams of harvestable size (>50mm shell length) that was recorded between 1990 and 1999.

Flat	10 year Average (1990-1999)	Longer Term Baseline (1974-1989)
Common Island	21.3	15.3
Hampton-Browns Confluence	11.0	9.8
Middle Ground	38.6	9.9

Units: #/m2 (arithmetic average)
Source: Seabrook Station
Note: The 10-year average was calculated for the data from 1990-1999. The management objective calls for using data from 1989-1999 for the 10-year average but this is actually an 11 year period.

c. Data Quality Objectives

The monitoring programs for this indicator should have 80% power for detecting a 5 #/sq. meter difference between the mean density and the goal with 0.05 as the level of the test. The critical difference of 5 #/sq. meter was chosen because it is approximately 10% of the 10-year average densities.

d. Data Analysis, Statistical Methods and Hypothesis

For each flat , the arithmetic mean densities for clam spat, juveniles, and adults will be calculated by summing the mean densities for the 1-25mm, 26-50mm, and >50mm size classes, respectively, using data tables in the Seabrook Station Annual Data Reports. The arithmetic mean density for adult clams will be compared to the 10 year average density for each flat. The specific hypothesis that will be tested is:

$$Ho: d \geq g; Ha: d<g$$

where d is the mean density, and g is the goal. Ultimately, a one-sample t-test with an alpha level of 0.05 will be used to determine whether the densities are significantly different from the goal. However, information on the variance in density between quadrats is not currently available, therefore only the mean density will be reported for this analysis. The mean density values will be compared to the goal.

In addition to comparing the most recent data to the 10 year average, the results will also be compared to longer term baseline densities. The NHEP Management Goal is the 10-year average for 1990-1999. During this period, the clam densities grew to unprecedented levels, due in part to the clam flats being closed for harvest. The longer-term baseline period of 1974-1989 encompasses more of the cyclic growth and decline of the clam populations.

e. Data Source

The clam populations in at the three major flats in Hampton Harbor will be assessed yearly by the Seabrook Station Soft Shell Clam Monitoring Program.

SHL4. Area of Clam Flats in Hampton Harbor

a. Monitoring Objectives

The objective of this supporting variable is to track the size of the three major clam flats in Hampton Harbor. This information will be combined with data on clam densities to estimate the standing stock of harvestable clams for another indicator.

The monitoring question for this indicator is:

- Has the area of clam flats in Hampton Harbor changed over time?

b. Measurable Goal

This is a supporting variable so no measurable goal has been established. These data will be collected to provide additional information to help interpret the results of other indicators.

c. Data Quality Objectives

The monitoring programs for this indicator should have data quality objectives of ±10% accuracy. Given that the 1995 flat area estimates ranged from 26-47 acres, the accuracy of the estimates should be approximately ±5 acres.

d. Data Analysis, Statistical Methods and Hypothesis

The area of each flat will be reported along with the error in the estimate. No statistical tests will be applied.

e. Data Source

The Seabrook Station Soft-Shell Clam Monitoring Program will provide data for this indicator.

SHL5. Standing Stock of Harvestable Oysters in Great Bay

a. Objective

The objective of this indicator is to estimate the total number of harvestable oysters in Great Bay (i.e., oyster of harvestable size in beds that are open for harvesting). This indicator will answer the following monitoring question:

- Has the number of harvestable clams and oysters tripled from 1999 levels?

This indicator will be used to report on progress towards a component of Shellfish Goal#1 which calls for the quantity of harvestable clams and oysters in NH's estuaries to be tripled.

b. Measurable Goal

In the NHEP Management Plan, Shellfish Goal #1 states that the quantity of harvestable clams and oysters in NH's estuaries should be tripled. The standing stock of harvestable oysters in 1999, the year the Management Plan was written, was 15,883 bushels. Tripling 15,883 bushels is approximately 50,000 bushels. Therefore, the goal for this indicator is 50,000 bushels.

c. Data Quality Objectives

Oyster standing stock is calculated from the area and density at the oyster beds. These parameters are being measured for other indicators (SHL1, SHL2). So long as the DQO for these two indicators are met, the DQO for this indicator will be satisfied.

d. Data Analysis, Statistical Methods and Hypothesis

The standing stock of harvestable oysters in each bed will be estimated by multiplying the average density of oysters >80mm by the most recent estimate of the bed size. If data on density or area are missing for a bed for a particular year, the standing stock will be estimated from the closest other available data for that bed. Results will be reported in bushels (for Great Bay, approximately 200 oysters equal 1 bushel). The standing stock will be summed for beds in areas open for harvesting. A separate standing stock calculation will be made for oysters >80mm in areas that are closed to harvesting.

For the standing stock in open areas, the specific hypothesis to be tested is:

$$Ho: s \geq g; Ha: s < g$$

where s is the total standing stock, and g is the goal. A rigorous statistical test of this hypothesis is not possible. Instead, the error bars for the estimated standing stock will be used to establish an approximate "confidence interval" of possible values for the estimate. If the goal falls above this interval, the null hypothesis will be rejected in favor of the alternative hypothesis. If the goal falls within or below the interval, the null hypothesis will not be rejected.

e. Data Source

Oyster bed areas and harvestable oyster densities will be provided by the NHF&G Oyster Resource Monitoring Program and the NHEP Oyster Bed Mapping Program. Maps of open and closed areas for shellfishing will be provided by the DES Shellfish Program.

SHL6. Standing Stock of Harvestable Clams in Hampton Harbor

a. Objective

The objective of this indicator is to estimate the total number of harvestable clams in Hampton Harbor (i.e., clams of harvestable size in Hampton Harbor flats that are open for harvesting).

This indicator will answer the following monitoring question:

- Has the number of harvestable clams and oysters tripled from 1999 levels?

This indicator will be used to report on progress towards a component of Shellfish Goal#1 which calls for the quantity of harvestable clams and oysters in NH's estuaries to be tripled.

b. Measurable Goal

The 30 year average (1971-2000) of clam standing stock in Hampton Harbor is approximately 8,500 bushels. This period of time spans several cycles of the clam population and, therefore, is representative of long term average conditions. The NHEP will use 8,500 bushels as a benchmark by which to judge whether clam standing stock in Hampton Harbor has changed over time.

c. Data Quality Objectives

Clam standing stock is calculated from the area and density at the clam flats. These parameters are being measured for other indicators (SHL3, SHL4). So long as the DQO for these other indicators are met, the DQO for this indicator will be satisfied.

d. Data Analysis, Statistical Methods, and Hypothesis

Seabrook Station calculates the the standing stock of harvestable clams in Hampton Harbor using the average density for each size clam on the flats (with 1 mm shell length increments for each size class), volume estimates for each size clam, and the most recent area of each flat. The most recent standing stock estimate will be compared to the goal. The data on standing stock will also be reviewed for trends.

e. Data Source

The Seabrook Station Soft Shell Clam Monitoring Program will provide the data for this indicator.

SHL7. Abundance of Shellfish Predators

a. Objective

The objective of this supporting variable is to track the relative abundance of the dominant clam and incidental oyster predator in NH tidal waters: green crabs (*Carcinus maenus*). This information will be used to help interpret changes in other indicators of shellfish density or standing stock, and will help to answer the following monitoring question:

- Are NH shellfish healthy, growing, and reproducing at sustainable levels?

b. Measurable Goal

This is a supporting variable so no measurable goal has been established. These data will be collected to provide additional information to help interpret the results of other indicators.

c. Data Quality Objectives

Data for this indicator will be provided by Seabrook Station monitoring programs. Since this is a supporting variable, so long as the DQO of the principal programs are met, the DQO for this indicator will be considered met.

d. Data Analysis, Statistical Methods and Hypothesis

The monthly catch-per-unit-effort (CPUE) of green crabs in Hampton-Seabrook Harbor will be charted versus time. The time series will be evaluated using the Mann Kendall test for trends.

e. Data Source

The Seabrook Station Soft Shell Clam Monitoring Program provides a time series of green crab abundance in Hampton Harbor.

SHL8. Clam and Oyster Spatfall

a. Objective

The objective of this supporting variable is to track the yearly spatfall of clams in Hampton Harbor and oysters in Great Bay. This information will be used to help interpret changes in other indicators of shellfish density or standing stock, and will help to answer the following monitoring question:

- Are NH shellfish healthy, growing, and reproducing at sustainable levels?

b. Measurable Goal

This is a supporting variable so no measurable goal has been established. These data will be collected to provide additional information to help interpret the results of other indicators.

c. Data Quality Objectives

Clam and oyster spat are measured by the same programs that provide data for indicators SHL2 and SHL3. So long as the DQO for these indicators are met, the DQO for this indicator will be met.

d. Data Analysis, Statistical Methods and Hypothesis

For oysters, spatfall is measured by the density of oysters less than 20 mm shell height during the fall season. For clams, the spat size class has typically been the 0-25 mm. This range is relatively large and may include some clams from the yearling age class. The average spat density at each major clam flat and oyster bed will be tracked versus time. No statistical tests will be applied.

e. Data Source

Data for this indicator will be provided by the NHF&G Oyster Resource Monitoring Program and the Seabrook Station Soft Shell Clam Monitoring Program.

SHL9. Recreational Harvest of Oysters

a. Objective

The objective of this supporting variable is to estimate how many oysters are harvested by recreational harvesters each year (Great Bay is not a commercial oyster fishery). This information is needed to answer the following monitoring question:

- Are NH shellfish being harvested at sustainable levels?

b. Measurable Goal

This is a supporting variable so no measurable goal has been established. These data will be collected to provide additional information to help interpret the results of other indicators.

c. Data Quality Objective

The data for this indicator will be oyster harvest license sales by NHF&G.

d. Data Analysis, Statistical Methods and Hypothesis

The number of oyster licenses sold per year will be presented to illustrate trends in harvest pressure for oysters.

e. Data Source

The number of oyster licenses sold per year will be provided by NH Fish and Game (603-271-6832).

SHL10. Recreational Harvest of Clams

a. Objective

The objective of this supporting variable is to estimate the how many clams are harvested from Hampton Harbor flats by recreational harvesters each year (Hampton Harbor is not a commercial clam fishery). This information is needed to answer the following monitoring question:

- Are NH shellfish being harvested at sustainable levels?

b. Measurable Goal

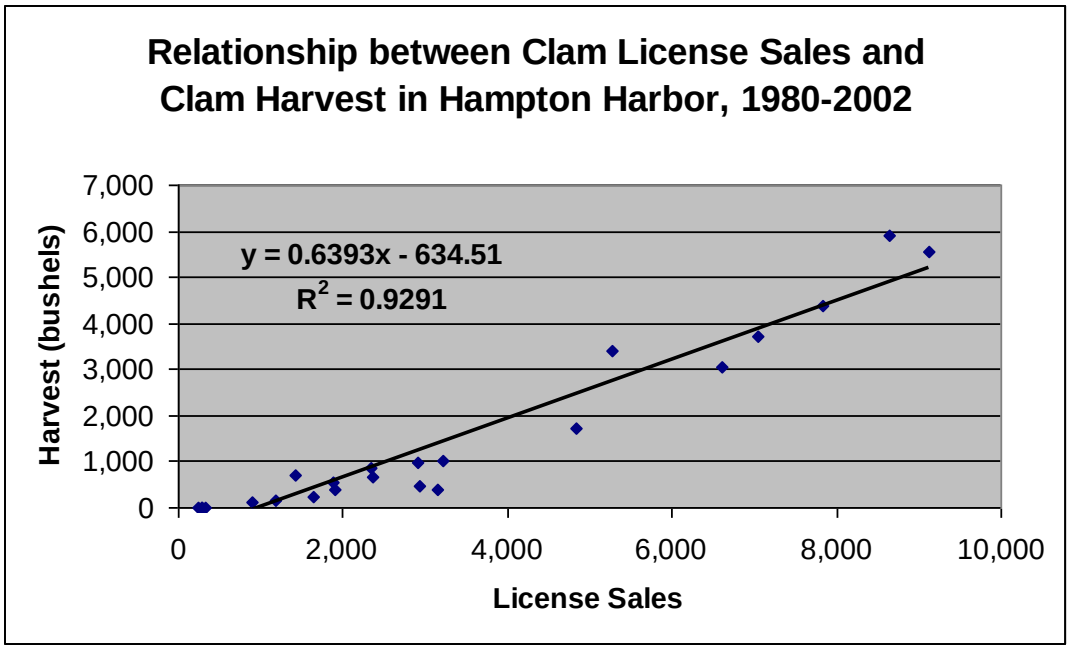
This is a supporting variable so no measurable goal has been established. These data will be collected to provide additional information to help interpret the results of other indicators.

c. Data Quality Objectives

The data for this indicator will be oyster harvest license sales by NHF&G.

d. Data Analysis, Statistical Methods and Hypothesis

The total number of clams harvested yearly will be estimated for the total license sales for recreational clam harvesting. For 23 years (1980-2002), the Seabrook Station estimated clam harvest from observations of clammers. The harvest estimates are well correlated with the number of clam license sales each year (r2=0.93, see figure). Therefore, the clam license sales and the regression equation will be be used as the continuing measure of harvest pressure in Hampton Harbor. The annual harvest will be tracked over time and compared to annual estimates of standing stock.



e. Data Source

The number of clamming licenses sold per year will be provided by NH Fish and Game (603-271-6832).

SHL11. Prevalence of Oyster Disease

a. Objective

The objective of this supporting variable is to estimate the prevalence of the oyster diseases, MSX and DERMO. This information is needed to answer the following monitoring question:

- Has the incidence of shellfish diseases changed significantly over time?

b. Measurable Goal

This is a supporting variable so no measurable goal has been established. These data will be collected to provide additional information to help interpret the results of other indicators.

c. Data Quality Objectives

The data quality objectives for this indicator are described in the QAPP for the NHF&G Oyster Disease Monitoring Program (NHF&G, 2001). The analytical methods should be able to detect levels of infection above 1,000 pathogens per gram (wet weight).

d. Data Analysis, Statistical Methods and Hypothesis

For each oyster bed, the percent of oysters infected with MSX or DERMO will be reported and tracked over time. No statistical tests will be applied.

e. Data Source

Data for this indicator are provided by the NHF&G Oyster Disease Monitoring Program with financial support from the NHEP.

SHL12. Prevalence of Clam Disease

a. Objective

The objective of this supporting variable is to estimate the prevalence of clam disease (sarcomastic neoplasia). This information is needed to answer the following monitoring question:

- Has the incidence of shellfish diseases changed significantly over time?

b. Measurable Goal

This is a supporting variable so no measurable goal has been established. These data will be collected to provide additional information to help interpret the results of other indicators.

c. Data Quality Objectives

The monitoring programs for this indicator should have data quality objectives of ±10% accuracy.

d. Data Analysis, Statistical Methods and Hypothesis

The average prevalence of neoplasia infection (both total and heavily infected) is tracked over time. No statistical tests are applied.

e. Data Source

Neoplasia was monitored at the major clam flats in Hampton Harbor in 1986-1987, 1989, 1996, 1997, 1999, and 2002 by the Seabrook Station Soft Shell Clam Monitoring Program.

HAB1. Salt Marsh Extent and Condition

a. Objective

The objective of this indicator is to report on the total area of the NH Seacoast covered by salt marshes as well the area of salt marshes that are degraded due to invasive species or tidal restrictions. This indicator will answer the following monitoring questions:

- Has there been any significant net loss or degradation of tidal wetlands in NH?
- Has the acreage of invasive species (phragmites, purple loosestrife) in NH salt marshes and wetlands significantly changed over time?

This indicator will be used to report on progress toward the following management objective:

- LND2-1 is: "Allow no loss or degradation of 6,200 acres of tidal wetlands in the NH coastal watershed".

b. Measurable Goals

The goal for this indicator is to have to the total area of salt marsh in the NH Seacoast greater than or equal to 6,200 acres.

c. Data Quality Objectives

The data quality objective for this indicator is an accuracy of +/- 5% in the area estimates of salt marsh in each of the following three areas: Hampton/Seabrook Harbor, Coastal Atlantic, and Great Bay.

d. Data Analysis, Statistical Methods and Hypothesis

Salt marshes will be mapped at the 1:24,000 scale from from color infrared imagery (CIR) flown during the spring. Under the Cowardin classification system, salt marshes would be classified as Estuarine-Intertidal-Emergent (Class "E2EM"). ArcView/ArcInfo software will be used to calculate the total acreage covered by E2EM wetlands in the coastal watershed. This total will be compared to the goal of 6,200 acres. The specific hypothesis to be tested is:

Ho: a >= 6200 acres; Ha: a < 6200 acres

where *a* is the area of E2EM acres derived from the aerial imagery. A rigorous statistical test of this hypothesis is not possible. Instead, the error bars on the total salt marsh area estimate will be used as an approximate "confidence interval". If the confidence interval of the estimate is entirely below 6,200 acres, the null hypothesis will be rejected in favor of the alternative hypothesis. If the confidence interval is greater than or contains 6,200 acres, the null hypothesis will not be rejected.

In addition, the area of degraded salt marshes due to invasive species (phragmites) and tidal restrictions will be listed. Information on the specific areas with degraded salt marshes will be used by the NH Coastal Program and others to target restoration projects.

Results will be reported for the NH Seacoast as a whole as well as for three subareas: Hampton/Seabrook Harbor, Coastal Atlantic, and Great Bay.

e. Data Source

The data source for this indicator will be geographic coverages of tidal wetlands.

HAB2. Eelgrass Distribution

a. Monitoring Objectives

The objective of this supporting variable is to track the area of eelgrass present in tidal tributaries to the Great Bay, Great Bay, and Little Bay. Water clarity is one of the main factors affecting the distribution of eelgrass. However, eelgrass can be affected by other factors such as disease on a rapid temporal scale. This indicator will provide information relevant to the following question:

- Has eelgrass habitat in Great Bay changed over time?

This indicator will provide supporting information on the following management goal:

- Land Use Goal #6: "Maintain habitats of sufficient size and quality to support populations of naturally occuring plants, animals, and communities.

b. Measurable Goal

Eelgrass distribution is a supporting variable so a measurable goal has not been established.

c. Data Quality Objectives

The data quality objectives for this indicator are described in the QAPP for the UNH Eelgrass Monitoring Program (Short and Trowbridge, 2003).

d. Data Analysis, Statistical Methods and Hypothesis

The method for eelgrass mapping in the Great Bay Estuary generally follows the standardized "C-CAP" protocol for mapping submerged aquatic vegetation (Coastal Change Analysis Program, NOAA). The aerial photographs are taken at both 3,000 ft and at 600 ft at low spring tide with roughly 60% overlap on a calm day without preceding rain events and when the sun was at a low angle to minimize reflection (between 7 and 10 am). The photographs are near-verticals, taken with a hand-held 35mm camera, which deviates from C-CAP's protocol, but follows a published method (Short and Burdick, 1996). Photographs are taken in late summer, usually late August or early September, depending on tides and weather, to capture the time of maximum annual eelgrass biomass. Ground truthing is done from a small boat at the same season as the photographs were taken. Observations are made at low tide. Samples are collected with an eelgrass sampling hook. Positions are determined using GPS. The ground truth surveys assess ten to twenty percent of the eelgrass beds in the estuary. The photographs, in the form of 35mm slides or digital computer images, are projected on a screen and the eelgrass images are transferred to a base map. For data analysis, ArcView/ArcInfo software is used to calculate the area of eelgrass coverage in each year in the different sections of the Great Bay Estuary. For the purposes of calculating acreage totals, all areas mapped as being eelgrass by UNH are included equally in the total regardless of the eelgrass density.

e. Data Source

The eelgrass distribution throughout the entire estuary is mapped each year by the UNH/JEL Seagrass Ecology Group, with funding from the NHEP.

HAB12. Eelgrass Biomass

a. Monitoring Objectives

The objective of this supporting variable is to track the biomass of eelgrass present in different sections of the Great Bay Estuary. This indicator will provide information relevant to the following question:

- Has eelgrass habitat in Great Bay changed over time?

This indicator will provide supporting information on the following management goal:

- Land Use Goal #6: "Maintain habitats of sufficient size and quality to support populations of naturally occuring plants, animals, and communities.

b. Measurable Goal

Eelgrass biomass is a supporting variable so a measurable goal has not been established.

c. Data Quality Objectives

The data quality objectives for this indicator are described in the QAPP for the UNH Eelgrass Monitoring Program (Short and Trowbridge, 2003).

d. Data Analysis, Statistical Methods and Hypothesis

The method for eelgrass mapping in the Great Bay Estuary is described for the HAB2 supporting variable. In addition to mapping eelgrass bed boundardies, each eelgrass bed is assigned a density based on visual observation: partial (10-30% cover), half (30-60% cover), some bottom (60-90% cover) and dense (90-100% cover). ArcView/ArcInfo software is used to calculate the area of eelgrass coverage in each density class in the different sections of the Great Bay Estuary. The biomass of eelgrass in Great Bay is calculated for each year by assuming a shoot density for each density class: partial (25 g/m^2); half (55 g/m^2); some bottom (85 g/m^2); and dense (250 g/m^2). The total area in each density class is multiplied by the shoot density for the class. The total biomass in metric tons is the sum of the biomass from each density class of eelgrass.

e. Data Source

The eelgrass distribution throughout the entire estuary is mapped each year by the UNH/JEL Seagrass Ecology Group, with funding from the NHEP.

HAB8. Anadromous Fish Returns

a. Objective

As a subset of the adult finfish, anadromous fish returns are indicative of conditions in the upper watershed. The juvenile fish need suitable habitat in the rivers and streams to thrive, adults need passage through dams and suitable upstream habitat to spawn. Therefore, changes in the anadromous fish returns could be due to many factors. The TAC felt that, despite the complexity of this indicator, tracking the returns of river herrings and smelt would be a useful indicator of ecological conditions in the coastal watershed as long as consideration was given to other factors that might affect fish returns (e.g., condition of the fish ladders). The objective of this supporting variable is to illustrate year to year trends in the abundance of anadromous finfish in the estuary. It will address the following monitoring question related to Land Use Goal #6:

- Has the number of anadromous fish returning to NH's coastal rivers changed over time?

This indicator will provide supporting information on the following management goal:

- Land Use Goal #6: "Maintain habitats of sufficient size and quality to support populations of naturally occuring plants, animals, and communities.

b. Measurable Goals

Since anadromous fish returns are supporting variables that will not be used to answer a management question, measurable goals have not been set.

c. Data Quality Objectives

Data for this indicator are provided by the NHF&G conducted under the F-61-R grant. As long as the DQO for this grant are met, the DQO for this indicator will be met.

d. Data Analysis, Statistical Methods and Hypothesis

Measurements of abundance for five anadromous fish species will be tracked for each year using data from NHF&G. For most anadromous fish, the measurements will be counts of fish passing through fish ladders. The species to be tracked are:

Species	Abundance Measure	Location	Source
Herring (*Alosa pseudoharengus* and *Alosa aestivalis)*	Passage through fish ladders (# of fish/yr)	Exeter, Lamprey, Oyster, Cocheco, Winnicut, and Taylor rivers	NHF&G F-61-R report Table 2-5
Shad (*Alosa sapidissima*)	Passage through fish ladders (# of fish/yr)	Exeter, Lamprey, and Cocheco rivers	NHF&G F-61-R report, Table 1-3
Salmon (*Salmo salar*)	Passage through fish ladders (# of fish/yr)	Lamprey and Cocheco rivers	NHF&G F-61-R report Table 4-4
Smelt, rainbow (*Osmerus mordax*)	CPUE	Great Bay Ice Fishery	NHF&G F-61-R report Table 3-6
Lamprey (*Petromyzon marinus*)	Passage through fish ladders (# of fish/yr)	Exeter, Lamprey, and Cocheco rivers	NHF&G records

Abundance will be plotted versus year to illustrate the trend in returns. The results will be annotated with any pertinent information such as the dates of fish ladder improvements. NHF&G also tracks abundance of two other anadromous fish: brown trout and striped bass. However, the abundance of these species are tracked by voluntary reports from anglers rather than designed surveys implemented by NHF&G staff. Therefore, the abundance results for these two species are considered inappropriate for this supporting variable.

e. Data Source

NH Fish and Game Anadromous Fish Monitoring Programs will provide data for this indicator.

HAB10. Abundance of Wintering Waterfowl

a. Objective

Waterfowl are one of most important wildlife species in the estuary. Approximately 75% of all the waterfowl that winter in New Hampshire do so in the seacoast region, mainly in the Great Bay or Hampton Harbor (NHF&G, 1995). Salt marshes and tidal flats of estuaries are the most important types of wetlands for waterfowl. Eelgrass and tidal flats provide winter forage for the birds (NHF&G, 1995). The population wintering over in any particular estuary along the Atlantic Flyway depends on multiple factors including the local climatic conditions and the total number of birds in the migration. Data collected on waterfowl in New Hampshire is combined with data from states along the Atlantic flyway to provide meaningful estimates of the total waterfowl population (NHF&G, 1995). Therefore, the objective of this supporting variable is track the abundance of wintering waterfowl in Great Bay and the Atlantic Flyway to illustrate changes over time. This supporting variable will be used to partially answer the following question:

- Has the population of wintering waterfowl on the NH coast changed over time?

This indicator will provide supporting information on the following management goal:

- Land Use Goal #6: "Maintain habitats of sufficient size and quality to support populations of naturally occuring plants, animals, and communities.

b. Measurable Goal

Since wintering waterfowl is a supporting variable that will not be used to answer an management question, a measurable goal has not been set.

c. Data Quality Objectives

Data for this indicator are provided by the NHF&G winter waterfowl monitoring program. As long as the DQO for this program are met, the DQO for this indicator will be met.

d. Data Analysis, Statistical Methods and Hypothesis

Annual mid-winter waterfowl counts will be compiled for the NH coastal region and the Atlantic Flyway. The latest years results will be compared to the 10-year average population for reference. The waterfowl species that will be compiled are:

- Mallard (*Anas platyrhynchos*)
- Black Duck (*Anas rubripes*)
- Greater/Lesser Scaup (*Aythya marila/affinis*)
- Canada Goose (*Branta canadensis*)

e. Data Source

The NHF&G Winter Waterfowl Aerial Surveys will provide the data for this indicator.

c. Conservation, Restoration, and Development Indicators

HAB6. Protected Conservation Lands

a. Objective

The objective of this indicator is to report on the total acres of lands protected from development in the coastal watershed. By repeating this assessment over time and stratifying the results by private and public lands, the indicator will be able to answer the following monitoring question:

- How much of the coastal watershed is protected from development?

This indicator will be used to report on progress toward the following management objectives:

- LND6-1: "By 2005, determine the existing acres of permanently protected land in the NH coastal watershed in the following categories: tidal shoreland, large contiguous forest blocks, wetlands with high habitat values, freshwater shorelands, and rare and exemplary natural communities."
- LND6-2: "Increase the acreage of protected land containing significant habitats in the NH coastal watershed through fee acquisition or conservation easements by 2010."

b. Measurable Goal

The NHEP Land Use Team set the following goal for this indicator: Increase the acres of protected private and public lands from baseline levels to 15% of the land area of coastal watershed and 15% of the land area of the coastal communities by 2010. This goal is consistent with the NH Everlasting campaign of the Society for the Protection of NH Forests which calls for 25% of each town to be protected in the next 25 years (SPNHF, 2001). The goal is also compatible with the Gulf of Maine Council on the Marine Environment's goal to protect an additional 5,000 acres in "coastal communities" (i.e., towns that border salt water) by 2006 (GOMC, 2002). Seventeen of the 42 NH coastal watershed communities contain tidal waters.

c. Data Quality Objectives

The acres of conservation lands are based on real estate transaction reports, not environmental measurements. Therefore, so long as the protocols for maintaining an accurate and complete database are followed, then the DQO for this indicator will be considered met.

d. Data Analysis, Statistical Methods and Hypothesis

The most recent coverage of conservation lands from GRANIT will be the primary data source for this indicator. The database will be queried to identify the conservation lands within the coastal watershed (HUC8 01060003). Lands will be grouped into categories representing the level of protection and management status. The total acres of public and private conservation lands in the coastal watershed and the 17 coastal communities will be calculated by summing the areas of individual conservation polygons within these two zones.

The land area in the coastal watershed will be calculated by subtracting the area covered by polygons of tidal waters and Great Ponds that fall within the boundary of the watershed. The percentage of the coastal watershed that is conserved will be calculated by dividing the total acres of conservation land by the total land area of the watershed. The same method will be used to determine the percent of conservation lands in the 17 coastal communities. The following hypothesis will be tested using the calculated percentages:

$$Ho: a \geq goal; Ha: a < goal$$

where *a* is the percent of the land area in the watershed or the coastal communities that is protected from development. Error bars on acreage totals will not be calculated because parcels under easement had been surveyed and therefore had accurate acreage values.

e. Data Source

The Conservation/Public Lands geographic datalayer will be the basis for this indicator.

HAB5. Protected Conservation Focus Areas in the Coastal Watershed

a. Objective

The objective for this supporting variable is to track the percentage of conservation focus areas in the coastal watershed that are already protected from development. The Land Conservation Plan for New Hampshire's Coastal Watersheds (TNC, 2006) will be the primary data source for this indicator. The following monitoring question will be addressed:

- How much of the conservation focus areas in the coastal watershed are protected from development?

This indicator will be used to report on progress toward the following management objectives:

- LND6-1: "By 2005, determine the existing acres of permanently protected land in the NH coastal watershed in the following categories: tidal shoreland, large contiguous forest blocks, wetlands with high habitat values, freshwater shorelands, and *rare and exemplary natural communities*."
- LND6-2: "Increase the acreage of protected land containing significant habitats in the NH coastal watershed through fee acquisition or conservation easements by 2010."

b. Measurable Goal

Since conservation of focus areas is a supporting variable that will not be used to answer a management question, measurable goals have not been set.

c. Data Quality Objectives

The acres of conservation lands are based on real estate transaction reports, not environmental measurements. Therefore, so long as the protocols for maintaining an accurate and complete database are followed, then the DQO for this indicator will be considered met.

d. Data Analysis, Statistical Methods and Hypothesis

The most recent coverage of conservation lands from GRANIT and the conservation focus areas from the Land Conservation Plan for New Hampshire's Coastal Watersheds will be the data sources for this indicator. ArcView software will be used to calculate the intersection of the conservation lands coverage and conservation focus areas coverage within the coastal watershed (HUC8 01060003). Lands will be grouped into categories representing the level of protection and management status. The indicator will be the percentage of conservation focus areas in HUC 01060003 that intersect the conservation lands coverage.

Error bars on acreage totals will not be calculated because parcels under easement have been surveyed and therefore have accurate acreage values.

e. Data Source

The geographic datalayers of the conservation focus areas and the conservation/public lands datalayer will be used for this analysis.

RST1. Restored Salt Marsh

a. Objective

The objective of this indicator is to track the cumulative acres of salt marsh with tidal restrictions that have been restored since NHEP implementation began (2000). This indicator will directly report on progress toward the following management objective:

- RST1-1A: Increase acreage of restored estuarine habitats by 2010: Restore 300 acres of salt marsh with tidal restrictions.

This indicator will partially answer the following monitoring question:

- Have restoration efforts resulted in a significant increase in the acreage of salt marshes?

b. Measurable Goal

The goal is to restore 300 acres of salt marsh by 2010.

c. Data Quality Objectives

The quality of the information for this indicator depends on the accuracy of the reported area restored for each project. The total restored area for a project is important to restoration project managers. Therefore, the information reported by restoration project managers will be considered to be sufficiently accurate for this indicator.

d. Data Analysis and Statistical Methods

The total acres of salt marshes that have been restored since January 1, 2000 will be recalculated each year and compared to the goal of 300 total acres. The salt marsh will be considered "restored" at the conclusion of the restoration project. The total area of restored salt marsh will be determined by the restoration project manager. No statistical tests will be applied.

e. Data Source

The most recent summary of salt marsh restorations in coastal New Hampshire will be obtained from the inventory maintained by the NH Coastal Program.

RST2. Restored Eelgrass Beds

a. Objective

The objective of this indicator is to track the cumulative acres of eelgrass beds that have been restored since NHEP implementation began (2000).

- Have restoration efforts resulted in a significant increase in the acreage of eelgrass?

This indicator will directly report on progress toward the following management objective:

- RST1-1A: Increase acreage of restored estuarine habitats by 2010: Restore 50 acres of eelgrass in Portsmouth Harbor, Little Bay, and the Piscataqua, Bellamy, and Oyster rivers.

b. Measurable Goal

The goal is to restore 50 acres of eelgrass beds by 2010.

c. Data Quality Objectives

The quality of the information for this indicator depends on the accuracy of the reported area restored for each project. The total restored area for a project is important to restoration project managers. Therefore, the information reported by restoration project managers will be considered to be sufficiently accurate for this indicator.

d. Data Analysis and Statistical Methods

The total acres of eelgrass beds that have been restored since January 1, 2000 will be recalculated each year and compared to the goal. The eelgrass bed will be considered "restored" at the conclusion of the restoration project. Only projects that actively plant eelgrass in areas will be considered restoration projects. Expanded eelgrass coverage due to improving water quality will not be considered eelgrass restoration. The total area of restored eelgrass bed will be determined by the restoration project manager. No statistical tests will be applied.

e. Data Source

Data for this indicator will be obtained from records of eelgrass restoration projects compiled by the UNH Seagrass Ecology Group.

RST3. Restored Oyster Beds

a. Objective

The objective of this indicator is to track the cumulative acres of oyster beds that have been restored since NHEP implementation began (2000).

This indicator will directly report on progress toward the following management objective:

- RST1-1A: Increase acreage of restored estuarine habitats by 2010: Restore 20 acres of oyster habitat in Great Bay and the tidal tributaries.

This indicator will partially answer the monitoring question of:

- Have restoration efforts resulted in a significant increase in the acreage and/or density of soft-shell clam and oyster beds?

b. Measurable Goal

The goal is to restore 20 acres of oyster beds by 2010. This is roughly equivalent to the known losses in oyster habitat in the Great Bay Estuary and its tributaries over the past 20 years.

c. Data Quality Objectives

The quality of the information for this indicator depends on the accuracy of the reported area restored for each project. The total restored area for a project is important to restoration project managers. Therefore, the information reported by restoration project managers will be considered to be sufficiently accurate for this indicator.

d. Data Analysis and Statistical Methods

The total acres of oyster beds that have been restored since January 1, 2000 will be recalculated each year and compared to the goal. The oyster bed will be considered "restored" at the conclusion of the restoration project. Only projects that actively transplant oysters to reefs or otherwise enhance oyster populations will be considered restoration projects. The total area of each restored oyster bed will be determined by the restoration project manager. No statistical tests will be applied.

e. Data Source

The NHEP Coastal Scientist will compile data on oyster restoration projects from contractors conducting oyster restoration work in the Great Bay.

LUD1. Impervious Surfaces in Coastal Subwatersheds

a. Objective

The objective of this indicator is to track the percentage by land area of impervious surfaces in each subwatershed of the coastal watershed over time. This indicator will answer the following monitoring questions:

- How much of New Hampshire's coastal watershed is covered by impervious surfaces?
- Has there been a significant change over time in the number of coastal NH watersheds (first or second order) that exceed 10% impervious cover?

This indicator will be used to report on progress toward the following management objective:

- LND1-1A: Minimize the amount of impervious surfaces and assess the impacts of water quality by keeping the total impervious surface in each sub-watershed below 10%

b. Measurable Goal

The goal is to have none of the subwatersheds in the coastal watershed with impervious surfaces covering more than 10% of the watershed area. In other states, impervious surfaces covering greater than 10% of the watershed area has resulted in water quality deterioration (CWP, 2003; Shueller, 1995). A recent New Hampshire study confirms this finding (Deacon et al., 2005). The proximity of the impervious surfaces to water bodies and stormwater management practices in effect may be more important than the total area in the watershed. Also, some emerging technologies and site designs can mitigate the stormwater runoff from impervious surfaces by incorporating infiltration basins and using permeable asphalt. However, the total area of impervious surfaces in a watershed is still a useful indicator for human development, habitat fragmentation, and the potential for deteriorated water quality and other hydrologic impacts.

The original goal from the NHEP Management Plan, which was set before the level of impervious surface cover was known, was to keep the percent impervious surfaces in all coastal watersheds less than 10%. Based on the monitoring results for 1990, 2000, and 2005, this goal is not being met, nor will the goal be met in the near future since impervious surfaces are unlikely to decline over time. As an interim goal, the NHEP should work to slow the growth of impervious surfaces in those watersheds that are still less than 10% impervious so that the number of watersheds exceeding 10% impervious does not increase from the current number of 10.

c. Data Quality Objectives

The estimate of imperviousness in a town or watershed should be accurate to ±10%.

d. Data Analysis, Statistical Methods and Hypothesis

Impervious surfaces will be mapped throughout the coastal watershed using satellite imagery. Using ArcView software, the total area of impervious surfaces in each HUC12 watershed or town will be calculated and then divided by the total land area of that watershed or town to estimate the percent impervious cover. The land area will be calculated by subtracting the areas of Great Pond and tidal waters polygons from the town boundary polygon. The specific hypothesis to be tested is:

$$Ho: p \leq 10\%; Ha\ p > 10\%$$

where p is the percent of impervious cover in the watershed. A rigorous statistical test of this hypothesis is not possible. Instead, confidence intervals for the percent impervious estimates for each watershed and town will be generated using the method of partial derivatives from Kline (1985). The uncertainty in each percent impervious calculation is +/-0.7%. This uncertainty was calculated in NHEP (2006c) for the average size watershed and town. Therefore, in order to account for uncertainty, a calculated value of percent imperviousness will be considered to be significantly higher than the goal of 10% if the calculated value is greater than 10.7%.

e. Data Source

The data source for this indicator will be geographic data layers of impervious surfaces in the coastal watershed.

LUD2. Rate of Sprawl – High Impact Development

a. Objective

There is no accepted metric for calculating the rate of sprawl. However, a common attribute of land use associated with sprawl is increasing land consumption per person. Therefore, conditions indicative of "sprawl" development in a town can be approximated using the ratio of the rate of land consumption to the rate of population growth. In order to capture the many facets of land development, the TAC decided to use three different indicators that are each reflective of different development patterns: high impact development, low-density residential development, and land fragmentation. This indicator is the first of these three "sprawl indicators".

Development creates impervious surface in the form of new buildings, new roadways, new driveways, and new parking lots. Sprawl-type development, such as commercial strip development with large parking lots and dispersed low-density residential development with long roadways and driveways, typically creates more impervious surface than compact development and redevelopment activities. An increase of impervious surfaces in a town or watershed is also a particularly good indicator of the level of high impact development (e.g., large shopping malls, highways). Impervious surface is expected to be highly correlated with acres of developed land, but is expected to provide a more accurate measure of sprawl-type development.

For this first indicator of sprawl, the ratio of the acres of imperviousness to the total population ("imperviousness per capita") will be calculated for each town. Ratios for different years will be compared to determine whether the imperviousness per capita is growing, declining, or remaining the same for a town. The rate of change in the ratios will be used to answer the following monitoring question:

- Is the coastal watershed experiencing "sprawl-type" development?

This indicator will report on progress toward the following management objective:

- LND1-2: Minimize the total rate of land consumption in the NH coastal watershed (as measured by acres of development per capita)

b. Measurable Goal

New development in coastal watershed towns between 2000 and 2010 should add no more than 0.1 acres of impervious surfaces per new resident. In 2000, the average imperviousness per capita in the coastal watershed was 0.2 acres/person. The NHEP goal is to cut in half the average rate of production of imperviousness per person for new construction. Specifically, the goal for each municipality will be calculated according the following formula:

$$Goal = \frac{impacres_{2000} + 0.1 \times (pop - pop_{2000})}{pop}$$

where $impacres_{2000}$ is the acres of impervious surfaces in the town in 2000, pop_{2000} is the population of the town in 2000, and pop is the population of the town at the time of the assessment.

c. Data Quality Objectives

The estimate of imperviousness per capita in a town or HUC12 watershed should have an accuracy of ±10%.

d. Data Analysis, Statistical Methods and Hypothesis

Impervious surfaces will be mapped throughout the coastal watershed using satellite imagery. Using ArcView software, the total area of impervious surfaces in each town will be calculated. The "imperviousness per capita" for each year will be calculated by dividing the total acres of impervious surfaces in the town by the town population. The specific hypothesis to be tested is:

$$Ho: p \leq g; \; Ha \; p > g$$

where p is the imperviousness per capita in a town and g is the goal for the town. A rigorous statistical test of this hypothesis is not possible. Instead, confidence intervals for the imperviousness per capita estimates for each town will be generated using the method of partial derivatives from Kline (1985). The uncertainty in each impervious surface per capita calculation is +/-0.015 acres/person. This uncertainty was calculated in NHEP (2003b) for the average size

watershed and town. Therefore, in order to account for uncertainty, a calculated value of impervious surfaces per capita will be considered to be significantly higher than the goal if the calculated value is greater than the goal by more than 0.015 acres/person.

US Census population totals for each town will be obtained from the NH State Data Center for even decade years. Town level population totals are not available from the US Census for mid-decade years (e.g., 2005). For these years, population totals will be estimated using the town population estimates from the NH Office of Energy and Planning and the state population estimate from the US Census Bureau. The fraction of the state population in each town will be calculated. The resulting fraction for each town will be subsequently multiplied by the state population to estimate the town population in the correct year.

e. Data Sources

The data source for this indicator will be geographic data layers of impervious surfaces in the coastal watershed. US census population totals for each town will be obtained from the NH State Data Center.

d. Research Indicators

Research indicators are indicators that are needed for management objectives or monitoring questions that are not being addressed by any of the other indicators. Implementation of these indicators is held up by lack of proven methods, lack of interpretation, or lack of resources. By designating a research indicator in this plan, the NHEP is expressing its interest in the development of this indicator through NHEP resources or by third parties.

BAC3. Trends in Wet-Weather Bacterial Indicators Concentrations

One of the NHEP's priorities is to reduce bacteria pollution caused by stormwater runoff. To that end, significant NHEP resources have been put toward reducing bacteria in stormwater runoff from the urban centers around the estuary. Therefore, a highly ranked monitoring question was "Has wet weather bacterial contamination changed significantly over time?" The NHEP found that the existing monitoring programs for bacteria indicator species did not have sufficient power to detect meaningful trends because of the high variability in water quality during storms (NHEP, 2002). Moreover, even high frequency sampling would not answer the question (NHEP, 2002b). Therefore, new methods or approaches are needed to answer this question. The specific research questions that need to be answered are:

- Is it possible to use probabilistic monitoring designs to accurately measure the aggregate effect of stormwater discharges to the estuary?
- Are there other monitoring designs that could answer this question with sufficient power?

BAC8. Bacteria Load from Wastewater Treatment Plants

Several municipal WWTF discharge treated effluent directly to NH's tidal waters. These bacteria loads are one of the factors controlling the ambient bacteria concentrations in the estuary. WWTF are required to report their monthly discharges of bacteria as part of the NPDES program. Therefore, in order to better understand the relationship between ambient concentrations, long-term trends in bacteria loading was included in the NHEP Monitoring Plan as a supporting variable. Data for this indicator were included in the 2003 Water Quality Indicator report (NHEP, 2003a). The indicator was not included in the 2006 report (NHEP, 2006a) because all of the WWTFs had changed permit monitoring requirements, which disrupted the trend analysis. It is expected that each time the WWTFs update their permits, the monitoring requirements will change. Therefore, it will not be possible to use NPDES permit reporting data to track trends in bacteria loads over the long term.
The TAC classified bacteria loads from WWTFs as a Research Indicator on 9/27/06. The NHEP will research alternative measures of WWTF performance relative to bacteria (e.g., frequency of permit violations) which could be used for trend analysis.

BAC9. Microbial Pathogens and Harmful Algae

One of the highly ranked monitoring questions was "Do NH tidal waters contain disease causing and biotoxic organisms (pathogenic bacteria, viruses, harmful algal blooms)?" There are no current monitoring programs for microbial pathogens to support this indicator. Furthermore, the methods for interpreting the public health risks from exposure to microbial pathogens have not been established. The specific research questions that need to be answered are:

- Which pathogens should be monitored (enteric human pathogens, indigenous pathogens, cryptosporidium/giardia, Pfisteria)?
- Are there cost-effective technologies for monitoring individual pathogens?
- Are there methods for interpreting the human health risk from exposure to individual pathogens?
- Can Microbial Source Tracking technologies be used to answer this monitoring question?

TOX9. Toxic Contaminants in Stormwater Runoff and Receiving Waters

NHEP management objective WQ2-1B is to "Reduce toxic contaminants levels in water so that no levels persist or accumulate according to State WQS in Env Ws 1700". Concentrations of toxic contaminants in water will be a transient phenomenon that will be difficult to detect in ambient waters. However, a recent study by Jones and Gaudette (2001) has been able to detect significant loads of some trace metals to the Great Bay Estuary from stormwater. At this point, more research is needed to answer a number of questions before toxic contaminants in stormwater can be used as an indicator for the NHEP. The most pressing research topics are:

- What is the relationship of stormwater inputs of toxic chemicals to sediment concentrations?
- What are the sources of toxic chemicals to stormwater and their relative importance?
- What can be done to eliminate inputs of stormwater toxic chemicals?
- Is there a cost effective way to monitor toxic contaminants in ambient water?

NUT4. Nuisance Macroalgae

One of the suspected manifestations of eutrophication in Gulf of Maine macrotidal estuaries is the proliferation of nuisance macroalgae, which prompted the monitoring question: "Is there evidence of proliferation of nuisance species associated with elevated nutrient loading?" However, no indicator has been established to answer this question because the methods for identifying and quantifying the impact of nuisance macroalgae have not been determined. Therefore, the following research questions need to be answered in order to develop this indicator:

- Which species of macroalgae should be monitored?
- What methods can be used to assess the proliferation of the target nuisance macroalgae?
- How can these results be interpreted to determine whether designated uses (e.g., swimming, boating) of the estuary are being impaired by the macroalgae?

NUT9. Percent of Estuary with Total Nitrogen Concentrations greater than Criteria

The objective of this indicator is to represent the distribution of total nitrogen concentrations in the estuary based on probabilistic sampling methods. The NHEP funds data collection for this indicator as part of the New Hampshire Estuaries Probability Based Monitoring Program. Numeric criteria for nitrogen in the estuary are being developed by the NHEP Technical Advisory Committee. After these criteria have been established, this indicator can be added to the Monitoring Plan.

NUT10. Eelgrass Nutrient Pollution Index

The eelgrass Nutrient Pollution Index (NPI) uses nitrogen concentrations in eelgrass and other eelgrass measurements to estimate the availability of nitrogen in estuarine systems. The eelgrass NPI has been suggested for the NHEP Monitoring Plan as a way to monitor the integrated effects of nitrogen loading to the estuary. However, the following research question needs to be answered:

- Can the eelgrass NPI be calibrated using mesocosm experiments to predict the nitrogen load above which the ecology of the Great Bay would be altered?

SHL13. Open Shellfish Beds in Estuarine Waters

In the NHEP Management Plan, Shellfish Goal #1 states that the percentage of shellfish beds open for harvesting should be increased to 75% of all beds. Objective SHL1-2 set a specific goal of 2,502 acres of open clam flats based on an estimate of the total acres of clam flats (3,369 acres). The TAC has concluded that a more accurate inventory of the total acres of shellfish resource areas (clam and oyster) in the estuary is needed before this goal can be adopted. Based on the results of this inventory and the locations of the identified shellfish resource areas relative to permanently closed areas (e.g., safety zones near WWTF), the TAC will either confirm that opening 75% of all shellfish resource areas is a realistic goal or recommend an alternative target consistent with the spirit of the management goal.

The shellfish resource areas in estuarine inventory will be the three major clam flats in Hampton Harbor, the six major oyster beds in Great Bay, and clam *habitat* in the Great Bay

Estuary. The inventoried shellfish resource areas will be georeferenced using GIS and overlayed by the GIS coverage of areas that are open for harvest to determine the percentage (by area) of shellfish resource areas that are in estuarine waters classified as "approved" or "conditionally approved" by the DES Shellfish Program.

Data on the oyster beds in Great Bay and clam flats in Hampton Harbor are readily available from other indicators ("Area of Oyster Beds in Great Bay" and "Area of Clam Flats in Hampton Harbor", respectively). However, a uniform and comprehensive assessment of clam *habitat* in Great Bay must be completed. The research questions that need to be answered for this indicator are:

- What methods should be used to develop a habitat suitability model for clam habitat in Great Bay?
- How should the results of the model be verified in the field?
- Which stations in Great Bay should be periodically reassessed for clam populations?

HAB3. Protected, Undeveloped Shorelands

The objective of this indicator was to track the amount of protected, undeveloped shorelands in the coastal watershed. Development in the shoreland buffer was originally measured by the presence of significant amounts of impervious surface for the 2006 Land Use and Development Indicator Report (NHEP, 2006c). However, this method probably underestimated developed shorelands because most shoreland development is too dispersed to be documented by the impervious surface mapping techniques. Moreover, the impervious surface data were meant to be aggregated on a town or watershed scale, not a 250 foot wide shoreland buffer. On 9/27/06, the TAC decided that this indicator should be reclassified as Research Indicator until more accurate methods are available for mapping development in the shoreland buffer.

HAB7. Abundance of Juvenile Finfish

Juvenile finfish are sensitive to estuarine conditions. Many juvenile fish species spend significant portions of their life history in the estuary, and are an important source of food. Since juvenile finfish occupy a lower niche in the food web, population dynamics are less complicated and more predictable. The objective of this indicator is to illustrate year to year trends in the abundance and diversity of juvenile finfish in the estuary. Research into methods, accuracy, and interpretation is needed to develop this indicator.

HAB12. Freshwater Wetland Functions

NHEP Objective LND5-1 is to "determine indicators for freshwater wetland functions". While the overall size of freshwater wetlands is important, the ability of these wetlands to perform their core functions is more important. Therefore, indicators for wetland function, not just size, are needed. Methods for assessing wetland functions are available, but are site-specific and, therefore, neither feasible nor applicable at the watershed scale. Research into methods, accuracy, and interpretation is needed to develop this indicator.

HAB13. Protected Wetlands with High Habitat Values

NHEP objective LND6-1 calls for an assessment of protected wetlands "with high habitat values" (aka, "ecologically important" wetlands). Ecologically important wetlands are identified through planning and on-the-ground assessments. The features that make a wetland ecologically important are a large size, intact condition and processes, intact/unfragmented buffers, as well as other qualities. The detailed assessments needed to determine which wetland should be in this class preclude synoptic surveys of the whole watershed for ecologically important wetlands. Therefore, the information about these wetlands is constantly changing based on new reports from the field.

The dataset that is the closest to a watershed-wide assessment is the work done by the Nature Conservancy (TNC) in 1994 to identify priorities for conservation for the Great Bay Resource Protection Partnership (GBRPP). TNC analyzed the information available at the time

for the 24 town region surrounding the Great Bay and identified the ecologically important wetlands (and supporting uplands). GBRPP uses this priority list, along with other factors, to decide how best to allocate land conservation resources. The NHEP provides funds to GBRPP for land conservation and ecological inventory purposes.

While the GBRPP priority wetlands cover a good portion of the coastal watershed, these wetlands were identified nearly a decade ago using the information available at that time. Since 1994, no organization has conducted a large scale resurvey for ecologically important wetlands in the coastal watershed, although smaller scale work has been done. Therefore, the data needed for this indicator does not exist and will have to be generated by the NHEP. Research is needed on methods for efficiently identifying ecologically important wetlands in the watershed. The NHEP should also look for opportunities to partner with other organizations interested in this information.

HAB14. Abundance of Adult Finfish

Although juvenile finfish are more sensitive to estuarine conditions, the TAC recommends that the relative abundance of adult finfish also be tracked. The monitoring programs for adult finfish are less developed than for juvenile finfish. Therefore, a number of research questions need to be answered before it will be possible to use adult finfish as an indicator for the NHEP.

HAB15: Abundance of Marine Aquatic Nuisance Species

In 2005, the NHEP added an action plan (RST-7) to "support the development and implementation of marine aquatic nuisance species management plans for NH's estuaries." An indicator is needed to report on progress related to this action plan. The monitoring question for this indicator will be: "Has the abundance or species distribution of marine aquatic nuisance species changed over time?"

HAB16: Freshwater Quantity in the Coastal Watershed

In 2005, the NHEP added an action plan (LND-37) to "support the development and implementation of water resource management plans to determine sustainable groundwater and surface water use in the coastal watershed." An indicator is needed to report on progress related to this action plan. The monitoring question for this indicator will be: "Is the use of freshwater in the coastal watershed sustainable?"

3. Administrative Indicators

For some of the NHEP management objectives, it is not possible to establish environmental indicators because these objectives are administrative in nature. “Administrative objectives” describe actions that should be taken rather than environmental conditions to be achieved. Therefore, NHEP’s progress on these objectives will be tracked by “administrative indicators” that document the activities the NHEP has undertaken relative to the objective.

The following is a list of the NHEP objectives that will be tracked by administrative indicators and a description of how these indicators will be reported. All administrative indicators will be reported on a triennial schedule coincident with the EPA Implementation Reviews unless otherwise noted.

Administrative Indicators for the NHEP

Management Objective	**Administrative Indicator**
WQ1-4: Reduce the number of known illicit connections in the NH coastal watershed by 50% by 2010 WQ1-5: Achieve 50% reduction of known illegal discharges into Great Bay, Hampton Harbor, and the tributaries by 2010.	The number of known illicit connections and known illegal discharges is constantly changing as new connections and discharges are identified and others are removed. The NHEP will track this objective by providing tabular information that describes: # of illicit connections and illegal discharges found, # connections/discharges eliminated, # estimated discharges remaining or undiscovered. This information will be updated by NH DES Watershed Planning staff, the NH DES Shellfish Program, and the NH DES Coastal Watershed Restoration Coordinator
SHL1-1: Maintain an approved National Shellfish Sanitation Program supported by the state.	NHEP will report on the status of financial support for the NH DES Shellfish Program.
SHL1-5: Survey each major oyster and soft-shell clam bed at a minimum of every 3 years for dimensions, density, and population structure.	The NHEP will report in tabular format the number of years that have passed since each major oyster bed and soft-shell clam flat have been surveyed. This information will be provided by the NHEP Coastal Scientist.
SHL4-1: Ensure that aquaculture practices do not adversely impact water quality or ecological health of NH’s estuaries.	The NHEP will coordinate with NH Fish & Game Region 3 and EPA Region I to report on this indicator. The permit requirements and any breeches of those requirements for all active aquaculture enterprises will be tracked and reported.
LND1-1B: Reduce stormwater runoff from future development in all sub-watersheds, especially where impervious surfaces already exceed 10%.	NHEP will coordinate with the UNH Stormwater Center to report the number of development projects employing stormwater reduction techniques by using LID practices in NHEP towns. In addition, all NHEP-funded projects aimed at reducing stormwater runoff from impervious surface will be reported.
LND3-2: Allow no new establishment or expansion of existing contamination sources (such as salt storage, junk yards, solid waste, hazardous waste, etc.) within the shoreland protection area as tracked by the Department of Environmental Services.	The NHEP will report any violations tracked by the NHDES Comprehensive Shoreland Protection Act (CSPA) staff and by NH DES Wetlands investigators. In addition, all NHEP projects associated with implementation of the CSPA will be reported.

Management Objective	Administrative Indicator
LND5-2: Establish a state and municipal regulatory framework necessary to prevent introduction of untreated stormwater into tidal and freshwater wetlands by 2010.	NHEP will track and report on legislative progress made on the development of rules to prevent the introduction of untreated stormwater in tidal and freshwater wetlands.
LND5-3: Increase use of buffers around wetlands in NH coastal watershed.	NHEP will report all NHEP-funded projects to develop buffers around wetlands. NHEP will coordinate with the NH DES Wetland Board to document any permit cases where buffers were used.
LND6-3: Support completion of state biomonitoring standards and increase the miles of rivers and streams meeting those standards by 2010.	NHEP will track and report on legislative progress by NH DES toward adopting standards for biomonitoring.

4. Inventory of Coastal and Estuarine Data Sources

The NHEP relies on many environmental programs and geographic data layers to supply data for the environmental indicators. Each data source used by the NHEP is listed below. In most cases, the NHEP provides direct financial support to develop or acquire the data.

a. Geographic Data Sources

Impervious Surfaces in Coastal NH
Description: The Complex Systems Research Center at the University of New Hampshire has created maps of impervious surfaces throughout coastal New Hampshire. The estimates were developed by classifying Landsat Thematic Mapper multispectral imagery, 30-meter resolution. The maps document the extent of impervious surfaces in 1990, 2000, and 2005. Details are available at: http://www.granit.sr.unh.edu/data/datacat/pages/coastalimperv90.pdf
http://www.granit.sr.unh.edu/data/datacat/pages/coastalimperv00.pdf
http://www.granit.unh.edu/data/datacat/pages/coastalimperv05.pdf
Availability: NH GRANIT (http://www.granit.unh.edu/)
Most Recent Data: 2005
NHEP Indicators Supported: LUD1, LUD2, HAB3
Future Updates Needed for NHEP Indicators: 2010 and every 5 years thereafter

Conservation/Public Lands

Description: NH GRANIT maintains a digital record of parcels of land of two or more acres that are mostly undeveloped and are protected from future development. Unique or adjoining smaller parcels, as well as other selected state-owned parcels may also be included. Details available at http://www.granit.sr.unh.edu/data/datacat/pages/cons.pdf.
Availability: NH GRANIT (http://www.granit.unh.edu/)
Most Recent Data: 2008 (update will be completed by 12/31/08)
NHEP Indicators Supported: HAB3, HAB5, HAB6
Future Updates Needed to Support NHEP Indicators: 2011 and every 3 years thereafter

Conservation Focus Areas

Description: The Nature Conservancy completed a land conservation plan for New Hampshire's coastal watershed in 2006. The plan identified conservation focus areas to guide land protection efforts. Details available at
http://www.granit.unh.edu/data/datacat/pages/lcp_conservation_focus_areas.pdf.
www.nhep.unh.edu/resources/pdf/land_conservation_plan-tnc-07.pdf
Availability: NH GRANIT (http://www.granit.unh.edu/)
Most Recent Data: August 2006
NHEP Indicators Supported: HAB5
Future Updates Needed to Support NHEP Indicators: A similar dataset is needed for the portion of the watershed in Maine.

Tidal Wetlands

Description: Salt marshes in NH's coastal watershed were mapped in 1983 for the National Wetlands Inventory. More detailed maps of Great Bay and Atlantic Coast wetlands were produced by UNH and Normandeau Associates, respectively. Information on these existing databases is available at:
http://www.granit.sr.unh.edu/data/datacat/pages/nwi.pdf

http://www.granit.sr.unh.edu/data/datacat/pages/coastwet.pdf
http://www.granit.sr.unh.edu/data/datacat/pages/gbwet.pdf
In 2004, the NH Coastal Program contracted with Normandeau Associates to map all the tidal wetlands in 2004 using aerial color infrared imagery (CIR) at a scale of 1:24,000 during the spring season. The GIS files from this project are available from the NH Coastal Program.
Availability: NH GRANIT (http://www.granit.unh.edu/) for older coverages. The 2004 coverage is available from the NH Coastal Program but will be added to NH GRANIT in the future.
Most Recent Data: 2004
NHEP Indicators Supported: HAB1
Future Updates Needed for NHEP Indicators: 2014

Eelgrass Cover

Description: Since 1986, UNH has annually mapped the distribution eelgrass in the Great Bay Estuary. The data collection methods have been documented in a Quality Assurance Project Plan. Details available at:
http://www.granit.unh.edu/data/datacat/pages/eelgrass2004.pdf
http://www.nhep.unh.edu/resources/qapps/unh_eelgrass_zostera-qapp-unh&des-03.pdf
Availability: NH GRANIT (http://www.granit.unh.edu/) for 2004 coverage. Coverages for additional years will be added to NH GRANIT in the future.
Most Recent Data: 2006
NHEP Indicators Supported: HAB2, HAB12
Future Updates Needed for NHEP Indicators: 2008 and every year thereafter

Oyster Beds

Description: The boundaries of the major oyster reefs were mapped in 1997 by Langan (1997). The NHEP funded the NH Fish and Game Department and UNH to map the beds again in 2001 and 2003, respectively. Details available at:
http://www.nhep.unh.edu/resources/qapps/oyster_reef_mapping-qapp-unh-03.pdf
Availability: NH DES
Most Recent Data: 2003
NHEP Indicators Supported: SHL1, SHL5
Future Updates Needed for NHEP Indicators: 2011

b. Water Quality and Biological Resources Data Sources

The New Hampshire Estuaries Project compiles data from many coastal and estuarine monitoring programs to assess the status and trends of environmental indicators in the Great Bay and Hampton/Seabrook Harbor. The following catalog is a summary of the coastal and estuarine monitoring programs that provide data for the NHEP environmental indicators from Chapter 2. This list is limited to long-term monitoring programs that do not have an end date. The catalog contains basic information about the parameters and monitoring design for each program. Details of the field and analytical methods can be obtained from the Quality Assurance Project Plan or SOP document for that program. Appendix B contains maps showing the sampling locations associated with most of these programs.

PROJECT: UNH TIDAL WATER QUALITY MONITORING PROGRAMS
PROJECT ID: NERRTWQ
JELTWQ

RESPONSIBLE ORGANIZATION
UNIVERSITY OF NEW HAMPSHIRE
JACKSON ESTUARINE LABORATORY
DURHAM, NH 03824
PROJECT MANAGER: JONATHAN PENNOCK

PROJECT INFORMATION

START DATE: 1/1/1988 DURATION: ONGOING

PURPOSE: TO MONITOR TRENDS IN PHYSICOCHEMICAL, BACTERIA, NUTRIENT, AND EUTROPHICATION PARAMETERS IN THE GREAT BAY AND HAMPTON HARBOR.

STUDY AREA: GREAT BAY, HAMPTON HARBOR

STUDY DESIGN
THE STUDY DESIGN HAS VARIED SINCE THE PROGRAM BEGAN. THE CURRENT STUDY DESIGN IS SUMMARIZED BELOW.
THE UNH MARINE PROGRAM CONDUCTS MONITORING OF BACTERIA, NUTRIENT AND EUTROPHICATION PARAMETERS AT STATIONS IN NH'S ESTUARIES. THE SAMPLING SCHEDULE FOR EACH STATION AND A DETAILED LIST OF ANALYTICAL PARAMETERS ARE PROVIDED IN THE FOLLOWING PARAGRAPHS. AFTER QA CHECKS, THE DATA ARE UPLOADED TO THE DES ENVIRONMENTAL MONITORING DATABASE. WATER QUALITY DATA (EXCEPT FOR BACTERIA) THAT ARE COLLECTED AT GBNERR DATASONDE STATIONS AND REPORTED THROUGH THE NERR CDMO ARE ASSOCIATED WITH THE "NERRTWQ" PROJECT IN THE DATABASE. ALL OTHER ROUTINE ESTUARINE WATER QUALITY DATA COLLECTED BY UNH ARE ASSOCIATED WITH THE JELTWQ PROJECT IN THE DATABASE.

JANUARY THROUGH MARCH 2008

- GRBAP (ADAMS POINT): MONTHLY MEASUREMENTS AT HIGH AND LOW TIDE OF PHYSICOCHEMICAL PARAMETERS, DISSOLVED NUTRIENTS, PARTICULATE NUTRIENTS, SUSPENDED SOLIDS, AND BACTERIA (JELTWQ).

APRIL THROUGH DECEMBER 2008

- GRBAP (ADAMS POINT): MONTHLY MEASUREMENTS AT HIGH AND LOW TIDE OF PHYSICOCHEMICAL PARAMETERS, DISSOLVED NUTRIENTS, PARTICULATE NUTRIENTS, SUSPENDED SOLIDS, BACTERIA, AND WATER CLARITY (JELTWQ).
- GRBCML (COASTAL MARINE LABORATORY): MONTHLY MEASUREMENTS AT HIGH AND LOW TIDE OF PHYSICOCHEMICAL PARAMETERS, DISSOLVED NUTRIENTS, PARTICULATE NUTRIENTS, SUSPENDED SOLIDS, BACTERIA, AND WATER CLARITY (JELTWQ).
- GRBCL (SQUAMSCOTT RIVER AT CHAPMAN'S LANDING): MONTHLY MEASUREMENTS AT HIGH AND LOW TIDE OF PHYSICOCHEMICAL PARAMETERS, DISSOLVED NUTRIENTS, SUSPENDED SOLIDS, BACTERIA, AND WATER CLARITY (JELTWQ).
- NH-0057A (UPPER PISCATAQUA RIVER): MONTHLY MEASUREMENTS AT LOW TIDE OF PHYSICOCHEMICAL PARAMETERS, DISSOLVED NUTRIENTS, SUSPENDED SOLIDS, AND WATER CLARITY (JELTWQ).

- GRBGB (GREAT BAY SONDE): MONTHLY MEASUREMENTS AT LOW TIDE OF PHYSICOCHEMICAL PARAMETERS, DISSOLVED NUTRIENTS, SUSPENDED SOLIDS, AND WATER CLARITY (NERRTWQ).
- GRBLR (LAMPREY RIVER SONDE): MONTHLY MEASUREMENTS AT HIGH AND LOW TIDE OF PHYSICOCHEMICAL PARAMETERS, DISSOLVED NUTRIENTS, SUSPENDED SOLIDS, AND WATER CLARITY (NERRTWQ). UNH WILL ALSO MEASURE BACTERIA FOR EACH STATION VISIT (JELTWQ).
- GRBOR (OYSTER RIVER SONDE): MONTHLY MEASUREMENTS AT HIGH AND LOW TIDE OF PHYSICOCHEMICAL PARAMETERS, DISSOLVED NUTRIENTS, SUSPENDED SOLIDS, AND WATER CLARITY (NERRTWQ). UNH WILL ALSO MEASURE BACTERIA FOR EACH STATION VISIT (JELTWQ)
- GRBSQ (SQUAMSCOTT RIVER SONDE): MONTHLY MEASUREMENTS AT LOW TIDE OF PHYSICOCHEMICAL PARAMETERS, DISSOLVED NUTRIENTS, SUSPENDED SOLIDS AND WATER CLARITY (NERRTWQ).

SUMMER INDEX PERIOD (JULY 1 THROUGH AUGUST 30, 2008)

- NH-0007A (HAMPTON HARBOR, 42 53' 43.8" N, 70 49' 30.7" W): THREE MEASUREMENTS OF BACTERIA PARAMETERS ON THREE SEPARATE DATES DURING THE PERIOD (JELTWQ).
- NH-0023A (LITTLE HARBOR, 43 3' 13.7" N, 70 43' 12.7" W): THREE MEASUREMENTS OF BACTERIA PARAMETERS ON THREE SEPARATE DATES DURING THE PERIOD (JELTWQ).
- NH-0052A (BELLAMY RIVER, 43 8' 2.4" N, 70 50' 49.2" W): THREE MEASUREMENTS OF BACTERIA PARAMETERS ON THREE SEPARATE DATES DURING THE PERIOD (JELTWQ).
- NH-0057A (PISCATAQUA RIVER, 43 9' 32.0" N, 70 49' 48.7" W): THREE MEASUREMENTS OF BACTERIA PARAMETERS ON SEPARATE DATES (JELTWQ).
- NH-0051A (LITTLE BAY, 43 07' 24.0" N, 70 50' 28.0" W): THREE MEASUREMENTS OF BACTERIA PARAMETERS ON THREE SEPARATE DATES DURING THE PERIOD (JELTWQ).

PARAMETERS FOR ANALYSIS

- DISSOLVED NUTRIENTS: AMMONIA, NITRATE+NITRITE, ORTHOPHOSPHATE, SILICA. EVERY RESULT FOR DISSOLVED NUTRIENTS WILL CONSIST OF TWO REPLICATE SAMPLES WHICH ARE BOTH ANALYZED FOR ALL OF THE PARAMETERS.
- PARTICULATE NUTRIENTS: TOTAL DISSOLVED NITROGEN, PARTICULATE NITROGEN, PARTICULATE CARBON. EVERY RESULT FOR PARTICULATE NUTRIENTS WILL CONSIST OF TWO REPLICATE SAMPLES WHICH ARE BOTH ANALYZED FOR ALL OF THE PARAMETERS.
- SUSPENDED SOLIDS: CHLOROPHYLL-A, PHEOPHYTIN, TOTAL SUSPENDED SOLIDS. EVERY RESULT FOR PARTICULATE NUTRIENTS WILL CONSIST OF TWO REPLICATE SAMPLES WHICH ARE BOTH ANALYZED FOR ALL OF THE PARAMETERS.
- BACTERIA: FECAL COLIFORMS, *ESCHERICHIA COLI*, AND ENTEROCOCCI. EVERY TENTH RESULT FOR BACTERIA WILL CONSIST OF TWO REPLICATE SAMPLES WHICH ARE BOTH ANALYZED FOR ALL OF THE PARAMETERS.
- WATER CLARITY: VERTICAL PROFILES OF PHOTOSYNTHETICALLY ACTIVE RADIATION (PAR) CONSISTING OF AT LEAST 8 DISCRETE MEASUREMENTS. EVERY TENTH PAR PROFILE WILL BE REPLICATED IN TRIPLICATE TO ASSESS THE ACCURACY OF THE METHOD.
- PHYSICOCHEMICAL: WATER TEMPERATURE, SALINITY, DISSOLVED OXYGEN, DISSOLVED OXYGEN SATURATION, AND WATER DEPTH. EVERY RESULT FOR PHYSICOCHEMICAL PARAMETERS WILL CONSIST OF ONE SET OF RESULTS FOR ALL OF THE PARAMETERS.

QUALITY ASSURANCE DOCUMENT: SOPS AND FINAL QAPP. THE FIELD AND LABORATORY METHODS WILL FOLLOW THE QA PROJECT PLAN FOR THE DISSOLVED ORGANIC NITROGEN, PARTICULATE NITROGEN, PARTICULATE CARBON AND WATER CLARITY MEASUREMENTS THAT WAS APPROVED BY EPA REGION I IN 2003 AND THE STANDARD OPERATING PROCEDURES USED BY THE GREAT BAY NATIONAL ESTUARINE RESEARCH RESERVE.
DOCUMENT AVAILABLE AT:
HTTP://WWW.NHEP.UNH.EDU/RESOURCES/QAPPS/UNH_NUTRIENT_AND-QAPP-UNH&DES-03.PDF
HTTP://NERRS.NOAA.GOV/PDF/SWMPPLAN.PDF

SEE APPENDIX B, FIGURE 1 FOR MONITORING LOCATIONS.

PROJECT: GBNERR DATASONDE PROGRAM
PROJECT ID: "NERRSND"

RESPONSIBLE ORGANIZATION
GREAT BAY NATIONAL ESTUARINE RESEARCH RESERVE
NH FISH AND GAME DEPARTMENT
225 MAIN STREET
DURHAM, NH 03824
PROJECT MANAGER: PETER WELLENBERGER

PROJECT INFORMATION

START DATE: 1/1/1995 DURATION: ONGOING

PURPOSE: TO PROVIDE A NEARLY CONTINUOUS RECORD OF PHYSICO-CHEMICAL WATER QUALITY IN GREAT BAY AND ITS TRIBUTARIES.

STUDY AREA: GREAT BAY AND ITS TIDAL TRIBUTARIES

STUDY DESIGN: PARAMETERS -- SALINITY, WATER LEVEL, CONDUCTIVITY, TEMPERATURE, PH, TURBIDITY, AND DISSOLVED OXYGEN. SAMPLING FREQUENCY -- MEASUREMENTS ARE MADE WITH IN-SITU DATASONDES AT 30 MINUTE INTERVALS. THE DATASONDES ARE DEPLOYED FOR TWO WEEK PERIODS DURING NON-WINTER MONTHS (MAY TO DECEMBER). STATIONS -- 4 SITES; GREAT BAY (GRBGB), SQUAMSCOTT RIVER (GRBSQ), LAMPREY RIVER (GRBLR), AND OYSTER RIVER (GRBOR). COMMENTS -- FUNDING PROVIDED BY NOAA VIA THE GREAT BAY NATIONAL ESTUARINE RESEARCH RESERVE.

QUALITY ASSURANCE DOCUMENT: SOPS ONLY
DOCUMENT AVAILABLE AT: DOWNLOAD METADATA ON METHODS FROM HTTP://CDMO.BARUCH.SC.EDU/.
WEBSITE: HTTP://WWW.GREATBAY.ORG

SEE APPENDIX B, FIGURE 1 FOR MONITORING LOCATIONS.

PROJECT: UNH DATASONDE PROGRAM
PROJECT ID: "JELSND"

RESPONSIBLE ORGANIZATION
UNIVERSITY OF NEW HAMPSHIRE
JACKSON ESTUARINE LABORATORY
DURHAM, NH 03824
PROJECT MANAGER: JONATHAN PENNOCK

PROJECT INFORMATION

START DATE: 1/1/2002 DURATION: ONGOING

PURPOSE: TO PROVIDE A NEARLY CONTINUOUS RECORD OF PHYSICO-CHEMICAL WATER QUALITY IN THE PISCATAQUA RIVER.

STUDY AREA: PISCATAQUA RIVER, PORTSMOUTH HARBOR

STUDY DESIGN: PARAMETERS -- SALINITY, WATER LEVEL, CONDUCTIVITY, TEMPERATURE, PH, TURBIDITY, AND DISSOLVED OXYGEN SAMPLING FREQUENCY -- MEASUREMENTS ARE MADE WITH IN-SITU DATASONDES AT 30 MINUTE INTERVALS. THE DATASONDES ARE DEPLOYED FOR TWO WEEK PERIODS DURING NON-WINTER MONTHS (MAY TO DECEMBER) IN THE RIVER AND YEAR ROUND IN PORTSMOUTH HARBOR. STATIONS -- 2 SITES; COASTAL MARINE LABORATORY IN PORTSMOUTH HARBOR (GRBCML) AND SALMON FALLS RIVER (GRBSFR). COMMENTS -- PARTIAL FUNDING PROVIDED BY USEPA VIA THE NH ESTUARIES PROJECT.

QUALITY ASSURANCE DOCUMENT: SOPS ONLY (THE SAME METHODS ARE USED AS FOR THE GBNERR DATASONDE PROGRAM)

SEE APPENDIX B, FIGURE 1 FOR MONITORING LOCATIONS.

PROJECT: NATIONAL COASTAL ASSESSMENT PROBABILITY BASED MONITORING
PROJECT ID: "NCAPBM"

RESPONSIBLE ORGANIZATION
NEW HAMPSHIRE DEPARTMENT OF ENVIRONMENTAL SERVICES
29 HAZEN DRIVE
CONCORD, NH 03302-0095
PROJECT MANAGER: PHILIP TROWBRIDGE

PROJECT INFORMATION

START DATE: 1/1/2000 DURATION: 12/31/2006

PURPOSE: TO ASSESS THE HEALTH AND CONDITION OF ESTUARIES THROUGHOUT THE UNITED STATES USING A PROBABILITY BASED SAMPLING DESIGN.

STUDY AREA: ALL ESTUARINE WATERS

STUDY DESIGN: PARAMETERS -- THREE MEDIA ARE TESTED: SEDIMENT, WATER QUALITY, AND FISH COMMUNTIY. SEDIMENT IS TESTED FOR: METALS, PAH'S, PCB'S, PESTICIDES, SEDIMENT TOXICITY, TOTAL ORGANIC CARBON, GRAIN SIZE, AND BENTHIC INFAUNA COMMUNITY COMPOSITION AND ABUNDANCE. THE WATER COLUMN IS TESTED FOR: TEMPERATURE, SALINITY, PH, DISSOLVED OXYGEN, SECCHI DEPTH, LIGHT ATTENUATION, NUTRIENTS (NO2+NO3, NH4, PO4, SI), CHLOROPHYLL-A, AND BACTERIA INDICATOR SPECIES (FECAL COLIFORMS, E.COLI, ENTEROCOCCUS). THE FISH COMMUNITY IS EVALUATED THROUGH STANDARDIZED TRAWLS IN THE SPRING, SUMMER, AND FALL. A SUBSET OF THE TARGET FISH SPECIES (WINTER FLOUNDER AND ATLANTIC TOMCOD) ARE SAMPLED FOR TOXIC CONTAMINANTS IN FISH TISSUE. SAMPLING FREQUENCY -- ALL THE STATIONS IN A PROBABILISTIC DESIGN ARE TESTED ONCE FOR EACH PARAMETER. THERE WERE TWO INDEPENDENT DESIGNS DURING THE STUDY PERIOD, 2000-2001 AND 2002-2005. STATIONS -- THE 2000-2001 DESIGN CONSISTED OF 80 SITES. THE 2002-2005 DESIGN CONSISTED OF 82 SITES. COMMENTS -- FUNDING PROVIDED FROM USEPA AS PART OF NATIONAL SURVEYS OF COASTAL WATERS. ADDITIONAL RESEARCH ACTIVITIES ARE ASSOCIATED WITH THIS PROGRAM.

QUALITY ASSURANCE DOCUMENT: FINAL QAPP
DOCUMENT AVAILABLE AT: HTTP://WWW.EPA.GOV/EMAP/NCA/HTML/DOCS/QAPROJPLAN.HTML
WEBSITE: HTTP://WWW.EPA.GOV/EMAP/NCA/

PROJECT: NEW HAMPSHIRE ESTUARIES PROBABILITY BASED MONITORING
PROJECT ID: "NHEPBM"

RESPONSIBLE ORGANIZATION
NEW HAMPSHIRE DEPARTMENT OF ENVIRONMENTAL SERVICES
29 HAZEN DRIVE
CONCORD, NH 03302-0095
PROJECT MANAGER: PHILIP TROWBRIDGE

PROJECT INFORMATION

START DATE: 1/1/2007 DURATION: ONGOING

PURPOSE: TO ASSESS THE HEALTH AND CONDITION OF NEW HAMPSHIRE'S ESTUARIES USING A PROBABILITY BASED SAMPLING DESIGN.

STUDY AREA: ALL ESTUARINE WATERS

STUDY DESIGN: PARAMETERS -- THE WATER COLUMN IS TESTED FOR: TEMPERATURE, SALINITY, PH, DISSOLVED OXYGEN, SECCHI DEPTH, LIGHT ATTENUATION, NUTRIENTS (NO2+NO3, NH4, PO4, SI), CHLOROPHYLL-A, AND BACTERIA INDICATOR SPECIES (FECAL COLIFORMS, E.COLI, ENTEROCOCCUS). SAMPLING FREQUENCY -- ALL THE STATIONS IN A PROBABILISTIC DESIGN ARE TESTED ONCE FOR EACH PARAMETER. THE PROBABLISTIC DESIGNS CONSIST OF 50 STATIONS THAT ARE SAMPLED OVER A TWO YEAR PERIOD (25 STATIONS PER YEAR). STATIONS – 50 RANDOMLY ASSIGNED STATIONS THROUGHOUT THE ESTUARIES. COMMENTS – PARTIAL FUNDING PROVIDED FROM NH DES VIA THE WATER QUALITY PLANNING SECTION AND THE NH COASTAL PROGRAM. PARTIAL FUNDING PROVIDED BY THE NH ESTUARIES PROJECT.

QUALITY ASSURANCE DOCUMENT: THIS PROJECT IS BEING COMPLETED FOLLOWING THE QA PROTOCOLS FROM THE NATIONAL COASTAL ASSESSMENT PROBABILITY BASED MONITORING PROGRAM.
DOCUMENT AVAILABLE AT: HTTP://WWW.EPA.GOV/EMAP/NCA/HTML/DOCS/QAPROJPLAN.HTML

PROJECT: AMBIENT RIVER MONITORING PROGRAM
PROJECT ID: "ARMP"

RESPONSIBLE ORGANIZATION
NEW HAMPSHIRE DEPARTMENT OF ENVIRONMENTAL SERVICES
29 HAZEN DRIVE
CONCORD, NH 03302-0095
PROJECT MANAGER: GREGG COMSTOCK

PROJECT INFORMATION

START DATE: 1/1/1989 DURATION: 12/31/2007

PURPOSE: TO CONDUCT WATER QUALITY SAMPLING OF RIVERS AND STREAMS TO DETERMINE IF WATER QUALITY SUPPORTS USES (I.E. SWIMMING, FISHING) DESIGNATED BY LEGISLATIVE CLASSIFICATION.

STUDY AREA: PRIMARY FOCUS WAS ON THE ANDROSCOGGIN, SACO AND PISCATAQUA RIVER BASINS PLUS 17 TREND MONITORING STATIONS LOCATED THROUGHOUT THE STATE.

STUDY DESIGN: MONTHLY SAMPLES FROM MARCH TO DECEMBER ARE COLLECTED AT NINE TRIBUTARIES TO GREAT BAY AND LITTLE HARBOR AS PART OF THE NH ESTUARIES PROJECT MONITORING PROGRAM. THE TRIBUTARY SAMPLES ARE TAKEN AT THE HEAD OF TIDE IN THE WINNICUT, SQUAMSCOTT, LAMPREY, OYSTER, BELLAMY, COCHECO, SALMON FALLS, SAGAMORE CREEK, AND BERRYS BROOK. ESTUARINE TRIBUTARY SAMPLES ARE ANALYZED FOR: DO, TEMPERATURE, CONDUCTIVITY, PH, TURBIDITY, TOTAL KJELDAHL NITROGEN, AMMONIA, SUM OF NITRATE AND NITRITE, TOTAL PHOSPHOROUS, BOD, E. COLI, CHLOROPHYLL-A, AND TSS. FUNDING FOR TRIBUTARY SAMPLES IS PROVIDED BY USEPA VIA THE NH ESTUARIES PROJECT.

QUALITY ASSURANCE DOCUMENT: FINAL QAPP
DOCUMENT AVAILABLE AT: ON FILE AT NH DES
WEBSITE: HTTP://WWW.DES.NH.GOV/

SEE APPENDIX B, FIGURE 3 FOR MONITORING LOCATIONS.

PROJECT: NHEP TIDAL TRIBUTARY MONITORING PROGRAM
PROJECT ID: "NHEPTTMP"

RESPONSIBLE ORGANIZATION
NEW HAMPSHIRE ESTUARIES PROJECT
UNIVERSITY OF NEW HAMPSHIRE
NESMITH HALL
131 MAIN STREET
DURHAM, NH 03824
PROJECT MANAGER: JENNIFER HUNTER

PROJECT INFORMATION

START DATE: 1/1/2008 DURATION: ONGOING

PURPOSE: TO MONITOR THE LOADS OF NUTRIENT DELIVERED TO THE GREAT BAY ESTUARY FROM TIDAL TRIBUTARIES.

STUDY AREA: TRIBUTARIES TO THE GREAT BAY ESTUARY

STUDY DESIGN: MONTHLY SAMPLES FROM MARCH TO DECEMBER ARE COLLECTED AT EIGHT TRIBUTARIES TO GREAT BAY. THE TRIBUTARY SAMPLES ARE TAKEN AT THE HEAD OF TIDE IN THE WINNICUT, SQUAMSCOTT, LAMPREY, OYSTER, BELLAMY, COCHECO, SALMON FALLS, AND GREAT WORKS RIVERS. SAMPLES ARE ANALYZED FOR: TEMPERATURE, CONDUCTIVITY, TOTAL NITROGEN, TOTAL PHOSPHOROUS, AND SUSPENDED SOLIDS. FUNDING FOR TRIBUTARY SAMPLES IS PROVIDED BY USEPA VIA THE NH ESTUARIES PROJECT.

QUALITY ASSURANCE DOCUMENT: FINAL QAPP
DOCUMENT AVAILABLE AT: HTTP://WWW.NHEP.UNH.EDU/RESOURCES/QAPPS/AMBIENT_RIVER_MONITORING-NHEP-08.PDF
WEBSITE: HTTP://WWW.NHEP.UNH.EDU

SEE APPENDIX B, FIGURE 3 FOR MONITORING LOCATIONS.

PROJECT: NHEP WASTEWATER EFFLUENT MONITORING PROGRAM
PROJECT ID: "NHEPWWMP"

RESPONSIBLE ORGANIZATION
NEW HAMPSHIRE ESTUARIES PROJECT
UNIVERSITY OF NEW HAMPSHIRE
NESMITH HALL
131 MAIN STREET
DURHAM, NH 03824
PROJECT MANAGER: JENNIFER HUNTER

PROJECT INFORMATION

START DATE: 1/1/2008 DURATION: 12/31/08 (REPEATED EVERY 3 YEARS)

PURPOSE: TO MONITOR THE LOADS OF NITROGEN FROM WASTEWATER TREATMENT FACILITIES IN THE WATERSHED OF THE GREAT BAY ESTUARY.

STUDY AREA: WATERSHED OF THE GREAT BAY ESTUARY

STUDY DESIGN: MONTHLY SAMPLES FROM FEBRUARY TO NOVEMBER ARE COLLECTED AT THE LARGEST WWTFS IN THE GREAT BAY WATERSHED. IN 2008, SAMPLES WERE TAKEN AT THE FOLLOWING WWTFS: KITTERY, BERWICK, SOMERSWOTH, ROCHESTER, DOVER, DURHAM, NEWMARKET, AND EXETER. PORTSMOUTH AND SOUTH BERWICK COLLECT THEIR OWN NITROGEN DATA. SAMPLES ARE ANALYZED FOR TOTAL NITROGEN AND TOTAL DISSOLVED NITROGEN. FUNDING FOR THIS PROGRAM IS PROVIDED BY USEPA VIA THE NH ESTUARIES PROJECT.

QUALITY ASSURANCE DOCUMENT: FINAL QAPP
DOCUMENT AVAILABLE AT:
HTTP://WWW.NHEP.UNH.EDU/RESOURCES/QAPPS/TOTAL_NITROGEN_CONCENTRATIONS-NHEP-08.PDF
WEBSITE: HTTP://WWW.NHEP.UNH.EDU

SEE APPENDIX B, FIGURE 4 FOR MONITORING LOCATIONS.

PROJECT: GULFWATCH PROGRAM
PROJECT ID: "GULFWTCH"

RESPONSIBLE ORGANIZATION
NEW HAMPSHIRE DEPARTMENT OF ENVIRONMENTAL SERVICES
29 HAZEN DRIVE
CONCORD, NH 03302-0095
PROJECT MANAGER: PHILIP TROWBRIDGE

PROJECT INFORMATION

START DATE: 1/1/1991 DURATION: ONGOING

PURPOSE: TO MONITOR MARINE SENTINEL SPECIES' EXPOSURE TO ORGANIC AND INORGANIC CONTAMINANTS.

STUDY AREA: GREAT BAY ESTUARY, RYE HARBOR, HAMPTON-SEABROOK HARBOR

STUDY DESIGN: PARAMETERS -- HEAVY METALS AND TOXIC ORGANIC CONTAMINANTS IN BLUE MUSSEL, OYSTER, AND CLAM TISSUE. SAMPLING FREQUENCY -- THREE ANNUAL TREND SITES FOR BLUE MUSSELS AND A ROTATING SCHEDULE FOR OTHER SITES. OYSTER AND CLAM TISSUE SAMPLES ARE TAKEN EVERY THREE YEARS. STATIONS -- THE THREE ANNUAL TREND SITES ARE LOCATED IN CLARKS COVE (PORTSMOUTH HARBOR), DOVER POINT, AND HAMPTON/SEABROOK HARBOR. ONE OR TWO OTHER STATIONS FOR BLUE MUSSELS ARE SAMPLED EACH YEAR. OYSTER AND CLAM TISSUE STATIONS ARE LOCATED AT NANNIE ISLAND AND HAMPTON HARBOR, RESPECTIVELY. COMMENTS -- THE GULF OF MAINE COUNCIL GULFWATCH PROGRAM FUNDS TWO SITES PER YEAR AND USEPA VIA THE NH ESTUARIES PROGRAM FUNDS 2 SITES/YEAR.

QUALITY ASSURANCE DOCUMENT: SOPS ONLY
DOCUMENT AVAILABLE AT: ON FILE WITH NHDES PROJECT MANAGER
WEBSITE: HTTP://WWW.GULFOFMAINE.ORG/GULFWATCH/

SEE APPENDIX B, FIGURE 2 FOR MONITORING LOCATIONS.

PROJECT: OYSTER DENSITY MONITORING PROGRAM
PROJECT ID: "FGOYSRES"

RESPONSIBLE ORGANIZATION
N.H. FISH AND GAME DEPARTMENT
225 MAIN STREET
DURHAM, NH 03824
PROJECT MANAGER: DOUG GROUT

PROJECT INFORMATION

START DATE: 1/1/1993 DURATION: ONGOING

PURPOSE: TO ASSESS THE ABUNDANCE AND COMMUNITY STRUCTURE OF OYSTERS AT BEDS IN THE GREAT BAY ESTUARY

STUDY AREA: MAJOR OYSTER BEDS IN THE GREAT BAY ESTUARY

STUDY DESIGN: PARAMETERS -- ADULT, JUVENILE, AND SPAT OYSTER DENSITY AT MAJOR OYSTER BEDS. SAMPLING FREQUENCY -- ANNUALLY IN OCTOBER/NOVEMBER. STATIONS: 6 SITES: ADAMS POINT, NANNIE ISLAND, WOODMAN POINT, OYSTER RIVER BED, PISCATAQUA RIVER BED, AND SQUAMSCOTT RIVER BED. METHODS -- DIVERS WILL COLLECT SAMPLES FROM EACH BED USING A HAPHAZARD DESIGN TO PROVIDE A REPRESENTATIVE SAMPLE OF THE OYSTERS IN WHOLE BED. A 0.25 M2 QUADRAT WILL BE RANDOMLY PLACED AND ALL OYSTER SHELL WILL BE COLLECTED BY DIVERS FROM WITHIN THE QUADRAT. LIVE OYSTERS WILL BE ENUMERATED AND SHELL LENGTH WILL BE MEASURED TO THE NEAREST MM FOR ADULTS AND SPAT. COMMENTS -- THE DES WATER QUALITY DATABASE DOES NOT CONTAIN ANY DATA FOR THIS PROJECT.

QUALITY ASSURANCE DOCUMENT: SOPS ONLY
DOCUMENT AVAILABLE AT: NHF&G OFFICES IN DURHAM

PROJECT: OYSTER DISEASE MONITORING PROGRAM
PROJECT ID: "FGOYSMSX"

RESPONSIBLE ORGANIZATION
N.H. FISH AND GAME DEPARTMENT
225 MAIN STREET
DURHAM, NH 03824
PROJECT MANAGER: DOUG GROUT

PROJECT INFORMATION

START DATE: 1/1/1995 DURATION: ONGOING

PURPOSE: TO DETERMINE THE PREVALENCE OF INFECTION AMONG OYSTERS IN GREAT BAY REEFS

STUDY AREA: GREAT BAY ESTUARY

STUDY DESIGN: PARAMETERS -- PREVALENCE OF MSX AND DERMO IN OYSTERS. SAMPLING FREQUENCY -- ANNUALLY. STATIONS -- SEVERAL SITES TESTED APPROXIMATELY ANNUALLY (ADAMS POINT BED, NANNIE ISLAND BED, WOODMAN POINT BED, OYSTER RIVER BED). OTHER SITES (PISCATAQUA RIVER BED AND SQUAMSCOTT RIVER BED) TESTED LESS FREQUENTLY. METHODS -- DETAILS PROVIDED IN APPROVED QAPP. COMMENTS -- FUNDING PROVIDED BY USEPA VIA THE NH ESTUARIES PROJECT.

QUALITY ASSURANCE DOCUMENT: FINAL QAPP
DOCUMENT AVAILABLE AT: HTTP://WWW.NHEP.UNH.EDU/RESOURCES/QAPPS/TESTING_OF_GREAT-QAPP-NHFG-02.PDF

PROJECT: SEABROOK STATION SOFT SHELL CLAM MONITORING PROGRAM
PROJECT ID: "SSCLAM"

RESPONSIBLE ORGANIZATION
SEABROOK STATION
P.O. BOX 300
SEABROOK, NH 03874
PROJECT MANAGER: AL LEGENDRE

PROJECT INFORMATION

START DATE: 1/1/1970 DURATION: ONGOING

PURPOSE: TO DETERMINE THE SPATIAL AND TEMPORAL PATTERNS OF ABUNDANCE OF VARIOUS LIFE STAGES OF SOFT-SHELL CLAMS IN THE VICINITY OF HAMPTON HARBOR, NH, AND DETERMINE WHETHER THESE PATTERNS HAVE BEEN AFFECTED BY OPERATION OF SEABROOK STATION.

STUDY AREA: HAMPTON HARBOR

STUDY DESIGN:
CLAM POPULATIONS: PARAMETERS -- CLAM DENSITY FOR SPAT, JUVENILE, AND HARVESTABLE AGE CLASSES, CLAM STANDING CROP. SAMPLING FREQUENCY -- YEARLY. STATIONS -- 5 FLATS ARE MONITORED, MULTIPLE STATIONS PER FLAT. METHODS -- THE CLAM FLATS ARE SURVEYED FOR ADULT AND SPAT DENSITY IN LATE FALL USING A RANDOM SAMPLING DESIGN. AT EACH SITE, A 1X2 FT2 QUADRAT IS DUG TO A DEPTH OF 45 CM WITH A CLAM FORK. LARGE CLAMS ARE ENUMERATED, MEASURED, AND RELEASED. FOR CLAM SPAT, THREE 4 INCH DIAMETER BY 4 INCH DEEP CORES ARE TAKEN FROM WITHIN A 1X2 FT2 QUADRAT. SPAT SAMPLES ARE SIEVED WITH A 1-MM MESH. THE SPAT RETAINED BY THE MESH ARE COUNTED AND MEASURED. THE CLAM DENSITY VALUES ARE USED TO ESTIMATE THE STANDING CROP OF CLAMS IN THE HARBOR.
SIZE OF THE CLAM FLATS. SAMPLING FREQUENCY -- APPROXIMATELY EVERY FIVE YEARS. THE FLATS HAVE BEEN MAPPED IN 1977, 1979, 1981, 1983, 1984, 1995, AND 2002. STATIONS -- THE FIVE MAJOR CLAM FLATS IN HAMPTON HARBOR. METHODS -- THE SIZE OF THE CLAM FLATS IN HAMPTON HARBOR ARE ESTIMATED USING LOW ALTITUDE AERIAL IMAGERY. MONOCHROMATIC AERIAL IMAGERY IS ACQUIRED FROM A QUALIFIED CONTRACTOR DURING A LOW, SPRING TIDE AND WHEN GLARE IS LOW. THE SCALE OF THE HARDCOPY PHOTOGRAPHS SHOULD BE APPROXIMATELY 1:1,500. THE SAND-WATER AND SAND-MARSH BOUNDARIES OF THE FLATS ARE TRACED THREE TIMES USING EITHER A DIGITIZER OR A PLANIMETER. THE AVERAGE AREA OF THE THREE ITERATIONS OF THE BOUNDARY WILL BE USED AS THE AREA OF THE FLAT.
GREEN CRAB POPULATIONS: PARAMETERS -- GREEN CRAB CPUE. SAMPLING FREQUENCY -- TWICE PER MONTH FOR GREEN CRABS. STATIONS -- 4 FOR CRAB ABUNDANCE. METHODS -- GREEN CRABS ARE COLLECTED USING 13-MM MESH, BAITED CRAB TRAPS DEPLOYED OVER 24 HOURS AT A DEPTH SUCH THAT THEY ARE AWASH AT MEAN LOW TIDE. THE TRAPS ARE SET AT FOUR STATIONS TWO TIMES PER MONTH APRIL THROUGH JANUARY.
CLAM DISEASE: PARAMETERS -- SARCOMATOUS NEOPLASIA IN CLAMS. SAMPLING FREQUENCY -- APPROXIMATELY EVERY THREE YEARS FOR NEOPLASIA. STATIONS -- VARIABLE. METHODS -- VARIABLE.

COMMENTS -- NORMANDEAU ASSOCIATES CONDUCTS THE MONITORING UNDER CONTRACT WITH SEABROOK STATION.

QUALITY ASSURANCE DOCUMENT: SOPS ONLY
DOCUMENT AVAILABLE AT: DETAILS OF METHODS PROVIDED IN SEABROOK STATION ANNUAL REPORTS

PROGRAM: ANADROMOUS FISH INVESTIGATIONS (F-61R REPORTING)
PROJECTS: RIVER HERRING RESTORATION PROGRAM
ATLANTIC SALMON RESTORATION PROGRAM
COASTAL SHAD RESTORATION PROGRAM
RAINBOW SMELT PROGRAM

RESPONSIBLE ORGANIZATION
N.H. FISH AND GAME DEPARTMENT
225 MAIN STREET
DURHAM, NH 03824
PROJECT MANAGER: DOUG GROUT

PROJECT INFORMATION

PURPOSE: TO MONITOR THE RETURNS OF ANADROMOUS FISH TO TIDAL RIVERS IN NEW HAMPSHIRE.

STUDY AREA: GREAT BAY ESTUARY, HAMPTON HARBOR

STUDY DESIGN:
NHF&G OPERATES FISH LADDERS ON SIX COASTAL NEW HAMPSHIRE RIVERS (COCHECO, EXETER, LAMPREY, OYSTER, WINNICUT, AND TAYLOR RIVERS) FROM EARLY APRIL TO LATE JUNE TO ALLOW PASSAGE OF ANADROMOUS FISH UPRIVER TO HISTORICAL SPAWNING AND NURSERY AREAS. THE FISH PASSING THROUGH EACH LADDER ARE COUNTED EITHER BY HAND PASSING OR ESTIMATED BY THE USE OF SMITH-ROOT MODEL 1100 ELECTRONIC FISH COUNTERS. COUNTS RECORDED BY THE ELECTRONIC FISH COUNTERS ARE ADJUSTED BY THE RESULTS OF REGULAR CALIBRATION COUNTS. A SUBSAMPLE OF THE FISH ARE SEXED, MEASURED, AND HAVE SCALE SAMPLES REMOVED FOR AGE/SPECIES DETERMINATION.
HERRING: PARAMETERS -- COUNTS, SEX, SIZE/AGE DISTRIBUTION OF RETURNING ADULT HERRING. SAMPLING FREQUENCY -- DAILY DURING SPRING RUNS, STARTING IN 1972. STATIONS -- FISH LADDERS IN THE COCHECO, EXETER, OYSTER, LAMPREY, TAYLOR AND WINNICUT RIVERS.
SALMON: PARAMETERS – COUNTS OF RETURNING OF ADULT SALMON. SAMPLING FREQUENCY -- DAILY DURING SPRING RUNS, STARTING IN 1992. STATIONS -- COCHECO AND LAMPREY RIVER FISH LADDER.
SHAD: PARAMETERS -- COUNTS, SEX, SIZE/AGE DISTRIBUTION OF RETURNING ADULT SHAD. SAMPLING FREQUENCY -- DAILY DURING SPRING RUNS, STARTING IN 1983. STATIONS -- FISH LADDERS AT COCHECO, EXETER AND LAMPREY RIVERS.

RAINBOW SMELT: PARAMETERS -- ABUNDANCE, SEX, AND AGE OF ADULT RAINBOW SMELT AND EGG DENSITY. SAMPLING FREQUENCY -- ANNUALLY DURING THE WINTER MONTHS (EGGS IN MARCH), STARTING IN 1978. STATIONS -- BELLAMY, OYSTER, LAMPREY, WINNICUT AND SQUAMSCOTT RIVERS. METHODS -- DATA COLLECTED THROUGH ANGLER INTERVIEWS, FISH MEASUREMENTS ON ANGLER HARVEST, AND EGG COUNTS.
LAMPREY: PARAMETERS – COUNTS OF RETURNING ADULT LAMPREY. SAMPLING FREQUENCY – DAILY DURING SPRING RUNS, STARTING IN 1985. STATIONS – FISH LADDERS ON THE COCHECO, EXETER, AND LAMPREY RIVERS.

QUALITY ASSURANCE DOCUMENT: SOPS ONLY
DOCUMENT AVAILABLE AT: NHF&G OFFICE IN DURHAM NH (SEE ANNUAL GRANT F-61R REPORT)

SEE APPENDIX B, FIGURE 5 FOR MONITORING LOCATIONS.

PROJECT: ANNUAL WATERFOWL AERIAL SURVEY
PROJECT ID: "FGWFOWL"

RESPONSIBLE ORGANIZATION
N.H. FISH AND GAME DEPARTMENT
225 MAIN STREET
DURHAM, NH 03824
PROJECT MANAGER: ED ROBINSON

PROJECT INFORMATION

START DATE: 1/1/1955 DURATION: ONGOING

PURPOSE: TO MONITOR TYPE AND QUANTITY OF WATERFOWL WINTERING IN GREAT BAY

STUDY AREA: GREAT BAY ESTUARY

STUDY DESIGN: PARAMETERS -- ABUNDANCE AND TYPE OF WATERFOWL PRESENT IN THE ESTUARY DURING WINTER MONTHS. SAMPLING FREQUENCY -- ANNUALLY IN JANUARY. STATIONS -- NO FIXED STATIONS, ONE DAY AERIAL OVERFLIGHT. METHODS -- FROM AN AIRCRAFT FLYING ABOUT 60 MPH AND 500 FEET ABOVE THE GROUND, 2 OBSERVERS COUNT BIRDS VISIBLE ON EITHER SIDE OF THE PLANE. FLYWAY STATES WITH EXTENSIVE HABITAT FLY ABOVE PREDETERMINED TRANSECTS OF HABITAT THAT ADEQUATELY SAMPLE WATERFOWL POPULATIONS. IN NEW HAMPSHIRE, BIOLOGISTS OF THE FISH AND GAME DEPARTMENT SURVEY ALL COASTAL HABITAT INCLUDING GREAT BAY, THE COASTLINE, THE HAMPTON AND SEABROOK MARSHES, AND THE ISLES OF SHOALS (ABOUT 50 LINEAR MILES, TOTAL). COMMENTS -- SIMULTANEOUS COUNT WITH OTHER EASTERN STATES. DATA ARE AGGREGATED FOR THE ATLANTIC FLYWAY TO ESTIMATE THE TOTAL POPULATION OF MIGRATING WATERFOWL. THE DES WATER QUALITY DATABASE DOES NOT CONTAIN ANY DATA FOR THIS PROJECT.

QUALITY ASSURANCE DOCUMENT: SOPS ONLY
DOCUMENT AVAILABLE AT: NHF&G OFFICES IN CONCORD

PROJECT: NHDES BEACH PROGRAM

RESPONSIBLE ORGANIZATION
NEW HAMPSHIRE DEPARTMENT OF ENVIRONMENTAL SERVICES
29 HAZEN DRIVE
CONCORD, NH 03302
PROJECT MANAGER: SONYA CARLSON

PROJECT INFORMATION

START DATE: 1/1/1989 DURATION: ONGOING

PURPOSE: MONITOR AND SAMPLE FRESHWATER AND MARINE PUBLIC BEACHES ON A ROUTINE BASIS THROUGHOUT THE SWIM SEASON. ISSUE AND POST ADVISORIES FOR BACTERIA AND CYANOBACTERIA.

STUDY AREA: STATEWIDE

STUDY DESIGN: FRESHWATER BEACHES ARE SAMPLED ONCE PER MONTH FROM MID-JUNE THROUGH LABOR DAY. TIER I MARINE BEACHES ARE SAMPLED WEEKLY AND TIER II MARINE BEACHES ARE SAMPLED

BI-WEEKLY FROM JUNE 1ST THROUGH LABOR DAY. ALL FRESHWATER BEACH SAMPLES ARE ANALYZED FOR E. COLI, WHILE ALL MARINE BEACH SAMPLES ARE ANALYZED FOR ENTEROCOCCI.

QUALITY ASSURANCE DOCUMENT: FINAL QAPP
DOCUMENT AVAILABLE AT: NHDES PROJECT OFFICER
WEBSITE: HTTP://WWW.DES.NH.GOV/BEACHES/INDEX.ASP

PROJECT: SHELLFISH ROUTINE MONITORING PROGRAM
PROJECT ID: "SHELLRMP"

RESPONSIBLE ORGANIZATION
NEW HAMPSHIRE DEPARTMENT OF ENVIRONMENTAL SERVICES
29 HAZEN DRIVE
CONCORD, NH 03302-0095
PROJECT MANAGER: CHRIS NASH

PROJECT INFORMATION

START DATE: 1/1/1988 DURATION: ONGOING

PURPOSE: THE SHELLFISH PROGRAM REGULARLY COLLECTS WATER QUALITY SAMPLES TO ENSURE THAT INFORMATION USED TO MAKE DECISIONS ON OPEN/CLOSED AREAS IS KEPT CURRENT, AND TO TRACK CHANGES IN WATER QUALITY OVER TIME.

STUDY AREA: ALL TIDAL WATERS

STUDY DESIGN: PARAMETERS -- FECAL COLIFORMS, TEMPERATURE, SALINITY. SAMPLING FREQUENCY -- APPROXIMATELY MONTHLY (9-12 SAMPLES PER STATION PER YEAR). STATIONS -- 60-75 SITES.

QUALITY ASSURANCE DOCUMENT: FINAL QAPP
DOCUMENT AVAILABLE AT: NHDES
WEBSITE: HTTP://WWW.DES.NH.GOV/WMB/SHELLFISH/

---

5. Data Management and Quality Assurance Plan

a. Data Management

A goal of the NHEP and its monitoring program is to promote a cooperative effort by all agencies and organizations who participate in monitoring activities, in order to maximize the usefulness of current monitoring efforts and available data. To achieve this goal, it is necessary to effectively manage the large volume of existing information as well as new information that will be developed through the NHEP monitoring program. Information now exists in multiple formats in a variety of places. Existing monitoring programs are designed to meet the missions of the various implementing organizations. The organizations use different procedures and protocols for data collection, analysis and storage. Coordination of data management among organizations is currently limited.

The NHEP Coastal Scientist is responsible for managing all environmental data needed for the NHEP's environmental indicators. The specific responsibilities of the NHEP Coastal Scientist related to data management are to:

- Compile and manage all environmental data for NHEP environmental indicators.
- Maintain metadata for each project that supplies data for the NHEP indicators in the DES Environmental Monitoring Database.
- Compile SOPs or QAPPs for each project that supplies data for the NHEP indicators.
- Maintain up-to-date geographic data files for coastal sampling locations, eelgrass distribution, shellfish resources, and impervious surfaces.
- Maintain and periodically publish an inventory of environmental monitoring programs for the coastal watershed. This inventory will be available electronically from the NHEP website.
- Distribute raw or interpreted environmental data from NHEP indicators upon request or via web-based downloads.
- Distribute guidance on uniform database formats compatible with the DES Environmental Monitoring Database to coastal partners.
- Compile as much of the NHEP data as possible into a centralized database that is accessible via the internet to facilitate data sharing between researchers.

b. Quality Assurance

It is extremely important that the data used by NHEP to calculate environmental indicators are accurate because these indicators will be used to verify attainment of management goals and objectives.

The NHEP Coastal Scientist will be responsible for quality assuring the data used by the NHEP according the following plan:

- EPA-approved Quality Assurance Project Plans (QAPPs) will be required for all NHEP-funded (EPA-funded) monitoring programs. Full QAPPs will not be required for *low-cost* research projects. Approved QAPPs for NHEP funded programs will be archived on the NHEP website.
- NHEP-funded projects which are not required to produce full QAPPs shall, however, produce, or use existing, written procedures for all sampling, testing, data validation/checking procedures and for addressing non-conformances in these procedures. Additionally, written guidance is required as to how field changes are made and approved. These guidances are referred to collectively as Standard Operating Procedures (SOPs). Data quality objectives and SOPs shall be documented and approved by the NHEP Coastal Scientist.

- For monitoring programs that are not funded by the NHEP but whose data are used by the NHEP, the NHEP Coastal Scientist will obtain either a QAPP or detailed SOPs.
- The NHEP Coastal Scientist will conduct a self audit of the NHEP Monitoring Program System annually as part of the DES Quality Management Plan. The self audit will identify problems encountered in the past year and recommend solutions to be implemented in the coming year.
- The NHEP Coastal Scientist and the TAC will evaluate the performance of all the monitoring programs relative to their data quality objectives (i.e., accuracy of individual measurements and statistical power of overall program). The first evaluation of all the monitoring programs was completed in 2002 (NHEP, 2002). The next evaluation will be completed in 2008-2009 as part of the 2009 State of the Estuaries report.

c. Document Control

All reports on the NHEP Monitoring Program or NHEP indicators will have a document control number assigned by the NHEP Coastal Scientist. The document control number will be the "version number" of the report. The purpose of the document control number is to avoid confusion when updates to the Monitoring Plan or indicator reports are produced.

6. Communications Plan

The NHEP will share the results of environmental monitoring with four audiences: EPA, the NHEP Management Committee, the scientific community, and the NHEP Strategic Communication Plan target audience. The schedule for reporting to these audiences is described in the following sections. The primary reports that communicate environmental status include periodic Progress Reports, environmental indicator reports, and State of the Estuaries reports.

a. Reports to EPA

For each Triennial Progress Review by EPA, NHEP will present a table summarizing the status of all the Environmental Indicators in the Monitoring Plan. Two columns will be added to Appendix A: Status and Comments. The status of environmental and administrative indicators relative to their goals will be reported in the first column. The age of the data used to calculate the status will be reported in the second column. The status of Supporting Variables and Research Indicators will not reported because these parameters do not have management goals.

b. Reports to the NHEP Management Committee

A summary of key environmental indicators will be presented to the NHEP Management Committee upon the request of the NHEP Director.

c. Reports to the Scientific Community

The NHEP Coastal Scientist will publish an inventory of monitoring programs and available data for the coastal watershed periodically. Members of the scientific community can receive raw data or databases used for the NHEP environmental indicators upon request. Technical data on all the environmental indicators will be summarized in a series of “indicator reports” every three years. These reports will be reviewed by the Technical Advisory Committee.

d. Strategic Communication Plan Target Audience

In 2003, the NHEP Public Outreach and Education Team drafted the first NHEP Strategic Communication Plan (SCP), which prioritizes communication activities and target audiences for the organization. Communication of monitoring information varies depending on strategic planning, however, typically a triennial “State of New Hampshire’s Estuaries” report will be produced using environmental indicator data and distributed to municipal planning officials. The release of this report, as well as other appropriate monitoring information, will be communicated to the public through in appropriate media. Periodic conferences to communicate environmental indicators and status to target audiences will be organized by the NHEP.

7. Implementation Plan

a. Progress to Date

January 2001: A committee of monitoring experts from the NHEP management committee selected a series of monitoring activities to be funded with NHEP implementation funds in 2001-2002, based on the degree to which each: 1) was relevant to NHEP goals, 2) added information to highly valued topics, 3) filled data gaps, 4) fulfilled management needs, and 5) was cost effective. The selected activities were funded by NHEP for 2001-2002.

February 2001: The NHEP completed a version of the NHEP Monitoring Plan, which was included in the NHEP Management Plan Approval Package.

April 2001: The NHEP Coastal Scientist was hired. The NHEP Coastal Scientist is responsible for implementing, evaluating, and updating the NHEP Monitoring Plan.

To support the efforts of the NHEP Coastal Scientist, the NHEP also established a Technical Advisory Committee to assist with reviewing monitoring progress, reviewing technical proposals submitted to NHEP, assessing effectiveness of the monitoring program, evaluating and revising the Monitoring Plan, and garnering funding for monitoring. The work of the TAC will be reported to the Management Committee either through the Coastal Scientist or the Chair of the TAC. The current (2008) membership of the TAC is listed in the following table.

NHEP Technical Advisory Committee (2008)

Jennifer Hunter	NHEP
Dave Kellam	NHEP
Derek Sowers	NHEP
Currier, Paul M.	NHDES
Comstock, Gregg	NHDES
Diers, Ted	NHDES/NHCP
Lucey, Kevin	NHDES/NHCP
Nash, Chris	NHDES
Kathy Mills	GBNERR/NHF&G
Jean Brochi	USEPA
Fay Rubin	UNH/CSRC
Fred Short	UNH/JEL
Jonathan Pennock	UNH
Rich Langan	UNH/CICEET
Robert Roseen	UNH/Stormwater Center
Ru Morrison	UNH
Steve Jones	UNH/JEL
Tom Ballestero	UNH

October 2001: The NHEP Coastal Scientist submitted a draft Baseline Environmental Measurement Interpretation Report to the TAC in compliance with EPA Supplemental Funding for FY01. This report identified a suite of potential environmental indicators for the NHEP. This report was a step toward implementing the NHEP Monitoring Plan because the adequacy of the NHEP monitoring plan can only be judged by its ability to support the NHEP indicators.

December 2001-January 2002: During this period, the TAC met twice (12/12/01, 1/3/02) to discuss the recommendations from the draft Baseline Environmental Interpretation Report and reach consensus on which indicators were needed by the NHEP. Six subcommittees were

appointed to work out the details for each of the recommended indicators. Each of the subcommittees met once in January 2002. The subcommittees' recommendations were reported back to the full TAC on 2/1/02 at which point the recommended suite of indicators was adopted.

March 2002: NHEP completed a substantial revision of its Monitoring Plan. Phase I comments from EPA on the February 2001 draft were addressed. The results of the indicator development process undertaken by the NHEP Coastal Scientist and TAC from October 2001 through January 2002 were included in this version of the plan.

September 2002: The NHEP completed an evaluation of the monitoring programs for the NHEP Monitoring Plan (NHEP, 2002). The monitoring programs for each indicator were reviewed to determine: (1) if the correct parameters were being measured with the correct analytical methods; (2) if the correct stations were being monitored; and (3) if the monitoring program had enough statistical power to meet the data quality objectives of the indicator. The result was a list of datagaps, an estimate of the budgets that would be need to correct all the datagaps, and recommendations for new data quality objectives for some indicators.

September 2002 – April 2003: The NHEP Coastal Scientist completed reports to the TAC on the status and trends of Shellfish, Water Quality, Critical Species/Habitats, and Land Use/Development Indicators. The TAC reviewed the reports and decided on a subset of important indicators that should be presented to the Management Committee.

September 2003: The NHEP produced a "State of the Estuaries" report using the environmental indicators that had been selected from the indicator reports by the TAC, the NHEP Coastal Scientist, and the Management Committee

October 2003: The NHEP held a "State of the Estuaries" Conference based on the SOE report.

April 2004: The NHEP completed a comprehensive update to the Monitoring Plan (version 4). The update incorporated recommended changes to data quality objectives from NHEP (2002), changes to indicator calculations that were recommended in the indicator reports, and updates to the monitoring program information. The revised plan was reviewed by the TAC. Comments by the TAC were incorporated and final version was produced on 6/30/04.

June 2004: The NHEP compiled an inventory of freshwater monitoring programs in the coastal watershed.

December 2005: The NHEP produced an inventory of coastal and estuarine monitoring programs in New Hampshire.

September 2005 – May 2006: The NHEP Coastal Scientist completed reports to the TAC on the status and trends of Shellfish, Water Quality, Critical Species/Habitats, and Land Use/Development Indicators. The TAC reviewed the reports and decided on a subset of important indicators that should be presented to the Management Committee.

September 2006: The NHEP produced a "State of the Estuaries" report using the environmental indicators that had been selected from the indicator reports by the TAC, the NHEP Coastal Scientist, and the Management Committee

October 2006: The NHEP held a "State of the Estuaries" Conference based on the SOE report.

July 2008: The NHEP completed a comprehensive update to the Monitoring Plan (version 5).

b. Next Steps

The NHEP Monitoring Plan will be considered "fully implemented" when the NHEP is able to *accurately* report on at least one indicator (environmental or administrative) for each management objective. The major steps that are still needed to reach full implementation are:

- Develop the research indicators for management objectives that do not have any environmental indicators or administrative indicators (LND5-1, SHL1-2, WQ2-1B).

- Identify any emerging issues for which monitoring programs/indicators should be added.

- Conduct a complete review of the monitoring programs and indicators (similar to NHEP, 2002) as part of the 2008-2009 indicator reports.

- Revise the Monitoring Plan to report on any new management goals and objectives after the new Comprehensive Conservation and Management Plan is developed in 2010. This revision will include the addition of monitoring programs and indicators for the portion of the watershed in Maine.

- Continue to fund and implement annual monitoring programs and special studies. The following table documents NHEP funding on monitoring programs from 2001-2009. The annual average for the total monitoring costs is $96,000. By the end of 2009, the NHEP will have invested $865,402 into monitoring programs or studies.

Year	Core Annual Programs	Other Monitoring Projects & Special Studies	Total	Cumulative Total
2001	$28,280	$40,825	$69,105	$69,105
2002	$32,963	$63,830	$96,793	$165,898
2003	$46,574	$73,220	$119,794	$285,692
2004	$47,900	$21,780	$69,680	$355,372
2005	$54,100	$63,645	$117,745	$473,117
2006	$52,650	$3,000	$55,650	$528,767
2007	$59,500	$81,200	$140,700	$669,467
2008 (budget)	$59,200	$64,935	$124,135	$793,602
2009 (budget)	$61,800	$10,000	$71,800	$865,402

- Periodically fund special monitoring projects according to the following schedule.

Special Monitoring Projects	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Impervious Surfaces	X					X					P					P
Conservation/ Public Lands				X		X			X			P				P
Tidal Wetlands					X										P	
Oyster Bed Maps			X	X						P					P	
Gulfwatch Oyster/ Clam Monitoring		X	X			X		X			P			P		
WWTF Effluent Monitoring			X						X			P				P

X = Latest available dataset
P = Needed future dataset
Yellow highlight denotes years for "State of the Estuaries" Conferences

8. References

Ballestero TP, Roseen RM, Brannaka LK (2004) Inflow and Loadings from Groundwater to the Great Bay Estuary, New Hampshire. A final report submitted to the NOAA/UNH Cooperative Institute for Coastal and Estuarine Environmental Technology (CICEET). Prepared by the University of New Hampshire, Department of Civil Engineering, Durham, NH. January 6, 2004. Available from: www.ciceet.unh.edu.

Bolster CH, Jones SH, Bromley JM (2003) Evaluation of effects of wastewater treatment discharge on estuarine water quality. A final report to the NH Department of Environmental Services and the NH Estuaries Project. University of New Hampshire, Durham, NH. Retrieved July 8, 2008 from http://nhep.unh.edu/resources/pdf/evaluationofeffects-unh-03.pdf.

CWP (2003) Impacts of Impervious Cover on Aquatic Systems. Watershed Protection Research Monograph Number 1. Center for Watershed Protection, Ellicott City, MD. March 2003. Available from: www.stormwatercenter.net.

Deacon, J.R., Soule, S.A., and Smith, T.E. (2005) Effects of urbanization on stream quality at selected sites in the Seacoast region in New Hampshire, 2001-03: U.S. Geological Survey Scientific Investigations Report 2005-5103, 18 p. Retrieved July 8, 2008 from http://pubs.usgs.gov/sir/2005/5103/.

EPA (1992) Monitoring Guidance for the National Estuary Program, EPA 842-B-92-004, U.S. Environmental Protection Agency, Office of Water, Washington DC, September 1992.

EPA (1999) Evaluation Guidelines for Ecological Indicators. US Environmental Protection Agency, Office of Research and Development, Washington DC. EPA/620/R-00/005g. October 1999.

EPA (2000) Guidance for assessing chemical contaminant data for use in fish advisories. EPA 823-B-00-007. U.S. Environmental Protection Agency, Office of Water, Washington DC. November 2000. Retrieved May 20, 2008 from http://www.epa.gov/waterscience/fish/guidance.html.

EPA (2005) National Coastal Condition Report II, EPA-620/R-03/002. U.S. Environmental Protection Agency, Office of Research and Development and Office of Water, Washington DC. Retrieved July 8, 2008 from http://www.epa.gov/owow/oceans/nccr/.

GOMC (2002) Action Plan 2001-2006. Gulf of Maine Council on the Marine Environment. Retrieved July 8, 2008 from http://www.gulfofmaine.org/council/action_plan/action_plan2001-06.pdf.

Grizzle, RE, MA Brodeur, HA Abeels, and JK Greene (2008) Bottom habitat mapping using towed underwater videography: Subtidal oyster reefs as an example application. *Journal of Coastal Research*, 24(1): 103-109.

Helsel DR and Hirsch RM (1992) Statistical methods in Water Resources. Elsevier, Amsterdam. 522 pp. Retrieved July 8, 2008 from http://pubs.usgs.gov/twri/twri4a3/.

Jones and Gaudette (2001) Stormwater-Related Bacterial and Trace Metal Contamination of New Hampshire Tidal Rivers. A final report to the New Hampshire Office of State Planning, Coastal Program. University of New Hampshire, Durham, NH. November 2001.

Kline SJ (1985) The purposes of uncertainty analysis. *Journal of Fluids Engineering*, 107: 153-160.

Langan (1997) Assessment of Shellfish Populations in the Great Bay Estuary. A Final Report to the NHEP. December 1997. Retrieved July 8, 2008 from http://nhep.unh.edu/resources/nev.htm.

Loder TC, Love JA, Kim JP and CG Wheat (1983) Nutrient and hydrographic data for the Great Bay Estuarine System, New Hampshire-Maine: Part II, January 1976 – June 1978. UNH-MP-D/TR-SG-83-4. University of New Hampshire Marine Program, Durham, NH.

NHDES (2005) Evaluation of Sediment Quality Guidance Document. NHDES-WD-04-9. New Hampshire Department of Environmental Services, Watershed Management Bureau, Concord, NH. April 2005.

NHDES (2008) State of New Hampshire 2008 Section 305(b) and 303(d) Consolidated Assessment and Listing Methodology. NHDES-WD-R-08-2. New Hampshire Department of Environmental Services, Water Division, Watershed Management Bureau, Concord, NH. Retrieved July 8, 2008 from http://des.nh.gov/WMB/swqa/03dListDRAFT.html.

NHEP (2000) Management Plan. New Hampshire Estuaries Project, Portsmouth NH. Retrieved July 8, 2008 from http://nhep.unh.edu/resources/pdf/nhepmanagementplan-nhep-05.pdf.

NHEP (2002) Evaluation of Monitoring Programs for the NHEP Monitoring Plan. NH Estuaries Project, Portsmouth, NH. September 27, 2002. Retrieved July 8, 2008 from http://nhep.unh.edu/resources/pdf/evaluationofmonitoring-nhep-02.pdf.

NHEP (2002b) Power Analysis for Dry-Weather Bacteria Trend Detection at Tributary Monitoring Stations. Internal Memorandum. NH Estuaries Project, Portsmouth, NH. Dec. 4, 2002.

NHEP (2003a) Environmental Indicator Report: Water Quality. New Hampshire Estuaries Project, Durham, NH.

NHEP (2003b) Environmental Indicator Report: Land Use and Development. New Hampshire Estuaries Project, Durham, NH.

NHEP (2005) Environmental Indicator Report: Shellfish. New Hampshire Estuaries Project, Durham, NH. Retrieved July 8, 2008 from http://nhep.unh.edu/resources/pdf/env-ind-shellfish-nhep-05.pdf

NHEP (2005b) Management Plan, 2005 Update. New Hampshire Estuaries Project, Durham, NH. Retrieved July 16, 2008 from http://www.nhep.unh.edu/resources/pdf/2005_ccmp_update(only)_-nhep-05.pdf

NHEP (2006a) Environmental Indicator Report: Water Quality. New Hampshire Estuaries Project, Durham, NH. Retrieved July 8, 2008 from http://nhep.unh.edu/resources/pdf/env_ind_water_quaity-nhep-06.pdf

NHEP (2006b) Environmental Indicator Report: Critical Habitats and Species. New Hampshire Estuaries Project, Durham, NH. Retrieved July 8, 2008 from www.nhep.unh.edu/resources/pdf/env_ind_critical_habitats_and-nhep-06.pdf

NHEP (2006c) Environmental Indicator Report: Land Use and Development. New Hampshire Estuaries Project, Durham, NH. Retrieved July 8, 2008 from http://nhep.unh.edu/resources/pdf/env_ind_land_use-nhep-06.pdf

NHEP (2006d) State of the Estuaries 2006. New Hampshire Estuaries Project, Durham, NH. Retrieved July 8, 2008 from http://nhep.unh.edu/resources/pdf/2006_state_of_the-nhep-06.pdf.

NHEP (2007) Progress Report. New Hampshire Estuaries Project, Durham. NH. Retrieved July 16, 2008 from http://www.nhep.unh.edu/resources/pdf/2007-nhep_progress-nhep-07.pdf.

NHF&G (1995) Wintering Waterfowl on Great Bay, Great Bay National Estuarine Research Reserve, Technical Report No. 2, December 1995.

NHF&G (2001) Quality Assurance Project Plan, Testing of Great Bay Oysters for Two Protozoan Pathogens, Draft for EPA Review. New Hampshire Fish and Game Department, Durham, NH. December 11, 2001. Retrieved July 8, 2008 from http://nhep.unh.edu/resources/qapps/testing_of_great-qapp-nhfg-02.pdf.

NHF&G (2002) Shellfish population and bed dimension assessment for the Great Bay Estuary. A final report to the N.H. Estuaries Project, New Hampshire Fish & Game Department, December 31, 2002. Retrieved July 8, 2008 from http://www.nhep.unh.edu/resources/pdf/shellfishpopulationand-nhfg-02.pdf.

Norall TL, Mathieson AC and CE Penniman (1982) Nutrient and hydrographic data for the Great Bay Estuarine System, New Hampshire-Maine: Part I, September 1973-December 1975. Jackson Estuarine Laboratory contribution #150, UNH-D/TR-83-1. University of New Hampshire Marine Program, Durham, NH.

NSSP (2005) Guide for the Control of Molluscan Shellfish. National Shellfish Sanitation Program, Accessed July 7, 2008 from http://www.cfsan.fda.gov/~ear/nss3-42d.html

Ollinger SV et al. (1993) A spatial model of nitrogen deposition for the Northeastern U.S. *Ecological Applications*, 3(3): 459-472.

Runkel, R.L., Crawford, C.G., and Cohn, T.A. (2004) Load Estimator (LOADEST): A FORTRAN Program for Estimating Constituent Loads in Streams and Rivers: U.S. Geological Survey Techniques and Methods Book 4, Chapter A5, 69 p. http://pubs.usgs.gov/tm/2004/tm4A5/

Schueller (1995). The importance of imperviousness. *Watershed Protection Techniques*, 1(3): 100-111.

Short FT and Burdick DM (1996) Quantifying eelgrass habitat loss in relation to housing development and nitrogen loading in Waquoit Bay, Massachusetts. *Estuaries*, **19**: 730-739.

Short FT and Trowbridge PT (2003) UNH Eelgrass (*Zostera marina*) Monitoring Program, Quality Assurance Project Plan. University of New Hampshire and NH Department of Environmental Services, Concord, NH. June 30, 2003. Retrieved July 8, 2008 from http://nhep.unh.edu/resources/qapps/unh_eelgrass_zostera-qapp-unh&des-03.pdf.

SPNHF (2001) New Hampshire Everlasting: An initiative to conserve our quality-of-life. Working Proposal. Society for the Protection of NH Forests, Concord, NH. September 22, 2001.

TNC (2006) Land Conservation Plan for New Hampshire's Coastal Watersheds. The Nature Conservancy, Concord, NH. Retrieved July 16, 2008 from http://www.nhep.unh.edu/resources/pdf/land_conservation_plan-tnc-07.pdf.

Triola, M.R. (1998) Elementary Statistics, Seventh Edition. Addison-Wesley, Reading, MA.

APPENDICES

APPENDIX A: NHEP MANAGEMENT GOALS AND OBJECTIVES AND THEIR ASSOCIATED MONITORING QUESTIONS AND ENVIRONMENTAL INDICATORS

Focus Area New	Management Goal	Management Objective	Monitoring Question	Environmental Indicator	Indicator Type	Goal
Water Quality	Water Quality Goal #1: Ensure that NH's estuarine waters and tributaries meet standards for pathogenic bacteria including fecal coliform, E. coli, and Enterococci	WQ1-1: Achieve water quality in Great Bay and Hampton Harbor that meets shellfish harvest standards by 2010.	Do NH tidal waters meet fecal coliform standards of the National Shellfish Sanitation Program for 'approved' shellfish areas?	BAC1: Acre-days of shellfish harvesting opportunities in estuarine waters	Environmental Indicator	100% of possible acre-days
			Has dry weather bacterial contamination changed significantly over time?	BAC2: Trends in dry weather bacterial indicators concentrations	Environmental Indicator	Significantly decreasing trends at tributary stations
			Has wet weather bacterial contamination changed significantly over time?	BAC3: Trends in wet weather bacterial indicators concentrations	Research Indicator	TBD
		WQ1-2: Minimize beach closures due to failure to meet water quality standards for tidal waters.	Do NH tidal waters, including swimming beaches, meet the state enterococci standards?	BAC4: Tidal bathing beach postings	Environmental Indicator	0 postings per year
				BAC6: Violations of enterococci standard in estuarine waters	Environmental Indicator	0% of estuarine area in violation of standard
		WQ1-3: Increase water bodies in the NH coastal watershed designated 'swimmable' by achieving state water quality standards.	Do NH designated freshwater beaches in the coastal watershed meet the state E. coli standards?	BAC7: Freshwater bathing beach postings	Environmental Indicator	0 postings per year
			Do NH surface freshwaters meet the state E. coli standards?	None. The TAC determined that the monitoring needed to accurately answer this question was not cost-effective.	None	None
		WQ1-4: Reduce the number of known illicit connections in the NH coastal watershed by 50% by 2010.	None	None	Administrative	50% reduction in sources by 2010.
		WQ1-5: Achieve 50% reduction of known illegal discharges into Great Bay, Hampton Harbor, and the tributaries by 2010.	None	None	Administrative	50% reduction in sources by 2010.
		No management objectives but useful for interpreting other indicators for this goal.	Do NH tidal waters contain disease causing and biotoxic organisms (pathogenic bacteria, viruses, harmful algal blooms)?	BAC9: Concentrations of microbial pathogens and harmful algae	Research Indicator	TBD
			None	BAC8: Bacteria load from wastewater treatment plants	Research Indicator	TBD
	Water Quality Goal #2: Ensure that NH's estuarine waters, tributaries, sediments, and edible portions of fish, shellfish, other aquatic life, and wildlife will meet standards for priority contaminants such as metals, PCBs, PAHs, and oil and grease.	WQ2-1A: Reduce toxic contaminants levels in indicator species so that no levels persist or accumulate according to FDA guideline levels.	Are shellfish, lobsters, finfish, and other seafood species from NH coastal waters fit for human consumption?	TOX1: Shellfish tissue concentrations relative to FDA standards.	Environmental Indicator	0% of stations with mean concentrations greater than FDA guidance values

Focus Area New	Management Goal	Management Objective	Monitoring Question	Environmental Indicator	Indicator Type	Goal
Water Quality	Water Quality Goal #2: Ensure that NH's estuarine waters, tributaries,	WQ2-1A: Reduce toxic contaminants levels in indicator species so that no levels persist	Are shellfish, lobsters, finfish, and other seafood species from NH coastal waters fit for human consumption?	TOX8: Finfish and lobster edible tissue concentrations relative to risk-based standards.	Environmental Indicator	Average concentrations of Hg and PCBs in target species less than risk-based standards
			Have the concentrations of toxic contaminants in estuarine biota significantly changed over time?	TOX3: Trends in shellfish tissue contaminant concentrations	Environmental Indicator	No increasing trends for any toxic contaminants at any locations
		WQ2-1B: Reduce toxic contaminants levels in water so that no levels persist or accumulate according to State WQS in Ws 1700.	Do NH tidal waters contain heavy metals, PCBs, PAHs, chlorinated pesticides, and other toxic contaminants that are harmful to humans, animals, plant, and other aquatic life?	TOX9: Toxic contaminants in stormwater runoff and receiving waters	Research Indicator	TBD
		WQ2-1C: Reduce toxic contaminants levels in sediment so that no levels persist or accumulate according to ER-M levels.	Do NH tidal sediments contain heavy metals, PCBs, PAHs, chlorinated pesticides, and other toxic contaminants that are harmful to humans, animals, plant, and other aquatic life?	TOX5: Sediment contaminant concentrations relative to NOAA guidelines	Environmental Indicator	0% of the estuaries with sediment concentrations greater than PEC values or five times TEC values
			Have the concentrations of toxic contaminants in sediment significantly changed over time?	TOX6: Trends in sediment contaminant concentrations	Environmental Indicator	No increasing trends for any toxic contaminants
			Is there evidence of toxic effects of contaminants in estuarine biota?	TOX7: Benthic community impacts due to sediment contamination	Environmental Indicator	0% of estuarine area with impacts to the benthic community due to sediment contamination.
	Water Quality Goal #3: Ensure that NH's estuarine waters and tributaries will meet standards for organic and inorganic nutrients, especially nitrogen, phosphorus, chlorophyll-a, dissolved oxygen, and biological oxygen demand.	WQ3-1: Maintain inorganic nutrients, nitrogen, phosphorus, and chlorophyll-a in Great Bay, Hampton Harbor, and their tributaries at 1998-2000 baseline levels. WQ3-2: Maintain organic nutrients in Great Bay, Hampton Harbor, and their tributaries at 1994-19	Have levels of dissolved and particulate nitrogen and phosphorus significantly changed over time?	NUT2: Trends in estuarine nutrient concentrations	Environmental Indicator	No increasing trends for any nitrogen or phosphorus species
				NUT9: Percent of estuary with total nitrogen concentration greater than criteria	Research Indicator	0% of estuarine waters listed as impaired for swimming due to nitrogen in 305(b) reports.
				NUT10: Eelgrass Nutrient Pollution Index (NPI)	Research Indicator	TBD
			Is there evidence of proliferation of nuisance species associated with elevated nutrient loading?	NUT4: Distribution of nuisance macroalgae	Research Indicator	TBD
			Has the total nitrogen load to Great Bay significantly changed over time?	NUT1: Annual load of nitrogen to Great Bay from WWTF and watershed tributaries	Environmental Indicator	Less than or equal to 2002-2004 nitrogen loading estimate (1097 tons/yr)
			Have levels of phytoplankton (chlorophyll-a) in NH waters changed significantly over time? Have surface tidal or freshwaters shown a significant change in turbidity (total suspended solids or nephalometric turbidity units) over time?	NUT3: Trends in estuarine particulate concentrations	Environmental Indicator	No increasing trends for chlorophyll-a or total suspended solids
			Do any surface freshwaters exhibit chlorophyll-a levels that do not support swimming standards?	NUT8: Percent of estuary with Chlorophyll-a Concentrations greater than State Criteria	Environmental Indicator	0% of estuarine waters listed as impaired for swimming due to chlorophyll-a in 305(b) reports.

Focus Area New	Management Goal	Management Objective	Monitoring Question	Environmental Indicator	Indicator Type	Goal
Water Quality	Water Quality Goal #3: Ensure that NH's estuarine waters and tributaries will meet standards for organic and inorganic nutrients, especially nitrogen, phosphorus, chlorophyll-a,	WQ3-3: Maintain dissolved oxygen levels at: >4 mg/L for tidal rivers; >6 mg/L for embayments (Great Bay and Little Bay); >7 mg/L for oceanic areas (Hampton Harbor and Atlantic Coast).	Do any surface tidal or freshwaters show less than 75% saturation of dissolved oxygen? For what period of time?	NUT5: Exceedences of the instantaneous dissolved oxygen standard in tidal waters	Environmental Indicator	0 days/year with violations of standard
				NUT6: Exceedences of the daily average dissolved oxygen standard in tidal waters	Environmental Indicator	0 days/year with violations of standard
		WQ3-4: Maintain NPDES permit levels for BOD at wastewater facilities in the NH coastal watershed.	Do any surface tidal or freshwaters show a significant change in biological oxygen demand?	NUT7: Trends in BOD loading to Great Bay	Environmental Indicator	No signficantly increasing trends in BOD loads from WWTFs

Focus Area New	Management Goal	Management Objective	Monitoring Question	Environmental Indicator	Indicator Type	Goal
Biological	Land Use Goal #6: Maintain habitats of sufficient size and quality to support populations of naturally occurring plants, animals, and communities.	No objectives but relevant to the goal	Has the acreage of waters supporting designated uses (fishing, swimming, shellfishing, etc.) significantly changed over time?	None. The methods for 305b assessments of designated use support change year-to-year. Therefore, this is not a stable indicator.	None	None
			Has the relative abundance, biology, and species composition of resident finfish changed significantly over time?	HAB7: Abundance of juvenile finfish	Research Indicator	TBD
				HAB14: Abundance of adult finfish	Research Indicator	TBD
			Has eelgrass habitat in the Great Bay changed over time?	HAB2: Eelgrass distribution	Supporting Variable	None
				HAB12: Eelgrass Biomass	Supporting Variable	None
			Has the population of wintering waterfowl on the NH coast changed over time?	HAB10: Abundance of wintering waterfowl	Supporting Variable	None
			Has the number of anadromous fish returning to NH's coastal rivers changed over time?	HAB8: Anadromous fish returns	Supporting Variable	None
			Has the abundance or species distribution of marine aquatic nuisance species changed over time?	HAB15: Abundance of marine aquatic nuisance species	Research Indicator	TBD
			Is the use of freshwater in the coastal watershed sustainable?	HAB16: Freshwater quantity in the coastal watershed	Research Indicator	TBD
	Shellfish Goal #1: Achieve sustainable shellfish resources by tripling the area of shellfish beds that are classified open for harvesting to 75% of all beds, and tripling the quantity of harvestable clams and oysters in NH's estuaries.	SHL1-1: Maintain an approved National Shellfish Sanitation Program supported by the state.	None	None	Administrative	The State has an approved NSSP program
		SHL1-2: Increase soft shell clam beds in Great Bay, Little Bay, and Hampton Harbor that are open for harvest to 2500 acres by 2010.	Are 75% of all shellfish (oyster, soft-shell clam) beds open for harvesting?	SHL13: Open shellfish beds in estuarine waters (percent by area)	Research Indicator	TBD
		SHL1-3: No net decrease in acreage of oyster beds from 1997 amounts for Nannie Island, Woodman Point, Piscataqua River, Adams Point, Oyster River, Squamscott River, and Bellamy River.	Has the area of oyster beds in Great Bay decreased from the 1997 levels?	SHL1: Area of oyster beds in Great Bay	Environmental Indicator	Greater than or equal to 1997 cumulative acreage for six primary beds (64.2 ac)

Focus Area New	Management Goal	Management Objective	Monitoring Question	Environmental Indicator	Indicator Type	Goal
Biological	Shellfish Goal #1: Achieve sustainable shellfish resources by tripling the area of shellfish beds that are classified open for harvesting to 75% of all beds, and tripling the quantity of harvestable	SHL1-4A: No net decrease in oysters (>80 mm) per square meter from 1997 amounts at Nannie Island, Woodman Point, Piscataqua River, Adams Point, and Oyster River.	Has the density of harvestable size oysters in Great Bay beds decreased from 1997 levels?	SHL2: Density of harvestable oysters at Great Bay beds	Environmental Indicator	Greater than or equal to 1997 density at six primary beds
		SHL1-4B: No net decrease in adult clams (>50 mm) per square meter from the 1989-1999 10-year average at Common Island, Hampton River, and Middle Ground.	Ha the density of harvestable size clams in Hampton Harbor decreased from the historic average?	SHL3: Density of harvestable clams at Hampton Harbor flats	Environmental Indicator	Greater than or equal to 1990-1999 10-year average density for three primary flats
		SHL1-5: Survey each major oyster and soft-shell clam bed at a minimum of every 3 years for dimensions, density, and population structure.	None	None	Administrative	Conduct surveys of the six major oyster beds every three years.
		No objectives but useful for interpreting other indicators or relevant to the goal.	Has the area of clam flats in Hampton Harbor changed over time?	SHL4: Area of clam flats in Hampton Harbor	Supporting Variable	None
			Has the number of harvestable clams and oysters in NH estuaries tripled from 1999 levels?	SHL5: Standing stock of harvestable oysters in Great Bay	Environmental Indicator	Greater than 50,000 bushels
				SHL6: Standing stock of harvestable clams in Hampton Harbor	Environmental Indicator	Greater than 8,500 bushels
			Are NH shellfish healthy, growing, and reproducing at sustainable levels?	SHL7: Abundance of shellfish predators	Supporting Variable	None
				SHL8: Clam and oyster spatfall	Supporting Variable	None
			Are NH shellfish being harvested at sustainable levels?	SHL9: Recreational harvest of oysters	Supporting Variable	None
				SHL10: Recreational harvest of clams	Supporting Variable	None
			Has the incidence of shellfish diseases significantly changed over time?	SHL11: Prevalence of oyster diseases	Supporting Variable	None
				SHL12: Prevalence of clam disease	Supporting Variable	None
	Shellfish Goal #2: Assure that shellfish are fit for human consumption and support a healthy marine ecosystem.	SHL2-1: Achieve water quality in GB and HH that will meet shellfish harvest standards by 2010.	None	None. This objective is also listed under Water Quality Goal #1 and will be addressed there.	NA-Duplicate	None
	Shellfish Goal #3: Provide opportunities and strategies for restoration of shellfish communities and habitat.	SHL3-1: Restore 20 acres of oyster habitat in GB and its tidal tributaries.	None	None. This objective is also listed under Habitat Restoration Goal #1 and will be addressed there.	NA-Duplicate	None
	Shellfish Goal #4: Support coordination to achieve environmentally sound shellfish aquaculture activities.	SHL4-1: Ensure that aquaculture practices do not adversely impact water quality or ecological health of NH's estuaries.	None	While water quality can be used to monitor individual aquaculture operations, the intent of this objective is to monitor aquaculture practices in general. Therefore, an adminstrative indicator will be used to track and report on aquaculture permits and	Administrative	No goal but the permit requirements and any breeches of those requirements for all active aquaculture enterprises will be tracked and reported.

Focus Area New	Management Goal	Management Objective	Monitoring Question	Environmental Indicator	Indicator Type	Goal
Biological	Land Use Goal #2: Maximize the acreage and health of tidal wetlands in the NH coastal watershed.	LND2-1: Allow no loss or degradation of 6200 acres of tidal wetlands in the NH coastal watershed and restore 300 acres of tidal wetlands degraded by tidal restrictions by 2010.	Have restoration efforts resulted in a significant increase in the acreage of tidal wetlands?	None. This question is also listed under Habitat Restoration Goal #1 and will be addressed there.	NA-Duplicate	None
			Has there been any significant net loss or degradation of tidal wetlands in NH? Has the acreage of invasive species (phragmites, purple loosestrife) in NH salt marshes and wetlands significantly changed over time?	HAB1: Salt Marsh Extent and Condition	Environmental Indicator	Greater than 6,200 acres
	Land Use Goal #5: Allow no net loss of freshwater wetlands functions in the NH coastal watershed.	LND5-1: Determine indicators for freshwater wetland functions.	Has there been any significant net loss or degradation of freshwater wetlands in NH?	HAB12: Indicators for freshwater wetland functions	Research Indicator	TBD
			Have restoration efforts resulted in a significant increase in the acreage of freshwater wetlands?	None. Without an assessment of baseline conditions, the effects of wetland restoration efforts cannot be made.	None	None
		LND5-2: Establish a state and municipal regulatory framework necessary to prevent introduction of untreated stormwater into tidal and freshwater wetlands by 2010.	None	None	Administrative	No goal but legislative progress made on the development of rules to prevent the introduction of untreated stormwater in tidal and freshwater wetlands will be reported.
		LND5-3: Increase use of buffers around wetlands in NH coastal watershed.	None	None	Administrative	No goal but all NHEP-funded projects to develop buffers around wetlands will be reported.

Focus Area New	Management Goal	Management Objective	Monitoring Question	Environmental Indicator	Indicator Type	Goal
Conservation, Restoration, and Development	Land Use Goal #6: Maintain habitats of sufficient size and quality to support populations of naturally occurring plants, animals, and communities.	LND6-1: By 2005, determine the existing acres of permanently protected land in the NH coastal watershed in the following categories: tidal shoreland, large contiguous forest blocks, wetlands with high habitat values, freshwater shorelands, rare and exempl	How much of the coastal watershed is protected from development?	HAB6: Protected conservation lands	Environmental Indicator	15% of land area of coastal watershed and coastal communities by 2010
		LND6-2: Increase the acreage of protected land containing significant habitats in the NH coastal watershed through fee acquisition or conservation easements by 2010	Has the acreage of permanently protected important habitats (tidal shorelines, wetlands, rare and exemplary natural communities, large contiguous forest tracts, wetlands with high habitat value, freshwater shorelands) significantly changed over time?	HAB3: Protected, undeveloped shorelands	Research Indicator	TBD
				HAB13: Acres of protected wetlands with high habitat values.	Research Indicator	TBD
			How much of the conservation focus areas in the coastal watershed are protected from development?	HAB5: Protected conservation focus areas in the coastal watershed	Supporting Variable	None
		LND6-3: Support completion of state biomonitoring standards and increase the miles of rivers and streams meeting those standards by 2010.	Have the miles of rivers and streams meeting high quality biomonitoring standards significantly changed over time?	None. The state has not yet developed biomonitoring standards for rivers and streams. There is no indicator for this management objective.	None	None
	Land Use Goal #3: Protect freshwater and tidal shorelands to ensure estuarine water quality.	LND3-1: Allow no new impervious surfaces or major disturbances of existing vegetation (except for water-dependent uses) in NH coastal watershed. In addition to state Shoreland Protection Act regulations, encourage additional reductions in shoreland impac	None	None. No indicator was developed because the goal is infeasible. There is no indicator for this management objective.	None	None
		LND3-2: Allow no new establishment or expansion of existing contamination sources (such as salt storage, junk yards, solid waste, hazardous waste, etc.) within the shoreland protection area as tracked by the Department of Environmental Services.	None	None	Administrative	No goal but violations tracked by the NHDES Comprehensive Shoreland Protection Act staff and by NH DES Wetlands investigators will be reported.
	Habitat Restoration Goal #1: Maintain habitats of sufficient size and quality to support populations of naturally occurring plants, animals, and communities	RST1-1A: Increase acreage of restored estuarine habitats by 2010: (1) Restore 300 acres of salt marsh with tidal restrictions.	Have restoration efforts resulted in a significant increase in the acreage of salt marsh?	RST1: Restored salt marsh	Environmental Indicator	Greater than 300 acres by 2010

APPENDIX B: MAPS OF COASTAL MONITORING STATIONS

Figure 1

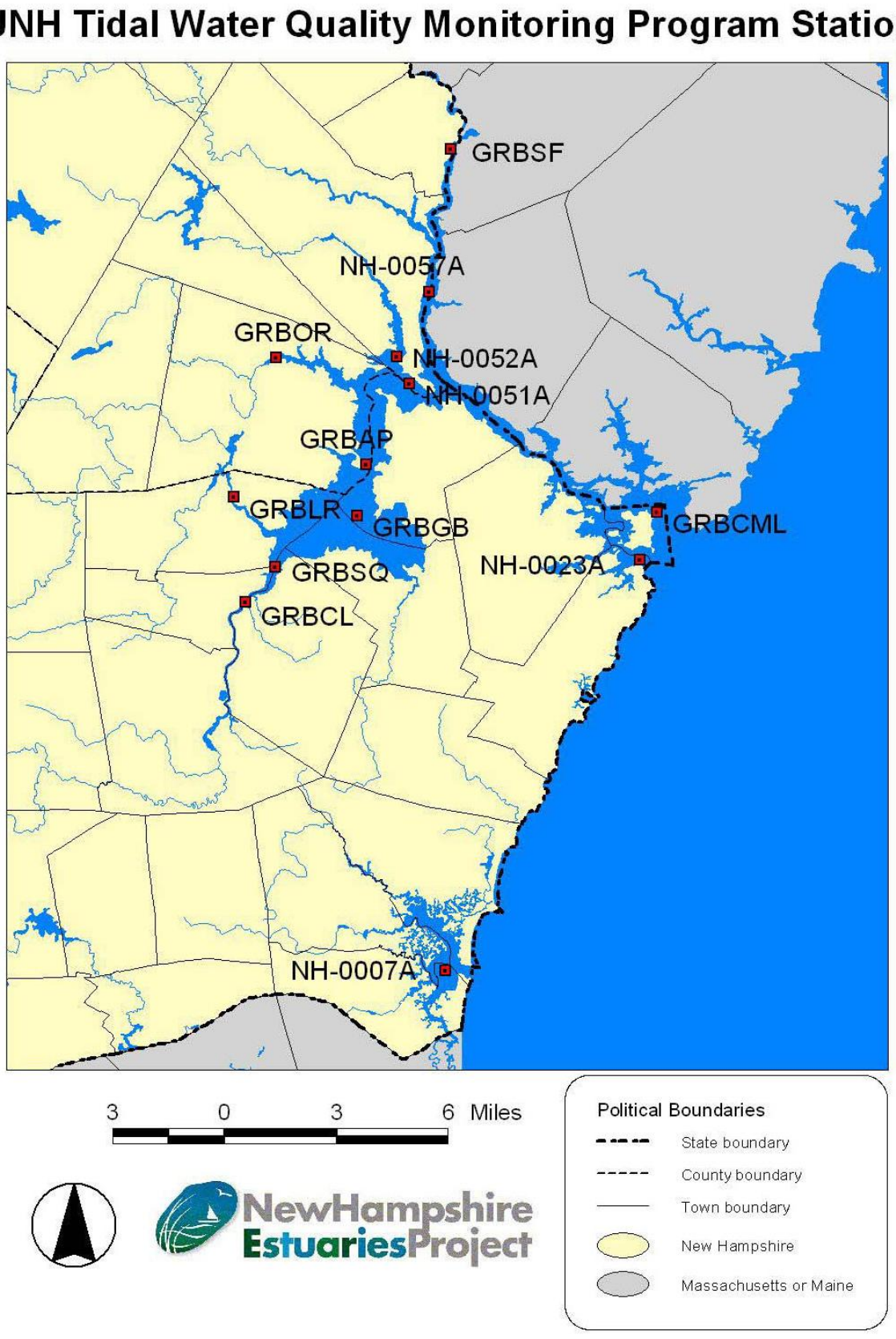

UNH Tidal Water Quality Monitoring Program Station
GRBSF
NH-0057A
GRBOR
NH-0052A
NH-0051A
GRBAP
GRBLR
GRBGB
GRBCML
NH-0023A
GRBSQ
GRBCL
NH-0007A
3 0 3 6 Miles
NewHampshire EstuariesProject
Political Boundaries
State boundary
County boundary
Town boundary
New Hampshire
Massachusetts or Maine

Figure 2

Gulfwatch Monitoring Program Stations

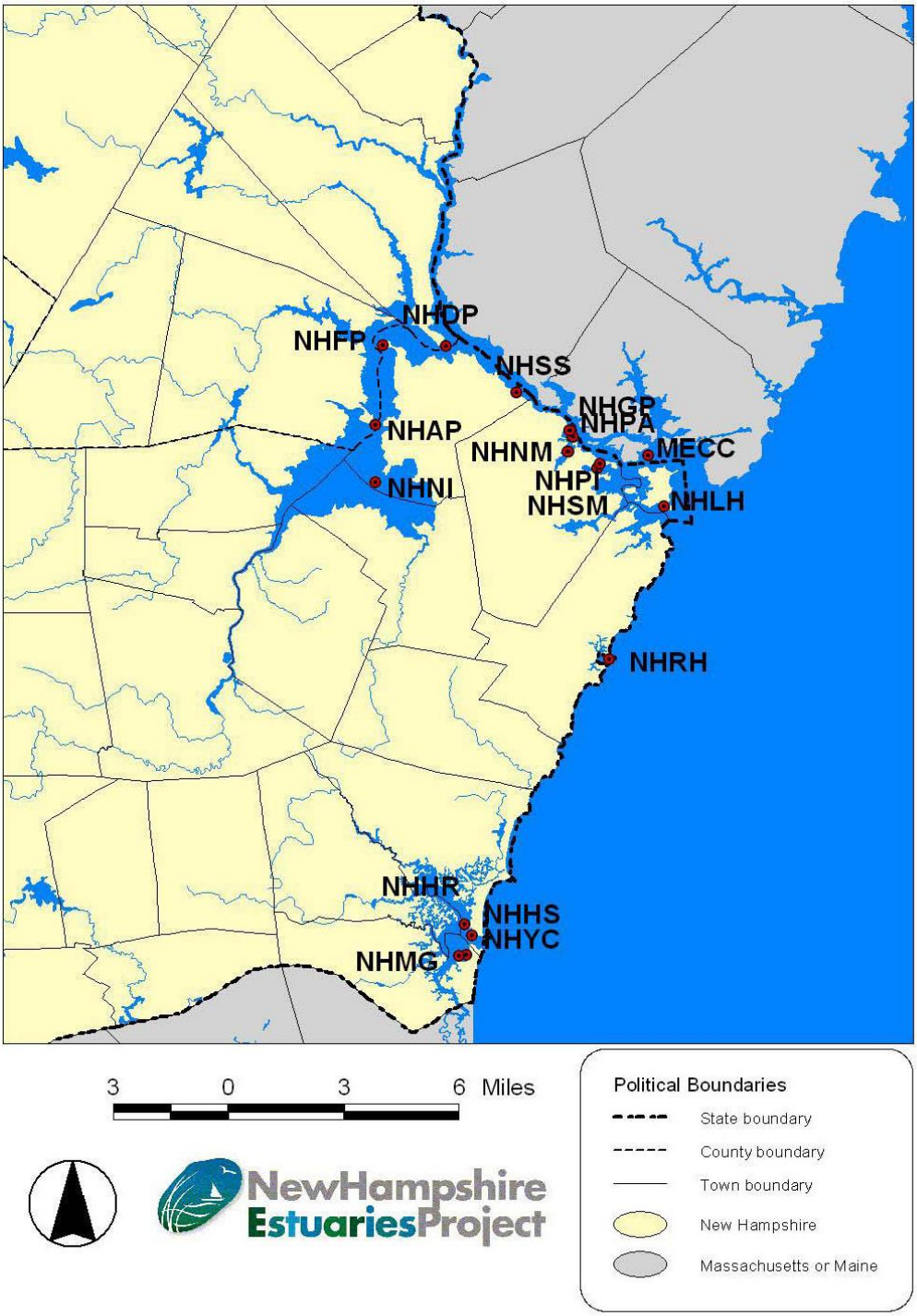


Figure 3

Stream Flow and Water Quality Stations on Tributaries to the Great Bay Estuary

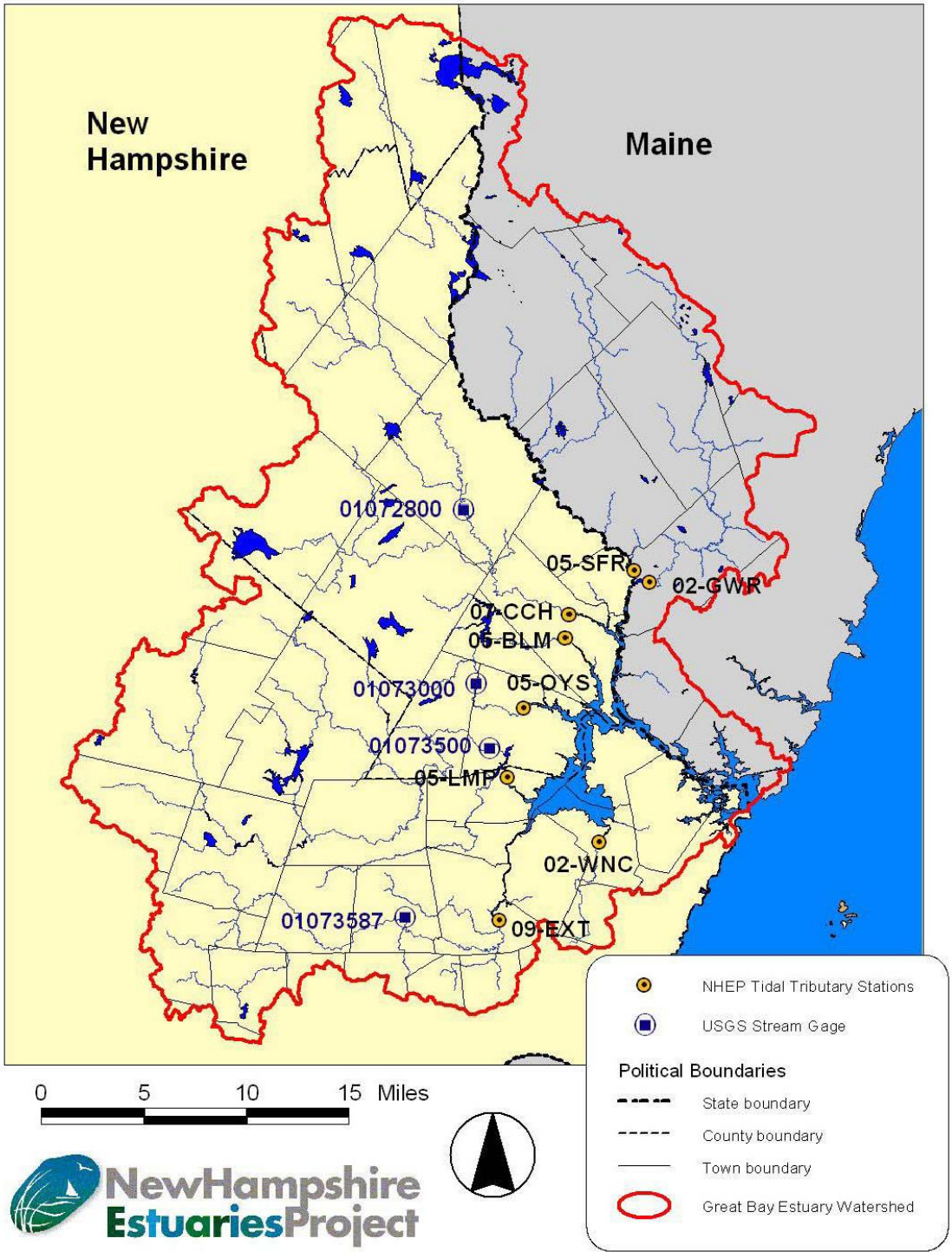


Figure 4: Wastewater Treatment Facilities in the Great Bay Estuary Watershed

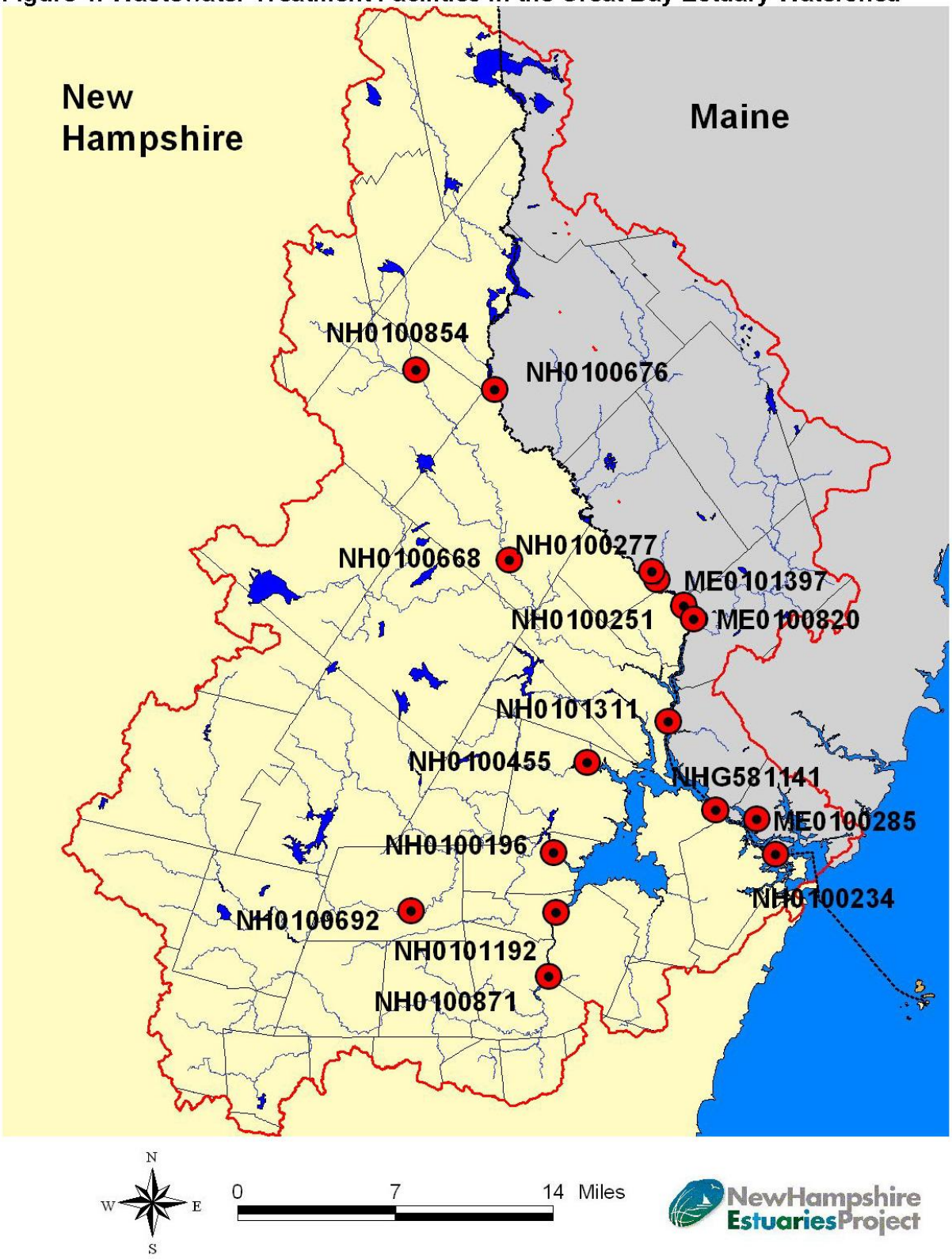


Figure 5

Anadromous Fish Passage Monitoring Locations