New Hampshire Estuaries Project

Monitoring Plan

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Chapter 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). 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 will employ two tiers of program tracking. The first tier will be 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 will be 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 will be assessed using the 'measurable' objectives that were developed to evaluate NHEP progress in attaining its programmatic goals. The progress toward the objectives will be 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** will be developed by the NHEP. This will include the following components:

1. <u>Assessments of Environmental and Administrative Indicators</u> - The attainment of program objectives and goals, will be assessed at least every two or three years as part of the National Estuary Program biennial implementation review process. Environmental measurements will be calculated for the environmental indicators outlined in this monitoring plan. Progress made towards administrative indicators will be compiled by the NHEP Director and staff.
2. <u>A Completion Rating for all Action Plans</u> - A completion rating for each action plan, based on the percentage of each Action Plan completed, will be determined on an ongoing basis. This information will be 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.

Tier 2: Specific Project Success
The NHEP will fund specific projects in order to implement the Action Plans outlined in the Management Plan. The NHEP will require and track 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 will require 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 will be negotiated for each project. The project database and the environmental monitoring will be 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 and the NHEP database. 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 will be using environmental indicators for two purposes. First, indicators will be used to report on progress toward Management Plan goals and objectives. Second, the indicators will be used to report on status and trends in water quality and estuarine resources through periodic "State of New Hampshire's Estuaries" reports to the public. This Monitoring Plan will describe how data from ongoing monitoring programs and NHEP-funded monitoring can be 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, 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 official start date for the NHEP).
- 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 has undertaken relative to the objective. For example, for the NHEP objective to "encourage 43 coastal communities to actively participate in addressing sprawl", the administrative indicator will report the number of communities engaged in smart growth activities and the NHEP actions to promote smart growth. The specific actions or variables that will be tracked for these administrative indicators are described in Chapter 9 of this Monitoring Plan.

Summary of All Indicators

Table 1 contains a comprehensive list of all the NHEP Management goals and objectives and their associated monitoring questions, indicators, and measurable goals. Nearly all of the management objectives (35 of 38, 92%) have been tied to at least one indicator, with a breakdown as follows: 21 of the 38 (55%) will be tracked using Environmental Indicators and 14 of the 38 (37%) will be tracked using Administrative Indicators. For the remaining 3 management objectives, research indicators have been identified that will be developed in the future. Table 1 also lists the 20 Supporting Variables that will be used to help interpret the indicators. In total, Table 1 contains 30 Environmental Indicators, 13 Administrative Indicators, 20 Supporting Variables, and 12 Research Indicators. The reason why there are so many more entries on Table 1 than management objectives (75 vs. 38) 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 the March 2003 Version of the Monitoring Plan

In February 2001, the NHEP submitted a Monitoring Plan to EPA as part of Management Plan approval package. EPA returned the plan with comments in July 2001. NHEP and EPA decided that the comments would be addressed in two phases. For the first phase, details on existing indicators would be added to the plan. For the second phase, new indicators needed to report on all the management objectives would be developed. In March 2002, a version of the plan was released which addressed all the Phase I revisions and some of the Phase II comments. For this version of the plan (released March 2003), the chapter on critical species and habitats indicators was updated to address the remainder of EPA's Phase II comments. Other chapters of the report have not been changed except for a few small edits to maintain consistency with the new species and habitats indicators in Chapter 7. In the future, the NHEP Coastal Scientist and the Technical Advisory Committee intend to periodically update the Monitoring Plan to reflect new knowledge, changing priorities, and emerging issues.

The goal of the NHEP Monitoring Plan is to specify the monitoring that is *necessary and sufficient* to track progress on *all* aspects of the NHEP Management Plan. To ensure that all aspects of the Management Plan are addressed each management objective will be matched with at least one indicator (environmental or administrative). For each environmental indicator, the Monitoring Plan will outline the optimal monitoring design.

An environmental indicator is only useful if it is supported by an active monitoring program in reality. All the environmental indicators in this version of the plan have ongoing monitoring programs. However, this may not always be the case, especially as new environmental indicators are developed. On a yearly basis, the NHEP Coastal Scientist and Technical Advisory Committee will prioritize the available monitoring funds between the different indicators. Environmental indicators that are not being monitored will remain in the Monitoring Plan to illustrate the gap between actual and needed funding levels for monitoring.

The Puget Sound Ambient Monitoring Program (PSAMP) adopted this same approach when developing their monitoring plan. Instead of designing a monitoring program to fit the constraints of the existing funding resources, PSAMP prepared a plan of the necessary and sufficient monitoring for comprehensive assessments of Puget Sound. Although the PSAMP plan has not been fully funded, it provides a benchmark by which current funding for monitoring can be compared to what is needed to provide adequate data for good decision-making. The PSAMP plan also provides a blueprint for how monitoring programs should be expanded if additional monitoring funds become available (EPA, 1992).

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 , the **environmental indicators** from Table 1 will be discussed in the following seven chapters (NHEP management goal is listed in parentheses):
Chapter 2: Bacteria and Disease-causing Organisms (Water Quality Goal #1)
Chapter 3: Toxic Contaminants (Water Quality Goal #2)
Chapter 4: Nutrients and Eutrophication (Water Quality Goal #3)
Chapter 5: Shellfish Resources (Shellfish Goals #1-4)
Chapter 6: Land Use (Land Use Goal #1)
Chapter 7: Critical Species and Habitats (Land Use Goals #2-6)
Chapter 8: Habitat Restoration (Habitat Restoration Goal #1)

Each chapter will include the following sections:

- Introduction
- Environmental Indicators
  - Monitoring Objectives
  - Measurable Goals and Performance Criteria
  - Data Analysis, Statistical Methods and Hypothesis
  - Field and Analytical Methods
  - Monitoring Design
- Research Indicators for Out-Years
- References

Chapter 9 will summarize the **administrative indicators** from Table 1.

These indicator summary chapters will be followed by:
Chapter 10: Data Management and Quality Assurance Plan
Chapter 11: Communications Plan
Chapter 12: Implementation Plan

D. References

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 (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.

NHEP (2000) New Hampshire Estuaries Project Management Plan, Portsmouth NH, 2000.

Table 1: NHEP Management Goals and Objectives and their associated Monitoring Questions and Environmental Indicators

Water Quality Goal #1: Ensure that NH's estuarine waters and tributaries meet standards for pathogenic bacteria including fecal coliform, *E. coli*, and enterococci

Management Objective	Monitoring Question	Environmental Indicator	Indicator Type	Goal
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?	Acre-days of shellfish harvesting opportunities in estuarine waters	Environmental Indicator	100% of possible acre-days
	Have fecal coliform, enterococci, and *E. coli* levels changed significantly over time?	Trends in dry weather bacterial indicators concentrations	Environmental Indicator	Significantly decreasing trends at tributary stations
	Has dry weather bacterial contamination changed significantly over time?			
	Has wet weather bacterial contamination changed significantly over time?	Trends in wet weather bacterial indicators concentrations	Environmental Indicator	Significantly decreasing trends at tributary stns
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?	Tidal bathing beach postings	Environmental Indicator	0 postings per year
		Trends in bacteria concentrations at tidal bathing beaches	Environmental Indicator	No increasing trends at any beaches
		Violations of water quality standard for swimming in ambient tidal waters	Environmental Indicator	0 violations per year
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?	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.	NA	NA
WQ1-4: Reduce the number of known illicit connections in the NH coastal watershed by 50% by 2010.	None.	None.	Administrative	NA
WQ1-5: Achieve 50% reduction of known illegal discharges into Great Bay, Hampton Harbor, and the tributaries by 2010.	None.	None.	Administrative	NA
No management objectives but useful for interpreting other indicators for this goal.	None.	Bacteria loading from municipal waste water treatment plants	Supporting Variable	NA
		Microbial source tracking	Supporting Variable	NA
	Do NH tidal waters contain disease causing and biotoxic organisms (pathogenic bacteria, viruses, harmful algal blooms)?	Concentrations of microbial pathogens and harmful alagae	Research Indicator	NA

Water Quality Goal #2: Ensure that New Hampshire'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.

Management Objective	**Monitoring Question**	**Environmental Indicator**	**Indicator Type**	**Goal**
WQ2-1A: Develop baseline of toxic impacts on ecological and human health by tracking toxic contaminants in water, sediment, and indicator species: blue mussels, tomcod, lobsters, and winter flounder. Long-term: 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?	Shellfish tissue concentrations relative to FDA standards.	Environmental Indicator	0% of stations with concentrations greater than FDA standards
		Public health risks from toxic contaminants in shellfish tissue	Environmental Indicator	0% of stations with unacceptable risks as determined by NHBHRA
		Finfish and lobster edible tissue concentrations relative to FDA standards.	Research Indicator	TBD
		Public health risks from toxic contaminants in finfish and lobster edible tissue	Research Indicator	TBD
	Have the concentrations of toxic contaminants in estuarine biota significantly changed over time?	Trends in shellfish tissue contaminant concentrations	Supporting Variable	NA
		Trends in finfish and lobster tissue contaminant concentrations	Supporting Variable	NA
WQ2-1B: Develop baseline of toxic impacts on ecological and human health by tracking toxic contaminants in water, sediment, and indicator species: blue mussels, tomcod, lobsters, and winter flounder. Long-term: 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?	Toxic contaminants in stormwater runoff and receiving waters	Research Indicator	NA
WQ2-1C: Develop baseline of toxic impacts on ecological and human health by tracking toxic contaminants in water, sediment, and indicator species: blue mussels, tomcod, lobsters, and winter flounder. Long-term: 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?	Sediment contaminant concentrations relative to NOAA guidelines	Environmental Indicator	0% of the estuaries with sediment concentrations greater than NOAA ERL values (see footnote 1)
	Have the concentrations of toxic contaminants in sediment significantly changed over time?	Trends in sediment contaminant concentrations	Supporting Variable	NA
	Is there evidence of toxic effects of contaminants in estuarine biota?	Demonstrated biological impact using sediment toxicity and benthic community IBI.	Research Indicator	NA

Water Quality Goal #3: Ensure that NH's estuarine waters and tributaries will meet standards for organic and inorganic nutrients, especially nitrogen, phosphorous, chlorophyll-a, dissolved oxygen, and biological oxygen demand.

Management Objective	Monitoring Question	Environmental Indicator	Indicator Type	Goal
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.	Have levels of dissolved and particulate nitrogen and phosphorous significantly changed over time?	Annual load of nitrogen to Great Bay from WWTF and watershed tributaries	Environmental Indicator	Less than or equal to 1996 loading estimates (641 tons/yr)
		Trends in estuarine nutrient concentrations	Supporting Variable	NA
		Eelgrass Nutrient Pollution Index	Research Indicator	NA
	Have levels of phytoplankton (chlorophyll-a) in NH waters changed significantly over time?	Frequency and duration of phytoplankton blooms in Great Bay	Research Indicator	NA
	Do any surface freshwaters exhibit chlorophyll-a levels that do not support swimming standards (partially support: 20-30 ug/l; does not support: >30 ug/l)	None. There are no swimming standards for chlorophyll-a	NA	NA
	Have surface tidal or freshwaters shown a significant change in turbidity (total suspended solids or nephalometric turbidity units) over time?	Trends in estuarine particulate concentrations	Supporting Variable	NA
	Is there evidence of proliferation of nuisance species associated with elevated nutrient loading?	Prevalence of nuisance macroalgae.	Research Indicator	NA
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?	Violations of the instantaneous dissolved oxygen standard in tidal waters	Environmental Indicator	0 days/year with violations of standard
		Violations 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?	Trends in BOD loading to Great Bay	Environmental Indicator	No signficantly increasing trends in BOD loads from WWTF or tributaries

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.

Management Objective	**Monitoring Question**	**Environmental Indicator**	**Indicator Type**	**Goal**
SHL1-1: Maintain an approved National Shellfish Sanitation Program supported by the state.	None.	None.	Administrative	NA
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?	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.	NA	Area of oyster beds in Great Bay	Environmental Indicator	Greater than or equal to 1997 acreage
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.	NA	Density of harvestable oysters at Great Bay beds	Environmental Indicator	Greater than or equal to 1997 density
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.	NA	Density of harvestable clams at Hampton Harbor flats	Environmental Indicator	Greater than or equal to 1990-1999 10-year average density
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	NA
No objectives but useful for interpreting other indicators or relevant to the goal.	NA	Area of clam flats in Hampton Harbor	Supporting Variable	NA
	Has the number of harvestable clams and oysters in NH estuaries tripled from 1999 levels?	Standing stock of harvestable oysters in Great Bay	Environmental Indicator	TBD
		Standing stock of harvestable clams in Hampton Harbor	Environmental Indicator	TBD
	Are NH shellfish healthy, growing, and reproducing at sustainable levels?	Abundance of shellfish predators	Supporting Variable	NA
		Clam and oyster spatfall	Supporting Variable	NA
	Are NH shellfish being harvested at sustainable levels?	Recreational harvest of oysters	Supporting Variable	NA
		Recreational harvest of clams	Supporting Variable	NA
	Has the incidence of shellfish diseases significantly changed over time?	Prevalence of oyster diseases	Supporting Variable	NA
		Prevalence of clam disease	Supporting Variable	NA

Shellfish Goal #2: Assure that shellfish are fit for human consumption and support a healthy marine ecosystem.

Management Objective	Monitoring Question	Environmental Indicator	Indicator Type	Goal
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	NA

Shellfish Goal #3: Provide opportunities and strategies for restoration of shellfish communities and habitat.

Management Objective	Monitoring Question	Environmental Indicator	Indicator Type	Goal
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	NA

Shellfish Goal #4: Support coordination to achieve environmentally sound shellfish aquaculture activities.

Management Objective	Monitoring Question	Environmental Indicator	Indicator Type	Goal
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 permit violations state-wide. See Table 9-1 for details.	Administrative	NA

<u>Land Use Goal #1</u>: NH Coastal watershed has development patterns that ensure the protection of estuarine water quality and preserve the rural quality of the watershed.

Management Objective	**Monitoring Question**	**Environmental Indicator**	**Indicator Type**	**Goal**
LND1-1A: Minimize the amount of impervious surfaces and assess the impacts of water quality by: (1) Keeping the total impervious surface in each sub-watersheds below 10% of the total land area;	Has there been a significant change over time in the number of coastal NH watersheds (first or second order) that exceed 10% impervious cover?	Percent of each subwatershed covered by impervious surface in 1990, 2000, and 2005	Environmental Indicator	0 first or second order subwatersheds with greater than 10% impervious surface cover.
	Has the rate of creation of new impervious surfaces in coastal NH watersheds significantly changed over time?			
LND1-1B: Reduce stormwater runoff from future development in all sub-watersheds, especially where impervious surfaces already exceed 10%.	None.	None.	Administrative	NA
LND1-2: Minimize the total rate of land consumption in the NH coastal watershed (as measured by acres of development per capita)	Has the rate of urban sprawl in coastal NH watersheds changed significantly over time?	Ratio of the percent increase in impervious surface to the percent increase in population for 1990-2000 and 2000-2005	Environmental Indicator	0 towns with increasing ratios
		Ratio of the percent increase in road miles to the percent increase in population for 1990-2000 and 2000-2005	Environmental Indicator	0 towns with increasing ratios
		Ratio of the percent decrease in unfragmented lands to the percent increase in population for 1990-2000 and 2000-2005	Environmental Indicator	0 towns with increasing ratios
LND1-3: Encourage 43 coastal watershed municipalities to actively participate in addressing sprawl.	None.	None.	Administrative	NA

Land Use Goal #2: Maximize the acreage and health of tidal wetlands in the NH coastal watershed.

Management Objective	Monitoring Question	Environmental Indicator	Indicator Type	Goal
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.	Has there been any significant net loss or degradation of tidal wetlands in NH?	Acres of salt marsh in coastal NH and acres of salt marsh degraded by tidal restrictions or phragmites.	Environmental Indicator	6,200 acres total of salt marsh in coastal NH
	Has the acreage of invasive species (phragmites, purple loosestrife) in NH salt marshes and wetlands significantly changed over time?			
	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	NA

Land Use Goal #3: Protect freshwater and tidal shorelands to ensure estuarine water quality.

Management Objective	Monitoring Question	Environmental Indicator	Indicator Type	Goal
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 impacts by 2010.	None.	None.	Administrative	NA
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	NA

<u>Land Use Goal #4</u>: Protect estuarine water quality by ensuring that groundwater impacts are minimized.

Management Objective	Monitoring Question	Environmental Indicator	Indicator Type	Goal
LND4-1: Determine the extent of groundwater resources and their contaminant load to Great Bay and Hampton Harbor by 2005.	None.	None.	Administrative	NA
LND4-2: Reduce and eliminate groundwater contaminants based on the outcome of Objective 1 by 2010.	Has the quality of groundwater entering NH estuaries significantly changed over time?	None. Groundwater loads to the estuary will change very slowly. The TAC decided that monitoring these slow changes would not be cost-effective. Instead, NHEP will report on the results of stand alone studies of groundwater loading to the estuaries.	Administrative	NA

<u>Land Use Goal #5</u>: Allow no net loss of freshwater wetlands functions in the NH coastal watershed.

Management Objective	Monitoring Question	Environmental Indicator	Indicator Type	Goal
LND5-1: Determine indicators for freshwater wetland functions.	None.	Indicators for freshwater wetland functions	Research Indicator	NA
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	NA
LND5-3: Increase use of buffers around wetlands in NH coastal watershed.	None.	None.	Administrative	NA
No objective but relevant to the goal: Allow no net loss of freshwater wetlands functions in the NH coastal watershed	Has there been any significant net loss or degradation of freshwater wetlands in NH?	None. Tracking all freshwater wetlands in the coastal watershed would be a monumental task. The TAC decided that this would not be cost-effective for the NHEP. Conservation of "wetlands with high habitat values" will be a Research Indicator under Land Use Goal 6.	NA	NA
	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.	NA	NA

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

Management Objective	Monitoring Question	Environmental Indicator	Indicator Type	Goal
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 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. **LND6-4**: Increase the use of buffers around wildlife areas and maintain contiguous habitat blocks in the NH coastal watershed 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?	Acres of protected, undeveloped tidal and freshwater shoreland	Environmental Indicator	TBD following baseline assessment in 2003
		Acres of protected, large unfragmented forest blocks	Environmental Indicator	TBD following baseline assessment in 2003
		Acres of protected wetlands with high habitat values	Research Indicator	TBD
		Percentage of rare and exemplary natural communities on protected lands	Supporting Variable	NA
	Has the acreage of privately owned lands managed to benefit wildlife and natural communities significantly changed over time?	Acres of conservation lands in the coastal watershed	Environmental Indicator	TBD following baseline assessment in 2003
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. NHEP support for standards development will be tracked.	Administrative	NA
No objectives but relevant to the goal.	Has the relative abundance, biology, and species composition of resident finfish changed significantly over time?	Abundance of juvenile finfish	Supporting Variable	NA
		Anadromous fish returns	Supporting Variable	NA
		Abundance of adult finfish	Research Indicator	NA
	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.	NA
	Do the following indicators show that water quality is suitable for aquatic life: aquatic insects/invertebrates, wildlife, fish, diatoms/algae, large bivalves, eelgrass, marshes?**	Eelgrass Distribution	Supporting Variable	NA
		Abundance of lobsters	Supporting Variable	NA
		Wintering waterfowl abundance	Supporting Variable	NA

** Note: Many of the species listed in this monitoring question are being tracked in other indicators: marshes (see LND2-1), large bivalves (see SHL4-1A/B), aquatic insects/invertebrates (see IBI indicator in WQ2-1C), fish (see juvenile/anadromous finfish above).

Habitat Restoration Goal #1: Maintain habitats of sufficient size and quality to support populations of naturally occurring plants, animals, and communities

Management Objective	Monitoring Question	Environmental Indicator	Indicator Type	Goal
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 tidal or freshwater wetlands?	Acres of restored salt marsh	Environmental Indicator	300 acres by 2010
RST1-1B: Increase acreage of restored estuarine habitats by 2010: (2) Restore 50 acres of eelgrass in Portsmouth Harbor, Little Bay, and the Piscataqua, Bellamy, and Oyster rivers.	NA	Acres of restored eelgrass	Environmental Indicator	50 acres by 2010
RST1-1C: Increase acreage of restored estuarine habitats by 2010: (3) Restore 20 acres of oyster habitat in Great Bay and the tidal tributaries.	Have restoration efforts resulted in a significant increase in the acreage and/or density of softshell clam and oyster beds?	Acres of restored oyster habitat	Environmental Indicator	20 acres by 2010

Definitions

NA = Not Applicable. "NA" in the "Indicator Type" column signifies that no indicator has been assigned to the monitoring question in that row. "NA"s were placed in the "Goal" column for all **supporting variables** and **administrative indicators** because these indicator types do not have quantifiable goals. "NA"s have also been placed in the "Goal" column for **research indicators** that will be developed as supporting variables (and therefore will not have a quantifiable goal).

TBD = To Be Determined. "TBD" has been placed in the "Goal" column for **research indicators** that will be developed as environmental indicators.

Footnotes

1. The goal is for 0% of estuarine area with sediments containing one or more compounds higher than NOAA ERL values (NOAA 1999). The NOAA Effects Range Low (ERL) has been adopted for the evaluation threshold. This is different from the management objective which is to keep sediment concentrations less than NOAA Effects Range Median (ERM) values. The TAC recommended this change because very few of the estuaries sediments exceed ERM values (only one contaminant at 1 out of 40 sites from 2000). Therefore, the percent of estuarine area greater than ERM values would not be a very sensitive indicator. The ERL values, which are lower than the ERM values, were adopted for the indicator instead. Because ERM values are always higher than ERL values, using ERL values for this indicator will ensure that the management objective is met.

Chapter 2: Bacteria and Disease-Causing Organisms

Monitoring Goal: To determine the status and trends of the sanitary quality of shellfish-growing and recreational waters.

A. Introduction

Since passage and ensuing enforcement of the first environmental protection legislation in the early 1970's, pollution of air, water and land resources has been significantly reduced. However, restrictions on uses of surface waters remain, largely because of unacceptable levels of microbial contamination. Microbial contaminants that can cause disease (pathogens) can be water-borne; thus, exposure to contaminated surface waters is a public health issue. Potential water-borne pathogens include a wide variety of bacteria, viruses, protozoan parasites and other microorganisms. The cause of most water-borne disease is thought to be enteric viruses of human origin. Bacterial and protozoan pathogens can be of human origin as well as natural flora from surface water environments. The variety of types and sources of pathogens makes assessment of the sanitary quality of surface waters a difficult proposition. The use of microbial indicator analyses is the accepted alternative strategy. However, no ideal indicator has been developed to meet all needs. For example, the use of microbial indicators of fecal contamination does not address issues related to nonfecal-borne pathogens. Thus, a sampling and analytical approach that includes a suite of indicators that address different issues is the best strategy to assess the sanitary conditions of surface waters.

Other important factors need to be addressed to provide an adequate understanding of the status and trends of microbial contamination in surface waters. Contaminant source identification is a critical step in determining the public health significance of microbial contaminants. Numerous new techniques are being developed and tested to differentiate between human-borne (potentially manageable) and nonhuman-borne (more difficult to manage) microbial contaminants throughout the U.S., including New Hampshire. Determining the fate of contaminants is necessary for development of effective management strategies. Seasonal factors such as rainfall frequency, evapotranspiration, migratory bird presence, wind speed and direction, temperature, tidal exposure, algal blooms, activities of indigenous organisms, regrowth of pathogens and indicators, and sunlight all affect microbial survival and fate. The relationships between microbial fecal indicators and pathogens and between fecal indicators and non-fecal pathogens are not understood. The relationship between human health risks and concentrations or incidence of pathogens and indicators is even less well understood. All of these factors should be addressed by research that complements the monitoring plan objectives so as to improve the effectiveness of the monitoring activities.

B. Environmental Indicators

Table 1 from Chapter 1 lists all the NHEP goals and objectives, monitoring questions, and their associated indicators. The section of this table for NHEP Water Quality Goal #1 (page 1) contains the list of indicators related to bacteria and disease causing organisms. Each of the environmental indicators for this goal will be explained in detail in the following sections. The administrative indicators for this goal are described in Chapter 9.

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

a. Monitoring Objectives

The objective of this **indicator** is to report on how much of the year the shellfish beds were 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 rarely). 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, which will answer the following monitoring question:

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

which will, in turn, 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 100% of all possible acre-days in estuarine waters open for harvesting.

This indicator will be tracked using records of administrative closures so performance criteria for monitoring programs do not need to be set. The data quality objectives for monitoring by the DES Shellfish Program are set by the National Shellfish Sanitation Program (NSSP, 1999).

c. Data Analysis, Statistical Methods, and Hypothesis

The acre-days of harvesting potential for the estuary will be taken from the DES Shellfish Program annual report. Acre-day calculations are based on updated growing water classifications and NHDES Shellfish Program records of all rainfall-closures, wastewater treatment plant failure-closures, emergency-closures, and others instituted during the year. Areas that are permanently closed due to their proximity to wastewater treatment plant outfalls or marinas, commonly referred to as "safety zones," are excluded from the acre-day calculation, as these areas are not closed for reasons of high bacteria. For reporting purposes, data on acre-days for the whole estuary will be split into the results for Great Bay-Little Bay only, Little Harbor only, and Hampton Harbor only.

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. The following hypothesis will be tested qualitatively:

$$Ho: a = g; \quad Ha: a \neq g$$

where a is the acre-days indicator and g is the goal.

d. Field and Analytical Methods

The DES Shellfish Program conducts water quality monitoring to update growing area classifications following protocols from NSSP (1999). The field and analytical methods for this program are described in Appendix A.

e. Monitoring Design

Monitoring by DES at the stations shown in Figure 2-1 is used to update the growing area classifications. The frequency of monitoring at the stations is described in Appendix A.

2. Trends in Dry-Weather Bacterial Indicators Concentrations

a. Monitoring Objectives

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 at fixed stations in the estuary and tributaries at a pre-determined frequency. For each sampling day, the conditions will be categorized as either "wet weather" or "dry weather" based on precipitation data. For the dry weather samples, the long-term trend in the concentrations will be assessed. Trends in wet weather concentrations will be assessed in another indicator. The trends from this indicator will answer the following monitoring questions:

- Have fecal coliform, enterococci, and *E. coli* levels changed significantly over time?
- Has dry-weather bacterial contamination changed significantly over time?

which will, in turn, 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 document a statistically significant decrease in concentrations at stations in the tidal tributaries to the estuary.

The monitoring program for this indicator should have 80% power for detecting a 10% change from 2000 concentrations over a 5 year period using 0.10 as the level of the test. The trends should be strongest in the tidal tributaries of Great Bay near NHEP pollution mitigation programs in the urban centers of Exeter, Newmarket, Durham, and Dover. Significant trends are not expected at the stations located in the middle of Great Bay (e.g., Adams Point).

c. Data Analysis, Statistical Methods and Hypothesis

For sites in Great Bay/Little Bay, Little Harbor, and Hampton Harbor, "dry weather" samples will be those collected when there has not been rain in the previous 4, 2, and 3 days, respectively, following the convention of the DES Shellfish Program for antecedent rainfall. The weather stations used by the DES Shellfish Program for these areas will be used to assess rainfall. Only samples collected at low-tide will be used.

The specific hypothesis to be tested with these data is:

$$Ho:\ m=0;\ Ha:\ m \neq 0$$

where m is the rate of change of bacteria concentrations over time. For stations with approximately monthly data on dry weather concentrations throughout the year, the Seasonal Kendall Test will be used to test for significant trends. For stations with less frequent dry weather samples during the year, the Mann-Kendall test will be used to test for trends between years. See Appendix B for the details of how the SKT and MKT will be used. Trend analysis will not be completed unless at least 5 years of data are available for a site. The results at each station will be plotted annually using GIS to illustrate spatial patterns after at least 5 years of data are available.

d. Field and Analytical Methods

Tidal water samples for bacteria analysis should be collected and analyzed using methods compatible with the GBNERR Ambient Monitoring Program (see Appendix A). Freshwater samples should be collected following the protocols of the DES Ambient Rivers Monitoring Program (see Appendix A).

e. Monitoring Design

The following monitoring programs will be used to collect the data for this indicator. The stations used by the National Coastal Assessment and DES Enhanced Ambient Rivers Program are followed by the station number in parentheses.

Program	Measurement	Stations	Frequency
GBNERR Ambient Monitoring	Fecal coliforms, Enterococci, *E. coli*	Adams Point, Lamprey River, Squamscott River	Monthly on high and low tide
NHCP Ambient Monitoring	Fecal coliforms, Enterococci, *E. coli*	Coastal Marine Laboratory	Monthly on high and low tide
National Coastal Assessment	Fecal coliforms, Enterococci, *E. coli*	Little Bay (51) Lamprey River (25) Oyster River (57) Bellamy River (64) Cocheco River (72) Salmon Falls R. (78) Upper Piscataqua R (67) Lower Piscataqua R (45) Back Channel (29) Little Harbor (23) Hampton Harbor (4,7,9) Rye Harbor (TBD)	Monthly March through December at low tide
DES Enhanced Ambient Rivers Program Monitoring	Enterococci, *E. coli*	Winnicut River (Win), Exeter River (9-Ext), Lamprey River (5-Lmp), Oyster River (5-Oys), Bellamy River (5-Blm), Cocheco River (7-Cch), Salmon Falls River (5-Sfr), Sagamore Creek (5-Sag), Berry's Brook (5-Ber)	Monthly from March through December (no tidal variation).

The stations to be used for this design are plotted on Figure 2-2.

<u>3. Trends in Wet-Weather Bacterial Indicators Concentrations</u>

a. Monitoring Objectives

The objective of this **indicator** is to measure the effects of wet weather pollution from stormwater runoff on ambient water quality. One of the NHEP's priorities is to reduce bacteria pollution caused by stormwater runoff. To that end, significant amounts of NHEP resources have been put toward reducing bacteria in stormwater runoff from the urban centers around the estuary. The traditional bacteria indicators species (Enterococci, and *Escherichia coli*) will be measured at the head of tide stations within the urban centers on the Great Bay tributaries. For each sampling day, the conditions will be categorized as either "wet weather" or "dry weather" based on precipitation data. The wet weather samples will be aggregated for the year and used to assess the long-term trends in the wet weather pollution to answer the following monitoring question:

- Has wet weather bacterial contamination changed significantly over time?

which will, in turn, 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 document a statistically significant decrease in wet weather concentrations at stations above the tidal dams in each of the urban centers.

The monitoring program for this indicator should have 80% power for detecting a 10% change from 2000 concentrations over a 5 year period using 0.10 as the level of the test.

c. Data Analysis, Statistical Methods, and Hypothesis

"Wet weather" samples must have been collected on days for which there was a cumulative rainfall of at least 0.5 inches over the day of sampling or the day before (Jones and Langan, 1996). Wet weather samples from each year will be grouped and compared to wet weather samples from other years to assess trends. The specific hypothesis to be tested with these data is:

$$Ho: m=0; Ha: m \neq 0$$

where m is the rate of change in bacteria concentrations over time. The Mann-Kendall test will be used to test for trends between years. See Appendix B for the details of how MKT will be used. Trend analysis will not be completed unless at least 5 years of data are available for a site. The results at each station will be plotted annual using GIS to illustrate spatial patterns after at least 5 years of data are available.

d. Field and Analytical Methods

The samples should be collected and analyzed using the protocols of the DES Ambient Rivers Program (see Appendix A).

e. Monitoring Design

(i) Phase I (2001-2002) Design

For the initial monitoring design, existing monitoring programs will be used to collect the data for this indicator (see following table for details).

Program	Measurement	Stations	Frequency
DES Enhanced Ambient Rivers Program Monitoring	Enterococci, *E. coli*	Winnicut (Win), Exeter River (9-Ext), Lamprey River (5-Lmp), Oyster River (5-Oys), Bellamy River (5-Blm), Cocheco River (7-Cch), Salmon Falls River (5-Sfr)	Monthly from March through December (no tidal variation).

The stations to be used by the NHEP for the trend analysis are plotted on Figure 2-3.

(ii) Phase II Design

The monitoring design for this indicator will need to be revised for 2003. Based on past studies, it is unlikely that a pre-established monthly sampling program will coincide with enough wet weather events of different sizes to allow statistical evaluation of trends. Ideally, this indicator should be assessed through a wet weather monitoring program at the stations listed in the table above. This program should follow the protocols of Jones and Langan (1996), which was able to detect significant differences between dry and wet weather concentrations by monitoring 8 storm events per year. Before the end of 2002, the design and costs of a wet weather monitoring program for this indicator will be developed.

4. Tidal Bathing Beach Postings

a. Monitoring Objectives

The objectives for this **indicator** are 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, which will answer the following monitoring question:

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

which will, in turn, 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 and Performance Criteria

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

This indicator will be tracked using records of administrative closures so performance criteria for monitoring programs do not need to be set. The data quality objectives for the water quality monitoring are set by the DES Beach Program.

c. Data Analysis, Statistical Methods, and Hypothesis

The DES Beach Program analyzes the water quality results for each beach and makes a determination whether or not to recommend posting. No other analysis is needed.

The number of postings is an exact measure. Therefore, statistical methods are not needed to compare the indicator to the goal. The following hypothesis will be tested qualitatively.

$$Ho: p = 0; Ha: p \neq 0$$

where p is the number of postings at tidal beaches per year.

d. Field and Analytical Methods

The samples should be collected using the DES Beach Program protocols (Appendix A).

e. Monitoring Design

The DES Beach Program collects three samples per week from each of the designated tidal bathing beach. The designated tidal bathing beaches in NH are plotted on Figure 2-4.

5. Trends in Bacteria Concentrations at Tidal Bathing Beaches

a. Monitoring Objectives

The objective of this **indicator** is to determine whether the bacteria concentrations at tidal bathing beaches are increasing or decreasing over time. The DES Beach Program monitors designated tidal bathing beaches along the Atlantic Coast of NH for Enterococci during the summer months (Memorial Day to Labor Day). These measurements of Enterococci concentrations can be used to assess trends in water quality at the beaches over the years. This information will be useful to managers to determine if pollution control efforts are having a positive effect and as advance warning of potential problems at beaches in the future. This indicator will provide useful supporting information to the management objective of:

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

b. Measurable Goal and Performance Criteria

The goal is for no tidal beaches to have significantly increasing trends in Enterococci concentrations.

The monitoring program for this indicator should have 80% power for detecting a 10% change from 2000 concentrations over a 5 year period using 0.10 as the level of the test.

c. Data Analysis, Statistical Methods, and Hypothesis

Routine monitoring data for each beach will be extracted from the DES Beach Program database. This will exclude samples taken to confirm an elevated concentration or to determine when the posting can be removed. For each beach, all the results for the summer season will be aggregated by calculating a geometric mean for the summer. The specific hypothesis to be tested with these data is:

$$Ho:\ m=0;\ Ha:\ m \neq 0$$

where m is the rate of change in bacteria concentrations over time. The Mann-Kendall Test will be used to assess significant trends over years. See Appendix B for the details of how MKT will be used. Trend analysis will not be completed unless at least 5 years of data are available for a site. The results at each station will be plotted using GIS to illustrate spatial patterns.

d. Field and Analytical Methods

The samples should be collected using the DES Beach Program protocols (Appendix A).

e. Monitoring Design

The DES Beach Program collects three samples per week from each of the designated tidal bathing beaches. The designated tidal bathing beaches in NH are plotted on Figure 2-4.

6. Violations of Enterococci Standard in Tidal Waters

a. Monitoring Objectives

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 (104 #/100ml for individual samples, 35 #/100ml for the geometric mean of 3 or more samples collected over 60 day period). This **indicator** will use measurements of Enterococci bacteria throughout the estuaries to determine the number of violations of the state standards, which will answer the following monitoring question:

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

which will, in turn, 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 and Performance Criteria

The goal is to have 0 violations of RSA 485-A:8 per year in the estuarine waters.

Determination of violations should be made with 80% confidence as a performance criterion.

c. Data Analysis, Statistical Methods, and Hypothesis

Concentrations will be evaluated relative to standards using the DES Assessment and Listing Methodology, which will be developed in 2002. The statistical approach for this assessment will likely use a binomial distribution, an assumed violation rate of 10% (EPA, 1997) , and a confidence level of 80%.

d. Field and Analytical Methods

Samples should be collected and analyzed using protocols consistent with the GBNERR Ambient Monitoring Program (Appendix A).

e. Monitoring Design

The following monitoring programs will be used to collect data for this indicator.

Program	Measurement	Stations	Frequency
GBNERR Ambient Monitoring	Enterococci	Adams Point, Lamprey River, Squamscott River	Monthly on high and low tide
NHCP Ambient Monitoring	Enterococci	Coastal Marine Laboratory	Monthly on high and low tide
National Coastal Assessment	Enterococci	Little Bay (51) Lamprey River (25) Oyster River (57) Bellamy River (64) Cocheco River (72) Salmon Falls R. (78) Upper Piscataqua R (67) Lower Piscataqua R (45) Back Channel (29) Little Harbor (23) Hampton Harbor (4,7,9) Rye Harbor (TBD)	Monthly March through December at low tide

The stations to be used for this design are plotted on Figure 2-5.

7. Freshwater Bathing Beach Postings

a. Monitoring Objectives

The objectives for this **indicator** are 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, which will answer the following monitoring question:

- Do NH freshwater beaches meet the state *E. coli* standards?

which will, in turn, 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 and Performance Criteria

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

This indicator will be tracked using records of administrative closures so performance criteria for monitoring programs do not need to be set. Data quality objectives for the beach monitoring are set by the DES Beach Program.

c. Data Analysis, Statistical Methods, and Hypothesis

The DES Beach Program analyzes the water quality results for each beach and makes a determination whether or not to recommend posting. No other analysis is needed.

The number of postings is an exact measure. Therefore, statistical methods are not needed to compare the indicator to the goal. The following hypothesis will be tested qualitatively.

$$Ho: p = 0; Ha: p \neq 0$$

where p is the number of postings at freshwater beaches per year.

d. Field and Analytical Methods

The samples should be collected using the DES Beach Program protocols (Appendix A).

e. Monitoring Design

The DES Beach Program collects three samples per month from each of the designated freshwater bathing beach. The designated freshwater bathing beaches in the coastal watershed have been plotted on Figure 2-6.

8. Bacteria Load from Wastewater Treatment Plants

a. Monitoring Objectives

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, this readily available information will be gathered and analyzed. This **supporting variable** will be helpful for interpreting other indicators related to the following management goal:

- Water Quality Goal #1: Ensure that NH's estuarine waters and tributaries meet standards for pathogenic bacteria including fecal coliform, *E. coli*, and Enterococci.

b. Measurable Goal and Performance Criteria

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

The monitoring program for this indicator should have 80% power for detecting a 10% change from 2000 concentrations over a 5 year period using 0.10 as the level of the test.

c. Data Analysis, Statistical Methods, and Hypothesis

For each WWTF, the mean monthly discharge and mean monthly total coliform concentration will be multiplied to estimate the mean monthly bacteria load. Trends in the monthly loads will be assessed using the Seasonal Kendall Test (see Appendix B for details). The specific hypothesis to be tested with these data is:

$$Ho:\ m=0;\ Ha:\ m \neq 0$$

where m is the rate of change in bacteria loading over time. The results for each WWTF will be analyzed separately and aggregated on a map using GIS.

Some of the wastewater treatment plants report bacteria discharge in units of total coliforms, while others report discharge in terms of fecal coliforms. Therefore, it will be necessary to convert measurements of total coliforms to fecal coliforms in order to have consistent results in an absolute sense. This will be facilitated by the results of a NHEP-funded study of WWTF effluent during 2002. The trend analyses will not be affected by having different reporting units for bacteria at different plants.

d. Field and Analytical Methods

The field and analytical methods followed by each facility are those required by their permit. The methods used by the different plants may be different. However, each facility is required to have a Quality Assurance Project Plan and an approved Monitoring Plan to ensure that data among the plants are compatible.

e. Monitoring Design

All the data needed to assess loading from WWTF is available through routine Discharge Monitoring Reports (DMR) filed by the facilities with the EPA. The monitoring design for each plant will depend on the conditions of its NPDES permit.

For this indicator, the WWTF that discharge directly to the tidal waters will be evaluated, which are: Exeter, Newfields, Newmarket, Durham, Dover, Portsmouth, Hampton, Newington, Kittery ME, and South Berwick ME. The location of the outfalls for these WWTF are shown in Figure 2-7.

9. Microbial Source Tracking

a. Monitoring Objectives

Microbial Source Tracking (MST) is a new technology that can identify the source of *E. coli* bacteria in water. The identification is made through comparison of the particular strains of *E. coli* in the sample to a library of *E. coli* strains associated with different species (human and animal). Knowing the source of the bacteria in the estuary will be of helpful for the NHEP to prioritize options for pollution control efforts in order to be more cost-effective. Therefore, microbial source tracking data will be used as a **supporting variable** to document the percent of the *E. coli* bacteria from human waste/sources at different stations in the estuary. This information will be used to interpret other indicators relevant to the following management goal:

- Water Quality Goal #1: Ensure that NH's estuarine waters and tributaries meet standards for pathogenic bacteria including fecal coliform, *E. coli*, and Enterococci.

b. Measurable Goal and Performance Criteria

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

The data quality objective for individual MST measurements is an accuracy of ± 20%.

c. Data Analysis, Statistical Methods, and Hypothesis

For each station assessed by MST, the percent of the *E. coli* strains attributed to human sources will be reported. The results for each station will be aggregated on a map using GIS. No hypothesis will be tested with these data.

d. Field and Analytical Methods

SOPs (and QAPPs) have been written as part of other ongoing projects for both the field and laboratory procedures involved with ribotyping of *E. coli* isolates.

e. Monitoring Design

(i) Phase I (2001-2002) Design

Two MST studies will be completed in the estuaries during 2001-2002. The NHEP/JEL MST study will characterize the sources of bacterial pollution in the Varney Brook watershed and in Hampton Harbor. The DES MST study will characterize the sources of bacterial pollution in Little Harbor and the Atlantic Coast. The stations that will be assessed for these studies are shown in Figure 2-8.

(ii) Phase II Design

During 2002, the NHEP will evaluate the Phase I monitoring design to determine whether the performance criteria and data quality objectives are being met. Based on this evaluation, the monitoring design may need to be changed for Phase II monitoring. Options for improving the design, if that is deemed necessary, are listed below.

- MST analysis should become an integral part of the ambient monitoring program. All or a subset of the stations being monitored for dry-weather bacteria trends (see Chapter 2, Section 2.e) should be tested for MST at least yearly. The needed frequency of monitoring is being researched during 2002.

C. Research Indicators for Out-Years

1. Microbial Pathogens and Harmful Algae

During the indicator development process, one datagap related to bacteria indicators was identified. This was the lack of direct monitoring of microbial pathogens. 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 NHEP cannot resolve these considerable difficulties during 2001-2002. Therefore, microbial pathogens will be considered a research indicator for the time being. The NHEP will aggressively advertise the datagap and will support other organizations who seek to address it.

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?

NHEP will investigate this research indicator during 2002 and attempt to answer its outstanding research questions.

D. References

EPA (1997) Guidelines for Preparation of the Comprehensive State Water Quality Assessments (305b reports) and Electronic Updates: Supplement. EPA-841-B-47-002B. Office of Water, Washington DC. September 1997.

Jones and Langan (1996) Assessment of Nonpoint Source Pollution in Tributaries Entering Great Bay. A final report to the New Hampshire Office of State Planning, New Hampshire Coastal Program. Jackson Estuarine Laboratory, University of New Hampshire, Durham, NH. July 1996.

NSSP (1999) National Shellfish Sanitation Program, Guide for the Control of Molluscan Shellfish, U.S. Department of Health and Human Services, Public Health Service, Food and Drug Administration, 1999 Revision.

Chapter 3: Toxic Contaminants

Monitoring Goal: To determine the status and trends of toxic contaminants in water, sediment and biota of coastal New Hampshire

A. Introduction

Since passage and ensuing enforcement of the first environmental protection legislation in the early 1970's, pollution of air, water and land resources has been significantly reduced. However, many contaminants are persistent in the environment, and historical pollution combined with present-day contamination results in exposure of humans and other biota to a variety of toxic contaminants in marine and estuarine environments. Contaminants that persist and accumulate in ecosystems are of special concern, as even low level chronic exposure to some of these chemicals can cause toxic effects.

There is a wide range of toxic contaminants of concern that may be categorized as either inorganic (trace or heavy metals) or organic contaminants. Toxic inorganic contaminants persist in the environment because they are elements that are not susceptible to breakdown. Biological and chemical processes can change the forms of these contaminants and affect their toxicity, availability, and mobility in the environment. Toxic organic contaminants include a wide range of chemicals, most of which are either exclusively human-made or are produced in greater quantity through human activities. Although virtually all organic compounds are susceptible to breakdown by microorganisms, environmental conditions in marine and estuarine ecosystems limit these processes and many toxic organic compounds persist. Many of the more persistent toxic organic compounds of concern in the marine environment are included in a few types of chemicals, including polychlorinated biphenyls (PCB), polyaromatic hydrocarbons (PAH), and chlorinated pesticides.

The variety of types and the sources and sinks of toxic contaminants present a challenge for environmental assessments in coastal surface waters. No single indicator exists that can be used to determine environmental exposure as a surrogate to analysis of samples for the full range of contaminants. Thus, initial studies to determine if toxic contaminants are present require expensive analyses which often limits further studies.

Once the presence and concentrations of toxic contaminants have been determined for sediments, water and biota, further studies to determine toxic effects need to be conducted. The process of monitoring toxic contaminant problems in coastal New Hampshire is aided by previous local studies that have identified which contaminants are present in elevated levels, and other studies from the literature that describe effects of contaminants on humans and susceptible species in marine and estuarine ecosystems.

B. Environmental Indicators

Table 1 from Chapter 1 lists all the NHEP goals and objectives, monitoring questions, and their associated indicators. The section of this table for NHEP Water Quality Goal #2 (page 2) contains the list of indicators related to toxic contaminants. Each of the environmental indicators will be explained in detail in the following sections. The administrative indicators are described in Chapter 9.

1. Shellfish Tissue Concentrations relative to FDA Standards

a. Monitoring Objectives and Performance Criteria

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?

and will directly 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 and Performance Criteria

The goal is for 0% of stations to have mean shellfish tissue concentrations greater than the following FDA guidance values (converted to dry-weight following the methods of Chase et al., 2001):

PARAMETER	FDA	UNITS	REF
As	86	ug/g	1
Cd	25	ug/g	1
Cr	87	ug/g	1
Pb	11.5	ug/g	1
Hg	6.7	ug/g	2
Ni	533	ug/g	1
Total DDT (DDT6)	33000	ng/g	2
Total PCBs (PCB24)	13000	ng/g	3
CHLORDANE	2000	ng/g	2
DIELDRIN	2000	ng/g	2
ALDRIN	2000	ng/g	2
HEPTACHLOR	2000	ng/g	2
HEPTACHLOR EPOXIDE	2000	ng/g	2
MIREX	700	ng/g	2

References for Guidance Values

FDA provides three different types of guidance on toxic contaminants in fish and shellfish tissue:

1. FDA Guidance Documents: No binding authority. A synopsis of information relevant to a national problem to assist local managers in setting consumption limits. [Available for As, Cd, Cr, Pb, Ni, see http://www.cfsan.fda.gov/~frf/guid-sf.html]
2. FDA Action Levels: Action levels and tolerances represent limits at or above which FDA will take legal action to remove products from the market. [Available for aldrin, dieldrin, chlordane, total DDT, heptachlor, heptachlor epoxide, mirex, and methylmercury, see http://www.cfsan.fda.gov/~lrd/fdaact.html]. Total DDT will be represented by “DDT6”

which is the sum of detected concentrations of the six DDT/DDE/DDD congeners: 2,4'-DDE, 4,4'-DDE, 2,4'-DDD, 4,4'-DDD, 2,4'-DDT, and 4,4'-DDT.

3. FDA Tolerances: The same as action levels except tolerances are legally-enforceable. [Only available for total PCBs, see 21 CFR 109.30]. Total PCBs will be represented by "PCB24" which is the sum of detected concentrations of 24 PCB congeners: PCB8, PCB18, PCB28, PCB29, PCB44, PCB50, PCB52, PCB66, PCB77, PCB87, PCB101, PCB105, PCB118, PCB126, PCB128, PCB138, PCB153, PCB169, PCB170, PCB180, PCB187, PCB195, PCB206, and PCB209. The PCB congeners selected for this summary match those used by the Gulfwatch Program (Chase et al., 2001).

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.

c. Data Analysis, Statistical Methods and Hypothesis

For data analysis, procedures for aggregating congeners, testing for normality, and calculating descriptive statistics from the Gulfwatch Program will be followed (Chase et al., 2001).

Statistical tests will be used to determine whether the mean concentration for each compound at each station is significantly higher than FDA standards. For each compound at each station, the replicate samples will be used to compute an average and standard deviation following the methods from Chase et al. (2001). The mean concentration will be tested against the FDA guidance value using a one sample t-test (one-sided) with an alpha value 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 at the station and g is the FDA guidance value.

d. Field and Analytical Methods

The field and analytical procedures from the Gulfwatch Program (Chase et al., 2001) will be used for this indicator.

e. Monitoring Design

The NH Gulfwatch Program and the NHEP oyster/clam monitoring program will provide the data for this indicator. The locations and frequency of monitoring for the various programs are listed in the following table.

Program	Measurement	Stations	Frequency
NH Gulfwatch	Metals, PCBs, PAHs, Pesticides in mussel tissue	Little Harbor (NHLH) Schiller Stn (NHSS) Dover Pt (NHDP) N. Mill Pond (NHNM) Clarks Cove (MECC) H/S Harbor (NHHS) Fox Point (NHFP) S. Mill Pond (NHSM) Rye Harbor (NHRH) Pierce Island (NHPI)	Yearly for MECC, once every 2 years for other sites. When a site is sampled, four replicates are taken and analyzed separately.
NHEP Oyster/Clam Tissue Monitoring (implemented by NH Gulfwatch)	Metals, PCBs, PAHs, Pesticides in oyster/clam tissue	Oysters: Nannie's Island, Adams Pt Clams: Middle Ground, Common Is.	One clam flat and one oyster bed each year.

The stations are plotted on Figure 3-1.

2. Public Health Risks from Toxic Contaminants in Shellfish Tissue

a. Monitoring Objectives and Performance Criteria

The objective of this **indicator** is to provide a clear answer to the following monitoring question:

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

which, in turn, is related to 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.

Under RSA 125-H, only the N.H. Bureau of Health Risk Assessment has the authority to conduct human health risk assessments and issue fish consumption advisories in New Hampshire. Therefore, for this indicator, NHEP will provide data to the NH Bureau of Health Risk Assessment to estimate the exposure to contaminants that a person would receive from eating shellfish and the health risk associated with this exposure.

b. Measurable Goals and Performance Criteria

The goal is to have 0% of stations with unacceptable health risks as determined by the NH Bureau of Health Risk Assessment.

The performance criteria for the monitoring programs for this indicator will be determined by NH BHRA based on the most recent toxicological values (e.g, Reference Dose, Cancer Slope Factors).

c. Data Analysis, Statistical Methods and Hypothesis

Data analysis will be conducted by NH BHRA following standard protocols for risk assessment (EPA, 1989; DES, 2001). The most recent toxicological values (Reference Doses, Cancer Slope Factors) will be downloaded from EPA's Integrated Risk Information System (www.epa.gov/iris). The cumulative risk from all contaminants will be estimated for each station. NH BHRA will determine which stations pose unacceptably high risks based on the results of the risk assessment. No statistical tests will be performed with these data.

d. Field and Analytical Methods

The field and analytical procedures are the same as for the "Shellfish Tissue Concentrations relative to FDA Standards" indicator.

e. Monitoring Design

The monitoring design is the same as for the "Shellfish Tissue Concentrations relative to FDA Standards" indicator.

3. Trends in Shellfish Tissue Contaminant Concentrations

a. Monitoring Objectives and Performance Criteria

The objective of this **supporting variable** is to answer the following monitoring question:

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

which will, in turn, 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.

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.

b. Measurable Goal and Performance Criteria

No goals have been established for this supporting variable. These data will be collected to provide the NHEP scientists with additional information to help interpret the results of hypothesis tests for other indicators.

The monitoring program for this indicator should have 80% power for detecting a 10% change from 2000 concentrations over a 5 year period using 0.10 as the level of the test.

c. Data Analysis, Statistical Methods and Hypothesis

For data analysis, procedures for aggregating congeners, testing for normality, and calculating descriptive statistics from the Gulfwatch Program will be followed (Chase et al., 2001).

Repeated measures Analysis of Variance (ANOVA) with a first-degree polynomial model will be used to determine whether there is a significantly increasing or decreasing linear trend in concentrations over time. This is consistent with the methods used by Chase et al. (2001) at all benchmark Gulfwatch sites. A significance level of 0.05 will be used for the test. The hypothesis that will be tested is:

$$Ho:\ m=0;\ Ha:\ m \neq 0$$

where m is the slope of a regression line over time.

d. Field and Analytical Methods

The field and analytical procedures from the Gulfwatch Program (Chase et al., 2001) will be used for this indicator.

e. Monitoring Design

(i) Phase I (2001-2002) Design

There is only one benchmark site in NH. It is Clarks Cove (MECC) in Portsmouth Harbor (see Figure 3-1). The Gulfwatch Program monitors this station yearly.

(ii) Phase II Design

During 2002, the NHEP will evaluate the Phase I monitoring design to determine whether the performance criteria and data quality objectives are being met. Based on this evaluation, the monitoring design may need to be changed for Phase II monitoring. Options for improving the design, if that is deemed necessary, are listed below.

- Two other benchmark sites should be added, one each in Hampton Harbor and the Great Bay Estuary, to provide data for shellfish species other than blue mussels (oysters: Great Bay; softshell clams: Hampton).

4. Trends in Finfish Tissue Contaminant Concentrations

a. Monitoring Objectives and Performance Criteria

The objective of this **supporting variable** is to answer the following monitoring question:

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

which will, in turn, 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.

In order to achieve this objective, the concentrations of toxic contaminants in "whole-fish" samples of winter flounder, tomcod, bluefish and striped bass, and lobster tissue will be measured in the estuary to assess trends over time. The contaminants that will be measured in the tissue are: heavy metals, PCBs, PAHs, and chlorinated pesticides. However, only PCB and mercury concentrations will be analyzed for trends over time since these two contaminants are responsible for all of the fish consumption advisories in coastal NH.

b. Measurable Goal and Performance Criteria

No goals have been established for this supporting variable. These data will be collected to provide the NHEP scientists with additional information to help interpret the results of hypothesis tests for other indicators.

The monitoring program for this indicator should have 80% power for detecting a 10% change from 2000 concentrations over a 5 year period using 0.10 as the level of the test.

c. Data Analysis, Statistical Methods and Hypothesis

Data for lobsters collected at representative sites will be evaluated for trends using the same methods as for shellfish samples (see previous section).

Data for finfish collected using a probabilistic sampling design will be evaluated using Horvitz-Thompson estimation techniques (EMAP, 1996) to estimate the mean and standard deviation for PCB and mercury concentrations in each target species in the entire NH seacoast.

For the estuary-wide trend analysis, mean concentrations for each chemical from 2002-2003 period will be compared with the mean concentrations from the 2000-2001 period using a two-sample t-test (two-sided) with an alpha level of 0.05. The specific hypothesis to be tested is:

$$Ho: u1-u2=0; \; Ha: u1-u2 \neq 0$$

where u1 is the mean concentration from 2000-2001 and u2 is the mean concentration from 2002-2003.

d. Field and Analytical Methods

The field and analytical methods for the National Coastal Assessment (Heitmuller 2000) should be followed.

e. Monitoring Design

(i) Phase I (2001-2002) Design

For the first two years of the National Coastal Assessment (2000-2001), tomcod and winter flounder were collected throughout the estuary using a probabilistic sampling design (see Figure 3-2). In 2001, lobsters were also collected from representative stations in Great Bay, Little Bay, and the Piscataqua River. The tomcod, winter flounder, and lobsters were analyzed for contaminant body burden by testing whole fish tissue. In 2002, the National Coastal Assessment will continue to monitor toxic body burdens of tomcod, winter flounder, and lobster. The sampling will be conducted on a 2-year rotating basis so that the next full assessment of the estuary will be completed after the 2003 season.

(ii) Phase II Design

During 2002, the NHEP will evaluate the Phase I monitoring design to determine whether the performance criteria and data quality objectives are being met. Based on this evaluation, the monitoring design may need to be changed for Phase II monitoring. Options for improving the design, if that is deemed necessary, are listed below.

- In the out-years, the monitoring program should be modified to capture toxic contaminants in bluefish and striped bass.

5. Sediment Contaminant Concentrations Relative to NOAA Guidelines

a. Monitoring Objectives and Performance Criteria

The objective of this **indicator** is to 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?

which will, in turn, 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.

In order to achieve this objective, the concentrations of toxic contaminants in surface sediment (0-2 cm) will be measured throughout the two estuaries. The target contaminants will be metals, PCBs, PAHs, and pesticides.

b. Measurable Goals and Performance Criteria

The goal is for 0% of estuarine area with sediments containing one or more compounds higher than NOAA ERL values (NOAA 1999). The NOAA Effects Range Low (ERL) has been adopted for the evaluation threshold. This is different from the management objective which is to keep sediment concentrations less than NOAA Effects Range Median (ERM) values. The TAC recommended this change because very few of the estuaries sediments exceed ERM values (only one contaminant at 1 out of 40 sites from 2000). Therefore, the percent of estuarine area greater than ERM values would not be a very sensitive indicator. The ERL values, which are lower than the ERM values, were adopted for the indicator instead. The ERL (and ERM) values that will be used for this assessment are listed in the following table (NOAA, 1999).

PARAMETER	ERL	ERM	UNITS
As	8.2	70	ug/g
Cd	1.2	9.6	ug/g
Cr	81	370	ug/g
Cu	34	270	ug/g
Pb	46.7	218	ug/g
Hg	0.15	0.71	ug/g
Ni	20.9	51.6	ug/g
Ag	1	3.7	ug/g
Zn	150	410	ug/g
Total PAH	4022	44792	ng/g
Total DDT	1.58	46.1	ng/g
Total PCB	22.7	180	ng/g
CHLORDANE	0.5	6	ng/g
DIELDRIN	0.02	8	ng/g

The data quality objective for the monitoring programs and statistical methods for this indicator is an accuracy of ± 15%.

c. Data Analysis, Statistical Methods and Hypothesis

Horvitz-Thompson estimation techniques (EMAP, 1996) will be used to estimate the percent of the whole Seacoast that is higher than an ERL. The variance for each estimate will be used to test for significant differences from zero percent. The specific hypothesis that will be tested is:

$$Ho: p = 0; Ha: p \neq 0$$

where p is the percent of the estuary with at least one compound greater than an ERL value. A one sample t-test (two-sided) with an alpha level of 0.05 will be used for the test.

Total PAHs, total DDT, and total PCB will be calculated from congener-specific data. The total will be calculated by summing the detected concentrations of the individual congeners. The list of congeners for PAHs, DDTs, and PCBs will match those used by the Gulfwatch Program (Chase et al. 2001):

Total PAH compounds "PAH24"	Total DDT compounds "DDT6"	Total PCB congeners "PCB24"
Naphthalene, 1-Methylnaphthalene, 2-Methylnaphthalene, Biphenyl, 2,6-Dimenthylnaphthalene, Acenaphthylene, Acenaphthalene, 2,3,5-Trimethylnaphthalene, Fluorene, Phenanthrene, Anthracene, 1-Methylphenanthrene, Fluoranthrene, Pyrene, Benzo[a]anthracene, Chrysene, Benzo[b]fluoranthrene, Benzo[k]fluoranthrene, Benzo[e]pyrene, Benzo[a]pyrene, Perylene, Indo[1,2,3-cd]pyrene, Dibenz[a,h]anthracene, Benzo[g,h,i]perylene	2,4'-DDE, 4,4'-DDE, 2,4'-DDD, 4,4'-DDD, 2,4'-DDT, 4,4'-DDT	PCB8, PCB18, PCB28, PCB29, PCB44, PCB50, PCB52, PCB66, PCB77, PCB87, PCB101, PCB105, PCB118, PCB126, PCB128, PCB138, PCB153, PCB169, PCB170, PCB180, PCB187, PCB195, PCB206, PCB209

d. Field and Analytical Methods

The field and analytical protocols of the National Coastal Assessment (Heitmuller, 2000) will be followed.

e. Monitoring Design

Data for this indicator will be obtained from the National Coastal Assessment. For this program, NH's estuaries have been divided into 80 equal-area hexagons. The stations are selected randomly within each of these hexagons following EMAP protocols. All 80 sites were sampled during 2000-2001 (Figure 3-2). The baseline assessment of estuarine sediments will be made using these data. For 2002-2005, 20 of the stations will be sampled each year. After all 80 stations have been retested, all the data will be used to make another estimate of the percent of the estuary with sediment concentrations greater than ERL values.

6. Trends in Sediment Contaminant Concentrations

a. Monitoring Objectives and Performance Criteria

The objective of this **supporting variable** is to answer the following monitoring question:

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

which will, in turn, 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 and Performance Criteria

No measurable goal has been set for this indicator. These data will be collected to provide the NHEP scientists with additional information to help interpret the results of other indicators for toxic contaminants.

The monitoring program for this indicator should have 80% power for detecting a 10% change from 2000-2001 concentrations over a 4 year period using 0.10 as the level of the test.

c. Data Analysis, Statistical Methods and Hypothesis

Trends in sediment concentrations will be assessed in two ways. First, the concentrations of priority pollutants (e.g., metals, PCBs, PAHs, and pesticides) in sediments from approximately the same location will be measured annually to assess year-to-year trends in certain locations. Second, average concentrations throughout the seacoast will be determined using a probabilistic sampling design at four year intervals to allow for an assessment of large scale trends in the estuaries.

For the year-to-year analysis at key sites, significant trends in concentration with respect to time will be tested at each site using a multiple linear regression that incorporates grain size, organic carbon, and other factors. This analysis will be conducted after 5 years of data have been collected at each site. Historical datasets of sediment concentrations will be mined to find data from past studies in the same area as the repeat stations in order to extend the time series of sediment concentrations.

For the estuary-wide trend analysis, mean concentrations for each chemical from 2002-2005 period will be compared with the mean concentrations from the 2001-2002 period using a two-sample t-test (two-sided) with an alpha level of 0.05. The specific hypothesis to be tested is:

$$Ho: u1-u2=0;\ Ha: u1-u2 \neq 0$$

where u1 is the mean concentration from 2000-2001 and u2 is the mean concentration from 2002-2005.

d. Field and Analytical Methods

Ongoing and future monitoring will follow the protocols from the National Coastal Assessment (Heitmuller, 2000).

e. Monitoring Design

In 2000-2001, sediment concentrations were monitored at 80 stations in the estuaries for the National Coastal Assessment (see Figure 3-2). A new set of 80 random stations in the estuary will be sampled between 2002 and 2005 for the National Coastal Assessment out-years. These sampling programs will provide the data needed to assess estuary-wide trends.

Five stations in the estuary will be sampled annually to provide a more intensive temporal trend database, and to evaluating the assumption that every four years is a valid time period for revisiting sample sites for estuary-wide trend analysis. The five sites for repeated sampling will be chosen in 2002.

C. Research Indicators for Out-Years

1. Finfish and Lobster Edible Tissue Concentrations Relative to FDA Guidelines

NHEP Objective WQ2-1A calls for reducing toxic contaminants in the tissues of finfish and lobster to below FDA guideline levels. FDA standards are applicable to edible portions of fish tissue. However, there are no ongoing monitoring programs for edible finfish and lobster tissue in New Hampshire. Several research questions need to be answered in order to design an adequate monitoring and evaluation procedure for this indicator:

- Which finfish and lobster species should be tested?
- What sampling design is representative of the fish that people eat?
- Which toxic contaminants should be monitored in the tissue?
- Are there any special procedures that should be followed to make the data useful to the public health agencies who are responsible for fish consumption advisories?

2. Public Health Risks from Toxic Contaminants in Finfish and Lobster Tissue

In addition to the previous research indicator, it is necessary to provide a clear answer to the following monitoring question: "Are shellfish, lobsters, finfish, and other seafood species from NH coastal waters fit for human consumption?" Under RSA 125-H, only the N.H. Bureau of Health Risk Assessment has the authority to conduct human health risk assessments and issue fish consumption advisories in New Hampshire. Therefore, for this indicator, NHEP will provide the data collected for the previous indicator to the NH Bureau of Health Risk Assessment to estimate the exposure to contaminants that a person would receive from eating finfish and lobster tissue and the health risk associated with this exposure.

3. Toxic Contaminants in Stormwater

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 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?

4. Sediment Toxicity and Benthic Community Index of Biological Integrity (IBI)

One monitoring question that is not answered by the recommended indicators is: "Is there evidence of toxic effects of contaminants in estuarine biota?" To answer this question, the NHEP will likely adopt the "sediment triad" approach whereby sediment chemistry, toxicity, and community assessments are combined to make a determination of biological impact. However, more research is needed on the technical aspects of approach before it can be used with confidence as an indicator for the NHEP. In particular, the research questions that need to be answered are:

- What is the most appropriate test organism for sediment toxicity tests in NH's estuaries?
- How should benthic community measurements be assessed to determine impairments?

D. References

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Chapter 4: Nutrients and Eutrophication

Monitoring Goal: To determine the status and trends of the eutrophic conditions in New Hampshire's coastal and estuarine waters

A. Introduction

Nutrient driven eutrophication has been identified as one of the major agents of ecosystem alteration in shallow estuarine and coastal areas. Typically, indicators of eutrophic conditions include high concentrations of phytoplankton (as measured by high concentrations of chlorophyll a) and associated turbidity; high abundance of epiphytic algal growth on submerged aquatic vegetation (SAV); proliferation of nuisance or opportunistic macroalgae; and elevated concentrations of water column nutrients.

As these conditions worsen (concentrations or abundances increase), there can be a loss of SAV due to shading by suspended particulates and epiphytes, and depressed dissolved oxygen (hypoxia and anoxia) resulting from the dark phase respiration and decay of phytoplankton and macroalgae. The latter conditions can have serious consequences for highly valued estuarine biota and can impair human uses such as fishing, shellfishing, swimming, and boating. Understanding the status and trends of eutrophic conditions cannot be accomplished by measuring a single parameter, therefore an effective monitoring program must be composed of a suite of measurements that includes some combination of the indicators listed above.

Indicators of eutrophication in New Hampshire's estuarine and coastal areas have been monitored at varying degrees of spatial and temporal coverage and continuity since the early 1970's. A synthesis of the data related to nutrient driven eutrophication collected through 1997 was prepared for the NHEP Technical Characterization report (NHEP 2001). Those results, as well as additional data collected since the first draft of the report was completed indicate that at present, the Great Bay Estuary exhibits moderate symptoms of eutrophication in limited geographic areas (Langan and Jones, 2000, Bricker et al. 1999). The limited amount of data available for Hampton Harbor (Langan and Jones, 2000, Bricker et al. 1999), Little Harbor and Rye Harbor and the seacoast (Langan, 2000), indicates no expression of eutrophic conditions at any of those locations at the present time.

With the population of the NH seacoast increasing at a rapid rate, it can be expected that nutrient loading will increase and that conditions will likely worsen. Conversely, if measures to reduce nutrient inputs, such as nitrogen and phosphorus removal from municipal wastewater, installation of stormwater BMPs, and advanced technologies for on-site treatment, are utilized, conditions may well improve. A properly designed comprehensive monitoring program will detect changes in both directions.

B. Environmental Indicators

Table 1 from Chapter 1 lists all the NHEP goals and objectives, monitoring questions, and their associated indicators. The section of this table for NHEP Water Quality Goal #3 (page 3) contains the list of indicators related to nutrients and eutrophication. Each of the environmental indicators for this goal will be explained in detail in the following sections. The administrative indicators for this goal are described in Chapter 9.

1. 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 effluent will be combined with measurements of flow to estimate the load. Available information on atmospheric and groundwater loading of nitrogen will also be compiled by the NHEP for reference, but these loading sources will not be included in this indicator. 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:

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

which will, in turn, 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 and Performance Criteria

The goal is for annual loads of total nitrogen to the estuary to be less than or equal to the estimated loading from 1996 listed in the Technical Characterization Report (296 tons/yr from WWTF, 345 tons/yr from tributaries, 641 tons/yr total).

The monitoring programs for this indicator should be able to detect a 10% change from 1996 levels. Nitrogen loading will not be evaluated statistically so it is not possible to specify the power or level of the test. However, since the total nitrogen load in 1996 was 641 tons per year, the data quality objective for the loading estimates must be an accuracy greater than ± 64 tons per year (10% of 1996 loads).

c. Data Analysis, Statistical Methods and Hypothesis

For data analysis, the same type of methods will be used as were used to estimate nitrogen loads in 1996 for the NHEP Technical Characterization Report (NHEP, 2000). Separate loading results will be reported for point sources and non-point sources (tributaries).

For tributaries, average monthly flow estimates for the Lamprey, Exeter, Oyster, Cocheco, and Salmon Falls rivers will be estimated from USGS stream gauges 01073500, 01073587, 01073000, 01072800, and 01072100, respectively. Flow at the tidal dam (the point of the water quality sample) will be estimated by watershed area transposition. Flows in the Bellamy River will be estimated using the average flow per square mile (cfsm) from the Oyster and Cocheco Rivers transposed to the area of the Bellamy River watershed. Flows in the Winnicut River will be estimated using the cfsm from the Oyster River transposed to the area of the Winnicut River watershed. The average monthly flow in each tributary will be multiplied by a monthly total nitrogen concentration (NO2+NO3+TKN) measurement to estimate the average monthly load from the tributaries.

For WWTF, the average monthly load will be the average monthly discharge multiplied by an estimate of the average nitrogen concentration in the effluent.

The total point source load will be the sum of the loads from the WWTF. The total non-point source load will be the load from the tributaries minus the WWTF load upstream of the tidal dams. This approach assumes that all of the nitrogen discharged from the upstream WWTF is delivered to the estuary. In reality, some of the nitrogen from the WWTFs could be assimilated in the upper reaches of the watershed. By making this assumption, this indicator may overestimate the point source contributions of nitrogen and underestimate the non-point source contributions. However, the total load (the sum of the point and non-point sources) should be without bias.

The annual loading estimates will be compared to the loads that were determined in 1996. The specific hypothesis to be tested is:

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

where l is the load (point or non-point source), and g is the goal. A rigorous statistical test of this hypothesis is not possible. Instead, uncertainty in the loading estimates for each tributary and WWTF will be propagated forward to estimate a confidence intervals for the point source and non-point source loads. If the goal falls below this interval, the null hypothesis will be rejected in favor of the alternative hypothesis. If the goal falls within or above the interval, the null hypothesis will not be rejected.

The results of this indicator will also be compared to modeled loads from the USGS SPARROW model and other nitrogen export models being developed for coastal New Hampshire. However, direct comparisons may not be possible because this indicator will not incorporate non-point source loads from the portion of the watershed from the tidal dams to the edge of the estuary. This constitutes 14% of the watershed, of which 14% of the land is under conservation easement or otherwise protected from development.

d. Field and Analytical Methods

For tributary monitoring, the field and analytical protocols for the DES Ambient Rivers Monitoring Program should be used (Appendix A). The nitrogen species that will be monitored are: NH4, NO2+NO3, and TKN. WWTF effluent will be monitored for according to the requirements of each plant's permit. Not all of the plants are required to test for nitrogen at this time. However, those that do are required to have a Quality Assurance Project Plan.

e. Monitoring Design

(i) Phase I (2001-2002) Design

The loading from the tidal tributaries will be estimated from monthly (March-December) nutrient concentrations collected by the DES Enhanced Ambient Rivers Monitoring Program at the head of tide stations on the Winnicut, Exeter, Lamprey, Oyster, Bellamy, Cocheco, and Salmon Falls Rivers.

Monthly average discharge from WWTF will be obtained from NPDES Discharge Monitoring Reports to EPA. For the WWTF required to test for nitrogen, monthly average nitrogen concentrations will also be obtained from DMRs. For the other WWTF, nitrogen concentrations in WWTF effluent will be estimated based on literature review, other WWTF measurements, or the NHEP-funded research project on WWTF impacts to the estuary which will begin in 2002.

The tributary stations, WWTF in the coastal watershed, and the USGS stream gauging stations that will be used are shown on Figure 4-1.

(ii) Phase II Design

During 2002, the NHEP will evaluate the Phase I monitoring design to determine whether the performance criteria and data quality objectives are being met. Based on this evaluation, the monitoring design may need to be changed for Phase II monitoring. A few options for improving the design, if that is deemed necessary, are listed below.

- Routine monitoring for total nitrogen at all WWTF in the coastal watershed would reduce the uncertainty in the point source loading estimate. The NHEP-funded research project on WWTF impacts will provide information on how much uncertainty would be eliminated with different sampling frequencies.
- A multivariate loading model similar to that used by the USGS to estimate fluvial loads to the Chesapeake Bay (see http://va.water.usgs.gov/chesbay/RIMP/methods.html) may be a more appropriate statistical model.
- A supporting variable on atmospheric deposition of nitrogen should be developed.

2. Trends in Estuarine Nutrient Concentrations

a. Monitoring Objectives

The objective of this **supporting variable** is to quantify long-term trends in nutrient concentrations (nitrate, nitrite, ammonia, and orthophosphate) in estuarine waters. This indicator will answer the following monitoring question:

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

which will, in turn, provide supporting information toward 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 and Performance Criteria

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.

The monitoring program for this indicator should have 80% power for detecting a 10% change from 2000 concentrations over a 5 year period using 0.10 as the level of the test.

c. Data Analysis, Statistical Methods and Hypothesis

For each station, trends in the monthly concentrations of the nutrient species will be assessed using the Seasonal Kendall Test (see Appendix B for details). The specific hypothesis to be tested is:

$$Ho:\ m=0;\ Ha:\ m \neq 0$$

where m is the rate of change of nutrient concentrations over time. Trend analysis will not be completed unless at least 5 years of data are available for a site. The results for each station will be analyzed separately and aggregated on a map using GIS.

d. Field and Analytical Methods

Samples should be collected and analyzed following the protocols used by the GBNERR Ambient Monitoring Program (see Appendix A).

e. Monitoring Design

(i) Phase I (2001-2002) Design

The following monitoring programs will be used to collect data for this indicator.

Program	Measurement	Stations	Frequency
GBNERR Ambient Monitoring	NO2+NO3, NH4, PO4	Adams Point, Lamprey River, Squamscott River	Monthly on high and low tide
NHCP Ambient Monitoring	NO2+NO3, NH4, PO4	Coastal Marine Laboratory	Monthly on high and low tide
National Coastal Assessment	NO2+NO3, NH4, PO4	Little Bay (51) Lamprey River (25) Oyster River (57) Bellamy River (64) Cocheco River (72) Salmon Falls R. (78) Upper Piscataqua R (67) Lower Piscataqua R (45) Back Channel (29) Little Harbor (23) Hampton Harbor (4,7,9) Rye Harbor (TBD)	Monthly March through December at low tide

The stations to be used in this design are plotted on Figure 4-2.

(ii) Phase II Design

During 2002, the NHEP will evaluate the Phase I monitoring design to determine whether the performance criteria and data quality objectives are being met. Based on this evaluation, the monitoring design may need to be changed for Phase II monitoring. One design change that is known to be needed is the addition of organic nitrogen (DON and PON) to the measurement suite at each station such that total nitrogen (TN) can be calculated. Currently, the monitoring programs only measure dissolved inorganic nitrogen.

3. Trends in Estuarine Particulate Concentrations

a. Monitoring Objectives

The objective of this **supporting variable** is to quantify long-term trends in particulate concentrations (total suspended solids, particulate organic matter) in estuarine waters. This indicator will answer the following monitoring question:

- Have surface tidal or freshwaters shown a significant change in turbidity over time?

which will, in turn, 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 and Performance Criteria

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.

The monitoring program for this indicator should have 80% power for detecting a 10% change from 2000 concentrations over a 5 year period using 0.10 as the level of the test.

c. Data Analysis, Statistical Methods and Hypothesis

For each station, trends in the monthly concentrations of the particulates will be assessed using the Seasonal Kendall Test (see Appendix B for details). The specific hypothesis to be tested is:

$$Ho:\ m=0;\ Ha:\ m \neq 0$$

where m is the rate of change of particulate concentrations over time. Trend analysis will not be completed unless at least 5 years of data are available for a site. The results for each station will be analyzed separately and aggregated on a map using GIS.

d. Field and Analytical Methods

Samples should be collected and analyzed following the protocols used by the GBNERR Ambient Monitoring Program (see Appendix A).

e. Monitoring Design

(i) Phase I (2001-2002) Design

The following monitoring programs will be used to collect data for this indicator.

Program	Measurement	Stations	Frequency
GBNERR Ambient Monitoring	TSS, POM	Adams Point, Lamprey River, Squamscott River	Monthly on high and low tide
NHCP Ambient Monitoring	TSS, POM	Coastal Marine Laboratory	Monthly on high and low tide
National Coastal Assessment	TSS	Little Bay (51) Lamprey River (25) Oyster River (57) Bellamy River (64) Cocheco River (72) Salmon Falls R. (78) Upper Piscataqua R (67) Lower Piscataqua R (45) Back Channel (29) Little Harbor (23) Hampton Harbor (4,7,9) Rye Harbor (TBD)	Monthly March through December at low tide

The stations to be used in this design are plotted on Figure 4-2.

(ii) Phase II Design

During 2002, the NHEP will evaluate the Phase I monitoring design to determine whether the performance criteria and data quality objectives are being met. Based on this evaluation, the monitoring design may need to be changed for Phase II monitoring. One design change that is known to be needed is a measurement of total light extinction (e.g., Secchi depth, or light extinction coefficient) at each station.

4. Eelgrass Distribution within Tidal Tributaries of Great Bay

a. Monitoring Objectives

The objective of this **supporting variable** is to track the area of eelgrass present in tidal tributaries to the Great Bay. Water clarity is one of the main factors affecting the distribution of eelgrass within the tidal tributaries of Great Bay. Eelgrass can be affected by other factors such as disease or physical disturbance by boats. However, in tidal tributaries, water quality is expected to be the dominant factor (Fred Short, pers. com). This indicator will be used to partially answer the following question:

- Have surface tidal or freshwaters shown a significant change in turbidity over time?

which will, in turn, provide supporting information on the following management objectives:

- WQ-3-1: Maintain inorganic nutrients, nitrogen, phosphorous, and chlorophyll-a in Great Bay, Hampton Harbor, and their tributaries at 1998-2000 baseline levels.
- WQ-3-2: Maintain organic nutrients in Great Bay, Hampton Harbor, and their tributaries at 1994-1996 baseline levels

b. Measurable Goals and Performance Criteria

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

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

c. Data Analysis, Statistical Methods and Hypothesis

For data analysis, GIS software will be used to calculate the area of eelgrass coverage in the tributaries in the following zones (shown on Figure 4-3):

Tributary	Zone of eelgrass quantification
Squamscott and Lamprey rivers	upstream of a line connecting Sandy Point and Moody's Point
Oyster River	upstream from a line across the mouth of the Oyster River
Bellamy River/Lower Little Bay	upstream of the lines connecting Cedar Point, Goat Island and eastern edge of the Bellamy River Bridge.

The data will not be evaluated statistically. However, for reference, the eelgrass distribution for each year will be compared to the maximum eelgrass distribution in recent years which occurred in 1996.

d. Field and Analytical Methods

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 3,000 ft at low spring tide with roughly 60% overlap on a calm day without preceding rain events and when the sun is 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 reflect the time of maximum eelgrass biomass.

The ground truthing is done from a small boat at the same season as the photographs are 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 10 - 20% 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. These maps are then digitized and verified using the ground truth data by placing the GPS points onto the digital image in ArcInfo.

e. Monitoring Design

The entire estuary is mapped each year by the UNH/JEL Seagrass Ecology Group using the methods described above.

5. Violations of Instantaneous Dissolved Oxygen Standard

a. Monitoring Objectives

The objective of this **indicator** is to estimate the number of violations in the estuary each year of the state water quality standard for instantaneous dissolved oxygen concentrations. Hypoxia is a common manifestation of eutrophication. In a system as well mixed as the Great Bay, hypoxic events are not likely to last longer than one tidal cycle. Therefore, dissolved oxygen measurements taken at a high frequency by in-situ sondes deployed near the sediments in the tidal tributaries (where hypoxia is the most likely) have the best chance of capturing hypoxic 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?

which will, in turn, 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 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 instantaneous standard. Another indicator will track violations 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 violations of the instantaneous standard.

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

c. Data Analysis, Statistical Methods and Hypothesis

Each in-situ measurement will be compared to the instantaneous standard of 5 mg/l using the following hypothesis:

$$Ho: x \geq 5 \ mg/l; \ Ha \ x < 5 \ mg/l$$

where x is the instantaneous dissolved oxygen reading. A rigorous statistical test of this hypothesis is not possible. Instead, the accuracy of the reading will be used for a confidence interval. If the standard of 5 mg/l falls above the interval, the null hypothesis will be rejected in favor of the alternative hypothesis (a violation of the standard has occurred). If 5 mg/l falls within or below the interval, the null hypothesis will not be rejected (no violation).

For each sonde, the number of days per year with at least one violation of the standard will be reported and compared to the goal of zero days with violations. Inter-annual trends will be assessed qualitatively using the frequency of days with violations relative to the number of full days that the sonde was deployed during July, August, and September. The number of violations and trends will be reported for each sonde independently but aggregated on a map.

d. Field and Analytical Methods

The protocols for the GBNERR System-Wide Monitoring Program will be used (see http://inlet.geol.sc.edu/cdmoweb/grb.html). Briefly, datasondes with in-situ dissolved oxygen sensors will be deployed at 0.5 meters above the sediments and make recordings every 30 minutes.

e. Monitoring Design

(i) Phase I (2001-2002) Design

Data sondes are currently deployed from March through December at stations in the Squamscott River, Lamprey River, Great Bay, and the Oyster River (Figure 4-4). The sondes are periodically removed for cleaning during their deployment.

(ii) Phase II Design

During 2002, the NHEP will evaluate the Phase I monitoring design to determine whether the performance criteria and data quality objectives are being met. Based on this evaluation, the monitoring design may need to be changed for Phase II monitoring. Options for improving the design, if that is deemed necessary, are listed below.

- In addition to the existing sonde stations, a sonde could be added in the Cocheco/Salmon Falls River area to monitor for potential hypoxic effects in this river system.

6. Violations of the Daily Average Dissolved Oxygen Standard

a. Monitoring Objectives

The objective of this **indicator** is to estimate the number of violations 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?

which will, in turn, 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 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 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 violations of the daily average standard.

The monitoring programs for this indicator should have 80% power for detecting differences of 5 units (%sat) between the daily mean concentration and the standard with 0.05 as the level of the test.

c. Statistical Methods and Data Analysis

The data analysis methods will be the same as were described for the previous indicator except that all the measurements of dissolved oxygen on a given day will be averaged. The average concentration will be compared to the standard of 75% using a one sample t-test (one-sided) with a 0.05 alpha level. The specific hypothesis to be tested is:

$$Ho: u \geq 75\%; Ha: u < 75\%$$

where u is the daily mean concentration.

d. Field and Analytical Methods

The same protocols as for the "Violations of the Instantaneous Dissolved Oxygen Standard" indicator will be used.

e. Monitoring Design

The same monitoring design as for the "Violations of the Instantaneous Dissolved Oxygen Standard" indicator will be used.

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

a. Monitoring Objectives

One factor that can lead to hypoxia in the estuary is the BOD load from WWTF and tidal tributaries. This **indicator** will track the monthly loading from the tributaries to Great Bay and the 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?

which will, in turn, 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 and Performance Criteria

The goal is for no WWTF or tributary 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.

The monitoring program for this indicator should have 80% power for detecting a 10% change from 2000 concentrations over a 5 year period using 0.10 as the level of the test.

c. Data Analysis, Statistical Methods and Hypothesis

The monthly BOD load from tributaries will be estimated following the same methods used to estimate nitrogen loading from the watershed (see indicator of "Annual Nitrogen Loads to Great Bay"). Monthly average BOD loads from WWTF will be taken from NPDES Discharge Monitoring Reports filed by the facility. The long-term trend in monthly load estimates will be determined by Seasonal Kendall Test using $p<0.10$ as critical value and two tailed test to determine significance (see Appendix B). The specific hypothesis to be tested is:

$$Ho: m=0; Ha: m \neq 0$$

where m is the rate of change in BOD loading over time. Each tiributary and WWTF will be evaluated separately, but the results will be combined on on a map.

d. Field and Analytical Methods

Tributary monitoring for BOD should follow the protocols of the DES Ambient Rivers Monitoring Program (Appendix A). WWTF do not have to monitor BOD in the same manner. However, each plant must have a Quality Assurance Project Plan to ensure the results are compatible.

e. Monitoring Design

(i) Phase I (2001-2002) Design

The loading from the tidal tributaries will be estimated from monthly (March-December) BOD concentrations collected by the DES Enhanced Ambient Rivers Monitoring Program at the head of tide stations on the Winnicut, Exeter, Lamprey, Oyster, Bellamy, Cocheco, and Salmon Falls Rivers. 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. The tributary stations, WWTF in discharging to tidal waters in the Great Bay Estuary, and the USGS stream gauging stations that will be used are shown on Figure 4-1.

(ii) Phase II Design

During 2002, the NHEP will evaluate the Phase I monitoring design to determine whether the performance criteria and data quality objectives are being met. Based on this evaluation, the monitoring design may need to be changed for Phase II monitoring. Options for improving the design, if that is deemed necessary, are listed below.

- A multivariate loading model similar to that used by the USGS to estimate fluvial loads to the Chesapeake Bay (see http://va.water.usgs.gov/chesbay/RIMP/methods.html) may be more appropriate.

C. Research Indicators for Out-Years

1. Frequency and duration of phytoplankton blooms in Great Bay

There is currently no indicator to answer the monitoring question: Have levels of phytoplankton (chlorophyll-a) in NH waters changed signficantly over time? The TAC determined that the best indicator for this question would be an index of the frequency and duration of elevated chlorophyll-a concentrations associated with phytoplankton blooms. The data for this indicator is currently being collected at four sondes in the estuary (Squamscott River, Lamprey River, Great Bay, and Oyster River) with in-situ fluorometers. However, the methods for interpreting these data have not yet been determined. The conceptual model is to use a threshold concentration and a threshold daily frequency of occurrence to identify when a bloom is occurring. Once these thresholds are established, the data from the in-situ sensors can be used to calculate the number of days per year when a bloom was observed in the estuary. Therefore, the specific research questions that need to be answered are:

- What fluorescence reading at each datasonde is indicative of a bloom?
- What is the frequency of elevated chlorophyll-a readings associated with a bloom?

2. 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?

3. 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 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:

- How would the NPI differ from the nitrogen loading indicator "Annual load of nitrogen to Great Bay from WWTF and watershed tributaries"?

The NHEP will research these topics during 2002 and 2003 to resolve the outstanding questions.

D. References

Bricker et al. (1999) National Estuarine Eutrophication Assessment: Effects of Nutrients on the Nation's Estuaries. NOAA, NOS, NCCOS, Special Projects Office, Silver Spring, MD, 71 pp

Langan and Jones (2000) A monitoring plan for the Great Bay Estuarine Research Reserve. Final Report. NOAA/NERR. April 1999. 77 pp.

NHEP (2000). A Technical Characterization of Coastal and Estuarine New Hampshire. Final Report to the New Hampshire Estuaries Project. S.H. Jones ed.

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

Chapter 5: Shellfish

Monitoring Goal: To determine the status and trends of molluscan shellfish populations in New Hampshire's coastal and estuarine waters

A. Introduction

The estuaries and coastal areas of New Hampshire are ideal habitat for a number of molluscan shellfish species. Molluscan shellfish are of economic importance as they support important recreational fisheries and have tremendous potential as aquaculture species. They are also excellent bioindicators of estuarine condition because they are relatively long lived, and integrate their environment over time. Additionally, because they are filter feeders, they play an important role in nutrient cycling, improving water clarity, and in removing significant quantities of nitrogen and phosphorus from the water column via phytoplankton and organic detritus consumption.

Epibenthic shellfish such as mussels, oysters and scallops provide valuable habitat for rich assemblages of invertebrates and fish while large infaunal bivalves oxygenate soft sediments with their burrowing activities. Oysters are considered by many estuarine ecologists to be a "keystone" species, and oyster beds in temperate estuaries are considered the equivalent of coral reefs in tropical seas. Many studies have shown that species density, diversity and biomass is significantly greater in oyster beds than on equivalent bottom without oysters.

Molluscan shellfish play an important role in the ecology and economy of New Hampshire's estuarine and coastal areas. Proper management of these important resources requires an understanding of the geographic location of the resource, the population size and structure, coverage area, habitat condition, and harvest pressure. Additionally, knowledge of the biotic and abiotic factors that influence shellfish populations must be understood for effective management.

Surveys of molluscan shellfish abundance and population structure have been conducted with varying degrees of consistency and thoroughness over the past several decades. With a few exceptions, such as softshell clams in Hampton Harbor, most databases are inadequate in temporal and spatial scale to accurately determine current status or predict trends. For some species, there is little or no data available. There are recent, reliable data for oysters and clams. Those data indicate that oyster populations in the Great Bay Estuary have declined dramatically in the past decade (Langan, 1997), and clam populations in Hampton Harbor have recovered from their mid-late 1980's decline and have been stable for the past few years (NAI, 1999).

It is important to continue to monitor clam and oyster populations, as well as those factors such as harvest pressure, predation, disease, and environmental factors that affect populations.

B. Environmental Indicators

Table 1 from Chapter 1 lists all the NHEP goals and objectives, monitoring questions, and their associated indicators. The section of this table for NHEP Shellfish Goals #1-4 (pages 4-5) contains the list of indicators related to shellfish resources. Each of the environmental indicators for these goals will be explained in detail in the following sections. The administrative indicators for these goals are described in Chapter 9.

1. Area of Oyster Beds in Great Bay

a. Monitoring Objectives

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

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	6.6
Woodman Point	37.3
Piscataqua River	12.8
Adams Point	4.0
Oyster River	1.8
Squamscott River	1.7

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.

The monitoring programs for this indicator should be able to detect a 10% change from 1997 levels. The change in areas will not be evaluated statistically so it is not possible to specify the power or level of the test. However, since the areas of the four largest beds were >4 acres in 1997, the data quality objective for the area estimates must be an accuracy greater than ± 0.5 acres (approximatley 10% of 1997 area for Adams Point).

c. Data Analysis, Statistical Methods and Hypothesis

For each oyster bed, the specific hypothesis to be tested is:

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

where a is the area of the bed, and g is the goal. 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. 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.

d. Field and Analytical Methods

The bed dimension will be based on substrate type (shells), not the presence of live oysters. Oyster beds will be mapped using a Klein 5000 sidescan sonar. Data acquisition, processing, and acoustic characterization of reefs will be done using "TracEd" and "Lassoo" software (proprietary software of the UNH Joint Hydrography Center). Existing maps of the general location of each reef will be used to guide the sonar surveys. Ground truthing will be accomplished through a combination of quadrat samples taken by divers (following the methods for assessing oyster density listed in the next section) and video techniques. The video system consists of an infrared camera designed for low-light conditions, custom frame, differential GPS, and camcorder for image recording. The number of video images taken at each site will be at least 40 (based on the same grid system as the dive samples). A ten second recording will be made at each site. The recordings will then be processed into still images using

ESRI's ArcInfo and Adobe Photoshop. Images for each site will then be combined into a montage and embedded into a GIS with the sidescan data.

e. Monitoring Design

(i) Phase I (2001-2002) Design

During 2001-2002, NHF&G will map the areas and locations of four major oyster beds (Nannie's Island, Woodman Point, Adams Point, and Oyster River). Approximate areas and locations of the other major oyster beds (Squamscott River and Piscataqua River) will be taken from Langan (1997). (See Figure 5-1)

(ii) Phase II Design

During 2002, the NHEP will evaluate the Phase I monitoring design to determine whether the performance criteria and data quality objectives are being met. Based on this evaluation, the monitoring design may need to be changed for Phase II monitoring. A few options for improving the design, if that is deemed necessary, are listed below.

- The six major oyster beds in Great Bay should be mapped every 5 years using sonar techniques (or other promising technologies).

2. Density of Harvestable Oysters at Great Bay Beds

a. Monitoring Objectives

The objective of this **indicator** is to estimate the average density of harvestable oysters at the six major oyster beds in Great Bay. This indicator report directly on the following management objective:

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

b. Measurable Goal and Performance Criteria

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	52
Woodman Point	158
Piscataqua River	32
Adams Point	106
Oyster River	60
Squamscott River	10.4

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.

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 1997 levels.

c. 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 (one-sided) with an alpha level of 0.05 will be used to determine whether the null hypothesis should be rejected. If the distribution of densities between quadrats deviates substantially from normal as determined by the Kolmogorov-Smirnov test, the t-test will be performed on log-transformed data or the non-parametric Wilcoxon Rank-Sum Test will be used (if at least 10 quadrats were collected from the reef).

d. Field and Analytical Methods

Divers will collect samples from each bed using a stratified random design to provide a representative sample of the oysters in whole bed. For each bed, the project team will generate a map on which an orthogonal grid will be superimposed. At least five cells at each bed will be randomly selected. In each selected grid cell, a 0.25 m^2 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.

e. Monitoring Design

(i) Phase I (2001-2002) Design

For the initial monitoring design, existing monitoring programs will be used to collect data for this indicator. The oyster beds at Nannie's Island, Woodman Point, Adams Point, and Oyster River are assessed yearly by the NHF&G Oyster Resource Program. The beds in the Piscataqua River and Squamscott River are not assessed on a fixed frequency. The locations of these beds are plotted in Figure 5-1.

(ii) Phase II Design

During 2002, the NHEP will evaluate the Phase I monitoring design to determine whether the performance criteria and data quality objectives are being met. Based on this evaluation, the monitoring design may need to be changed for Phase II monitoring. Options for improving the design, if that is deemed necessary, are listed below.

- All six of the oyster beds should be assessed at least once every three years.

3. Density of Harvestable Clams at Hampton Harbor Flats

a. Monitoring Objectives

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. This indicator will report directly on the following management objective:

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

b. Measurable Goal and Performance Criteria

The goal is for each flat to at least maintain the 10-year average density (for >50mm) as monitored by the Seabrook Station Environmental Monitoring Program (the numbers reported are the arithmetic average of each year's geometric mean density):

Clam Flat	10-yr Density (#/sq. meter)
Middle Ground	61
Common Island	43
Confluence	19

This 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.

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.

c. Data Analysis, Statistical Methods and Hypothesis

For each flat, the geometric mean of the number of clams >50mm 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 (one-sided) with an alpha level of 0.05 will be used to determine whether the null hypothesis should be rejected. Because the density goal is expressed as a geometric mean, both the quadrat results and the goal will be log transformed prior to the t-test.

d. Field and Analytical Methods

The clam flats will be surveyed in late fall. Sample sites will be chosen at random. The number of sites per flat will be proportional to the variance in density that has been observed in that flat historically. At each site, a 1 ft. by 2 ft. quadrat will be dug to a depth of 45 cm with a clam fork. Large clams will be removed from the sediment in the field, enumerated, measured, and released (NAESCO, 2000).

e. Monitoring Design

The clam populations in at the three major flats in Hampton Harbor will be assessed yearly for the Seabrook Station Soft Shell Clam Monitoring Program. Common Island, Middle Ground, the Confluence flat are plotted on Figure 5-2.

4. 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.

b. Measurable Goal and Performance Criteria

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.

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.

c. 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.

d. Field and Analytical Methods

For the clam flats in Hampton Harbor, the areas will be estimated using methods compatible with previous assessments by Normandeau Associates for the Seabrook Station Environmental Monitoring Program. Monochromatic aerial imagery will be acquired from a qualified contractor (e.g., Sewell Inc., Eastern Topographics) 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 will be 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.

e. Monitoring Design

(i) Phase I (2001-2002) Design

As part of the Seabrook Station Environmental Monitoring Program, Normandeau Associates will map the three major flats in Hampton Harbor (Figure 5-2) during August of 2002. The last time the flats were mapped was 1995.

(ii) Phase II Design

During 2002, the NHEP will evaluate the Phase I monitoring design to determine whether the performance criteria and data quality objectives are being met. Based on this evaluation, the monitoring design may need to be changed for Phase II monitoring. A few options for improving the design, if that is deemed necessary, are listed below.

- The clam flats should be mapped at least every other year.

5. Standing Stock of Harvestable Oysters in Great Bay

a. Monitoring Objectives

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?

which will, in turn, 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 and Performance Criteria

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 TAC has concluded that a more accurate assessment of both density and size for oyster beds is needed before this goal can be adopted. Based on the results of this assessment, the TAC will either confirm that tripling the standing stock of harvestable oysters is a realistic goal or recommend an alternative target consistent with the spirit of the management goal.

Oyster standing stock is calculated from the area and density at the oyster beds. These parameters are being measured for other indicators. So long as the performance criteria for these other indicators are met, the data quality objectives for this indicator will be satisfied.

c. 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. 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.

d. Field and Analytical Methods

The field and analytical methods for the area and density assessments were described for the indicators of "Area of Oyster Beds in Great Bay" and "Density of Harvestable Oysters at Great Bay Beds".

e. Monitoring Design

There is no additional monitoring for this indicator.

6. Standing Stock of Harvestable Clams in Hampton Harbor

a. Monitoring Objectives

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?

which will, in turn, 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 and Performance Criteria

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 assumption behind this goal for clams was to maintain the current standing stock in Hampton Harbor, while increasing the overall standing stock by opening other areas of the Hampton/Seabrook and Great Bay estuaries. While this plan may yet work, the TAC has concluded that it would not be cost effective to accurately monitor clam standing stock in the Great Bay Estuary because it is a large area and because the clams are not concentrated in well-defined locations. Without being able to quantify the standing stock throughout the estuaries, it will not be possible to know whether the goal of tripling the resource has been reached.

As an alternative, the TAC has proposed to monitor the standing stock of clams in Hampton Harbor. Hampton Harbor is the main clam resource area in the NH coast and, because of its compact size, it is feasible to monitor the standing stock in this area yearly. However, the TAC does not recommend that the goal of tripling the resource be applied to this indicator at this time. After an analysis of historical data and the potential for new Hampton Harbor flats to be opened for harvest, the TAC will either confirm that the tripling goal is realistic or recommend an alternative target consistent with the spirit of the management goal.

Clam standing stock is calculated from the area and density at the clam flats. These parameters are being measured for other indicators. So long as the performance criteria for these other indicators are met, the data quality objectives for this indicator will be satisfied.

c. Data Analysis, Statistical Methods, and Hypothesis

The standing stock of harvestable clams in each flat will be estimated by multiplying the average density of clams >50mm by the most recent estimate of the flat size. Results will be reported in bushels (for Hampton Harbor, approximately 1200 clams equal 1 bushel). The standing stock will be summed for flats in areas open for harvesting. A separate standing stock calculation will be made for clams >50mm 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.

d. Field and Analytical Methods

The field and analytical methods for the area and density assessments were described for the indicators of "Area of Clam Flats in Hampton Harbor" and "Density of Harvestable Clams at Hampton Harbor Flats".

e. Monitoring Design

There is no additional monitoring for this indicator.

7. Abundance of Shellfish Predators

a. Monitoring Objectives

The objective of this **supporting variable** is to track the relative abundance of the dominant clam and 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 and Performance Criteria

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.

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

c. Data Analysis, Statistical Methods and Hypothesis

The monthly catch-per-unit-effort (CPUE) of green crabs in various locations throughout the Great Bay and Hampton Harbor will be tracked versus time. No statistical tests will be applied.

d. Field and Analytical Methods

In Hampton Harbor, green crabs will be collected using 13-mm mesh, baited crab traps deployed over 24 hours at a depth such that they are awash at mean low tide (NAESCO, 2000).

In the Great Bay Estuary, green crabs will be collected using a beach seine hauls by boat using a 30.5 m long by 1.8 m high bag seine with 6.4 mm mesh deployed 10 - 15 m from the beach. Seine hauls will all be conducted during daylight hours and be constrained to the period of approximately two hours before to two hours after low tide. Seines will be set into the current and in water depths less than six feet to prevent the foot rope of the net from coming off the bottom. With each seine haul, surface salinity (ppt) and temperature (^{o}C) will be measured and substrate type at the station will be observed and recorded. If the following crustacean species of special interest are captured, they will be identified and enumerated: rock crab (*Cancer irroratas*), Jonah crab (*Cancer borealis*), green crab (*Carcinus maenas*), horseshoe crab (*Limulus polyphemus*), and American lobster (*Homarus americanus*) (NHF&G, 2001).

e. Monitoring Design

In Hampton Harbor, green crab traps will be set at four stations two times per month April through January. This monitoring is part of the Seabrook Station Environmental Monitoring Program.

In the Great Bay Estuary, a single seine haul will be made at 11 stations during the months of June through November. This monitoring is conducted by NHF&G for the Juvenile Finfish Seine Survey Program.

The stations where green crabs will be assessed in the estuary are shown in Figure 5-3.

8. Clam and Oyster Spatfall

a. Monitoring Objectives

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 and Performance Criteria

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.

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

c. 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. The average spat density at each major clam flat and oyster bed will be tracked versus time. No statistical tests will be applied.

d. Field and Analytical Methods

The methods for assessing oyster density and age classes were described for the "Density of Harvestable Oysters in Great Bay Beds".

For clams, at each station, three 4 inch diameter by 4 inch deep cores will be taken from within a 1 ft. by 2 ft. quadrat. Samples will be sieved with a 1-mm mesh. The clams retained by the mesh will be counted and measured.

e. Monitoring Design

The monitoring design for oysters will be the same as for the "Density of Harvestable Oysters in Great Bay Beds" indicator (see Figure 5-1). The monitoring design for clams will be the same as for the "Density of Harvestable Clams in Hampton Harbor Flats" indicator (see Figure 5-2).

9. Recreational Harvest of Oysters

a. Monitoring Objectives

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 and Performance Criteria

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.

The monitoring programs for this indicator should have data quality objectives of ±25% accuracy.

c. Data Analysis, Statistical Methods and Hypothesis

The total number of oysters harvested yearly will be estimated for the entire Great Bay Estuary. The harvest will be tracked over time and compared to the annual estimate to standing stock. No statistical tests will be applied to these data.

d. Field and Analytical Methods

The recreational harvest of oysters will be estimated from a mail survey of oyster harvest licensees following the same methods as were used for the 1997 survey by NHF&G (NHF&G, 1997).

e. Monitoring Design

The recreational oyster harvest survey will be conducted every 3 years.

10. Recreational Harvest of Clams

a. Monitoring Objectives

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 and Performance Criteria

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.

The monitoring programs for this indicator should have data quality objectives of ±25% accuracy.

c. Data Analysis, Statistical Methods and Hypothesis

The total number of clams harvested yearly will be estimated for the Hampton Harbor flats. The annual harvest will be tracked over time and compared to annual estimates of standing stock. No statistical tests will be applied to these data.

d. Field and Analytical Methods

The clam flats in Hampton Harbor are open on Fridays and Saturdays for the periods January 1 through Memorial Day and Labor Day through December 31, except when they are closed by NHF&G due to high bacteria concentrations. On the Fridays when the flats are open, the number of harvesters on the flats are recorded. The number of harvesters on the following Saturday is estimated based on a historical relationship between Friday and Saturday harvest pressure. Assuming that each harvester takes his limit (10 liquid quarts per person per day), the total harvest for the day can be estimated. The daily harvests are totaled to estimate the yearly harvest.

e. Monitoring Design

The total harvest of clams from Hampton Harbor is recorded by the Seabrook Station Environmental Monitoring Program. The results are reported yearly in annual reports (NAESCO, 2000).

11. Prevalence of Oyster Disease

a. Monitoring Objectives
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 and Performance Criteria

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.

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

c. 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.

d. Field and Analytical Methods

The field and analytical methods used for this process are described in the QAPP for the NHF&G Oyster Disease Monitoring Program (NHF&G, 2001b).

e. Monitoring Design

(i) Phase I (2001-2002) Design

For the initial monitoring design, existing monitoring programs will be used to collect data for this indicator. The oyster beds at Nannie's Island, Woodman Point, Adams Point, and Oyster River are assessed yearly by the NHF&G Oyster Resource Program. The beds in the Piscataqua River and Squamscott River are not assessed on a fixed frequency. The locations of these beds are plotted in Figure 5-1.

(ii) Phase II Design

During 2002, the NHEP will evaluate the Phase I monitoring design to determine whether the performance criteria and data quality objectives are being met. Based on this evaluation, the monitoring design may need to be changed for Phase II monitoring. Options for improving the design, if that is deemed necessary, are listed below.

- All six of the oyster beds should be assessed at least once every three years.

12. Prevalence of Clam Disease

a. Monitoring Objectives

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 and Performance Criteria

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.

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

c. Data Analysis, Statistical Methods and Hypothesis

Clams are considered neoplastic if 100% of the assayed blood cells are neoplastic. Therefore, for each clam flat, the prevalance of clams with 100% neoplastic cells will be reported. This prevalence will be tracked over time. No statistical tests will be applied.

d. Field and Analytical Methods

The field and analytical methods used for past assessments have evolved over time. For future assessments, field and analytical protocols should be established.

e. Monitoring Design

(i) Phase I Design

For the initial monitoring design, existing monitoring programs will be used to obtain data for this indicator. Neoplasia was monitored at the major clam flats in Hampton Harbor in 1986-1987, 1989, 1996, 1997, and 1998 by the Seabrook Station Environmental Monitoring Program. No monitoring has been conducted since 1998.

(ii) Phase II Design

During 2002, the NHEP will evaluate the Phase I monitoring design to determine whether the performance criteria and data quality objectives are being met. Based on this evaluation, the monitoring design may need to be changed for Phase II monitoring. A few options for improving the design, if that is deemed necessary, are listed below.

- Neoplasia in clams from the Hampton Harbor flats should be assessed annually.

C. Research Indicators for Out-Years

1. 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?

D. References

Langan (1997) Assessment of Shellfish Populations in the Great Bay Estuary. A Final Report to the NHEP. December 1997.

NAESCO (2000) 1999 Seabrook Station Environmental Monitoring Program Report. North Atlantic Energy Service Corporation, Seabrook NH. December 2000.

NAI (1999) 1998 Environmental Monitoring in the Hampton-Seabrook Area: A Characterization of Environmental Conditions During the Operation of the Seabrook Station. Normandeau Associates, Bedford NH. October 1999.

NHF&G (2001). Year 2000 Atlantic Coastal Fisheries Cooperative Management Act Report. NH Fish & Game Department, Marine Fisheries Division, Durham, NH. 2001.

NHF&G (2001b) 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

NHF&G (1997) Great Bay Oyster Harvest Survey. A final report to the N.H. Estuaries Project, New Hampshire Fish & Game Department, December 31, 1997.

Chapter 6: Land Use and Development

Monitoring Goal: To determine the status and trends of land use and development in coastal New Hampshire

A. Introduction

The Seacoast of New Hampshire has a long history as an important center of commerce and industry in the state and region. The economy of the Seacoast has rebounded from the recession of the late 1980's to perform well in the second half of the 1990's and into the year 2000. Employment statistics are high and development to accommodate residential housing needs and services is booming. Part of the draw for people to live in the Seacoast is the pleasing aesthetics of natural coastal scenery and a clean environment. As population and development have increased in coastal New Hampshire over the last fifty years, expectations for improved water quality and safety of recreational waters have also increased. This is paradoxical because increased population and development are almost inevitably accompanied by increased pollution and habitat fragmentation and degradation. In addition, marine resource based industries are a vital part of the local economy, and these industries depend on a clean environment. Thus, land use, development and habitat protection are issues that are of increasing concern in the Seacoast.

The first big impact of land development on the Seacoast came with the onset of agriculture in the mid-1880's. The clearing of forests for cropland was accompanied by further habitat fragmentation by road construction. Automobiles, the state highway system and the Interstate Highway Act all resulted in further fragmentation of forests and provided the means for development in more areas of the Seacoast (NHCRP, 1997).

At present, water and habitat quality in the Seacoast are being degraded by increased stormwater runoff associated with the cumulative effects of increased development and impervious surfaces. In addition, shoreline development has diminished the aesthetics of many areas and drinking water supplies are being overtaxed. In nearly all of the Seacoast municipalities, remaining developable land is at a premium and development in areas outside of urban centers has accelerated problems associated with sprawl.

The costs of sprawling development include new demands for municipal services and infrastructure such as roads, fire, police and rescue services, and public sewer and water expansions. The result is a spreading need for pollution control (MSPO, 1997). Generally, sprawl also results in the decline of the historic downtown centers of cities and towns, increased taxes and increased costs for commuters. Habitat loss, degradation, and fragmentation also occur. For these reasons, it is important that planning for future development incorporate consideration for preventing further environmental degradation and protecting important habitats.

B. Environmental Indicators

Table 1 from Chapter 1 lists all the NHEP goals and objectives, monitoring questions, and their associated indicators. The section of this table for NHEP Land Use Goal #1 (page 6) contains the list of indicators related to land use and development. Each of the environmental indicators for this goal will be explained in detail in the following sections. The administrative indicators for this goal are described in Chapter 9.

1. Impervious Surfaces in Coastal Subwatersheds

a. Monitoring Objectives

The objective of this **indicator** is to estimate the percentage by land area of impervious surfaces in each subwatershed of the coastal watershed in 1990, 2000, and 2005. This indicator will answer the following monitoring question:

- Has there been a significant change over time in the number of coastal NH watersheds (first or second order) that exceed 10% impervious cover?
- Has the rate of creation of new impervious surfaces in NH coastal watersheds significantly changed over time?

which will, in turn, 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 and Performance Criteria

The goal is have none of the subwatersheds on the coast 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 (Shueller, 1995). The proximity of the impervious surfaces to water bodies may be more important than the total area in the watershed. However, the total area of impervious surfaces in a watershed is a useful indicator for human development and the potential for water quality impacts.

The estimate of impervious surfaces should have a data quality objective of ±10% accuracy.

c. Data Analysis, Statistical Methods and Hypothesis

Impervious surfaces will be mapped throughout the coastal watershed using satellite imagery (see methods below). Using ArcView software, the total area of impervious surfaces in each first order (HUC10) and second order (HUC12) watershed will be calculated and then divided by the total area of that watershed to estimate the percent impervious cover (see Figure 6-1). The specific hypothesis to be tested with these data 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, the error bars for the impervious area estimates will be used as an approximate "confidence interval". If the confidence interval of the estimate is entirely above 10%, the null hypothesis will be rejected in favor of the alternative hypothesis. If the confidence interval is less than or contains 10%, the null hypothesis will not be rejected. The results for 1990, 2000, and 2005 will be reported separately.

d. Field and Analytical Methods

The Complex Systems Research Center (CSRC) at the University of New Hampshire will create the maps of impervious surfaces in coastal New Hampshire following the methods described in their proposal (excerpt inserted below).

The estimates will be developed by classifying Landsat Thematic Mapper multispectral imagery, 30-meter resolution. A single TM image (path 12, row 30) provides coverage for the entire coastal area. The GRANIT database, resident at CSRC, contains an archived image from September 27, 2000, which will provide the current "view" of the study area. 1990 imagery will be purchased to provide source data for the earlier date in the range. Each of these images will be processed through a series of traditional supervised and sub-pixel classifications to derive the targeted impervious surface acreage data. A recent pilot project (Rubin and Justice, 2001) demonstrated that sub-pixel processing methodologies applied to TM data generate satisfactory acreage calculations for impervious surface coverage within coastal New Hampshire.

The proposed effort will proceed in a number of phases. The first phase will comprise a standard supervised classification of the TM imagery for each date. Much of the field data required to support this activity is available as a result of prior image processing activities in the coastal area, and can be readily applied. The product of this phase will be a two-class data set for the study area: developed/urban and other.

The second phase is designed to accommodate the estimation of "proportion of imperviousness" in each cell. The imagery will be processed using the Erdas Imagine sub-pixel classification algorithm, which allows for the detection of materials smaller than a full image pixel. Detection is based on evaluating the spectral properties of each pixel, and reporting the percentage of a material of interest (MOI) in each cell. Researchers will utilize the two-class data from the first phase to "mask" the source TM image, thereby subsetting those cells in the original image that are presumed to be developed. This subset will then be utilized in a second round classification using the sub-pixel processing module. As in past image processing activities, we may iterate through these phases several times to generate satisfactory results.

Note that the spatial extent of the impervious surface (the MOI) within each pixel is not identified. Rather, the entire pixel is reported as having a certain percentage of the MOI. By factoring the area of each pixel by the percent of that pixel containing the MOI, acreage summaries may be generated.

The next phase will comprise the incorporation of road rights-of-way, which may be omitted in the image classification processing due to their relatively narrow, linear shape. Road centerline data from the NH Department of Transportation will be buffered to reflect the approximate width of the pavement. Finally, all data will be subjected to on-screen verification and editing. A number of ancillary data sets, including National Wetlands Inventory data and digital photography, will be used to eliminate erroneously mapped data elements.

The image classification phase will be followed by an accuracy assessment phase. Standard classifications yield results that report a feature type for each polygon. However, the proposed technique will result in calculations of levels of imperviousness per feature. This may make it difficult to apply standard accuracy assessment methodologies. However, the researchers will develop an approach to assess the reliability of the product that is easily understandable by potential users. At a minimum, windshield surveys of randomly selected impervious surface features will indicate whether the results of the mapping activity are reliable.

The primary product of the proposed effort will be a GIS gridded data set that spatially represents the impervious surface features in coastal New Hampshire. The corresponding attribute table will report on the degree of imperviousness for each cell in ranges of 10%. The data layer will be accompanied by a full metadata record (or a description of the data).

e. Monitoring Design

CSRC, under contract with the NHEP, will conduct the baseline assessment in 2002 using data from 1990 and 2000. Subsequent assessments will occur at approximately 5 year intervals.

2. Rate of Sprawl – High Impact Development

a. Monitoring Objectives

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".

One **indicator** for high impact development (e.g., large shopping malls, highways) is the increase of impervious surfaces in a town or watershed. To evaluate "sprawl" development, the following ratio will be calculated for each town and region for the periods 1990-2000 (baseline) and 2000-2005: the percent increase in imperviousness to the percent increase in population. Ratios greater than 1 would be indicative of "sprawl" development. The ratios for the two different periods will be compared to answer the following monitoring question:

- Has the rate of urban sprawl in coastal NH watersheds changed significantly over time?

which will, in turn, 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 and Performance Criteria

The goal is for no towns in the coastal watershed to have higher ratios for the 2000-2005 period than for the 1990-2000 period (i.e., no increasing rates of sprawl).

The data quality objective for the ratio estimate is an accuracy of ±10%.

c. Data Analysis, Statistical Methods and Hypothesis

Ratios of the percent increase in imperviousness and population will be calculated for each of the 43 towns in the coastal watershed and for groups of towns functionally linked by transportation systems.

The results of this indicator will be used in several ways. First, the town and regions with ratios from 1990-2000 greater than 1 will be identified for NHEP efforts to reduce sprawl. Second, the ratios for the 1990-2000 and 2000-2005 periods will be compared. The specific hypothesis to be tested is:

$$Ho: r(1990\text{-}2000) - r(2000\text{-}2005) \geq 0; \; Ha: r(1990\text{-}2000) - r(2000\text{-}2005) < 0$$

where r(1990-2000) is the ratio for the 1990-2000 period and r(2000-2005) is the ratio for the 2000-2005 period. A rigorous statistical test of this hypothesis is not possible. Instead, an approximate "confidence interval" of the difference between the two ratios will be calculated based on uncertainty in the underlying data. If the confidence interval is less than zero, the null hypothesis will be rejected in favor of the alternative hypothesis. If the confidence interval contains or is greater than zero, the null hypothesis will not be rejected.

d. Field and Analytical Methods

See previous indicator for a description the methods for assessing impervious surfaces.

e. Monitoring Design

Data on impervious surfaces will be taken from CSRC impervious surface mapping project for the NHEP. Data on population growth in coastal towns will be taken from the US Census. The baseline assessment will be made in 2002 using data from 1990 and 2000. Subsequent assessments will occur at approximately 5 year intervals.

3. Rate of Sprawl – Low-Density, Residential Development

a. Monitoring Objectives

The objective of this **indicator** is to estimate the rate of low-density residential development in the towns of the coastal watershed. The second of three indicators of "sprawl" development, this indicator will use increases in road miles in each town to estimate new low-density, residential development (subdivisions). Similar to the previous indicator, the ratio of the percent increase in road miles to the percent increase in population will be calculated for each town and region. This ratio will be calculated for two periods, 1990-2000 (baseline) and 2000-2005, to partially answer the following monitoring question:

- Has the rate of urban sprawl in coastal NH watersheds changed significantly over time?

which will, in turn, 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 and Performance Criteria

The goal is for no towns in the coastal watershed to have higher ratios for the 2000-2005 period than for the 1990-2000 period (i.e., no increasing rates of sprawl).

The data quality objective for the ratio estimate is an accuracy of ±10%.

c. Data Analysis, Statistical Methods and Hypothesis

Ratios of the percent increase in road miles and population will be calculated for each of the 43 towns in the coastal watershed and for groups of towns functionally linked by transportation systems. The results of this indicator will be used in several ways. First, the town and regions with ratios from 1990-2000 greater than 1 will be identified for NHEP efforts to reduce sprawl. Second, the ratios for the 1990-2000 and 2000-2005 periods will be compared. The specific hypothesis to be tested is:

$$Ho: r(1990\text{-}2000) - r(2000\text{-}2005) \geq 0; \quad Ha: r(1990\text{-}2000) - r(2000\text{-}2005) < 0$$

where r(1990-2000) is the ratio for the 1990-2000 period and r(2000-2005) is the ratio for the 2000-2005 period. A rigorous statistical test of this hypothesis is not possible. Instead, an approximate "confidence interval" of the difference between the two ratios will be calculated based on uncertainty in the underlying data. If the confidence interval is less than zero, the null hypothesis will be rejected in favor of the alternative hypothesis. If the confidence interval contains or is greater than zero, the null hypothesis will not be rejected.

d. Field and Analytical Methods

No field or analytical methods will be used for this indicator.

e. Monitoring Design

Summary statistics on road miles per town will be obtained from NHDOT. Data on populations will be taken from the US Census. The baseline assessment will be made in 2002 using data from 1990 and 2000. Subsquent assessments will occur at approximately 5 year intervals.

4. Rate of Sprawl - Fragmentation

a. Monitoring Objectives

The objective of this **indicator** is to estimate the rate at which towns are losing unfragmented habitat blocks due to development patterns. The third of three indicators of "sprawl" development, this indicator will use the loss of unfragmented forest blocks to illustrate the effects of new road construction on habitat. This indicator is needed because the location of roads relative to habitat is of equal importance as the miles of roads. Similar to the previous two indicators, the ratio of the absolute value percent decrease in acres in unfragmented blocks to the percent increase in population will be calculated for each town and region. This ratio will be calculated for two periods, 2000-2005 (baseline) and 2005-2010, to partially answer the following monitoring question:

- Has the rate of urban sprawl in coastal NH watersheds changed significantly over time?

which will, in turn, 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 and Performance Criteria

The goal is for no towns in the coastal watershed to have a higher ratio for the 2005-2010 period than for the 2000-2005 period (i.e., no increasing rates of sprawl).

The data quality objective for the ratio estimate is an accuracy of ±10%.

c. Data Analysis, Statistical Methods and Hypothesis

Ratios of the absolute value percent decrease in unfragmented area and population will be calculated for each of the 43 towns in the coastal watershed and for groups of towns functionally linked by transportation systems. The results of this indicator will be used in several ways. First, the town and regions with ratios from 2000-2005 greater than 1 will be identified for NHEP efforts to reduce sprawl. Second, the ratios for the 2000-2005 and 2005-2010 periods will be compared. The specific hypothesis to be tested is:

$$Ho: r(2000\text{-}2005) - r(2005\text{-}2010) \geq 0; \; Ha: r(2000\text{-}2005) - r(2005\text{-}2010) < 0$$

where r(2000-2005) is the ratio for the 2000-2005 period and r(2005-2010) is the ratio for the 2005-2010 period. A rigorous statistical test of this hypothesis is not possible. Instead, an approximate "confidence interval" of the difference between the two ratios will be calculated based on uncertainty in the underlying data. If the confidence interval is less than zero, the null hypothesis will be rejected in favor of the alternative hypothesis. If the confidence interval contains or is greater than zero, the null hypothesis will not be rejected.

d. Field and Analytical Methods

Contiguous forest blocks greater than 250 acres in size will be calculated using ArcView software from Landsat imagery and other land use themes such as roads. The land use theme for roads is continuously updated by NHDOT. Therefore, although historical Landsat images can be purchased, it is not possible to determine unfragmented lands in the past because the road coverage from the past is no longer available. This is the reason why the periods of assessment for this indicator differ from the other two "sprawl indicators".

e. Monitoring Design

The baseline assessment will be made in 2002 using Landsat and road data from 2000. Subsquent assessments will occur at approximately 5 year intervals.

C. Research Indicators for Out-Years

There are no research indicators for this goal.

E. References

MSPO (1997) The Cost of Sprawl. Executive Department, Maine State Planning Office, Augusta, ME. 20 pp.

NHCRP (1997) Report of ranked environmental risks in New Hampshire. New Hampshire Comparative Risk Project , Concord, NH.

Rubin and Justice (2001) Final Report: Impervious Surface Mapping Pilot Project, 2001.

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

Chapter 7: Critical Species and Habitats

Monitoring Goal: To determine the status and trends of critical species and habitats in New Hampshire's coastal and estuarine waters.

A. Introduction

Habitat is the setting in which plants or animals feed, find shelter and reproduce. Plants and animals require specific types and quality of habitat that meets their particular needs. New Hampshire's estuaries and the surrounding upland regions provide a wealth of unique and productive habitats that support a diverse array of plant and animal populations, including threatened and endangered species.

The key to maintaining the diverse assemblages of these species is protecting and restoring appropriate habitats. Pollution, impacts from development, and inappropriate human disturbances can degrade, fragment, and destroy habitat as well as alter species composition. Therefore, it is important to identify the location and extent of critical habitats, and to monitor change in those habitats over time. It is equally important to identify plant and animal species that are indicators of habitat and overall ecosystem condition and to track changes in the abundance of these species over time.

NH's estuaries and coastal watershed encompass too many diverse habitats and species for the NHEP to monitor them all. Given the focus of the NHEP on the estuaries, the highest priority for indicators has been placed on estuarine habitats (e.g., salt marshes, eelgrass, and undeveloped shorelands) and estuarine aquatic species (e.g., finfish, lobsters, and waterfowl). Upland indicators are also included but with a focus on land conservation efforts in the watershed to reflect the NHEP's traditional support for these projects.

B. Environmental Indicators

Table 1 from Chapter 1 lists all the NHEP goals and objectives, monitoring questions, and their associated indicators. The section of this table for NHEP Land Use Goals #2 through #6, contains the indicators for critical species and habitats. Each of the indicators for these goals will be explained in detail in the following sections. Administrative indicators for these goals are described in Chapter 9.

The first set of indicators listed below are for critical habitats, some of which have measurable goals from the NHEP Management Plan. Following this, there is a set of supporting variables for critical species. The supporting variables do not have measurable goals because the biology of these populations are not understood well enough to predict the effects of management actions on abundance.

HAB1. Salt Marsh Extent and Condition

a. Monitoring Objectives

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?"

which will, in turn, 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 and Performance Criteria

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. The performance criteria are an accuracy of +/- 5% in the area estimates for each of the three areas: Hampton/Seabrook Harbor, Coastal Atlantic, and Great Bay.

c. Data Analysis, Statistical Methods and Hypothesis

Salt marshes will be mapped from aerial imagery using the methods described in the next section. 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:

$$Ho: a >= 6200 \text{ acres}; Ha: a < 6200 \text{ acres}$$

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.

d. Field and Analytical Methods

Salt marshes will be mapped from aerial color infrared imagery (CIR) at a scale of 1:24,000 during the spring season. The imagery will be interpreted by experienced analysts using the Cowardin classification system. A fraction of the classifications will be checked by field visits. Field visits will be spread around the NH Seacoast with at least one confirmation site in Hampton/Seabrook Harbor, Coastal Atlantic, and Great Bay.

e. Monitoring Design

The study area will be all the tidal coastline of NH: from the Massachusetts border to the Maine border along the coast, around the edges of Great Bay, and to the head of tide on all the tidal tributaries to Great Bay. The study area is approximately covered by the six NWI 7.5 minute quadrangles numbered 155, 156, 169, 170, 171, and 186.

The first round of data collection will be in 2003. Mapping will be repeated every 5 years.

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:

- “Do the following indicators show that water quality is suitable for aquatic life: aquatic insects/invertebrates, wildlife, fish, diatoms/algae, large bivalves, *eelgrass*, marshes?

which will, in turn, 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 and Performance Criteria

Eelgrass distribution is a supporting variable so neither measurable goals nor performance criteria have been established.

c. Data Analysis, Statistical Methods and Hypothesis

For data analysis, ArcView/ArcInfo software will be used to calculate the area of eelgrass coverage in the following areas (see Figure 7-1):

Area	Zone of eelgrass quantification
Squamscott and Lamprey rivers	upstream of a line connecting Sandy Point and Moody’s Point
Oyster River	upstream from a line across the mouth of the Oyster River
Bellamy River/Lower Little Bay	upstream of the lines connecting Cedar Point, Goat Island and eastern edge of the Bellamy River Bridge.
Great Bay	From boundary of Squamscott/Lamprey Rivers to Adams Pt.
Little Bay	From Adams Pt to Gen. Sullivan Bridge minus Oyster and Bellamy Rivers.

The data will not be evaluated statistically. However, for reference, the eelgrass distribution for each year will be compared to the maximum eelgrass distribution in recent years which occurred in 1996.

d. Field and Analytical Methods

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 3,000 ft at low spring tide with roughly 60% overlap on a calm day without preceding rain events and when the sun is 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 (Fred Short, *pers. com.*). Photographs are taken in late summer, usually late August or early September, depending on tides and weather, to reflect the time of maximum eelgrass biomass.

The ground truthing is done from a small boat at the same season as the photographs are 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 10 - 20% 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. These maps are then digitized and verified using the ground truth data by placing the GPS points onto the digital image in ArcInfo.

e. Monitoring Design

The entire estuary is mapped each year by the UNH/JEL Seagrass Ecology Group using the methods described above.

HAB3. Shoreland Development and Protection

a. Monitoring Objectives

The objective of this **indicator** is to track the amount of development in the tidal and freshwater shorelands of the coastal watershed. Development will be measured by the presence of significant amounts of impervious surface. The undeveloped shorelands will be further stratified into “protected” and “unprotected” categories depending on whether they are permanently protected from development. This indicator will answer the following monitoring question:

- “Has the acreage of permanently protected important habitats (tidal shorelines….freshwater shorelines…) significantly changed over time?”

which will, in turn, 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.”
- LND6-4: “Increase the use of buffers around wildlife areas and maintain contiguous habitat blocks in the NH coastal watershed by 2010.”

b. Measurable Goals and Performance Criteria

The goal will be to increase the acres of permanently protected, undeveloped shorelands from 2000 levels by 2010. Tidal and freshwater shorelands will be assessed separately. After assessing baseline data, the TAC will recommend a feasible goal for the percent increase in protected habitat to be adopted by the NHEP Management Committee. The performance criteria for this indicator will also be determined at this time because the acceptable error depends on the goal.

c. Data Analysis, Statistical Methods and Hypothesis

The primary data source for this indicator is a GIS coverage of impervious surfaces in the coastal watershed with a resolution of 30m x 30m (0.22 acre). Each pixel will be assigned a percentage of impervious surfaces based on sub-pixelization analysis (see a more detailed description of this projects for Land Use Indicator #1). A pixel will be considered “developed” if impervious surfaces cover greater than 20% of its area. The threshold of 20% was chosen using NOAA’s impervious surface coefficients for different land use types (NOAA, 2002) . Developed land has a median coefficient between 30 and 40%. The coefficients for other land use types were between 10% and zero.

Shorelands will be defined as land within 250 feet of tidal waters, salt marshes (E2EM wetlands from the NWI), great ponds/lakes, and third order or higher rivers. This definition matches the jurisdiction of the Comprehensive Shoreland Protection Act (RSA 483-B) with the exception that the Act only covers 4th order or higher rivers. Pertinent hydrography features will be buffered to a width of 250 feet and the total acres of freshwater and tidal shorelands will be estimated using ArcView/ArcInfo software. Next, the acres of land with >20% impervious surfaces within the buffer will be calculated. Finally, the most recent theme of conservations lands will be used to identify and quantify the acres of undeveloped shorelands that are also protected.

Total acreage of developed, undeveloped/unprotected, and undeveloped/protected shorelands will be presented in tabular form stratified by watershed for freshwater shorelands and by coastal location (e.g., Great Bay tributaries, Great Bay, Portsmouth Harbor/Little Harbor, Atlantic Coast, Hampton Harbor) for tidal shorelands. The percent increase from baseline for undeveloped, protected tidal shorelands and undeveloped, protected freshwater shorelands will be compared to the goal. The specific hypothesis to be tested is:

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

where *a* is the percent increase in undeveloped, protected shorelands (freshwater and tidal evaluated separately). A rigorous statistical test of this hypothesis is not possible. Instead, the error bars on the percent increase estimate will be used as an approximate "confidence interval". If the confidence interval of the estimate is entirely below the goal, the null hypothesis will be rejected in favor of the alternative hypothesis. If the confidence interval contains or is above the goal, the null hypothesis will not be rejected.

d. Field and Analytical Methods

The primary data source for this indicator is a coverage of impervious surfaces in the coastal watershed with a resolution of 30m x 30m (see a more detailed description of this project for Land Use Indicator #1).

e. Monitoring Design

Baseline analysis of 2000 levels of impervious surfaces will be completed in 2003. This assessment will be repeated every 5 years.

HAB4. Unfragmented Forest Blocks

a. Monitoring Objectives

The objective of this **indicator** is to report on the total acreage of protected, large, unfragmented forest blocks in the coastal watershed. This indicator will answer the following monitoring question:

- "Has the acreage of permanently protected important habitats (…large contiguous forest tracts….) significantly changed over time?"

which will, in turn, 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."
- LND6-4: "Increase the use of buffers around wildlife areas and maintain habitat blocks in the NH coastal watershed by 2010."

b. Measurable Goals and Performance Criteria

The goal for this indicator is for the total acreage of protected forest blocks in the coastal watershed to increase from baseline (2001) levels. After assessing baseline data, the TAC will recommend a feasible goal for the percent increase in protected habitat to be adopted by the NHEP Management Committee. The performance criteria for this indicator will also be determined at this time because the acceptable error in the estimates depends on the goal.

c. Data Analysis, Statistical Methods and Hypothesis

A layer with the unfragmented forest blocks greater than 250 acres in size will be generated following the methods in the next section. ArcView/ArcInfo software will be used to calculate both the total acres in these blocks as well as the total number of large forest blocks situated in the coastal watershed. The most recent conservation lands layer will be use to select the forest blocks (whole or partial) that are permanently protected from development. The percent increase from baseline in acres of permanently protected lands in large forest blocks will be compared to the goal. The specific hypothesis to be tested is:

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

where *a* is the percent increase in protected, large forest blocks. A rigorous statistical test of this hypothesis is not possible. Instead, the error bars on the protected forest block estimate will be used as an approximate "confidence interval". If the confidence interval of the estimate is entirely below the goal, the null hypothesis will be rejected in favor of the alternative hypothesis. If the confidence interval contains or is above the goal, the null hypothesis will not be rejected.

d. Field and Analytical Methods

Contiguous forest blocks greater than 250 acres in size will be calculated using ArcView/ArcInfo software. Forest blocks will be identified as areas classified as forest in the 2001 NH Land Cover data (Landsat) and physically defined by other land cover types, mainly roads, but also non-forest land cover and water. Road data will be derived from NH DOT road centerlines and/or USGS digital line graph data and will not include jeep trails or other unmaintained roads.

e. Monitoring Design

The baseline assessment will be made in 2003 using Landsat and road data from 2001. Subsquent assessments will occur at approximately 5 year intervals.

HAB5. Rare and Exemplary Natural Communities

a. Monitoring Objectives

The objective for this **supporting variable** is to track the percentage of known rare and exemplary natural communities in the coastal watershed that exist on land protected from development. The NH Natural Heritage Program (NHP) will be the primary data source for this indicator. The following monitoring question will be addressed:

- "Has the acreage of permanently protected important habitats (…rare and exemplary natural communities….) significantly changed over time?"

which will, in turn, 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."
- LND6-4: "Increase the use of buffers around wildlife areas and maintain contiguous habitat blocks in the NH coastal watershed by 2010."

b. Measurable Goals and Performance Criteria

Since rare and exemplary natural communities is a supporting variable that will not be used to answer an management question, neither a goal nor performance criteria have been set.

c. Data Analysis, Statistical Methods and Hypothesis

The NH Natural Heritage Bureau will query the NHP database (using unshifted georeference points and polygons) for the total number and area of the NHP records that are within the coastal watershed. The following quadrangles from the NH Natural Heritage Program will be used: 114-115, 126-128, 138-142, 152-156, 166-171, 182-186, 202. The records from these quadrangles will be clipped using the watershed boundary of HUC8 01060003. Only records whose location is known to within 300 feet (PRECISION="S") and that have been field verified since 1980 will be used. The NH Natural Heritage Bureau will then determine the number and area of the records that occur on land protected from development using all the properties in the most recent conservation lands database.

The NH Natural Heritage Bureau will provide the NHEP with details, such as the name and quality, for the communities that occur on protected public lands. Using the information provided by the NH Natural Heritage Bureau, the table on the next page will be completed.

d. Field and Analytical Methods

The NH Natural Heritage Bureau collects information on rare and exemplary natural communities through surveys for specific projects – normally on the scale of several towns at a time. Therefore, the NHI does not represent a synoptic and comprehensive survey of rare and exemplary communities throughout the coastal watershed. New information is constantly added to the database through either surveys of new areas or changes over time observed during repeat surveys.

The database is mainly populated with information on plant communities because the Bureau's mandate comes from the Native Plant Protection Act of 1987 (RSA 217-A). However, the NHI also maintains data on rare wildlife species in cooperation with the NHF&G Nongame and Endangered Species Program.

e. Monitoring Design

A baseline assessment will be conducted in 2003 using data collected through 2002. Subsequent assessments will be repeated every 5 years. Comparisons will be based on acres protected of known records at the start of each 5 year period, not on any records added during the interim.

Record Type	Location	No. of records in Watershed	No. records on Protected Lands*	Area in Watershed (acres)	Area Protected (area)
Plant community	Estuarine				
	Palustrine				
	Terrestrial				
Plant community system	Estuarine				
	Palustrine				
	Terrestrial				
Plant species	NA			NA	NA
Insects	NA			NA	NA
Mussels	NA			NA	NA
Fish	NA			NA	NA
Birds	NA			NA	NA
Reptiles	NA			NA	NA
Amphibians	NA			NA	NA
Reptiles	NA			NA	NA

*All properties in the most recent conservation lands data layer.

HAB6. Conservation Lands

a. Monitoring Objectives

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:

- "Has the acreage of privately owned lands managed to benefit wildlife and natural communities significantly changed over time?"

which will, in turn, 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."
- LND6-4: "Increase the use of buffers around wildlife areas and maintain contiguous habitat blocks in the NH coastal watershed by 2010."

b. Measurable Goals and Performance Criteria

The goal for this indicator will be to increase the acres of private and public lands from baseline levels. After assessing baseline data and relevant land conservation goals set by the Gulf of Maine Council on the Marine Environment, the TAC will recommend a feasible goal for the percent increase in protected habitat to be adopted by the NHEP Management Committee. The acres of conservation lands database is based on real estate transaction reports, not environmental measurements. Therefore, performance criteria are not needed.

c. Data Analysis, Statistical Methods and Hypothesis

The most recent coverage of conservation lands in the state 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 of publicly-owned and privately-owned and further stratified to generate the table shown on the next page. The total acres of public and private conservation lands each will be tallied and then the percent increase from baseline will be compared to the goal. The specific hypothesis to be tested is:

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

where *a* is the percent increase in the area of protected lands. A rigorous statistical test of this hypothesis is not needed.

d. Field and Analytical Methods

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. GRANIT updates this database annually.

e. Monitoring Design

A baseline assessment will be conducted in 2003. Repeat assessments will be made every 5 years.

Type (Field “PPTYPE”)	Owner (Field “PPAGENCY”)	Number of Parcels	Acres of Land
Easements and Deed Restrictions on Private Lands			
Agricultural Preservations Restriction (“AR”)	Private		
Conservation Easement (“CE”)	Private		
Deed Restriction (“DR”)	Private		
Historic Preservation Easement (“HP”)	Private		
Scenic Easement (“SE”)	Private		
Protective Easement (for Water Supply Lands) (“PE”)	Private		
Open Space Areas of Developments (“SA”)	Private		
Publicly-Owned Lands (“FO”)	Town/County (“<20000”)		
	State (“30000-40000”)		
	Federal (“20000-30000”)		
	NGO (“50000-60000”)		
	Other / Quasi-Public Entities (“40000-50000”)		
Other (“FE”, “LE”, “RV”, “RW”, “EI”)	NA		
Subtotal – Private	NA		
Subtotal – Public	NA		
Grand Total	**NA**		

HAB7. Juvenile Finfish

a. Monitoring Objectives

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 **supporting variable** is to illustrate year to year trends in the abundance and diversity of juvenile finfish in the estuary. It will address the following monitoring question related to Land Use Goal #6:

- "Has the relative abundance, biology, and species composition of resident finfish changed significantly over time?"

which will, in turn, 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 and Performance Criteria

Since juvenile finfish is a supporting variable that will not be used to answer an management question, neither a goal nor performance criteria have been set.

c. Data Analysis, Statistical Methods and Hypothesis

Data on juvenile finfish in the estuary will be analyzed and presented in four ways.

First, for each year, the average catch per unit effort (CPUE) for the most abundant species will be calculated and compared to the range of observations from previous years. The geometric mean CPUE for all months combined for the selected species will be taken from the annual reports by NHF&G for the Atlantic Coastal Fisheries Cooperative Management Act (see NHF&G, 2001). The species for which data will be presented are:

- Killifish (*Fundulus* spp.)
- Flounder, winter (*Pleuronectes americanus*)
- Silverside, atlantic (*Menidia menidia*)
- Herring, atlantic (*Clupea harengus*)
- Herring blueback (*Alosa aestivalis*)
- Smelt, rainbow (*Osmerus mordax*)

These species were selected by querying data from 2000 for finfish species which reproduce in the estuary with an abundance at least 1% of the total CPUE. Cumulatively, these species accounted for greater than 90% of the total CPUE of finfish (crabs and lobsters were removed from the dataset). Results from the estuarine stations (in Great Bay and the Piscataqua River) and for all the harbor stations (Little Harbor and Hampton Harbor) will be reported separately because these areas have different environments with different fish assemblages. Results for all the stations in each set of stations will be averaged. The NHF&G stations in each of these groupings are listed below (see Figure 7-2):

Estuarine Stations	Harbor Stations
54, 72, 93, 107, 147 (Great Bay/Little Bay) 30, 35, 39 (Piscataqua River)	5, 7, 9 (Little Harbor) 23, 25, 29, 33 (Hampton Harbor)

The average CPUE for each species in each area will be compared to the range of all the previous observations (1997 to the year preceding the most recent data). Only five years of data are available on juvenile fish populations so the range of previous observations is not expected to represent "baseline" conditions or to define the full range of possible outcomes. However, by making comparisons to previous data, the results from the latest year can be viewed in the context of what has been seen before.

The second manner in which these data will be presented is through a species diversity index. The Simpson index (D) is a measure of the probability of selecting a pair of individuals of the same species from a single random sample of the community. Therefore, if there is little diversity in the fish community, the Simpson index will be close to 1. Conversely, the value for D will be closer to zero if there is a wide mix of species present. The range of D is from 0 to 1. For example, in the case where 50 fish of one species and 1 fish each of three other species were collected, the value for D would be approximately 0.9, representing the high probability of randomly picking two fish of the dominant species. The equation for the Simpson index (D) (Simpson, 1949) is:

$$D = \sum_i p_i = \frac{\sum_i n_i (n_i - 1)}{N(N-1)}$$

where p_i is the proportion of each species i in the community, n_i is the number of fish collected for species i and N is the total number of fish collected. Because the data from the NHF&G surveys are reported in terms of CPUE, not total number of fish, this equation will need to be modified slightly. The CPUE values will be multiplied by the effort required to capture one fish of the least abundant species and then rounded to the closest integer. These numbers will be used in the equation above to estimate the diversity. All species of finfish captured in the seine surveys during the year will be used to calculate the Simpson index. The results will be reported for each year and compared to the range of previous observations.

The third way that the juvenile finfish data will be presented is a species richness index (S). The species richness index is simply the number of species observed each year.

The fourth report format on juvenile finfish will be a table containing the annual geometric mean CPUE for all species at all stations monitored during that year. This table will be taken directly from the NHF&G Atlantic Coastal Fisheries Cooperative Management Act reports. The purpose of this table is to provide reviewers with understanding of all the data on juvenile finfish that exists and of the variability within the data.

d. Field and Analytical Methods

The following is an excerpt from the latest NHF&G ACFCMA report (NHF&G, 2001) describing the field methods used for the seine surveys:

> "Beach seine hauls were conducted by boat using a 30.5 m long by 1.8 m high bag seine with 6.4 mm mesh deployed 10 - 15 m from the beach. A single seine haul was made at each station during the months of June through November. Seine hauls were all conducted during daylight hours and constrained to the period of approximately two hours before to two hours after low tide. Seines were set into the current and in water depths less than six feet to prevent the foot rope of the net from coming off the bottom.
>
> With each seine haul, surface salinity (ppt) and temperature (^{o}C) were measured and substrate type at the station was observed and recorded.
>
> All fish captured were identified to the lowest possible taxon (species level was the target) and enumerated. All finfish captured were measured total length to the nearest millimeter up to a maximum of 25 individuals per species per seine haul sample. In addition, if the following crustacean species of special interest were captured, they were identified and enumerated: rock crab (*Cancer irroratas*), Jonah crab (*Cancer borealis*), green crab (*Carcinus maenas*), horseshoe crab (*Limulus polyphemus*), and American lobster (*Homarus americanus*)."

e. Monitoring Design

Seine samples are collected monthly from June to November at 15 fixed location stations in New Hampshire’s estuaries (see Figure 7-2). The stations are located throughout the estuaries according to the following distribution:

- 4 stations in Hampton Harbor
- 3 Stations in Little Harbor
- 3 stations in Piscataqua River
- 5 stations in the Great Bay and Little Bay.

Station locations were chosen using one or more of the following criteria: the presence of historical seine sampling data from a given location, spatial distributions of the sites within an area, and the suitability of the site for seining (NHF&G, 2001).

HAB8. Anadromous Fish Returns

a. Monitoring Objectives

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 relative abundance, biology, and species composition of resident finfish changed significantly over time?"

which will, in turn, 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 and Performance Criteria

Since anadromous fish is a supporting variable that will not be used to answer an management question, neither a goal nor performance criteria have been set.

c. 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. 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 (2001b) F-61-R report Table 2-5
Shad (*Alosa sapidissima*)	Passage through fish ladders (# of fish/yr)	Exeter, Lamprey, and Cocheco rivers	NHF&G (2001b) F-61-R report, Table 1-3
Salmon (*Salmo salar*)	Passage through fish ladders (# of fish/yr)	Lamprey and Cocheco rivers	NHF&G (2001b) F-61-R report Table 4-4
Smelt, rainbow (*Osmerus mordax*)	CPUE	Great Bay Ice Fishery	NHF&G (2001b) F-61-R report Table 3-6
Lamprey	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 less appropriate for this supporting variable than the data on the four other species listed above.

d. Field and Analytical Methods

NHF&G operates seven 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 (NHF&G, 2001b). Data from the fish ladders are used to track the herring, shad, lamprey, and salmon returns.

For the rainbow smelt CPUE, NHF&G conducts a creel survey. The methods for this survey are described in this excerpt from the 2001 F-61-R report for smelt (NHF&G, 2001b):

> "The winter smelt fishing creel survey is conducted from roughly ice in to ice out. In 2000 this occurred from December 29 to March 8. Four areas of major smelt angling activity have been identified and surveyed throughout this project period: the Lamprey, Oyster/Bellamy and Squamscott rivers and Great Bay.
>
> The survey was conducted using a random schedule of two hour survey periods between 0600 - 2400 hours. Randomization was accomplished by using random numbers to select starting time and location from a table which only includes the period from 2 hours before to 4 hours following the high tide. The survey is limited to this time period because of the lack of fishing activity around low tide. Survey site selection was weighted by relative fishing effort from past surveys. At least one survey was scheduled for each day of the week with supplemental surveys added to ensure that each location was surveyed at least once during each weekday period and once during a weekend. The methodology resulted in a sampling intensity of roughly 7-9% of the time periods and locations on weekends and 4-5% on weekdays.
>
> Survey personnel interviewed all anglers (or a sub-sample if they were unable to interview all anglers in the two hour survey period) for catch and effort (hours fished) information. The information collected was expanded by strata (weekend/weekday, location and month) to provide estimates of catch, effort and catch per unit effort (CPUE) by month and location. The number of potential time blocks, 3 two-hour blocks per fishing day, was used to estimate total effort and catch by area and month.
>
> Length and sex information, as well as scales for aging, were taken weekly from a sample of the angler harvest. Sampling goals were 25 fish per location, per week for each week of the fishery. Scales were double aged using methods described by Bailey (1964)."

e. Monitoring Design

The monitoring design for this program is described in the previous section.

HAB9. Abundance of Lobsters

a. Monitoring Objectives

The commercial fishery for lobster is the largest and most important fishery in New Hampshire. Although lobsters are not exclusively dependent on conditions in the estuary to survive, a crash in the lobster population would be a cause for concern both ecologically and commercially. The objective for this **supporting variable** is to track the overall abundance of lobsters (total and legal size) to illustrate any trends over time. It will address the following monitoring question related to Land Use Goal #6:

- "Has the relative abundance, biology, and species composition of resident finfish changed significantly over time?"

which will, in turn, 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 and Performance Criteria

Since lobster abundance is a supporting variable that will not be used to answer an management question, neither a goal nor performance criteria have been set.

c. Data Analysis, Statistical Methods and Hypothesis

Measurements of lobster abundance will be tracked for each year using data from NHF&G. Specifically, the annual total catch per trap haul set over day (Total CTHSOD), marketable CTHSOD, and juvenile CTHSOD for all areas of the NH coast will be plotted against year to illustrate trends over time. Annual statistics for total, marketable, and juvenile CTHSOD will be taken from the NHF&G Atlantic Coastal Fisheries Cooperative Management Act (ACFCMA) report.

d. Field and Analytical Methods

The following excerpt from the 2001 ACFCMA report (NHF&G, 2001) describes the field and analytical methods that will be used.

> "Lobsters were sampled on a monthly basis from June through October in three areas; the Piscataqua River, along the New Hampshire coast, and at the Isles of Shoals (Figure 3-1). Samples were taken during day trips aboard a commercial lobster boat fishing New Hampshire waters. Day trips were either a trip combining river and coastal samples, or a trip offshore to the Isles of Shoals. The data collected enabled the calculation of total catch per trap haul set-over-day (CTHSOD) and marketable catch per trap haul (CTH). Most trawls consisted of a 10 trap set line (i.e. 10 traps tied to one haul line). During each trip from June - October, all lobsters were sampled from nearly every trawl allowing a length frequency distribution to be plotted for the entire catch. Data collected on sea sampled lobsters consisted of sex, length (mid-dorsal carapace length to the nearest millimeter), shell condition (i.e. molt stage), and the V-notched and ovigerous condition were noted for females."

e. Monitoring Design

The monitoring design is described in the previous section.

HAB10. Abundance of Wintering Waterfowl

a. Monitoring Objectives

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:

- "Do the following indicators show that water quality is suitable for aquatic life: aquatic insects/invertebrates, *wildlife*, fish, diatoms/algae, large bivalves, eelgrass, marshes?

which will, in turn, 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 and Performance Criteria

Since wintering waterfowl is a supporting variable that will not be used to answer an management question, neither a goal nor performance criteria have been set.

c. 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*)
- Goldeneye (*Bucephala clangula*)
- Bufflehead (*Bucephala albeola*)
- R.B. Merganser (*Mergus serrator*)
- Canada Goose (*Branta canadensis*)

d. Field and Analytical Methods

Data on the abundance of wintering waterfowl in NH are collected by NHF&G using aerial surveys. Other states, the U.S. Fish and Wildlife Service, and the Canadian Wildlife Service conduct similar surveys all along the Atlantic Flyway at approximately the same time. The results of all the surveys are compiled to estimate the population of waterfowl migrating along the flyway during that year. The methods used by NHF&G are described below in an excerpt from NHF&G (1995):

> "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 survey 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)."

Data from the aerial surveys are supplemented by field observations every other week at fixed locations by volunteers for the Great Bay NERR Wintering Waterfowl Monitoring Program.

e. Monitoring Design

The monitoring design was described in the previous section.

C. Research Indicators for the Out-Years

1. 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 consistently provides funds to GBRPP for this purpose.

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.

2. 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.

3. 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. Therefore, research into methods, accuracy, and interpretation is needed to develop this indicator.

4. Salt Marsh Degradation from Grid Ditching and Increased Freshwater Runoff

The indicator HAB1 will track the acreage of salt marsh in the NH seacoast that is degraded due to invasive species or tidal restrictions. Two other important causes of salt marsh degradation are hydrologic alterations from grid ditching or increased freshwater discharge to the salt marsh. There are currently no established methods for systematically identifying areas of salt marsh that are degraded due to these factors. Therefore, research is needed on methods to identify salt marshes degraded from these factors using aerial imagery.

D. References

NHF&G (2001) Final Report on Programs Improving Management of ASMFC Managed Species in New Hampshire, January 1, 2000 - March 31, 2001. NH Fish and Game Department, Marine Fisheries Division, Durham, NH. 2001.

NHF&G (2001b) New Hampshire's Marine Fisheries Investigations, Anadromous Fish Investigations, Grant F-61-R, January 1, 2000 - March 31, 2001. NH Fish and Game Department, Marine Fisheries Division, Durham, NH. 2001.

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

NOAA (2002) Impervious Surface Mapping Tool. NOAA Coastal Remote Sensing Center, www.csc.noaa.gov/crs/is/.

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Chapter 8: Habitat Restoration

A. Introduction

In addition to maintaining existing habitat, the NHEP has set goals for the restoration of certain habitat types. In particular, the NHEP Restoration objectives are:

- RST1-1A: Increase acreage of restored estuarine habitats by 2010: Restore 300 acres of salt marsh with tidal restrictions.
- RST1-1B: 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.
- RST1-1C: Increase acreage of restored estuarine habitats by 2010: Restore 20 acres of oyster habitat in Great Bay and its tidal tributaries.

B. Environmental Indicators

Table 1 from Chapter 1 lists all the NHEP goals and objectives, monitoring questions, and their associated indicators. The section of this table for NHEP Habitat Restoration Goal #1 (page 10) contains the list of indicators related to habitat restoration. Each of the environmental indicators for this goal will be explained in detail in the following sections.

1. Restored Salt Marsh

a. Monitoring Objectives

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.

and partially answer the following monitoring question:

- Have restoration efforts resulted in a significant increase in the acreage of tidal or freshwater wetlands?

b. Measurable Goal and Performance Criteria

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

No performance criteria have been set for this indicator because the number of restored salt marsh acres will be directly reported by salt marsh restoration projects.

c. Data Analysis, Statistical Methods, and Hypothesis

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.

d. Field and Analytical Methods

No field data will be collected for this indicator.

e. Monitoring Design

No field data will be collected for this indicator.

2. Restored Eelgrass Beds

a. Monitoring Objectives

The objective of this indicator is to track the cumulative acres of eelgrass 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 50 acres of eelgrass in Portsmouth Harbor, Little Bay, and the Piscataqua, Bellamy, and Oyster rivers.

b. Measurable Goal and Performance Criteria

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

No performance criteria have been set for this indicator because the number of restored eelgrass acres will be directly reported by the eelgrass restoration projects.

c. Data Analysis, Statistical Methods, and Hypothesis

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.

d. Field and Analytical Methods

No field data will be collected for this indicator.

e. Monitoring Design

No field data will be collected for this indicator.

3. Restored Oyster Beds

a. Monitoring Objectives

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.

and partially answer the monitoring question of:

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

b. Measurable Goal and Performance Criteria

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.

No performance criteria have been set for this indicator because the number of restored oyster habitat acres will be directly reported by the oyster restoration projects.

c. Data Analysis, Statistical Methods, and Hypothesis

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 will be considered restoration projects. Expanded oyster density or bed size due to improving water quality or decreasing effects of disease will not be considered oyster restoration. The total area of each restored oyster bed will be determined by the restoration project manager. No statistical tests will be applied.

d. Field and Analytical Methods

No field data will be collected for this indicator.

e. Monitoring Design

No field data will be collected for this indicator.

D. Research Indicators for the Out-Years

None

E. References

None

Chapter 9: 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 biennial schedule coincident with the EPA Implementation Reviews unless otherwise noted.

<u>Table 9-1: Administrative Indicators for the NHEP</u>

Management Objective	**Administrative Indicator**
WQ1-4: Reduce the number of known illicit connections in the NH coastal watershed by 50% by 2010.	The number of known illicit connections is constantly changing as new illicit connections are identified and others are removed. The NHEP will track this objective by providing tabular information that describes: # of illicit connections found, # connections eliminated, # estimated discharges remaining or undiscovered. This information will be updated by NH DES Watershed Planning staff.
WQ1-5: Achieve 50% reduction of known illegal discharges into Great Bay, Hampton Harbor, and the tributaries by 2010.	The number of known illegal discharges is constantly changing as new discharges are identified and existing discharges are removed. The NHEP will track this objective by providing tabular information that describes the # of known direct discharges and the # of direct discharges eliminated. The information will be provided through 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 Minimum Impact Development (MID) program to report the number and acreage of development projects employing stormwater reduction techniques by using MID practices. In addition, all NHEP-funded projects aimed at reducing stormwater runoff from impervious surface will be reported.

Management Objective	Administrative Indicator
LND1-3: Encourage 43 coastal watershed municipalities to actively participate in addressing sprawl.	NHEP will report the number of communities engaged in smart growth activities, and the type of activity undertaken, by polling the Regional Planning Commissions, the Natural Resource Outreach Coalition, the Minimum Impact Development program, and other smart growth initiatives on a biennial basis. NHEP activities to promote smart growth will also be reported.
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 impacts by 2010.	NHEP will report the number and type of NHEP-funded activities with a focus on reducing shoreland impacts from impervious surface development.
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.
LND4-1: Determine the extent of groundwater resources and their contaminant load to Great Bay and Hampton Harbor by 2005.	NHEP will report the results of two recent studies on groundwater inflows and groundwater nutrient loading to Great Bay and Hampton-Seabrook Harbor. The study of Hampton-Seabrook Harbor will be conducted in 2002 with funding from NHEP.
LND4-2: Reduce and eliminate groundwater contaminants based on the outcome of Objective 1 by 2010.	NHEP will report the number and type of NHEP-funded activities with a primary focus on reducing groundwater pollution in the coastal watershed.
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.
LND6-4: Increase the use of buffers around wildlife areas and maintaining contiguous habitat blocks in the NH coastal watershed by 2010.	NHEP will report on all NHEP-funded projects to increase buffers around wildlife habitat. NHEP will also track the # of communities employing the NH F&G wildlife manual.

Chapter 10: 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 will be 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 will be to:

- Compile and manage all environmental data for NHEP environmental indicators.
- Maintain and publish biennially (starting in 2002) an inventory of environmental monitoring programs and available data for the coastal watershed. This inventory will be available electronically from the NHEP website and in hardcopy upon request.
- Distribute raw or interpreted environmental data from NHEP indicators upon request or via web-based downloads.
- Distribute guidance on uniform formats for environmental databases to coastal partners.

B. Quality Assurance

It is extremely important that the data used by NHEP to calculate environmental indicators is 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. The NHEP Coastal Scientist will summarize the "QAPP status" for NHEP-funded programs quarterly, and provide this information to the EPA Project Officer. The most recent QAPP status summary is provided in Appendix D.
- 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 evaluate the performance of monitoring programs relative to their performance criteria (i.e., accuracy of individual measurements relative to data quality objectives, and statistical power of overall program) on an annual basis beginning in 2002. During this evaluation, the field and analytical protocols for the various programs will be compared to ensure that data from the different programs can be combined.

Chapter 11: Communications Plan

The NHEP will share the results of environmental monitoring with four main audiences: EPA, the NHEP Management Conference, the public, and the scientific community. The schedule for reporting to these audiences is described in the following sections.

A. Reports to EPA

For each Biennial Review by EPA, NHEP will present a report on the status and trends of indicators from this plan. For the first review in 2002, the NHEP report will consist of this Monitoring Plan plus trend analysis for a few selected indicators because many monitoring programs are just beginning. In 2004, a full report on the status and trends of all NHEP indicators (environmental and administrative) will be submitted.

B. Reports to the NHEP Management Conference

An annual summary of key environmental indicators will be presented to the NHEP Management Conference. The first report of this kind will be made by September 2002 and will be repeated annually.

C. Reports to the Public

The first "State of New Hampshire's Estuaries" report to the public was published by the NHEP in November 2000. This report will be updated biennially using key environmental indicators starting in 2003. In addition, NHEP outreach staff will help communicate interpreted data to the public through newsletter articles, fact sheets, press releases, and the NHEP website (www.state.nh.us/nhep).

D. Reports to the Scientific Community

The NHEP Coastal Scientist will publish an inventory of monitoring programs and available data for the coastal watershed coincident with the EPA Biennial Reviews starting in 2002. Members of the scientific community can receive raw data or databases used for the NHEP environmental indicators upon request.

Chapter 12: Implementation Plan

A. Progress to Date

January 2001: A committee of monitoring experts from the NHEP management conference 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 and are described, along with other ongoing monitoring programs, under the "Phase I (2001-2002) Monitoring Design" sections of related indicators. ***The costs to the NHEP for all 2001-2002 programs are summarized in Appendix C.***

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.

Table 12-1: The NHEP Technical Advisory Committee

Name	Organization
Tom Ballestero	UNH
Gregg Comstock	NHDES
Paul Currier	NHDES
Ted Diers	OSP-NHCP
Taylor Eighmy	UNH
Steve Jones, Chair	UNH-JEL
Natalie Landry	NHDES
Richard Langan	UNH-CICEET
Cynthia Lay McLaren	OSP-NHEP
Joanne McLaughlin	OSP-NHCP
Stephen Mirick	ASNH
Chris Nash	NHDES
Chris Neefus	UNH
Fay Rubin	UNH-CSRC
Fred Short	UNH-JEL
Brian Smith	NHF&G
Phil Trowbridge	NHDES

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.

B. Timeline for Full Implementation

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: (1) statistical review of the monitoring programs for each indicator to be sure that there is sufficient power to detect trends/differences; (2) review of field and analytical methods for various programs to ensure compatibility; and (3) development of the research indicators listed in the Critical Species and Habitats Chapter. NHEP's schedule for reaching full implementation by 2004 is listed below.

By 6/3/02

- Submit environmental results materials for EPA's 2002 Implementation Review.

By 9/30/02

- Conduct an evaluation of statistical power and methods compatibility for indicators.
- Prepare workplan for 2003 monitoring funds based on the results of EPA's 2002 Implementation Review and statistical power/methods evaluation.

By 12/31/02

- Update the Monitoring Plan with indicators for critical species and habitats and any changes to the monitoring design for 2003.

By 12/31/03

- Update the Monitoring Plan with any other research indicators deemed feasible by the TAC and any changes to the monitoring design for 2004.
- Develop a "decision framework" for translating the results from indicators into recommended management actions.

From 2004 onwards, the NHEP Coastal Scientist will conduct an annual evaluation of the NHEP monitoring program with assistance from the Technical Advisory Committee. The purpose of the annual evaluation is to reassess monitoring priorities and needs and to restructure the NHEP-funded monitoring activities as necessary. The annual evaluation will be in the form of a report, which will be shared with the Technical Advisory Committee and the NHEP Director.

Appendix A: Field and Analytical Methods

A. Great Bay National Estuarine Research Reserve (GBNERR) Ambient Monitoring Program

Sampling Design

This program follows a systemic sampling design in time at three fixed stations. Samples are collected monthly on the high and low tides at one station in the Great Bay (Adams Point) and two stations in the tidal tributaries (Squamscott River, Lamprey River). The sampling dates are set in advance based on the timing of high/low tide and sunrise-sunset. Therefore the program is independent of weather events.

Bacteria Indicator Species Measurement Procedures

Collection procedures consisted of immersing sterile, polyethylene, 1 liter bottles approximately 20 cm below the surface with the capped opening facing into the prevailing current, then removing the cap, filling the bottle nearly full, and recapping the bottle, all below the surface. All samples were placed in iced coolers immediately following collection, stored at 5°C at JEL, and analyzed within 24 hours of sampling. All analyses were done in duplicate on each sample. Enterococci, the standard indicator for marine recreational waters in both New Hampshire and Maine, was measured using a standard membrane filtration method and mE agar incubated at 41°C for 48 hours, with standard confirmation steps (U.S. EPA, 1986). Fecal coliforms and *Escherichia coli* were measured using a standard membrane filtration method and mTEC agar incubated at 44.5°C for 24 hours, with standard confirmation steps (U.S. EPA, 1986). *C. perfringens*, a conservative tracer of fecally contaminated water, was detected using membrane filtration and mCP agar incubated at 44.5°C for 24 hours, with standard confirmation tests (Bisson and Cabelli 1978).

Nutrients and Physical Parameters Measurement Procedures

Monthly sampling included measurements of temperature and salinity using a YSI model 33 CST meter; dissolved oxygen using a YSI model 55 dissolved oxygen meter; pH using a Fisher Acumet model 1000 field pH meter. Replicate subsurface grab water samples were collected following UNH JEL SOP 1.05 (Langan 1992a), processed and analyzed for total suspended solids, POM, chlorophyll a and phaeopigments following UNH JEL SOP 1.06 (Langan 1992b).

The filtrate was analyzed for $NO_2 + NO_3^-$ concentration (Lachat method #30-107-04-1-A, Lachat Instruments 1991) and NH_4+ concentration (Lachat method 11-107-06-1-C, Lachat Instruments 1991) on a LACHAT Quick-Chem nutrient autoanalyzer. PO_4^{-3} concentration was measured using the orthophosphate method for wet chemistry as described in Strickland and Parsons (1968) with variation as described in Wolf and Langan (1992).

References:

Bisson, J.W. and V.J. Cabelli. 1978. Membrane filtration enumeration method for *Clostridium perfringens*. Appl. Environ. Microbiol. 37: 55-66.

Lachat Instruments. 1991. Operating manual for the Quick Chem Autoanalyzer Lachat Instruments. Milwaukee, Wisconsin.

Langan, R. 1992a. UNH JEL Standard operating procedure for water sampling for suspended solids, chlorophyll, and nutrients. JEL SOP 1.05. In: Standard operating procedures and field methods used for conducting ecological risk assessment case studies. Mueller et al. eds. 1992. USEPA, US Navy (NRaD) Technical Document 2296.

Langan, R. 1992b. UNH JEL Standard operating procedure for water sample filtration and analysis of total suspended solids, chlorophyll and phaeopigments. JEL SOP 1.06. In: Standard operating procedures and field methods used for conducting ecological risk assessment case studies. Mueller et al. eds. 1992. USEPA, US Navy (NRaD) Technical Document 2296.

Strickland, J.D.H. and T.R. Parsons. 1968. A Practical Handbook of Seawater Analysis. Fisheries Research Board Of Canada, Ottawa,1968.

U.S. Environmental Protection Agency (U.S. E.P.A.). 1986. Test methods for *Escherichia coli* and enterococci in water by the membrane filtration procedure, EPA 600/4-85/076. U.S. Environmental Protection Agency , Environmental Monitoring and Support Laboratory, Cincinnati, OH.

Wolf, J.S. and R. Langan. 1992. Standard operating procedure for analysis of seawater samples for phosphate (PO43-) using wet chemistry procedure. JEL SOP 1.07. In: Mueller et al. (eds.), Standard Operating Procedures and Field Methods Used for Conducting Ecological Risk Assessment Case Studies. USEPA, US Navy (NRaD) Technical Document 2296. pp. 381-383.

B. DES Shellfish Program

The following is an excerpt from the DES Shellfish Program Quality Assurance Project Plan (draft).

B1 – Sampling Process Design

Water samples are collected to monitor water quality of growing areas on a routine (prescheduled) basis, as well as at selected sites following some rainfall events (conditional/ closed status sampling) or following significant pollution events (emergency closure/ closed status sampling). Both routine water and closed status sampling is conducted by DES throughout the calendar year. Tables 6 – 11 and Figures 1 – 6 provide descriptions and locations for these sampling sites.

All water samples are analyzed for fecal coliform according to national (FDA) protocol, as outlined in the National Shellfish Sanitation Program: Guide for the Control of Molluscan Shellfish (1999 Revision). Fecal coliform is analyzed as an indicator of harmful bacteria and viruses that may be present in shellfish. The National Shellfish Sanitation Program requires that routine water quality samples used to determine growing water classification be analyzed at FDA-certified laboratories. The Shellfish Program uses the FDA-certified DHHS and DES laboratories to analyze routine samples for fecal coliform concentrations.

In addition, pH and salinity may also be measured. The following paragraphs will describe each of the circumstances and frequency under which these water samples are collected. The descriptions reference procedures described in the 1999 revision of the "National Shellfish Sanitation Program: Guide for the Control of Molluscan Shellfish."

Routine Monitoring

The NSSP outlines several sampling strategy options for routine monitoring of growing areas. Proper selection of sampling strategy largely depends on the types of pollution sources that affect the growing area, and the kinds of hydrographic or meteorologic conditions that generate significant contamination. The sampling strategy most appropriate for NH growing waters, especially those in which harvesting is allowed, is that described for Conditionally Approved areas.

All areas classified as Conditionally Approved based on the effects of non-point sources of pollution such as rainfall events, stormwater runoff, and seasonal variations, will be sampled a minimum of six (6) times per year. Samples will be prescheduled at the start of each calendar year and collected on a monthly basis under the conditions the growing area would be in the open status. Depending on the conditional criteria applicable to the growing area and the likelihood of all six prescheduled samples being collected under the conditions the growing area would be in the open status, additional sampling runs may be prescheduled at the start of the calendar year. These additional sampling runs may be scheduled as monthly runs, or extra sampling runs within particular months, to ensure collection of a minimum of six monthly samples obtained under the conditions the growing area would be open for harvest. If in a particular year the additional prescheduled runs will not ensure collection of six applicable samples, additional sampling runs will be added to the schedule as needed to ensure a minimum of six samples will be collected under the conditions the growing area would be open for harvest.

Routine water samples are collected at pre-determined sample sites (Tables 6 – 11, Figures 1 – 6) based on the location of pollution sources, tidal conditions and the boundaries of shellfish growing areas.

Conditional/ Closed Status

When areas classified as Conditionally Approved are placed in the closed status per the criteria established in the area's sanitary survey and management plan, water sampling shall not be required to reopen the area provided the terms of the management plan are followed. However, water sampling may be used on an event-by-event basis to establish the appropriate time for reopening an area. Areas will remain in the closed status until NHDES determines bacterial levels have declined to safe concentrations. Determinations may be based upon water sampling results.

Emergency Closure/ Closed Status

When accidental releases of pollution (e.g., pump station failures, sewer line ruptures, or other events) require immediate "emergency" closure of growing areas, water sampling may be used to verify the spatial impact of the event, and to determine when the areas may be returned to the open status. Such sampling will be conducted at sites selected by NHDES, and will be designed to document the impact of the event, and the decline in pollution levels. Areas will remain in the closed status until NHDES determines bacterial levels have declined to safe concentrations. Such determinations may be based upon water sampling results.

B2-Sampling Method

One temperature control water sample is collected at the beginning of each sampling run. It is marked "temperature control" and labeled with the date and growing area. The temperature control is kept in the cooler and transported to the laboratory with the collected water samples. The control temperature is measured and recorded when samples are delivered to the laboratory to confirm that the proper temperature was maintained, preferably between 0-10°C, during sample collection and transport. Water samples delivered to the laboratory at a temperature greater than 10°C may not rejected. For example, samples collected from ambient waters measuring 25°C and immediately delivered to the laboratory will likely not have cooled to less than 10°C during transportation. Such samples may be deemed acceptable, especially if the temperature at time of delivery is less than that at the time of collection. The decision to accept or reject samples with a temperature of over 10°C at the time of delivery will be at the discretion of the receiving laboratory and the NHDES Shellfish Program.

Table 1: Routine Monitoring-Laboratory Parameters

Parameter	Collection Method	Sample Container	Sample Preservation	Holding Time	Method Reference
Fecal Coliform	Grab	250 mL-clear, polyethylene, sterilized bottle or Whirl-Pak®	Cool, 0-10°C	24 hours	NSSP, 1999 [1]
pH	Grab	250 mL-clear, polyethylene, sterilized bottle or Whirl-Pak®	Cool, 0-10°C	24 hours	NSSP, 1999 [1]
Salinity	Grab	250 mL-clear, polyethylene, sterilized bottle or Whirl-Pak®	Cool, 0-10°C	N/A	SM2550B[2]

[1] *National Shellfish Sanitation Program, Guide for the Control of Molluscan Shellfish, U.S. Department of Health and Human Services, Public Health Service, Food and Drug Administration, 1999 Revision.*

[2] *Standard Methods for the Examination of Water and Wastewater, 20th Edition, 1998.*

Sample collection date, weather, air temperature, average wind speed and wind direction are recorded on the field data sheet. Air temperature is measured using a Reotemp, stainless steel, bi-metal thermometer or equivalent. Wind speed is measured using a Kestrel Pocket Wind Meter or equivalent. The average wind speed is recorded after measuring for 30 seconds. Wind direction is measured in degrees relative to magnetic north. At each sampling site, collection time, water temperature, waterfowl, wildlife and other observations that may have an impact on water quality are recorded on the field data sheet.

Water temperature at each sample site is measured using a Reotemp, stainless steel, bi-metal thermometer or equivalent. Water temperature is measured by placing the thermometer in the water until the thermometer reading has stabilized. If this method is not appropriate for the field conditions, a sample will be collected in a sample bottle and the water will be discarded after the temperature has been recorded. The temperature is measured by looking squarely at the face of the thermometer. The thermometer is calibrated annually at a minimum.

Table 2: Routine Monitoring-Field Parameters

Parameter	Collection Method	Sample Container	Measurement Time	Method Reference
Water Temperature	Reotemp Thermometer	250 mL-clear, polyethylene, sterilized bottle or Whirl-Pak®	Upon sample collection	NSSP, 1999 [1]
Air Temperature	Reotemp Thermometer	N/A	Beginning of sample run	QAPP, 2002[2]
Wind Speed	Kestrel Pocket Wind Meter	N/A	Beginning of sample run	QAPP, 2002[2]
Wind Direction	Observation / Compass	N/A	Beginning of sample run	QAPP, 2002[2]

[1] *National Shellfish Sanitation Program, Guide for the Control of Molluscan Shellfish, U.S. Department of Health and Human Services, Public Health Service, Food and Drug Administration, 1999 Revision.*

[2] *Quality Assurance Project Plan for Shellfish Water Quality Monitoring, NH Dept. of Environmental Services, January 2002.*

Samples are collected in 250- mL clear, polyethylene, sterilized bottles supplied by the DHHS/DES laboratories or 18-oz. Whirl-Paks®. On sample bottle labels or Whirl-Paks®, the sample date and sample site identification are recorded.

Water samples are collected by boat unless shallow water depths require shore sampling. The bacterial sample is collected by positioning the mouth of the bottle/ Whirl-Pak® opposite the direction of tidal flow and thrusting the bottle/ Whirl-Pak® 8-12 inches under the surface of the water using a continuous "U" shaped motion until almost full, leaving a one-inch air space. Samples are collected with the container completed submerged, so as to minimize the collection of water on the immediate surface.

Samples are collected without disturbing the substrate. If the substrate is disturbed the sample is collected away from the disturbed area to minimize contamination possibilities.

Samples are stored on ice or ice pack in a light-tight cooler until delivery to the laboratory within 24 hours of sample collection. The DHHS and DES laboratory analyzes the water sample for fecal coliform concentration.

B3- Handling and Custody Requirements

The original field data sheet or transcribed information is transferred to the DHHS or DES laboratory. Chain of custody is recorded on the field and/or lab data sheet (Appendices A and B). This is completed when samples exchange hands between sample collection and delivery to the laboratory. Water temperature of the temperature control is measured and recorded on the data sheet at the time of sample delivery. Following completion of the water sample analysis by DHHS/DES, field data sheets and laboratory results are forwarded to the DES Shellfish Program office.

B4-Analytical Methods

All water samples are analyzed at one of two laboratories on Hazen Drive in Concord: the NHDHHS Public Health Laboratory or the NHDES Laboratory. Samples are analyzed for fecal coliform using the MPN(LST-EC) or MPN(A1) tests. These tests are FDA accepted, yield similar results and can be used for routine, post-rainfall, or emergency/ closed status sampling. If results are needed within 24-48 hours, the MPN(A1) test (which can typically be completed in 24 hours) is used.

For DHHS analytical methods and requirements please refer to the microbiology policies within the NHPHL Quality Assurance Plan. The NHPHL Quality Assurance Plan is on file at the NHDHHS Public Health Laboratory. For NHDES analytical methods and requirements please refer to the Standard Operating Procedure for the MPN test in addition to the Quality Systems Manual: State of New Hampshire Department of Environmental Services Laboratory Services Unit. Both documents are on file at the NHDES Laboratory.

Samples sent to the DHHS laboratory are also analyzed for pH and salinity using an Corning Model 320 pH meter and a Leica Model 10419 temperature-compensated salinity refractometer.

A YSI Model 85 Handheld Oxygen, Conductivity, Salinity, and Temperature System is used occasionally in the field. The Operations Manual is located in the NHDES Shellfish Program Office.

B5-Quality Control Requirements

Table 3 summarizes laboratory and field quality control samples.

Table 3: Laboratory and Field Quality Control Samples

Analyses	Laboratory Duplicates	Sterility Tests	Process Control	Media Batch Controls	Field Duplicates
Fecal coliform-DHHS	**1/10 samples**	**Done with each set of shellfish samples**	**Done with each set of shellfish samples**	**1-2 / batch of media**	**See note #1**
Fecal coliform-DES	**1/20 samples**	**N/A**	**Done with each set of shellfish samples**	**Per batch of media**	**See note #1**
pH -DHHS	**none**	**N/A**	**Calibrated per set of samples**	**N/A**	**See note #1**
Salinity-DHHS	**20% of samples**	**N/A**	**Calibrated per set of samples**	**N/A**	**See note #1**
Temperature Control	**N/A**	**N/A**	**1 per set of samples**	**N/A**	**N/A**

#1. The collection of field duplicates was discontinued in 2000.

B6/B7 – Instrument/Equipment Inspection, Maintenance and Calibration

Field instruments used during water sample collection include a Kestral Pocket Wind Meter, Compass, Reotemp thermometer and YSI 85 Salinity meter. Wind meters and compasses are not used if damaged or giving inaccurate readings. The Reotemp thermometer is calibrated annually at a minimum. The date of calibration is recorded on a piece of tape attached to the thermometer. The YSI 85 Salinity meter is tested, inspected and maintained as specified in the operations manual, which is on file at the NHDES Shellfish Program Office.

Laboratory instruments and equipment are inspected, maintained and calibrated by the laboratory. Refer to the NHPHL Quality Assurance Plan, the NHDES Standard Operating Procedures for the MPN test and the Quality Systems Manual: State of New Hampshire Department of Environmental Services Laboratory Services Unit. All documents are on file at the respective laboratories in Concord.

B8-Inspection/Acceptance Requirements for Supplies and Consumables

Sample bottles and Whirl-Paks are inspected by laboratories and/or field personnel before sample collection. Bottles that may have been contaminated are returned to the laboratory for sterilization. Possibly contaminated Whirl-Paks are discarded.

B9-Non-direct Measurements

Tidal data are used in making decisions on when to sample. Samples are collected under low tide conditions as discussed in Section B1. Data on time of low tide are acquired from National Oceanic and Atmospheric Administration tide charts, using times for the Portland, ME base station. Using this information and the tidal lag for each sampling site, the appropriate tidal conditions for sampling can be determined.

Rainfall data are used to determine if a growing area should be placed in the closed status. Primary weather stations from which data are acquired are located in Portsmouth (Pease International Airport) and Seabrook (North Atlantic Energy Service Corporation), NH. Data from stations in Durham (University of New Hampshire) and Greenland (National Weather Service) are used as needed.

Data from GIS have been generated by NHDES Shellfish Program staff in conjunction with NHDES Information Resources Management Unit staff. Maps (Figures 1–6) have been generated to display sample site locations.

C. NHCP/JEL Ambient Monitoring Program

The field and analytical protocols for the NHCP Ambient Monitoring Program are identical to those used for the GBNERR Ambient Monitoring Program. Laboratory analyses are conducted by UNH Jackson Estuarine Laboratory. One station is monitored by this program: the Coastal Marine Laboratory on New Castle Island in Portsmouth Harbor.

D. DES Beach Program

Sampling Design

DES's public beach inspection is operated from mid-June to Labor Day. About 170 public bathing beaches on lakes, rivers, and impoundments are inspected monthly, while coastal public beaches are inspected on a weekly basis. An inspector collects three bacteria samples from each beach, takes note of potential problem areas, inspects the toilet facilities, and confers with lifeguards on duty. *E. coli* is the bacteria used as a standard for New Hampshire freshwater beaches. *Enterococci* is the indicator organism used at our seacoast beaches.

Sample Collection Procedures (from DES Fact Sheet WW-BB-13)
When collecting an *E. coli* bacterial sample from a natural swimming area such as a lake or pond, the sample should be collected where the water is approximately one meter deep. Samples should be collected from the left perimeter, the right perimeter, and the center of the swimming area. This "bracketing" of the area ensures that the sample results are indicative of water quality of the entire swim area and not just one particular spot. Note: If the beach area is less than 100 feet, it is generally sufficient to take only two samples, each a third of the distance form either end of the beach.

In the case of a swim area located on a natural flow through watercourse, such as a brook or river, samples should be collected upstream, at the public beach area, and down stream. In streams or rivers in which it is difficult to collect a sample at the desired one meter depth, locate the deepest area with a moving current and follow the sample procedure.

1. Always utilize a sterilized bottle when collecting *E. coli* samples.
2. If a state laboratory bottle is utilized, remove the cap carefully. The protection paper covering the cap should remain intact.
3. Hold the cap with the paper cover in one hand, and with the other hand turn the bottle upside down so the opening is facing the water surface. Make sure you never touch the opening of the bottle neck.
4. With a downward thrust moving away from your body, dip the bottle at least a foot below the surface. Fill the bottle with one sweeping motion and discard a few milliliters to allow some head (air) space.
5. Replace the cap carefully over the bottle with the paper still intact and tighten the cap.
6. Slide the elastic band from the cap and over the bottle neck.
7. Mark the site location, the name of the public beach, and the date and time the sample was collected. Make sure to always use a waterproof marking pen.

Laboratory Analytical Procedures
Samples are analyzed by the DES Laboratory using SOP 10.43d for *E. coli* and SOP 10.43e/10.43b for Enterococci.

E. DES Enhanced Ambient Rivers Program

Sampling Design
Grab samples are collected monthly between March and December on pre-determined days. Eight tributaries to the Great Bay and Little Harbor are sampled. For Great Bay, these stations are located at the upstream edge of the dams that separate the tidal and freshwater portions of the rivers (the “head of tide”). For Little Harbor, the two tributaries (Sagamore Creek, and Berry’s Brook) are not dammed so the samples are taken in the upstream reaches of the tributaries.

Sample Collection Methods for Field and Laboratory Analysis

The samples are collected following protocols from the DES Volunteer Rivers Assessment Program (below):

Bridge Sampling:

1. Lower the bucket from the upstream side of the bridge to the river and gather some water (doesn’t have to be full). Pull the bucket up, swish the water around in the bucket to rinse and dump the water off the bridge. Repeat this process two more times.
2. Return the bucket to the river on the upstream side of the bridge and fill as slowly as possible

(you may wish to weight the bucket).
3. Pull the bucket up and carry to a safe location (away from the road!) for analyses.
4. If you are collecting samples for analysis of additional parameters, pour water from your bucket into labeled bottles and preserve them properly (in a cooler on ice). Submit the samples to the laboratory within the sample holding time appropriate to each test (for more information, call NHDES Laboratory Services at 271-3445).

Offshore Sampling:

1. Carefully wade out into the river until the flowing portion of the water is comfortably within arm's reach. Do not enter the water above your waist, and do not enter the water if there is any concern for your safety. Be sure to have someone on shore that knows where you are.
2. Position yourself facing upstream and rinse the bucket in the river three times. **Do not collect the water that is running over your legs/boots.** With the bucket facing upstream and held along side your body, **slowly** dip the lip of the bucket into the flowing water and allow the bucket to fill.
3. Carefully return to shore with the full bucket and place it on the bank for immediate analysis.
4. If you are collecting samples for laboratory analysis, wade out into the river and collect water in a sterilized *E. coli* bottle (directions below, steps #5 and #6) and transfer the water to shore in a labeled and prepared bottle (some bottles contain acids that should not be released into the river). Preserve them properly (in a cooler on ice), and submit the samples to the laboratory within the sample holding time appropriate to each test (for more information, call NHDES Laboratory Services at 271-3445).
5. If the sample is to be analyzed for *E. coli,* wade out into the river, open a labeled, sterilized *E. coli* bottle and turn it upside-down before immersing it in the river. Be careful not to put your fingers or any other material on any surface on the inside of the bottle. Move the bottle from downstream to upstream as you fill the bottle. Dip the bottle into the river in a "U"-shaped scooping motion, turning the bottle right side-up at the bottom of the "U". **Do not collect the water that is running over your legs/boots.**
6. Replace the cap on the bottle and carry the sample to shore. Preserve the bacteria sample properly (in a cooler on ice) and submit the sample to a laboratory within the sample holding time appropriate to the test (usually 6 hours).

<u>Field Measurement Procedures</u>

Field measurements are made using the following instruments:
- DO/Temperature: YSI Model 95
- PH: Orion Model 210A
- Turbidity: Lamotte Model 2020
- Conductivity: YSI Model 30

Field instruments are calibrated each sampling day following protocols from the DES Volunteer Rivers Assessment Program.

<u>Analytical Laboratory Procedures</u>

The samples collected from the field are analyzed by the DES Laboratory for:
- *E. coli* (SOP 10.43d)
- Nitrate+Nitrite (SOP 10.15f)
- Total Kjeldahl Nitrogen (SOP 10.16c)
- Ammonia (10.14c)
- Total Phosphorous (SOP 10.20a)

- Chlorophyll-a (analysis by DES Limnology Center using Method SM10200H from Standard Methods, 20th Ed., 1998)
- Total Suspended Solids (SOP 10.23)
- Biological Oxygen Demand (5-day) (SOP 10.02)

Appendix B: Statistical Methods

A. Seasonal Kendall Test

The Seasonal Kendall Test (SKT) is a non-parametric test for consistent trends over time for variables that exhibit seasonal variability (Hirsch and Slack, 1984). The SKT is a generalization of the Mann-Kendall Test (Gilbert, 1987), so it can be performed on data in any distribution, accommodate missing values, and handle censored data. To account for the effects of seasonality, the trends for each season are estimated independently. The seasonal trends are then combined to determine an overall trend over the period of record. The SKT is popular with the USGS and has been recommended by the EPA as an effective statistical method for assessing trends in water quality variables that exhibit seasonality (Griffith, 2001; Loftis, 1989).

The SKT will be run using FORTRAN code developed by the USGS. The output of the SKT code reports the Kendall tau, the Seasonal Kendall statistic (s), an estimated linear trend equation, and the probability (p) of exceeding the absolute value of s (two-tailed test). If p is less than 0.10 (two-tailed test), the null hypothesis of no significant trend will be rejected in favor of the alternative hypothesis that a significant trend exists.

B. Mann-Kendall Test

The Mann-Kendall Test (MKT) is a non-parametric test for a consistent trend in time ordered data. This test can be performed on data in any distribution, accommodate missing values in the dataset, and handle censored values (e.g., <MDL) (Gilbert, 1987). Seasonal or other cyclic variation is not taken into consideration by the MKT. Therefore, this test will not be used with environmental datasets that exhibit significant cyclic variation. However, it will be used to assess long-term trends in yearly measurements of parameters such as bacteria concentrations at beaches during the summer months.

Calculations of the MKT will be performed using FORTRAN code for the Seasonal Kendall Test developed by the USGS. When this code is run using one datapoint per year, the computations are equivalent to the MKT. Significant trends will be those with $p<0.10$ as determined by a two-tailed test.

C. Convention for Reporting Trends

Trends will be evaluated at and reported for individual stations. Data from multiple stations will not be combined to estimate an overall trend for the estuary. To illustrate geographic variation (or homogeneity) within the estuary, the results of the trend analyses at individual stations will be plotted on a map of the coastal zone.

For cases where a significant trend exists, the trend will be reported in terms of percent increase (decrease) from a reference year (e.g., 2000). This rate will be calculated by dividing the slope of the trend by the central tendency value from the reference year and then multiplying the fraction by 100.

The value of Kendall's tau will also be reported for each significant trend. Kendall's tau ranges between –1 and 1 and represents the strength of the correlations of the variable with time. The greater the absolute value of tau, the stronger the correlation.

D. References

Gilbert, R.O. (1987) Statistical Methods for Environmental Pollution Monitoring, Van Nostrand Reinhold, New York, 313 pp.

Griffith, LM. Et al (2001) Data analysis considerations in producing 'comparable' information for water quality management purposes. A report to the National Water Quality Monitoring Council. February 2001.

Hirsch R.M., and Slack, J.R. (1984) A non-parametric trend test for seasonal data with serial dependence, *Water Resources Research*, **20**(6): 727-732.

Loftis, J.C. (1989) An evaluation of trend detection techniques for use in water quality monitoring programs, EPA-600-3-89-037. USEPA, Office of Research and Development, Environmental Research Laboratory, Corvallis, OR.

Appendix C: Monitoring Program Costs

NHEP Costs for Water Quality Monitoring

Organization	Program	Indicators Suppported	2001	2002	Out-Years
NHDES	Shellfish Program	Shellfishing acre days	$0	$0	TBD
NHF&G / GBNERR	Ambient Monitoring Program	Dry weather bacteria trends; Trends in estuarine nutrients/particulates	$0	$0	TBD
NHCP / UNH-JEL	Ambient Monitoring Program	Dry weather bacteria trends; Trends in estuarine nutrients and particulates	$0	$0	TBD
NHDES	Beach Program	Tidal beach postings; Freshwater beach postings; Bacteria trends at tidal beaches	$0	$0	TBD
NHDES	Tidal Ambient Monitoring Program	Dry weather bacteria trends; Violations of Enterococci standard; Trends in estuarine nutrients/particulates	$4,325	$0	TBD
NHDES	Enhanced Ambient Rivers Program	Dry weather bacteria trends; Wet weather bacteria trends; Nitrogen loading; BOD loading	$8,000	$9,000	TBD
UNH-JEL	Microbial Source Tracking (MST) Monitoring	Microbial source tracking	$22,500	$22,500	TBD
Individual WWTF	NPDES Discharge Monitoring Reports	Bacteria loading; Nitrogen loading; BOD loading	$0	$0	TBD
TBD	Wet Weather Monitoring	Wet weather bacteria trends	NA	NA	TBD
NHF&G / GBNERR	System-Wide Monitoring Program (datasondes)	Dissolved oxygen standard violations	$10,000	$10,000	TBD
NHDES	NH Gulfwatch Program	Toxic contaminants in shellfish (versus FDA stds, risk assessment, trends)	$3,280	$3,280	TBD
NHDES	Oyster/Clam Tissue Monitoring (a component of NH Gulfwatch)	Toxic contaminants in shellfish (versus FDA stds, risk assessment, trends)	$5,000	$5,000	TBD
NHDES	National Coastal Assessment	Toxic contaminants in finfish/lobster (trends); Toxic contaminants in sediment (status, trends); Dry weather bacteria trends; Violations of Enterococci standard; Trends in estuarine nutrients and particulates	$0	$0	TBD
	Total		$53,105	$49,780	TBD

NHEP Costs for Shellfish Resource Monitoring

Organization	Program	Indicators Suppported	2001	2002	Out-Years
NHF&G	Oyster Bed Mapping	Area of oyster beds; Standing stock of oysters	$14,000	$0	TBD
NHF&G	Oyster Resource Program	Density of oysters; Standing stock of oysters; Oyster spatfall	$0	$0	TBD
Seabrook Station	Clam Monitoring Progam	Density of clams; Area of clam flats; Clam standing stock; Clam spatfall; Clam harvest; Clam disease; Shellfish predators	$0	$0	TBD
NHF&G	Juvenile Finfish Seine Survey	Shellfish predators	$0	$0	TBD
NHF&G	Oyster Harvest Survey	Oyster harvest	$0	$0	TBD
NHF&G	Oyster Disease Monitoring Program	Oyster disease	$2,000	$2,000	TBD
	Total		$16,000	$2,000	TBD

NHEP Costs for Land Use Assessments

Organization	Program	Indicators Suppported	2001	2002	Out-Years
UNH-CSRC	Impervious Surface Mapping Contract	Impervious surfaces in coastal watersheds; Rate of sprawl-high impact development	$0	$21,485	TBD
	Total		$0	$21,485	TBD

NHEP Costs for Monitoring Plan Coordination and Implementation

Organization	Program	Outputs	2001	2002	Out-Years
NHDES	NHEP Coastal Scientist	Data Coordination and Management; Coordination of Technical Advisory Committee; Annual Indicators Report; Monitoring Plan Review, Evaluation, and Update	$36,200	$75,000	$75-80,000
	Total		$36,200	$75,000	$75-80,000

Summary of All NHEP Monitoring Costs

Program	2001	2002	Out-Years
Water Quality Monitoring	$53,105	$49,780	TBD
Shellfish Resource Monitoring	$16,000	$2,000	TBD
Land Use Assessments	$0	$21,485	TBD
Monitoring Plan Coordination and Implementation	$36,200	$75,000	$75-80,000
Grand Total	**$105,305**	**$148,265**	**TBD**

Appendix D: Quality Assurance Project Plans for N.H. Estuaries Project Monitoring Activities

Contact: Phil Trowbridge, DES/NHEP, ptrowbridge@des.state.nh.us

Revised: 4/12/02

Table 1: Year 5 Activities with a monitoring component

Code	Activity	Responsible Party	QAPP Status	Expected availability	Comments
A-4-a	Shoreline Surveys	DES Shellfish Program	In process	6/30/02	The activity will be covered by the "Sanitary Surveys and Special Studies" QAPP for the DES Shellfish Program. A draft of this QAPP is being reviewed within DES.
A-4-b	Great Bay Coast Watch Assistance with Shoreline Surveys	Great Bay Coast Watch	In process	6/30/02	The activity will be covered by the "Sanitary Surveys and Special Studies" QAPP for the DES Shellfish Program. A draft of this QAPP is being reviewed within DES.
A-6	Stormwater technologies - Performance evaluation	JEL	Not started	6/30/02	This project has not yet begun. JEL will assign a lead person in the coming months to prepare the QAPP. The study itself will follow EPA's Stormwater Source Area Treatment Technology Verification Protocol.
B-1-b	Hampton/Seabrook Special Projects (rainfall, autumn dry weather)	DES Shellfish Program	In process	6/30/02	The activity will be covered by the "Sanitary Surveys and Special Studies" QAPP for the DES Shellfish Program. A draft of this QAPP is being reviewed within DES.
B-1-c	Miscellaneous studies for shellfish sanitary surveys	DES Shellfish Program	In process	6/30/02	The activity will be covered by the "Sanitary Surveys and Special Studies" QAPP for the DES Shellfish Program. A draft of this QAPP is being reviewed within DES.
B-1-d	Investigate natural purging of microbial contaminants in softshell clams from H/S Harbor	JEL	Not necessary	---	This is a small project that is already 75% complete.

Code	Activity	Responsible Party	QAPP Status	Expected availability	Comments
B-2-a B-2-b B-2-c	Shellfish Program ambient monitoring and emergency sampling	DES Shellfish Program	Draft sent to EPA	6/30/02 for final version	The draft "Water Quality Monitoring" QAPP for the DES Shellfish Program was submitted to EPA Region I on 3/1/02.
B-3-a B-3-b	Paralytic Shellfish Poison (PSP) monitoring	DES Shellfish Program	Draft sent to EPA	6/30/02 for final version	The draft "PSP Monitoring" QAPP for the DES Shellfish Program was submitted to EPA Region I on 4/5/02.
B-3-c	Gulfwatch Program	JEL	Done	---	The Gulfwatch Program completed an QAPP in 1998. NHEP will obtain a copy of the original QAPP from the principal investigator. If there have been changes in protocols since the QAPP was written, a letter will be submitted to EPA describing these changes.
B-3-d	Determination of softshell clam and oyster exposure to toxic contaminants	JEL	Done	---	This project will be conducted under the Gulfwatch Program QAPP.
B-4-a	Oyster disease testing	NHF&G	Done	---	Final QAPP submitted to EPA Region I on 3/22/02. All the EPA comments on the draft were addressed.
B-4-b	Clam bed and oyster reef dimensions	NHF&G	Not started	6/30/02	
E-2	Stream assessment and water quality monitoring	Cocheco River Watch	Done	---	QAPP approved by EPA on 9/30/99.
M-1	Ribotyping of E.coli strains to track sources of fecal contamination	JEL	In process	6/30/02	
M-2	RECOMS water quality monitoring program	GBNERR	Not necessary	---	See note at bottom of this table*.

Code	Activity	Responsible Party	QAPP Status	Expected availability	Comments
M-3	Ambient, microbial indicators, and shellfish monitoring restructuring	DES	Not started	12/31/02	This QAPP will be for NHEP-funded ambient monitoring programs starting in 2003. Freshwater sampling programs will be covered by the DES Ambient Monitoring Program QAPP, which will be updated by 6/30/02. A QAPP for tidal water quality monitoring will be prepared after the NHEP Monitoring Plan is revised in 2002 (see note at the bottom of this table**).

*The NHEP contributes funds to the "operation and maintenance" of a series of data loggers recording temperature, salinity, DO, and turbidity in the Great Bay (the RECOMS water quality monitoring program). The funding goes to the Jackson Estuarine Laboratory at UNH to partially support a technician who services the loggers. However, bulk of the project (including project management and all data collection and processing) is done by the Great Bay National Estuarine Research Reserve (GBNERR) with federal support and assistance from NOAA. The loggers and instruments are part of a network of NOAA stations in estuaries across the country. NOAA has standard protocols for data capture, a national data management office, and QA/QC protocols for the system. No QAPP is available for this program, but SOPs and QA methods are published online at: http://inlet.geol.sc.edu/cdmoweb/home.html. Great Bay specific metadata is available at: http://inlet.geol.sc.edu/cdmoweb/grb.html.

** The NHEP is providing funding for an interim two-year monitoring program of tidal waters in the estuary (2001-2002). NHEP is supporting the cost of additional analyses for nutrients and microbial indicators on samples collected by the DES Shellfish Program. Samples for nutrients are collected and analyzed monthly from March to December at 7 sites following SOPs used by the UNH Jackson Estuarine Laboratory. Samples for bacteria indicators are collected monthly May to September at 11 sites following SOPs used by DES. A QAPP has not been developed for this monitoring program because this is an interim monitoring program which will terminate in 2002 and be replaced by the NHEP's comprehensive water quality monitoring plan. However, the SOPs used for the program are on file at the DES Pease Field Office. A QAPP for the tidal water quality component of the NHEP Monitoring Plan will be completed by the end of 2002.

Table 2: Year 6 Activities with a monitoring component (excluding activities also on the Year 5 list)

Code	Activity	Responsible Party	QAPP Status	Expected availability	Comments
A-1	WWTF pollutant loading investigation	UNH	Not started	6/30/02	This project has not yet begun.
NA	Juvenile Clam Mortality Study	Univ. of Maine at Machias	In process	6/30/02	Field work for this project began in November 2001 and will be completed in July 2002. A draft QAPP has been submitted by the PI for NHEP review.
B-3	Shellfish restoration and enhancement projects	TBD	Not started	NA	This project has not yet been awarded to a contractor. A QAPP will be required under the MOA/contract.
C-1	Coastal watershed impervious surface calculation	UNH-CSRC	Not necessary	---	This project will be based on remote sensing data. No environmental measurements will be made for this project. The NHEP will provide oversight of the methods used by the contractor to ensure accuracy but a standard QAPP is not necessary.
C-4	Hampton/Seabrook Harbor Groundwater Characterization	UNH	Draft sent to EPA	6/30/02 for final version	A draft of this QAPP was sent to EPA on 4/4/02.
D-1	Upland and freshwater wetland restoration	TBD	Not started	NA	This project has not yet been awarded to a contractor. A QAPP will be required under the MOA/contract.

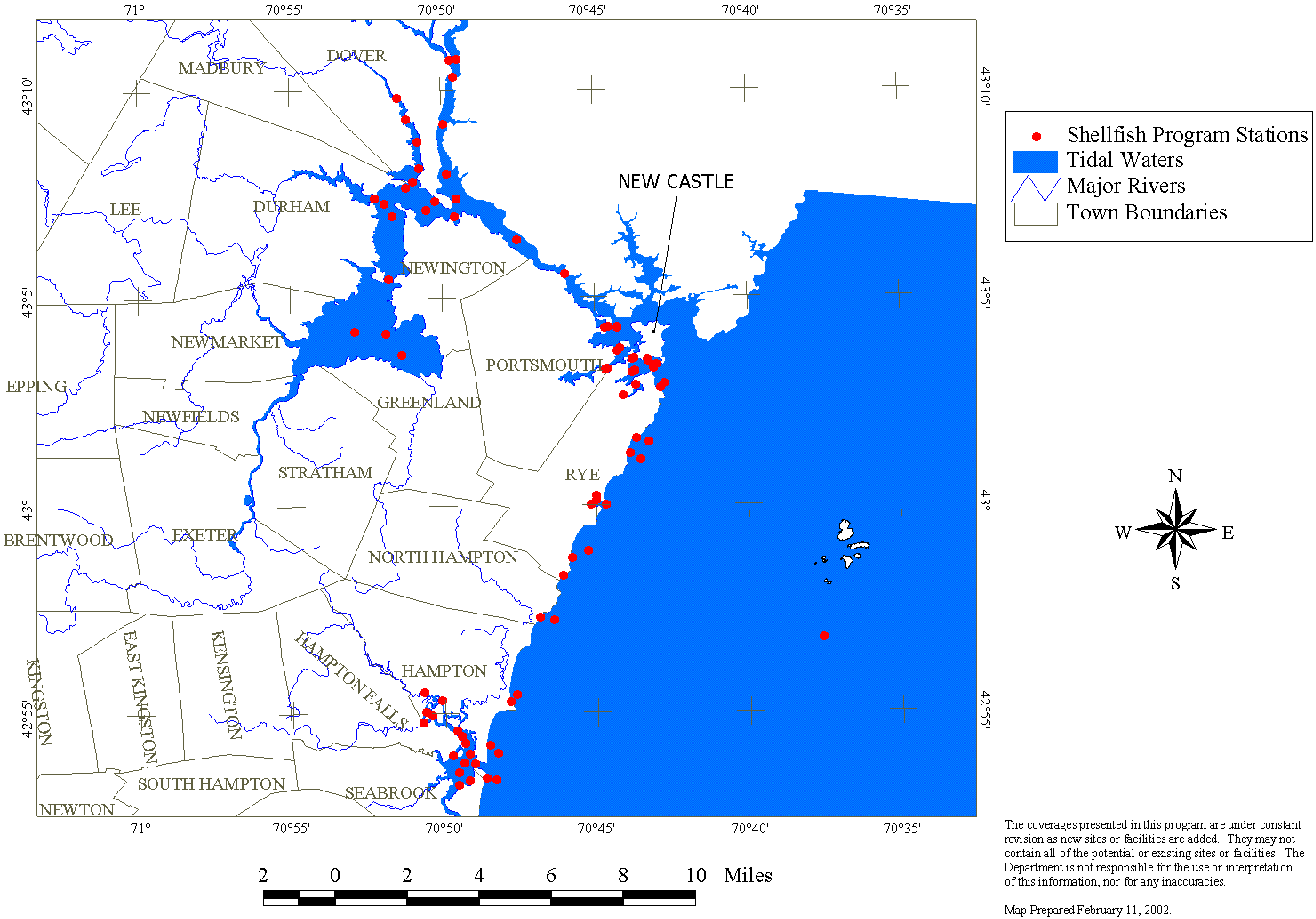
Table 3: Year 6 Supplemental Funds Activities with a monitoring component

Code	Activity	Responsible Party	QAPP Status	Expected availability	Comments
NA	Deploy a data sonde in the Salmon Falls River to test for hypoxia	JEL	Not necessary	---	This project will be conducted under the protocols of the RECOMS water quality monitoring program (see M-2 in Table 1).
NA	Mapping Eelgrass in the Great Bay Estuary	JEL	Not necessary	---	No new data will be collected for this project. Existing data will be compiled.
NA	Determination of Nitrogen in Effluent from Wastewater Treatment Facilities that Discharge into New Hampshire Coastal Waters	UNH	Not necessary	---	This project will be conducted under the QAPP for the WWTF pollutant loading investigation (see A-1 in Table 2).

Table 4: Year 5 Undesignated Funds Activities with a monitoring component

Code	Activity	Responsible Party	QAPP Status	Expected availability	Comments
NA	TMDL Study for Hampton Harbor	DES	Not started	6/30/02	

Figure 2-1: DES Shellfish Program stations for classifying growing areas.



The coverages presented in this program are under constant revision as new sites or facilities are added. They may not contain all of the potential or existing sites or facilities. The Department is not responsible for the use or interpretation of this information, nor for any inaccuracies.

Map Prepared February 11, 2002.

Figure 2-2: Stations for assessing trends in dry weather bacteria concentrations.

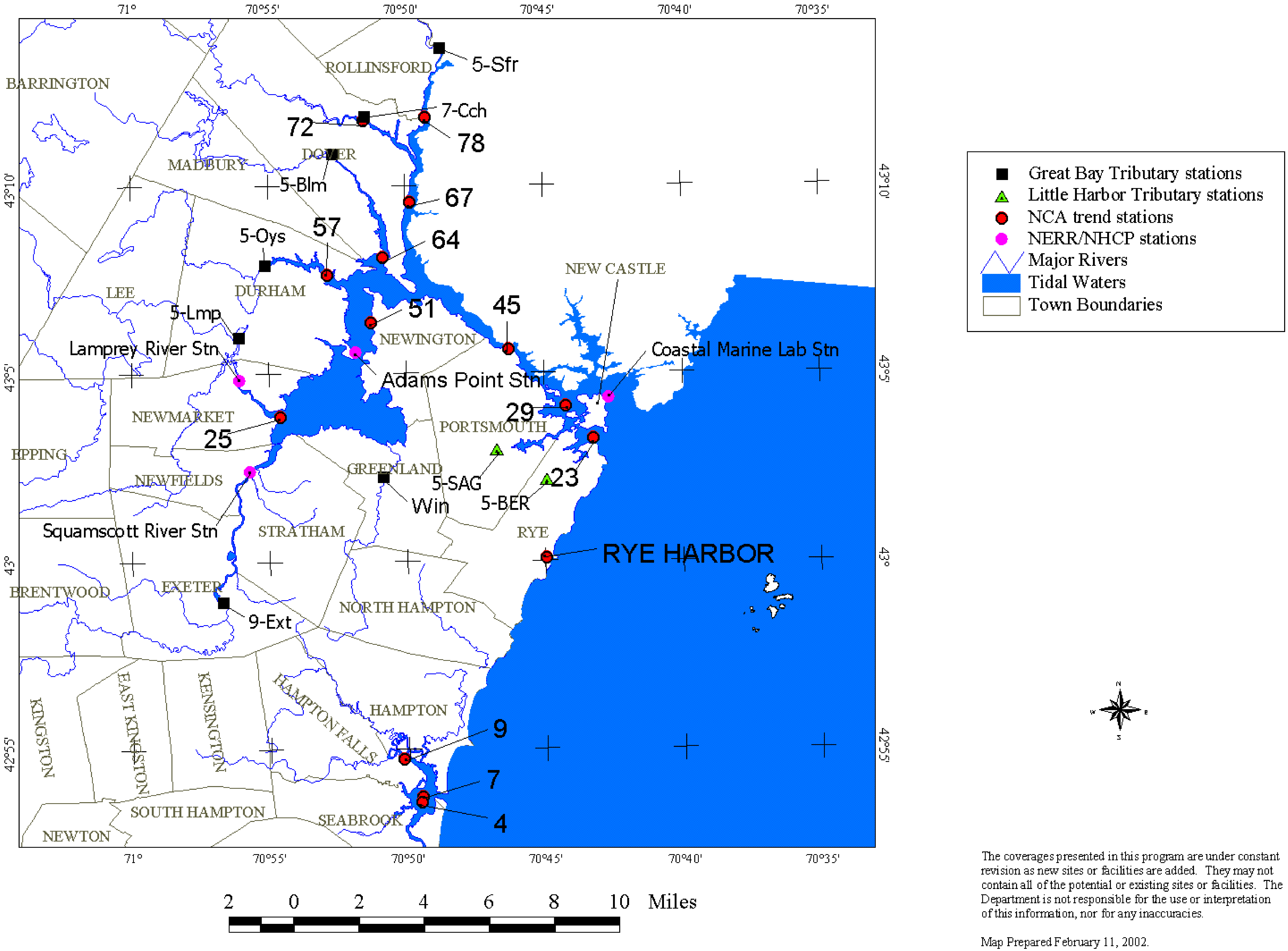
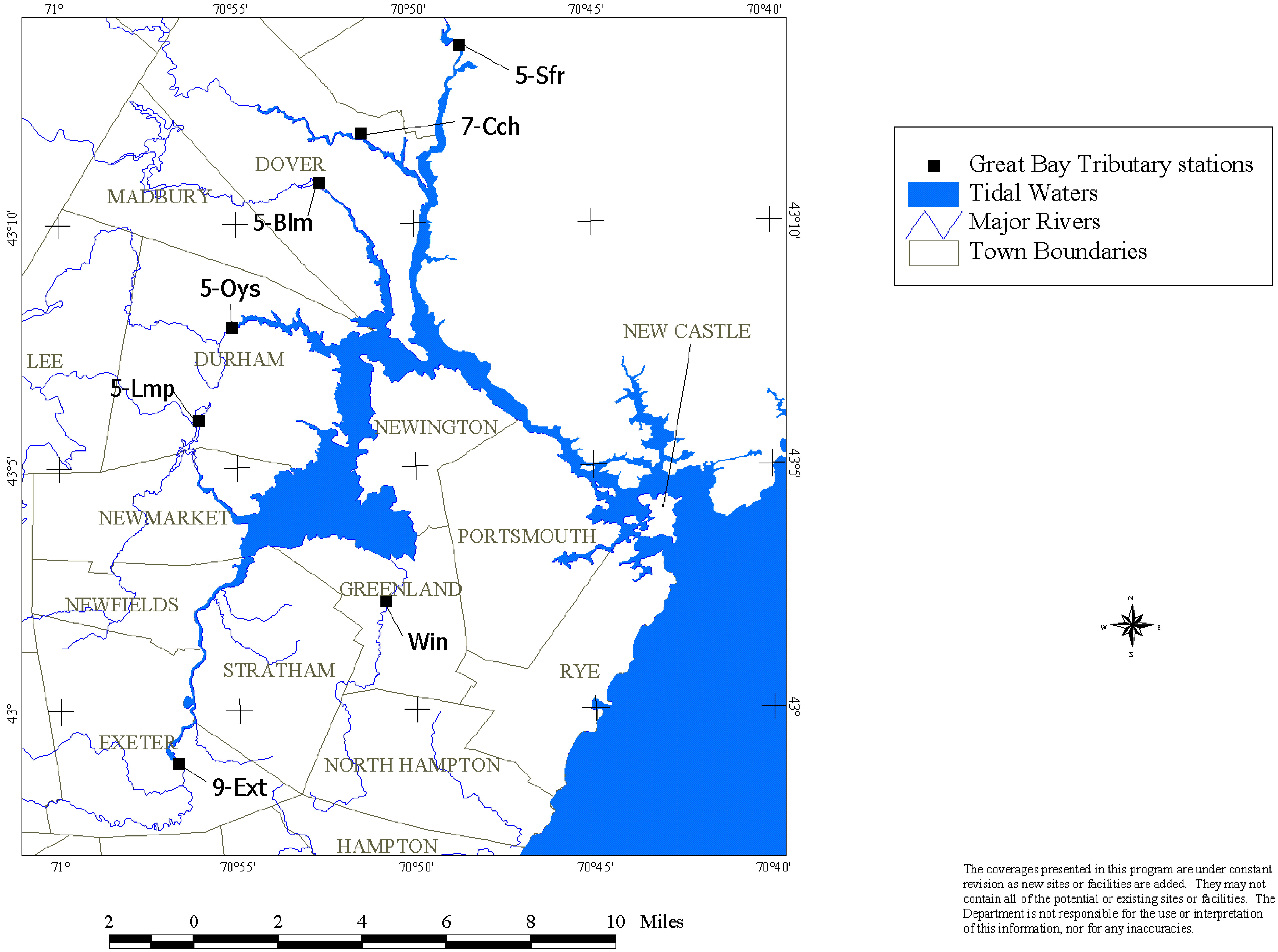


Figure 2-3: Stations for assessing trends in wet weather bacteria concentrations.



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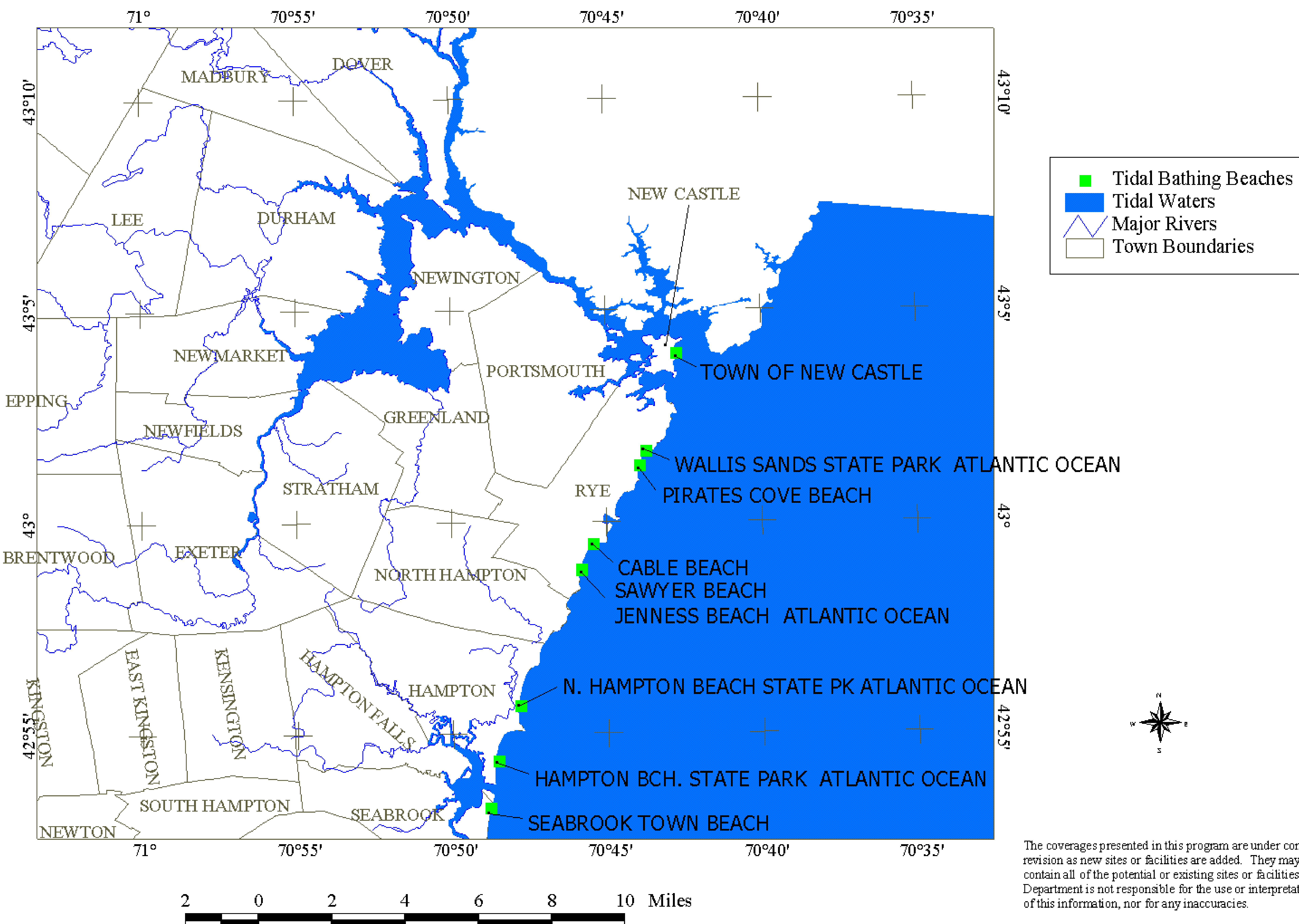
Map Prepared February 11, 2002.

Figure 2-4: Designated tidal bathing beaches in New Hampshire



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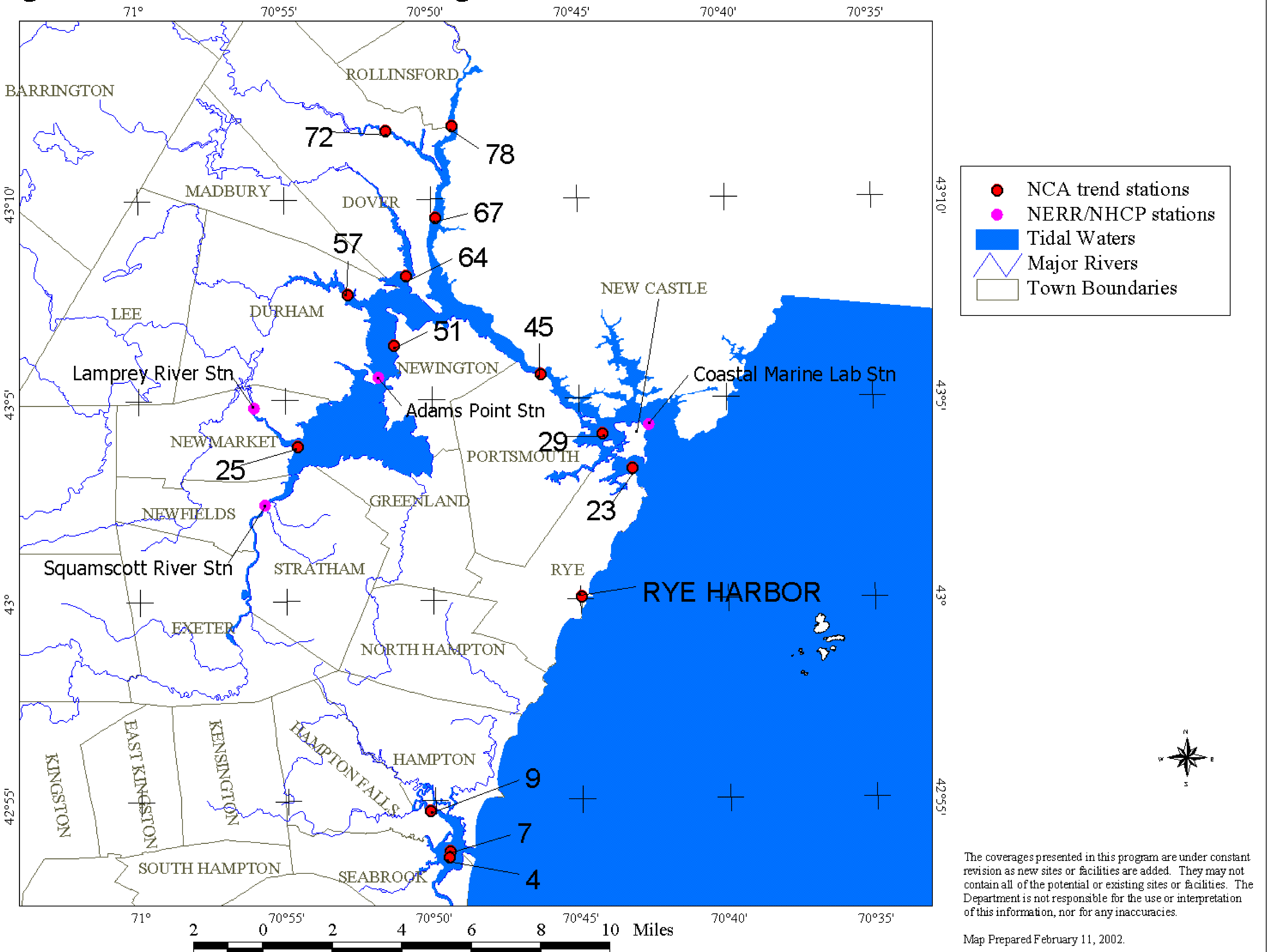
Map Prepared February 11, 2002.

Figure 2-5: Stations for assessing Enterococci standards in ambient tidal waters.



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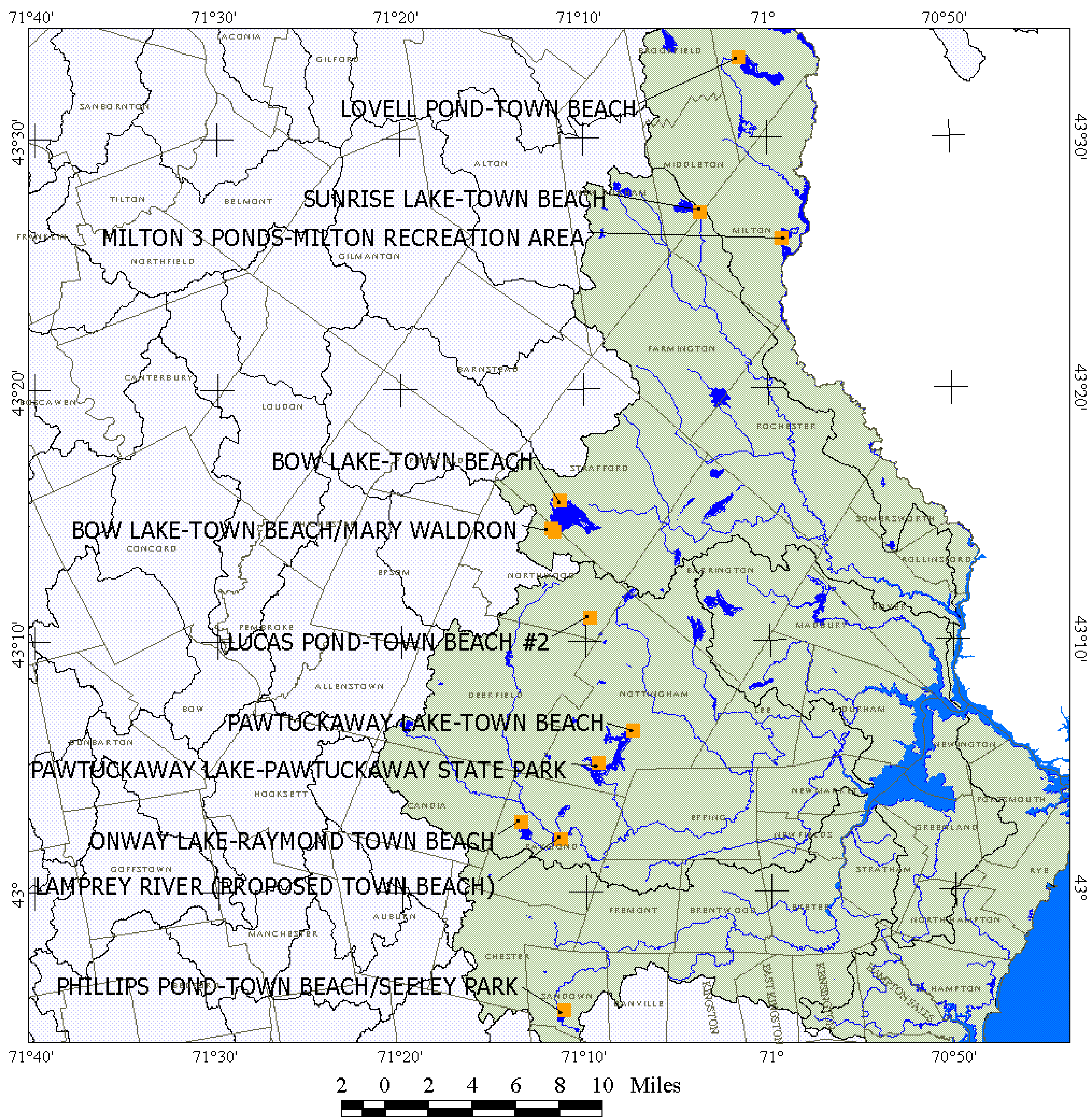
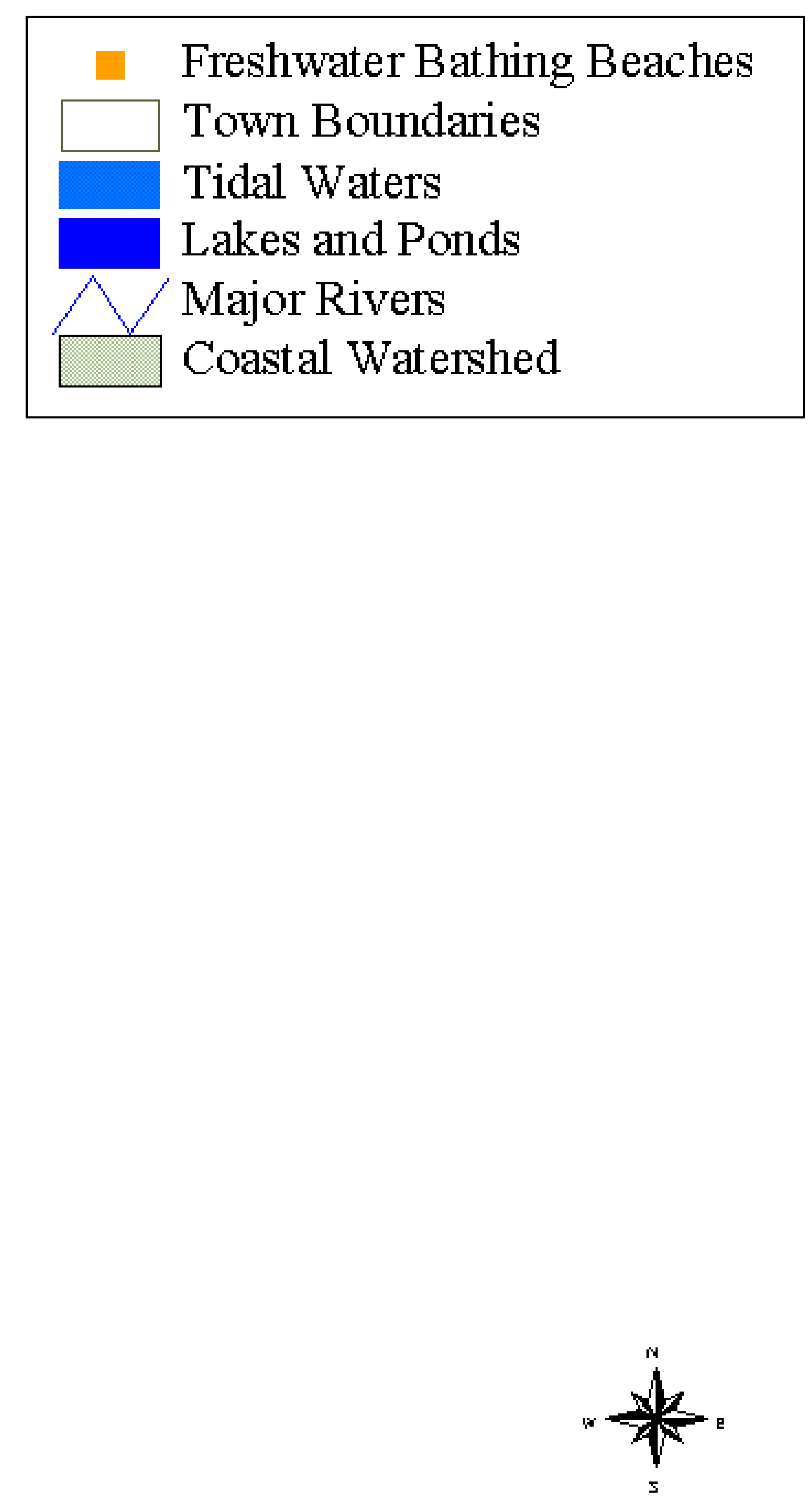
Map Prepared February 11, 2002.

Figure 2-6: Designated freshwater bathing beaches in NH's coastal watershed





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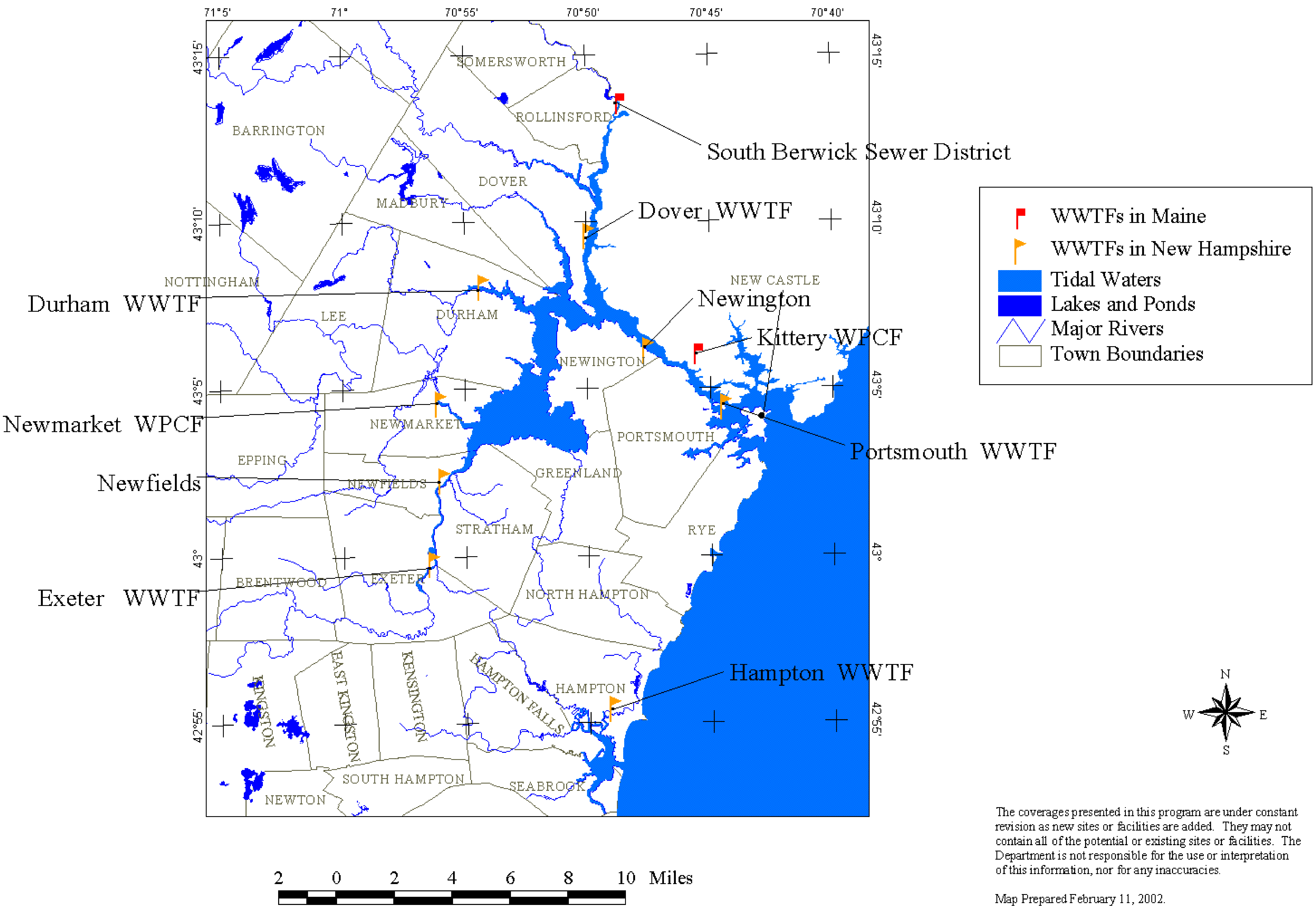
Map Prepared February 11, 2002.

Figure 2-7: Wastewater treatment plants that discharge to New Hampshire tidal waters.



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Map Prepared February 11, 2002.

Figure 2-8: Locations of MST studies in 2001-2002.

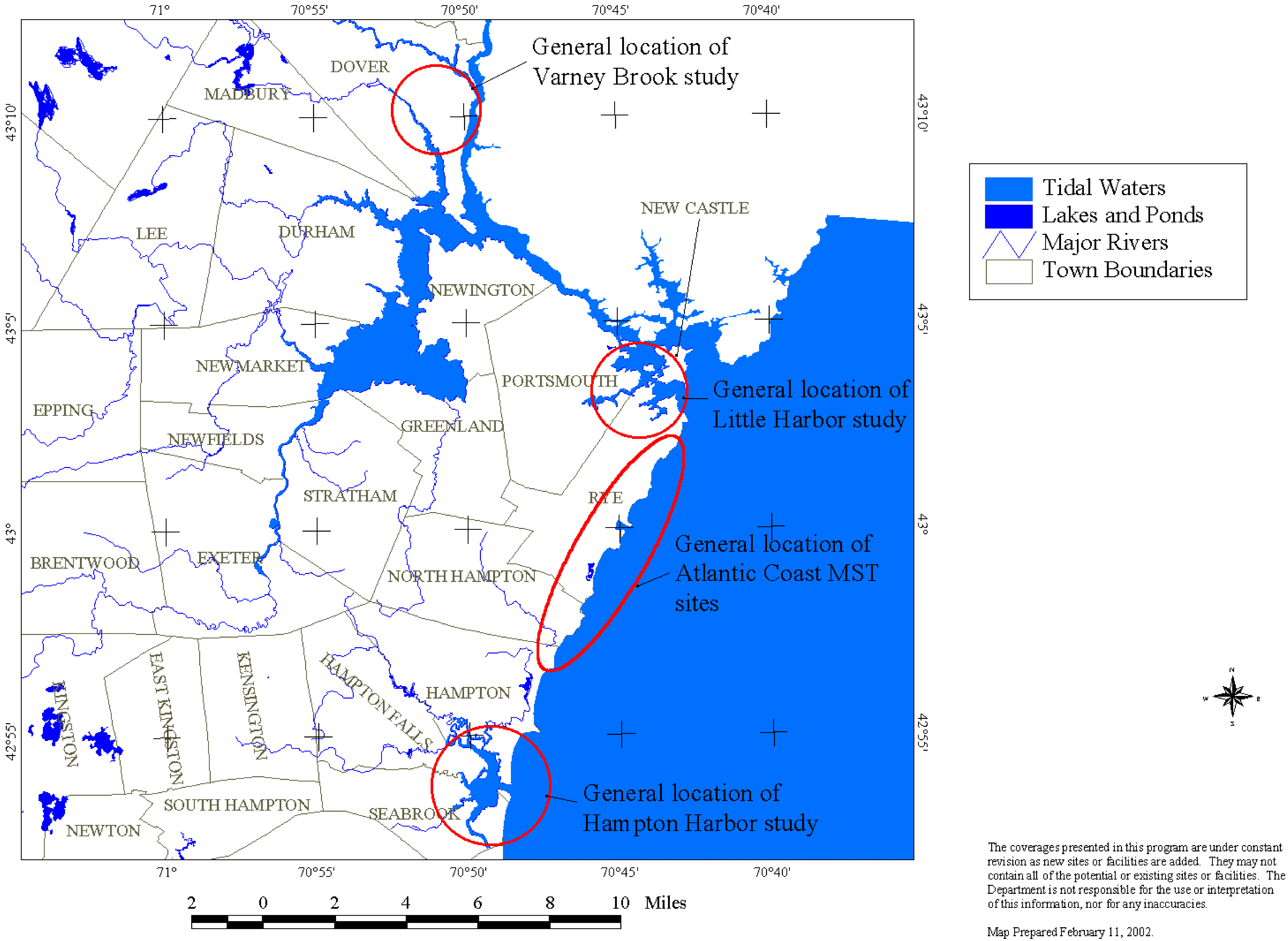
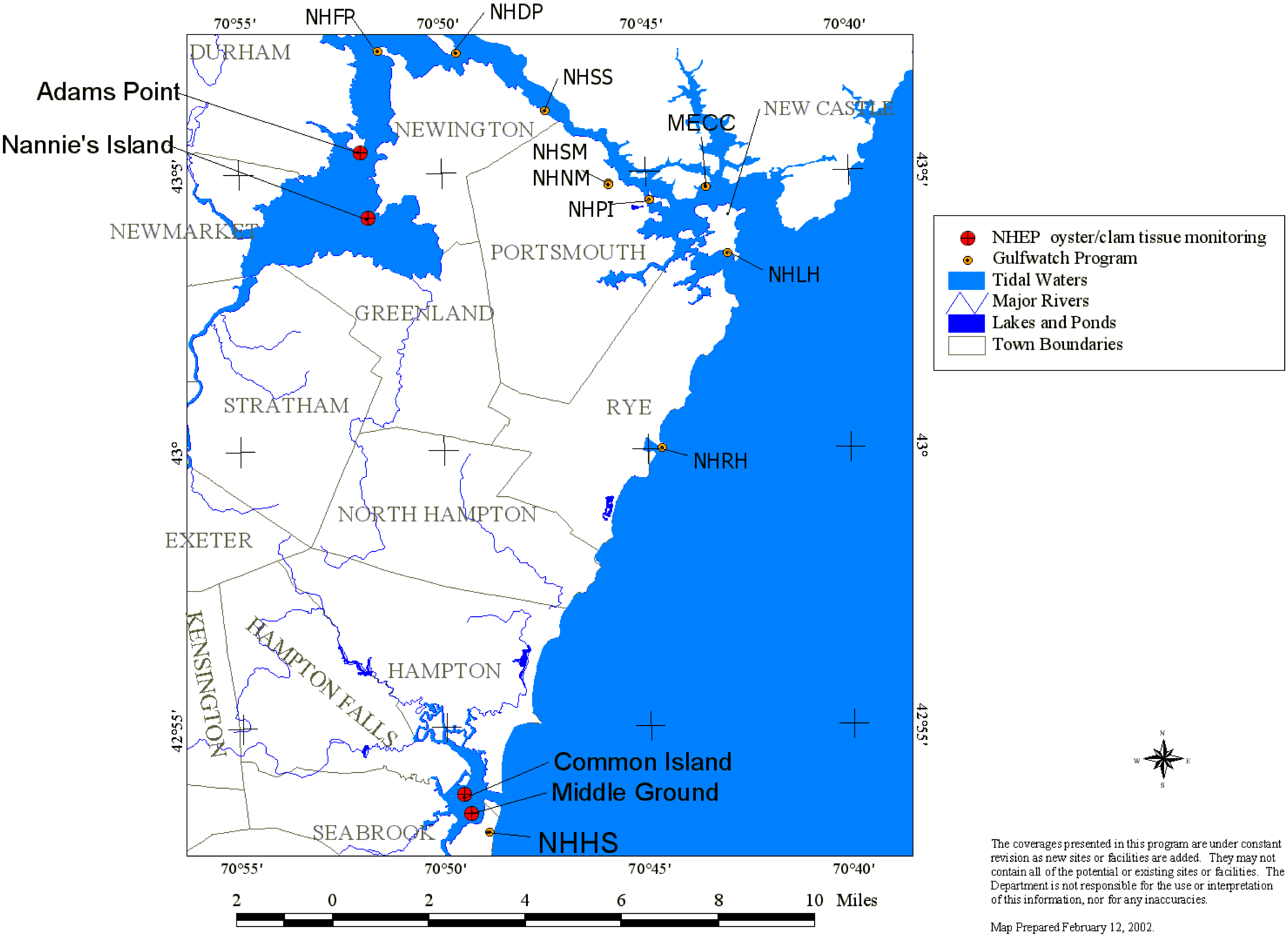


Figure 3-1: Stations for toxic contaminants in shellfish tissue monitoring.



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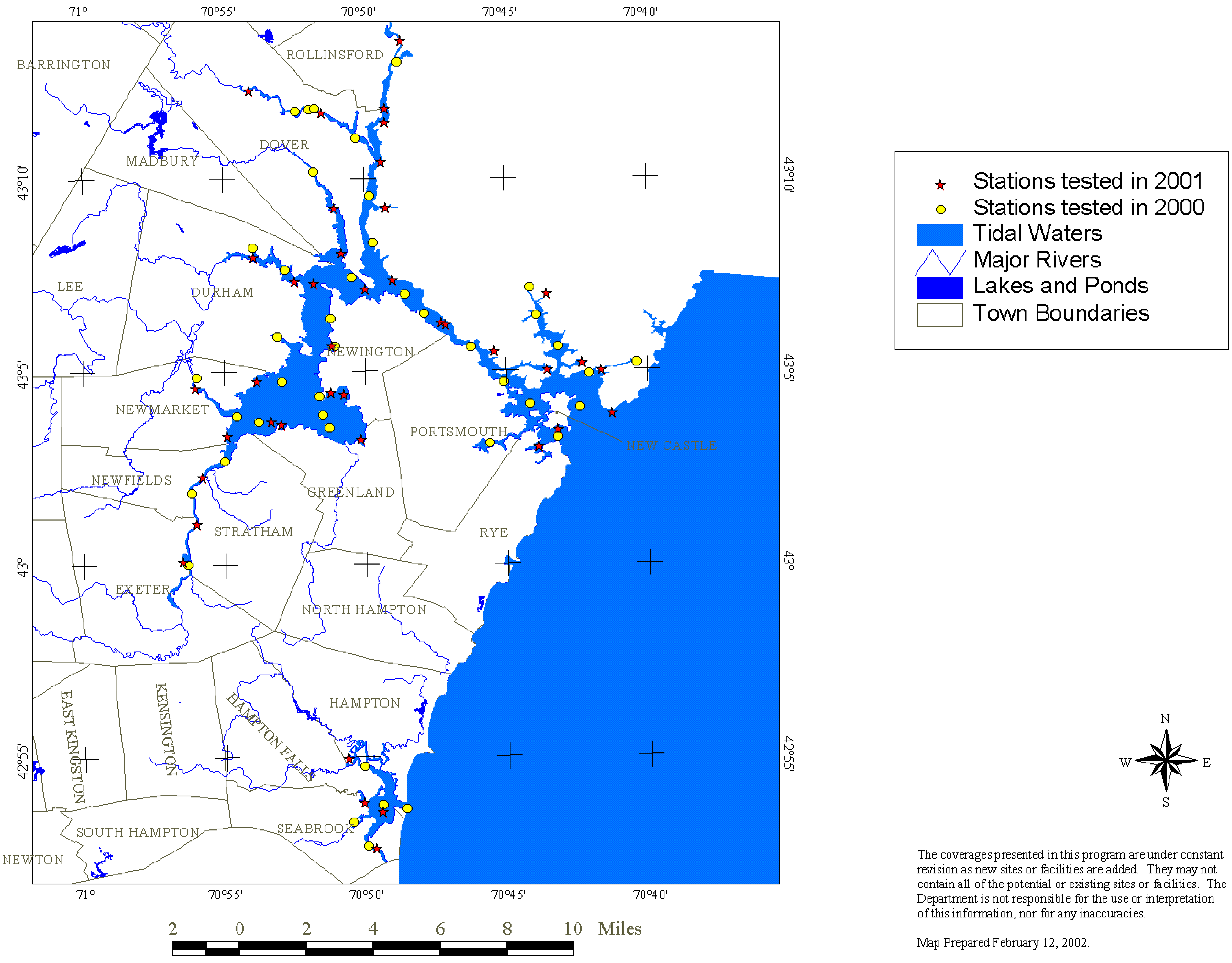
Map Prepared February 12, 2002.

Figure 3-2: Stations for National Coastal Assessment monitoring.



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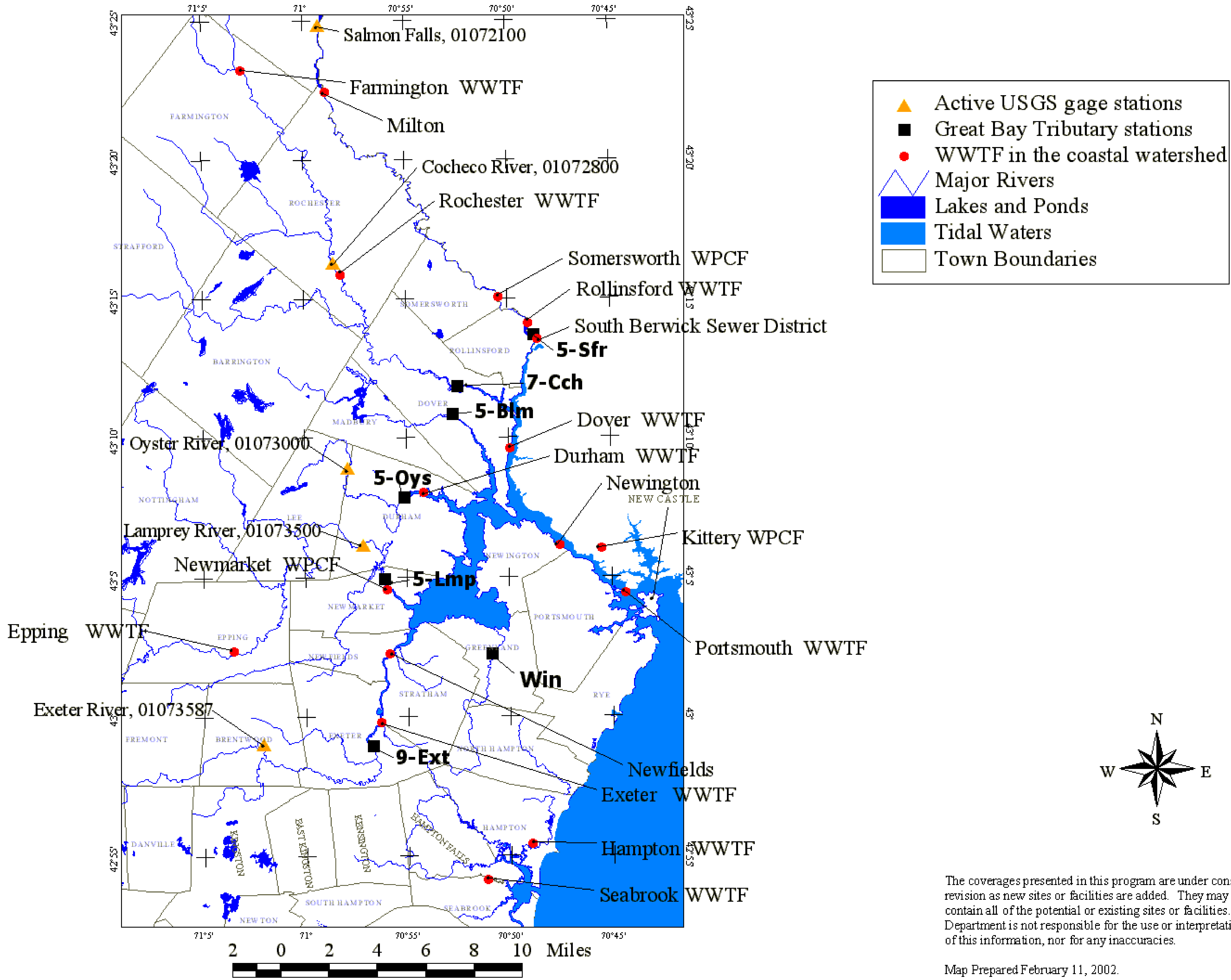
Map Prepared February 12, 2002.

Figure 4-1: Great Bay tributary monitoring stations, WWTF/WPCF, and USGS stream gage locations in the coastal watershed.



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Map Prepared February 11, 2002.

Figure 4-2: Estuarine stations for nutrients and eutrophication parameters

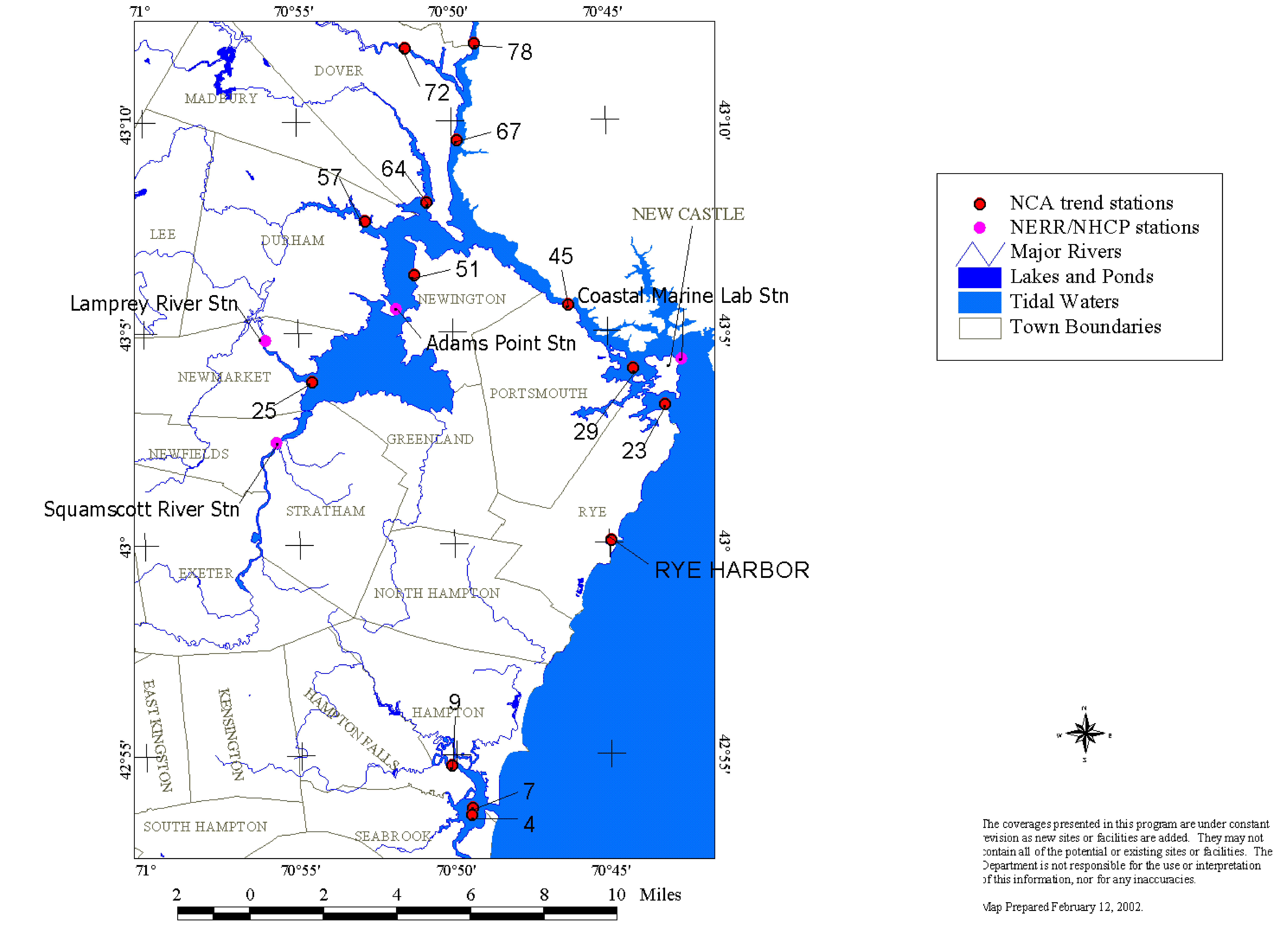
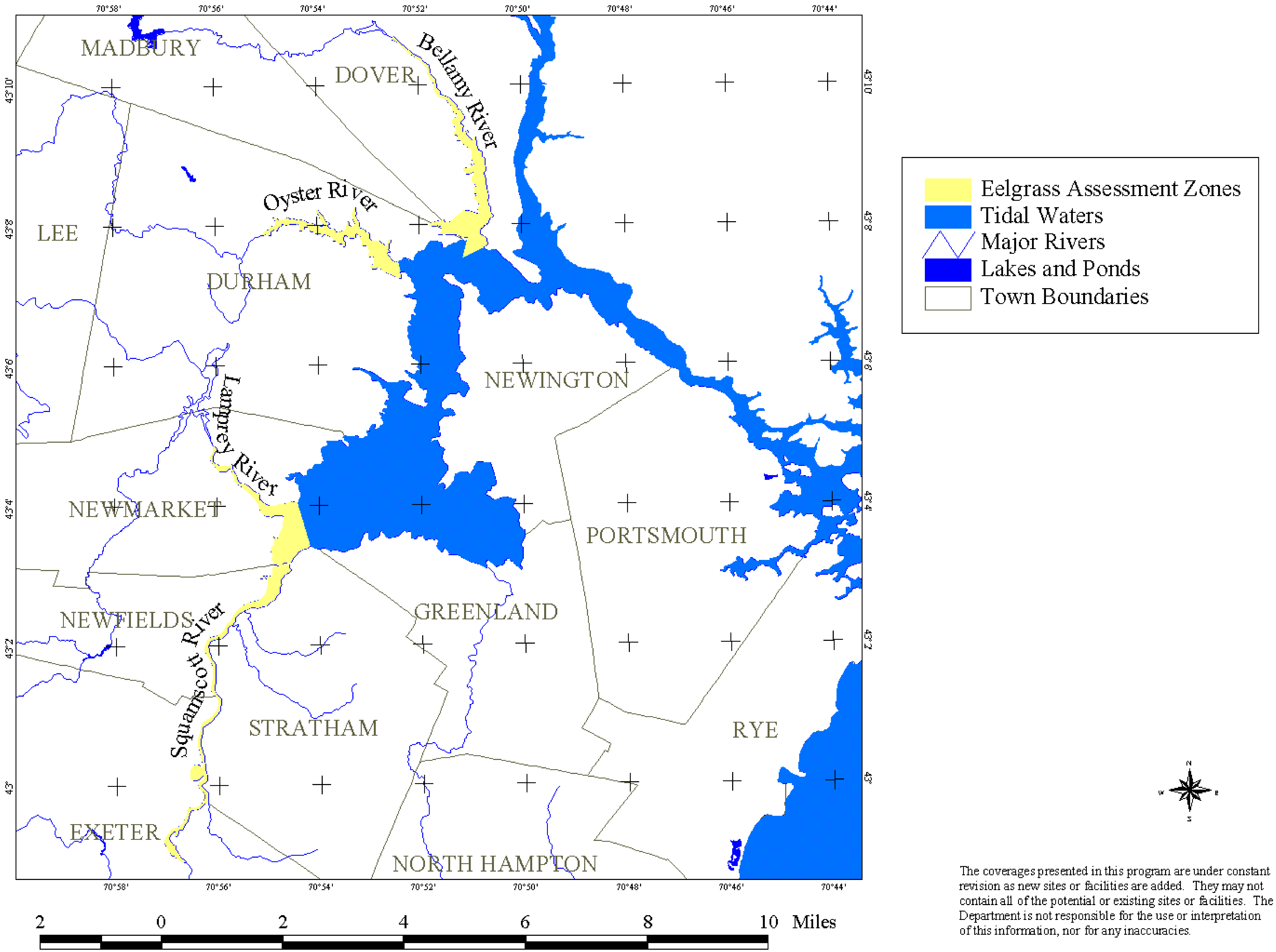


Figure 4-3: Zones for assessing eelgrass distribution in Great Bay tributaries.



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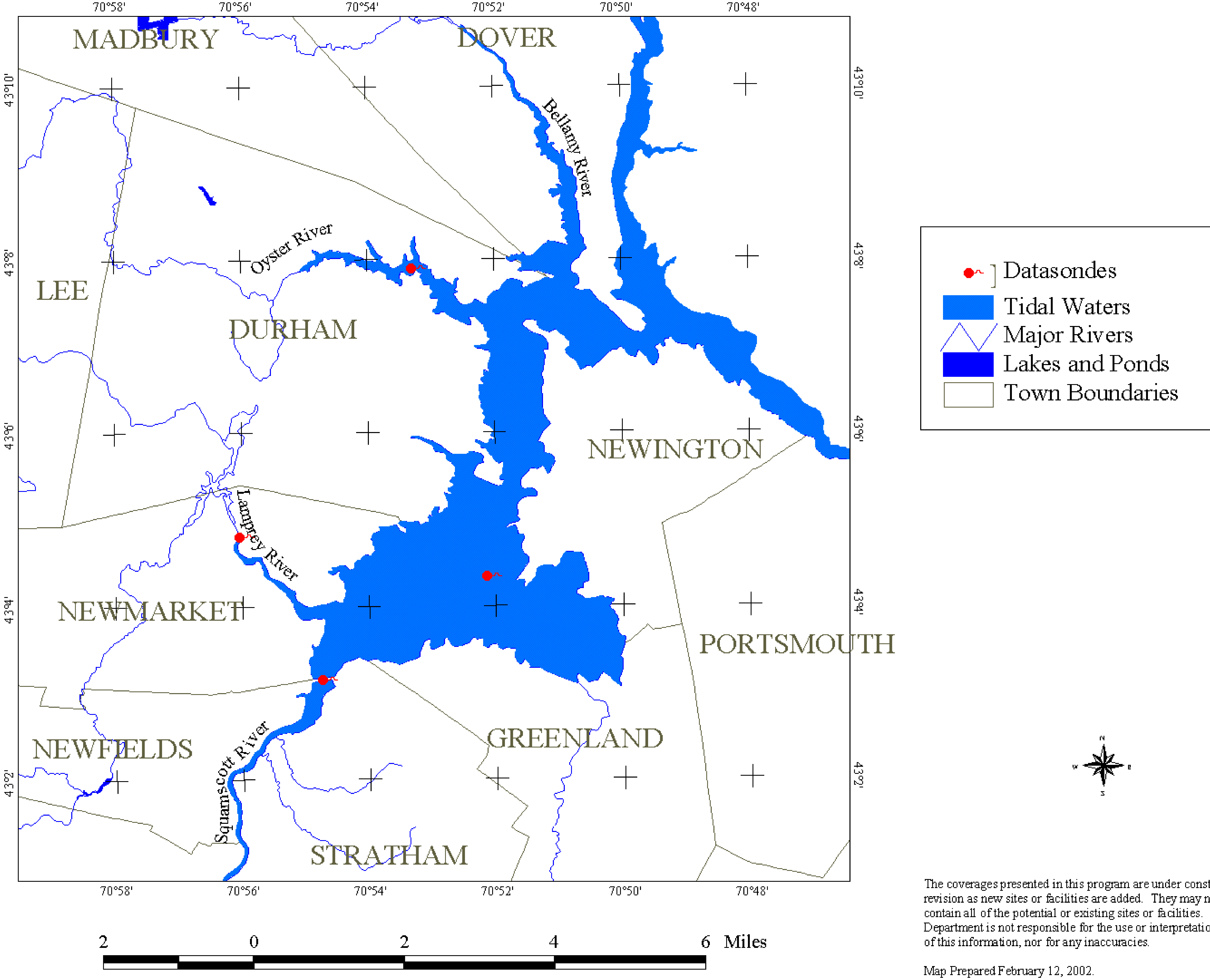
Map Prepared February 12, 2002.

Figure 4-4: Location of datasondes in the Great Bay Estuary.



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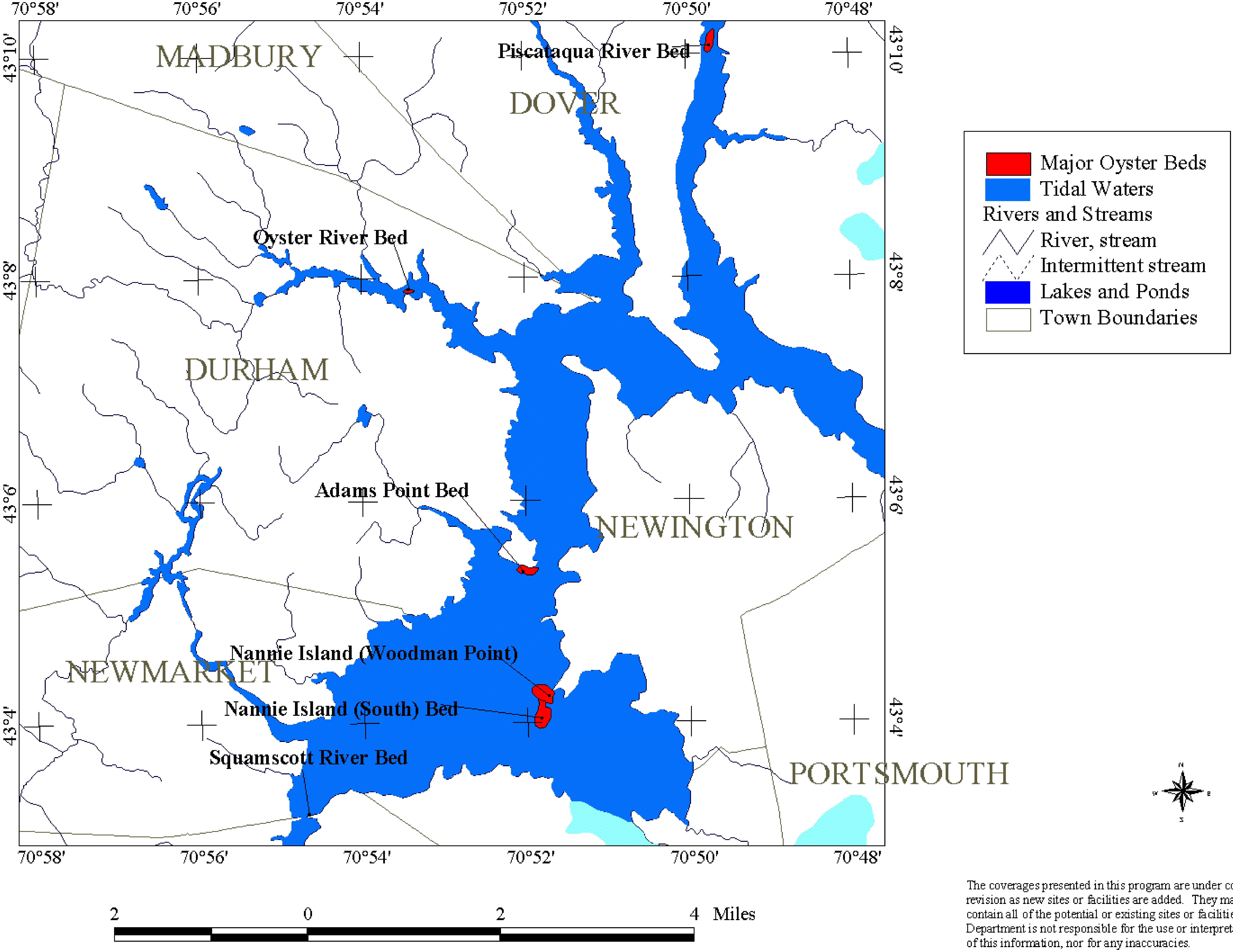
Map Prepared February 12, 2002.

Figure 5-1: Major Oyster Beds in Great Bay.



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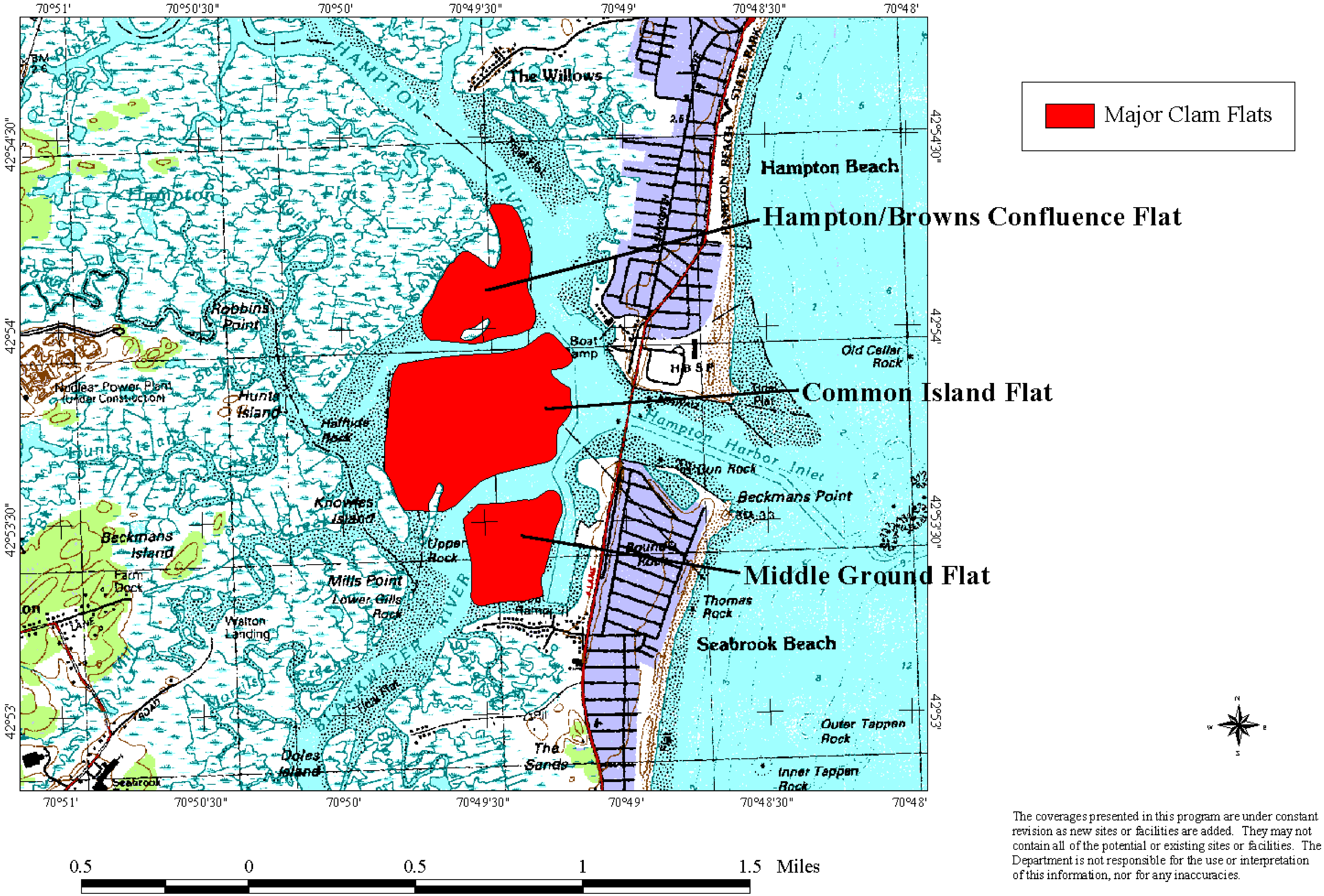
Map Prepared February 12, 2002.

Figure 5-2: Major Clam Flats in Hampton Harbor.



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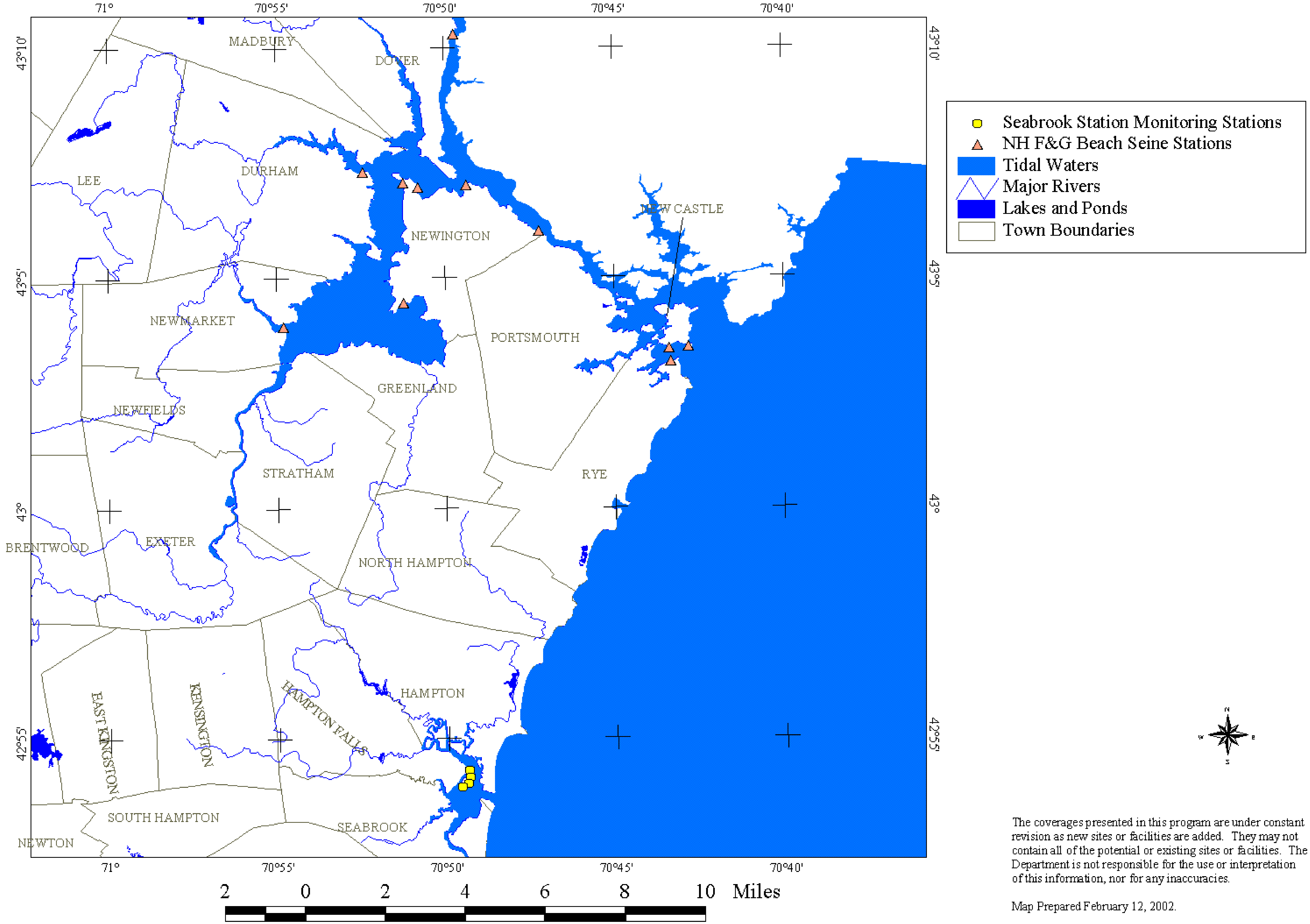
Map Prepared February 12, 2002.

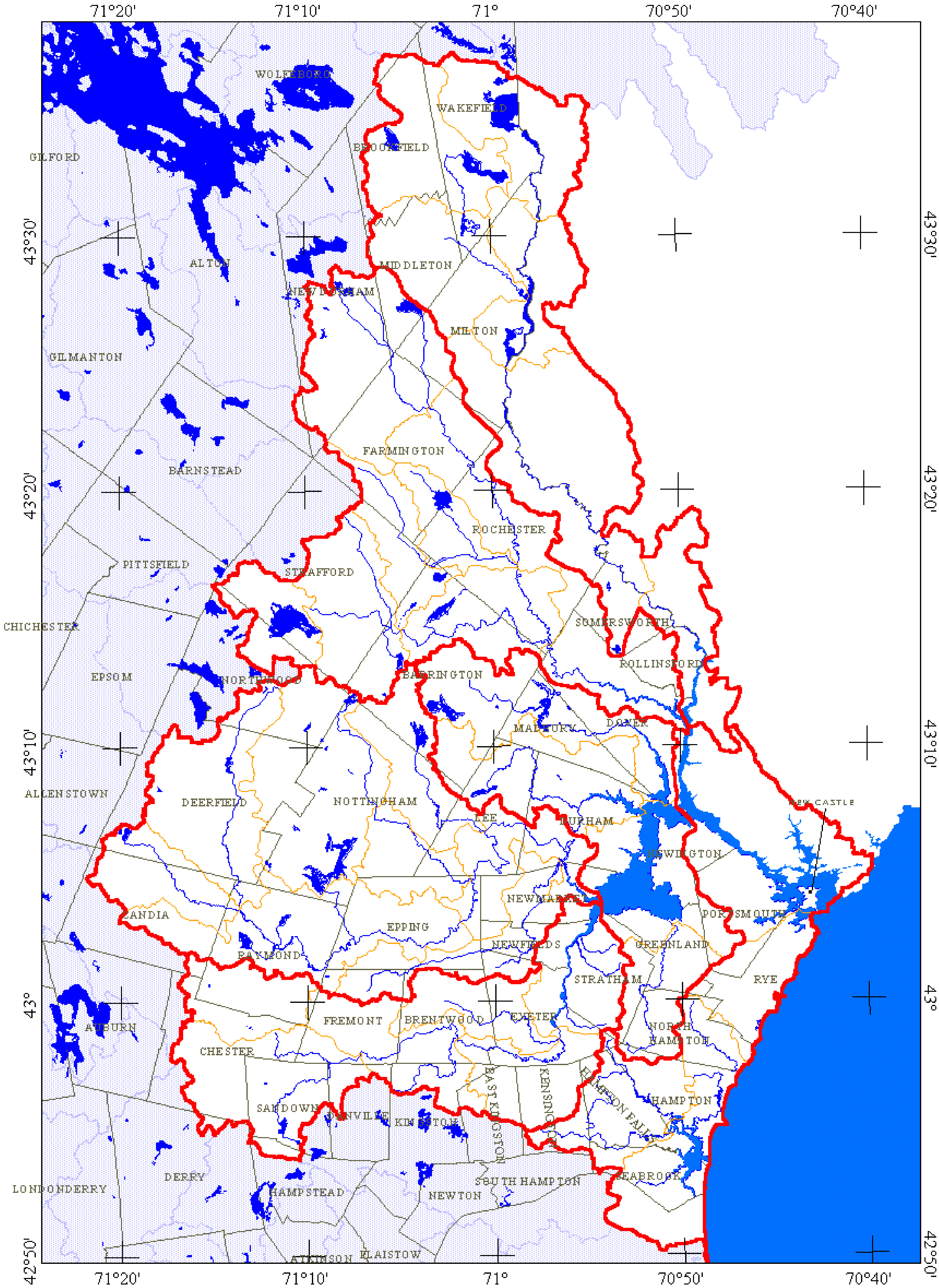
Figure 5-3: Locations for Shellfish Predator Sampling.

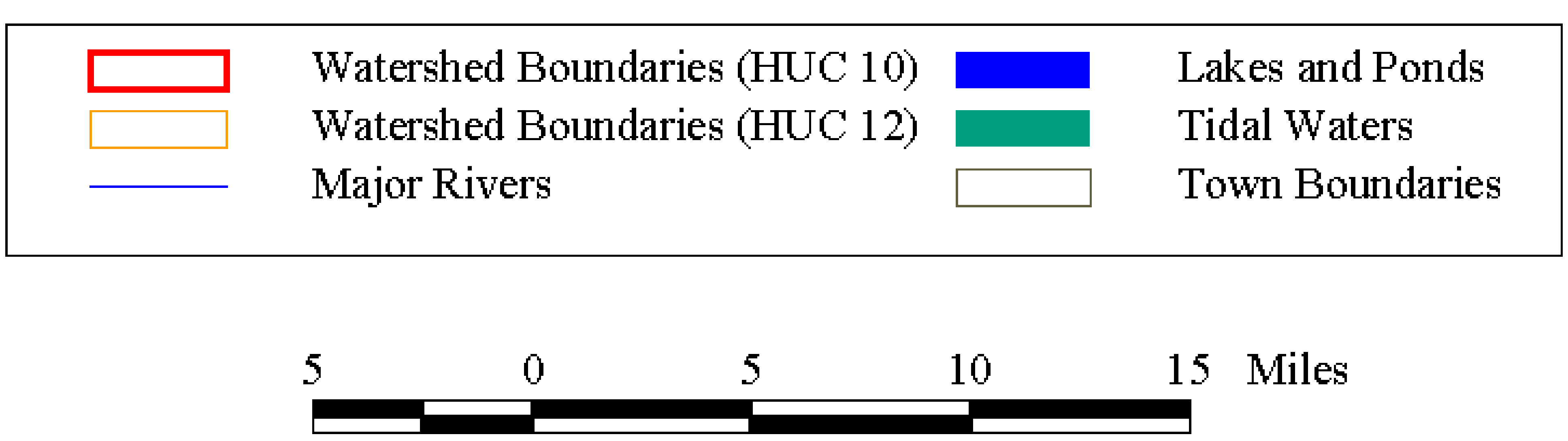


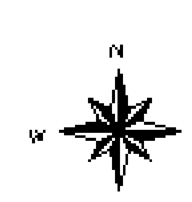
The coverages presented in this program are under constant revision as new sites or facilities are added. They may not contain all of the potential or existing sites or facilities. The Department is not responsible for the use or interpretation of this information, nor for any inaccuracies.

Map Prepared February 12, 2002.

Figure 6-1: Subwatersheds within the coastal watershed.







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Map Prepared February 12, 2002.

Figure 7-1: Zones for assessing eelgrass distribution in Great Bay

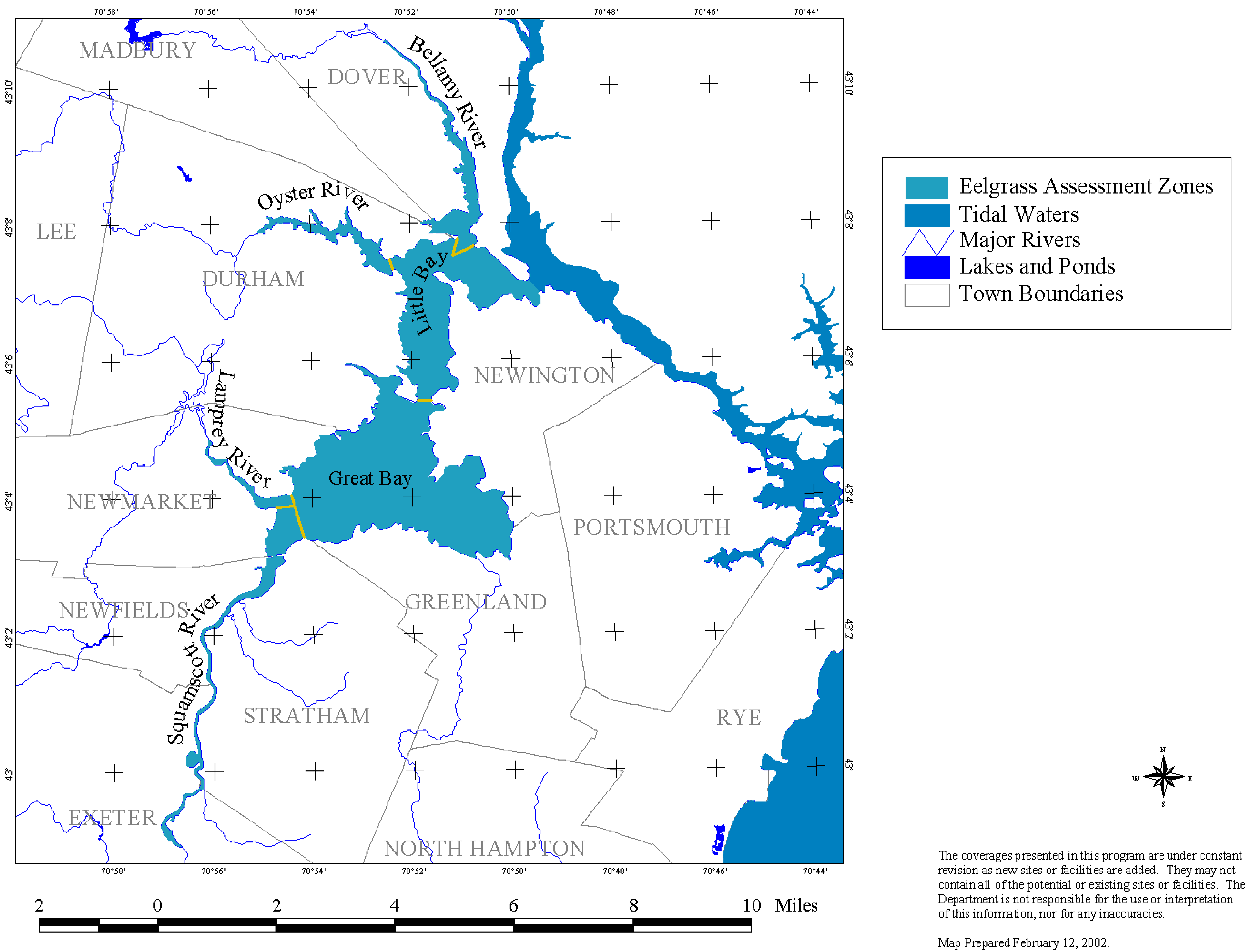
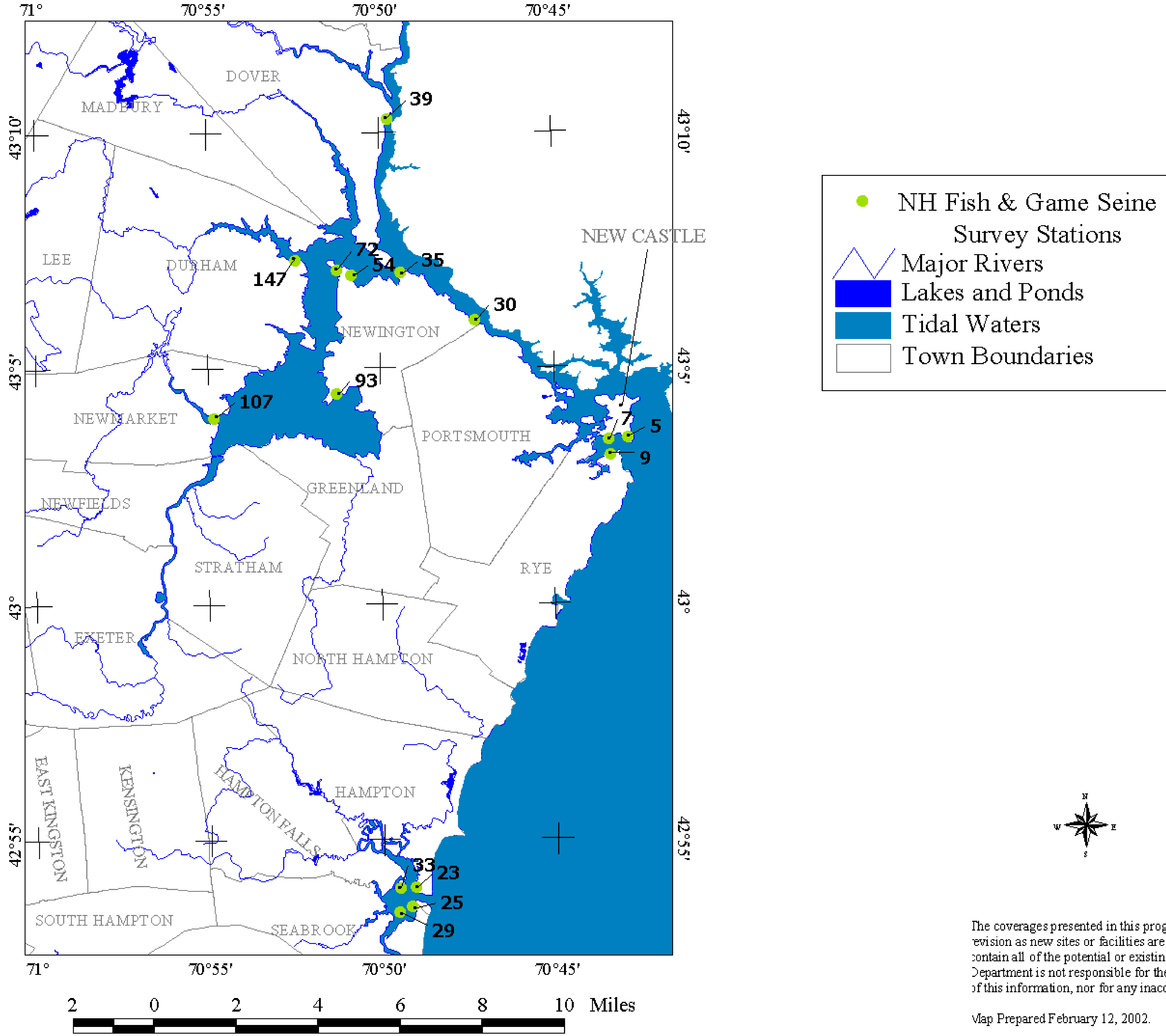


Figure 7-2: Location of NH Fish & Game Seine Survey Stations



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Map Prepared February 12, 2002.