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Evaluation of Effects of Wastewater Treatment Discharge on Estuarine Water Quality

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Evaluation of Effects of Wastewater Treatment Discharge on Estuarine Water Quality

A final report to the New Hampshire Department of Environmental Services
and the New Hampshire Estuaries Project

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EXECUTIVE SUMMARY

This report marks the completion of a two-year project focused on observed and estimated effects of wastewater treatment facilities (WWTFs) on estuarine water quality within the New Hampshire (NH) Seacoast region. This study was designed and carried out in an effort to help the NH Department of Environmental Services (NHDES) and NH Estuaries Project (NHEP) evaluate the effects of WWTF effluent quality on bacterial and nutrient concentrations in New Hampshire's estuarine waters, as well as to help NHDES/NHEP identify related WWTF infrastructure problems. An extensive database of bacterial and nutrient concentrations in effluent collected post-disinfection from 9 NH WWTFs and 2 Maine WWTFs that discharge into the Great Bay and Hampton/Seabrook estuaries was developed. The data were used to determine ratios between different bacterial indicators in WWTF effluent, estimates of in-stream bacterial concentrations following effluent discharge to receiving waters and estimates of nutrient loading from selected WWTFs.

Shellfish bed closures caused by WWTF discharges have been minimal in recent years, only 13 in the 9 NH WWTFs in ~ 3.5 years, with most of the closures caused by infrastructure problems (CSOs). Mechanical failure and human error were less frequent causes of significant discharges from WWTFs. WWTFs frequently discharged no detectable bacterial indicators, although the concentrations and ratios between the different indicators (except for fecal coliforms and *Escherichia coli*) when they were detected were highly variable over time. Total coliforms appeared to be largely unsuitable as an indicator of the presence of other fecal-borne microorganisms. Estimates made on in-stream bacterial concentrations following dilution of measured bacterial effluent concentrations showed no indicator to exceed maximum contaminant levels for New Hampshire surface waters.

Nutrient data were much less variable than indicator bacteria, especially when comparisons were made at the same WWTF during short time periods, although widely different concentrations were measured between a few WWTFs. Estimates of annual nutrient loading from each WWTF were made using the effluent data collected from March, 2002 to April, 2003 at all but the Newfields, NH WWTF. $\text{NH}_4^+\text{-N}$ loading was the most significant N species discharged into the Great Bay Estuary. Of the 7 major WWTFs within the Great Bay Estuary, Portsmouth WWTF had the highest loading rates for TDN, $\text{NH}_4^+\text{-N}$, DON and DOC whereas the Dover WWTF had the highest loading rate for $\text{NO}_3^-\text{-N}$. However, the Portsmouth WWTF is near the mouth of the Piscataqua River and therefore only a portion of the nutrients are likely to be transported back into the upper portions of the Great Bay Estuary. For the whole NH Seacoast, the Hampton WWTF had the highest loading rate for $\text{NO}_3^-\text{-N}$ to estuarine waters. No measurements or estimates of concentrations or impacts of effluent-discharged nutrients in receiving waters were made, although other studies have not documented any chronic impacts in NH tidal waters. The relative impact of WWTF-borne nutrients relative to other (land-based nonpoint, atmospheric) sources is not well understood.

The relative risk to estuarine water quality from leaking sewer infrastructure for each of the municipalities was also evaluated using a number of sources, including GIS overlays (when available), municipal resources (sewer plans) and NH Shellfish Program (NHSFP) information. Sewer infrastructure investigations were also performed in an effort to identify unrecognized or unreported infrastructure deficiencies. Several concerns and potential problem areas were identified. The relative significance of infrastructure compared to WWTF effluent quality and treatment processes for impacts on receiving water quality suggests infrastructure is of more concern, especially for microbial contaminants. Significant nutrient impacts have not been documented in NH tidal waters, although further assessments of effluent levels and fate and effects in receiving waters would provide needed information to address this potential issue.

INTRODUCTION

The control of fecal-borne contamination in the Great Bay Estuary of New Hampshire (NH) has been a concern for a number of years, dating back at least to as early as 1944 (NHDES, 2001). However, a more diligent and noteworthy focus on the quality of surface waters within NH began in 1987, consisting of increased water quality monitoring and enforcement. This occurred because of the Federal Water Pollution Control Act (or the Clean Water Act (CWA) of 1972), as reauthorized by the Water Quality Act of 1987, required NH to submit a report describing the status of ground and surface waters to the US Environmental Protection Agency (USEPA) and Congress every two years. Since that time notable water quality improvements have been observed for both fresh and tidal surface waters in New Hampshire (NHDES, 2001). Much of this improvement is attributed to improvements in sewage treatment operations and nonpoint source pollution controls.

Despite the general improvements in water quality, estuarine waters within the Great Bay Estuary (GBE) have experienced long periods of impairment. The impaired classifications of estuaries have in large part been attributed to the presence of bacterial indicators of fecal contamination in associated surface waters. Septic systems, land disposal of solid wastes, stormwater runoff, combined sewer overflows (CSOs), and point sources have been commonly cited as the most common sources of bacterial pollution within the Great Bay Estuary according to 305(b) reports prepared by NHDES. However, more recent studies using ‘microbial source tracking’ methods have indicated that some areas and sites are subject to significant non-human fecal contamination, including wild animals and birds (Jones, 2003; Jones and Landry, 2003). As monitoring and assessment efforts have increased in the past decade, the identification of previously unrecognized causes of pollution have been documented, indicating that there is a need to continue the reduction or elimination of sources of bacterial, nutrient and toxic chemical contaminants responsible for these impairments.

This project is in response to the recognition that quantitative information related to the potential significance of WWTF overflows and sewage infrastructure-related problems that may result in the contamination of shellfish-growing and recreational surface waters

in the NH Seacoast by bacteria and nutrients is largely lacking. The data reported here were used to determine the significance of bacterial indicator discharge to estuarine surface waters, in addition to estimating the chronic loading of nutrients into estuarine surface waters from WWTFs. The findings in this report reflect a limited effort to provide such estimates and to compile quantitative data and information. It is intended that the data and information collected for this project will serve as a useful next step for NHDES/NHEP to address potential WWTF issues in the Seacoast of New Hampshire.

The overall goal of this project was to initiate data collection, compilation and interpretation in support of developing a better understanding of the potential impacts of WWTF effluent on estuarine water quality in NH. Specifically, monitoring efforts were focused on the 11 WWTFs with discharges into tidal waters. Nine of these WWTFs are located in NH (Dover, Durham, Exeter, Hampton, Newfields, Newington, Newmarket, Portsmouth, and Seabrook) and 2 are located in Maine (South Berwick and Kittery).

As agreed upon by NHDES/NHEP and the contractor in a Memorandum of Agreement (MOA), the general objectives of this project included: (1) the review of existing information regarding shellfish closures, as well as analyzing possible relationships between meteorological conditions and shellfish closures and WWTF hydraulic overloading; (2) the sampling of WWTF effluent in an effort to determine bacterial indicator concentrations and ratios and to characterize nitrogen loading; and (3) to compile available information pertaining to sewer infrastructure, including the location of critical infrastructure locations and to determine the amount of sewer pipe located within 150 and 300 feet of contiguous water bodies. Data that were collected and analyzed during the course of this study are discussed below.

PROJECT FINDINGS

The following subsections include the findings of this multifaceted project. Each subsection includes a general overview of data collection methods, results and a discussion of the analyses for each of the abovementioned objectives.

Review of Existing Information

Guidance and initial information regarding the project was obtained by reviewing “A Technical Characterization of Estuarine and Coastal New Hampshire” (NHEP, 2000). In addition, NH Shellfish Program Annual Reports for 2000 and 2001 were reviewed (Nash, 2000; Nash and Chapman, 2001). Using these resources, a general understanding of the historical water quality and shellfish harvesting locations was compiled (Table 1). (Additional long-term water quality monitoring programs with information relevant to estuarine water quality are listed in Table 2)

Water quality improvements throughout the Great Bay and Hampton/Seabrook Harbor estuaries have allowed for an expansion of approved and conditionally approved

harvesting areas, especially when compared to conditions cited in 1960 (NHWPC, 1960). Changes in bacterial indicator standards have also resulted in shellfish bed classification changes. Improvements in WWTF and sewage treatment processes have further improved water quality, resulting in more approved shellfish areas. The involvement of various state shellfish agencies and other groups has allowed for more frequent and meaningful monitoring throughout the estuaries leading to extensive data collection and analysis. As a result, detailed water quality data have provided information on a variety of pollution sources, problem conditions, hydrodynamic influences and other factors that have been used to more accurately classify shellfish waters leading to greater use of shellfish resources.

Despite steady increases in the areas open to shellfishing, the rate of increase has slowed since 1998. Reportedly, this slowing trend is related to transitions between governing State agencies. It should be noted, however, that despite the slowed rate of estuarine openings, 92.5% of total coastal shellfish waters have been opened for harvesting. Further efforts are underway to classify all harvesting areas by 2005 and to perform wet weather studies to determine how weather related events influence the quality of shellfish harvesting areas.

Two studies with nutrient concentration data in WWTF effluent are reported by NHEP (2001). Mitnik (1994) measured total nitrogen and phosphorus in effluent from the Milton, Somersworth, Rollinsford and Dover, NH WWTFs and the Berwick and South Berwick, ME WWTFs. Depressed concentrations of dissolved oxygen (DO) were detected in the lower freshwater portion of the Salmon Falls River (Mitnik and Valteau, 1996), and were attributed to phosphorus loading from the 5 WWTFs that discharged to that portion of the river. Jones and Langan (1994) reported dissolved nitrogen concentrations from the Durham WWTF and its influence on surrounding water quality. The plume from the Durham WWTF reportedly caused elevated nitrogen concentrations up to the tidal dam and at downstream sites, and accounted for an estimated 42% of the annual nitrogen loading to the Oyster River. Although DO measurements were not made in the 1993-94 study, DO measurements made by other more recent studies do not indicate any significant problems in the Oyster River.

The NHEP (2001) report used discharge data where available and estimates for other WWTFs to estimate annual loading of total nitrogen to the Great Bay Estuary. In descending order, the largest contributors were Portsmouth, Rochester, Dover, Exeter, Berwick and Kittery WWTFs. Overall, WWTFs were estimated to contribute 41% of the total nitrogen loading to the Great Bay Estuary. In general, the Great Bay and Hampton/Seabrook estuaries do not exhibit low DO, high nutrient and chlorophyll *a* concentrations or evidence of system-wide eutrophication in tidal waters (NHEP, 2001). However, with the potential for increased nutrient loading to occur from point and nonpoint sources as the human population in the Seacoast increases, continued assessments of water quality are necessary to track any possible changes that may occur.

Relationship Between Plant Discharge, Precipitation and Bacterial Concentrations

To investigate the impact of wet weather events on plant discharge we analyzed discharge and precipitation data from Dover and Hampton WWTFs. The period of record (POR) for the Dover data set was March 1, 2000 to March 31, 2002 with the exception of the month of April 2000. The POR for the Hampton data set was March 1, 2001 to April 30, 2002. Plant discharge data were obtained from the monthly operational reports (MORs) and precipitation data (1, 3, and 5 day total precipitation) were obtained from weather stations located at Durham and Greenland for Dover and Hampton WWTFs, respectively. For Dover the mean WWTF discharge was calculated as 2.77 MGD with a standard deviation of 0.93. For Hampton the mean WWTF discharge was 2.17 MGD with a standard deviation of 0.53. We focused our attention on high flow events; as a result we only selected flow data that exceeded the 95th percentile range. (The 95th percentile was calculated as 4.3 MGD for Dover WWTF and 2.58 MGD for Hampton WWTF) We then looked for relationships between these high flows and daily precipitation data. To account for antecedent conditions we also looked for relationships between high-flow discharges and 3-day and 5-day precipitation totals.

The results from both WWTFs show only a minor relationship between high-flow plant discharges and precipitation events (Figures 1 and 2). In each data set there exists a single extreme event, 11.49 MGD on 3/22/2001 for Hampton and 16.8 MGD on 3/22/2001 for Dover caused by an extreme 1-day precipitation event that exceeded 4 inches. It is clear from the data (Figures 1 and 2) that less extreme high-flow plant discharge does not appear to be strongly controlled by precipitation at either of the 2 WWTFs we assessed. Regression analyses, not shown here, further supports this conclusion in that less than 40 % (when extreme events of 3/22/01 were removed from the analysis) of the observed variability in plant discharge could be explained by precipitation. In other words, high flows from WWTFs can occur with or without significant weather-related events.

There does exist, however, a clear relationship between WWTF discharge and time of year (Tables 3 and 4). Of the 36 events that exceeded the 95th percentile for Dover, 34 occurred in the months of March and April. The other 2 occurred in December of 2000. Similar results were observed for Hampton where 19 of the 21 high-flow events occurred in the months of March and April. It is likely that these high flows primarily occur during the spring due to snow melt, spring rains and low evapotranspiration, all of which would result in increased soil moisture content and a rise in the water table. Under these conditions infiltration of subsurface water into infrastructure leading to the WWTFs may be occurring. This hypothesis is supported by groundwater level data recorded by the USGS at Lee, NH. (This location is the closest USGS groundwater-recording site to our study area) For the years 2000 and 2001 groundwater levels were at or near their maximum value for the year during the months of March and April. In the year 2002 groundwater levels began increasing in March to a maximum level in June.

Another noteworthy result of this analysis is that with the exception of the event recorded on March 22, 2001 where both plant discharge and fecal coliform counts were at their maximum values for both WWTFs, there were no observed relationships between high-

flow plant discharge and fecal coliform counts for the period of record analyzed. This preliminary analysis suggests that the quantity and quality of WWTF effluent is not strongly correlated with precipitation under the conditions included in this evaluation. Obviously, both quantity and quality of effluent are greatly affected by precipitation events of great magnitude, as in the case of the 3/22/01 storm. Bacterial concentrations in effluent diminished greatly, especially at Hampton WWTF in the days following the initial high flow day, probably as a result of reinstatement of effective treatment measures despite continued elevated flow conditions. Thus, high magnitude precipitation events cause high flow and elevated bacterial concentrations in discharged effluent, while less significant precipitation events (<2"/24 h) have little or no impact on flow and effluent bacterial concentrations. Thus, treatment is only impaired by precipitation under conditions of greatly elevated flow caused by extreme precipitation events.

Determination of Predominant Cause of Shellfish Bed Closures

Overflows and illicit discharges from WWTFs and associated sewer infrastructure (i.e., combined sewer overflows, pump stations, pipes) continue to be a potential threat to estuarine water quality. In an effort to understand and determine the predominant causes of shellfish bed closures related to WWTF and infrastructure shortcomings, closure memos and Inter-Department Communication letters were obtained from the NH Shellfish Program. The data provided by the NH Shellfish Program were reviewed and compiled into a summary table designed to describe the reported occurrences, including the municipalities involved and the associated causes. The "causes" were categorized into the following four major event classifications: 1) weather events, 2) mechanical failure, 3) infrastructure failure and 4) human error. It should be noted that the closure memos were generated based upon reports from WWTF operators following a problem at their respective facility. National Pollutant Discharge Elimination Service (NPDES) requirements for each of the WWTFs requires that all WWTF operators report the discharge of raw sewage or a bypass of the disinfection system to the NHDES.

A total of 49 events causing discharge of untreated sewage from January 1, 2000 to April 14, 2003 were reported to NHDES Shellfish Program (Table 5). Of the 9 New Hampshire communities considered in this study, 7 communities provided details of overflows and illicit discharges during this time frame. The towns of Exeter and Seabrook provided the most frequent input regarding the status of their SSO and WWTF operation with 21 and 15 communications, respectively. The majority of these communications were in regards to events that did not result in shellfish bed closures. In fact, none of the events reported by Seabrook resulted in closures. Six events reported by Exeter, however, resulted in closures. These events were all weather related.

Of the 49 events reported to NHDES from January 1, 2000 to April 14, 2003, 13 resulted in shellfish bed closures. Weather-related events resulted in a total of 6 closures during this period of time, all of which were due, in at least part, to discharges by the Town of Exeter, in most cases associated with discharges from permitted CSOs. (In all cases

involving the Exeter WWTF, extreme rainfall events were listed as the cause of the discharge). Dover, Portsmouth and Newmarket WWTFs contributed to 2 of these 6 weather-related closures. Three closures were caused by human error, 2 at Portsmouth and 1 at Dover. The remaining 4 closures were caused by mechanical failure. Overall, considering that most WWTFs discharge sewage almost 24 hours per day, 7 days per week 365 days in the year, the fact that shellfish bed closures were caused by WWTFs only 13 times in ~3.5 years illustrates the infrequent nature of this as a water quality issue. It is the rare extreme event that causes major discharges that has the greatest potential impact of WWTF discharges on estuarine water quality. It should be noted, however, that full compliance with the NPDES requirement of reporting discharge of raw sewage or a bypass of the disinfection system to the NHDES has not yet been achieved, therefore some events may not have been recorded.

A review of water quality data from databases listed in Table 2 was done to determine if any events listed in Table 5 had documented impacts on water quality. Not all the databases had data available for the full time period covered (January 2000 to April 2003). The approach was to review water quality on, before and after dates when WWTF-related discharges occurred at sites in close proximity or “downstream”(considering both low and high tide flow directions) of the WWTF discharges. For the 13 shellfish bed closures, there were data available for nearby sites on only 3 of the dates in which discharges caused closures, and data available within 4 days following two of the discharge/closure dates. There were no data for sites in close proximity within 7 days following the other 8 discharge dates. However, there were also data available for one other date on which a mechanical failure caused the discharge of untreated effluent in Hampton, but there was no closure.

Water quality data from the NHDES Shellfish Program, the Great Bay Coast Watch (GBCW) (Reid et al., 2003), the NH National Coastal Assessment and the JEL/GBNERR SWMP databases were useful for assessing impacts of discharges on water quality at nearby monitoring sites. There were 3 discharge dates on which monitoring data were available. In all 3 cases concentrations of fecal coliforms at nearby sites were elevated relative to normal conditions. For example, on 2 dates in 2000 and 2001 when mechanical failure occurred at the Portsmouth WWTF, GBCW data for a site in Kittery upstream of the outfall pipe had the highest fecal coliform concentrations of the year at high tide. In the third case, a weather event and a mechanical failure caused an untreated discharge from the Exeter WWTF in 2002. Water quality on the same date downstream at Chapmans Landing was highly contaminated, and fecal coliform levels at Adams Point were also elevated, especially at low tide. For the 2 discharge dates where data were available at sites downstream from the Exeter WWTF within 4 days following the discharge and shellfish bed closure, there was evidence for impaired water quality on one of the dates and no evidence of impairment on the other date. Water quality was unimpaired (fecal coliform concentrations all <10/100 ml) at sites in Hampton Harbor on the same day as a mechanical failure at the Hampton WWTF that did not trigger a closing. Thus, although limited data were available, there was evidence of water quality impairments that supported shellfish bed closure decisions made following untreated discharges from WWTFs. In addition, the data were also consistent with the fact that

when closures were not made, there was little evidence of impact. No water sampling was timed to coincide with accidental discharges, a strategy that would need to be implemented by some program to adequately document possible impacts.

WWTF Sampling

Eleven WWTFs within the Great Bay Estuary and Hampton/Seabrook watersheds were sampled on a monthly basis at locations identical to those used by the NH Seacoast WWTF operators for approximately one year (March, 2002 to April, 2003) for the following constituents of concern (COCs): *Escherichia coli*, fecal coliform, total coliform, enterococci, total dissolved nitrogen (TDN), nitrate (NO_3^- -N), ammonium (NH_4^+ -N), dissolved organic nitrogen (DON) and dissolved organic carbon (DOC). For the purposes of this study, comparisons between the data collected during this study and data collected during NPDES monitoring at individual WWTFs were not performed. Details of the sampling procedures and quality assurance steps can be found in the QAPP associated with this project. The QAPP is on file at NHDES and at the University of New Hampshire.

On the day of sampling one effluent grab sample was collected from each of the WWTFs following dechlorination. Bacteriological samples were collected in sterilized 1-liter HDPE bottles using a fitted-sampling stick designed to grasp the sample bottles. After sample collection, samples were stored in a cooler with ice and delivered to the lab. Nutrient samples were collected in acid washed 60-ml HDPE bottles and were field filtered and stored at 4°C until analysis. *E. coli*, fecal coliform, total coliform, and enterococci were enumerated using standard membrane filtration methods, which included the filtering of between 2.5 and 100 ml of sample (depending on the source of the sample and the analysis being performed) through a 0.45- μm pore size filter in duplicate. Fecal coliform and *E. coli* were enumerated following Standard Method 9213D.3 (APHA, 1995), total coliforms were enumerated following Standard Method 9222 B (APHA, 1998), and enterococci were enumerated following Standard Method 9230C (APHA, 1998).

Nutrient analyses were performed by the University of New Hampshire Water Quality Analysis Laboratory (WQAL). Nutrients tested for included DOC, TDN, NO_3^- -N, and NH_4^+ -N. Samples were analyzed for NH_4^+ -N and NO_3^- -N using a Lachat “QuikChem” method. Specifically, NH_4^+ -N was analyzed with the phenol hypochlorite method and sodium nitroprusside enhancement (Lachat QuickChem Method 10-107-06-1F) and NO_3^- -N was analyzed by cadmium reduction (Lachat QuickChem Method 10-107-04-1B). DON was calculated by subtracting NH_4^+ -N and NO_3^- -N from TDN concentrations. DOC and TDN were quantified with a Shimadzu TOC 5000 (platinum-catalyzed high temperature combustion) and an ANTEK Nitrogen detector (Sugimura and Suzuki 1988; Merriam et al. 1996). DOC was determined by calculating the difference between total carbon and inorganic carbon. Non-purgeable organic carbon was not considered an acceptable surrogate for DOC in this study, as the volatile organic component in some of the samples was presumed to be high.

Bacterial Indicator Ratios

Due to the fact that WWTFs within the NH Seacoast utilize different indicator organisms as the sole bacterial indicator to monitor effluent, it is not possible to directly compare WWTF effluent quality or to estimate total loading without collecting and analyzing samples for multiple bacterial indicators (as was done in this study). To provide a method in which comparisons of effluent quality could be made, regression analyses were performed between bacterial indicator concentrations observed during monthly sampling events at each WWTF. Comparisons were made only with enumeration data; data that were below detection limit (BDL) or too numerous to count (TNTC) were not used in the regression analysis. Only 5 TNTC values were observed during the duration of the study and were not incorporated into the ratio calculations. On the other hand, approximately 164 BDL values were observed, indicating that a number of bacterial indicator concentrations were low much of the time during the sampling period. This suggests consistently effective treatment at most of the WWTFs.

The bacterial concentrations used in the analysis were \log_{10} transformed. This was deemed necessary as untransformed data were non-normally distributed. The regression analyses performed between bacterial indicator concentrations exhibited low to moderate correlations for the majority of comparisons (Table 6, Figure 3). The least significant relationship was observed between total coliform and fecal coliform concentrations ($R^2=0.4138$, $p<0.05$) and the most significant relationship was found between *E. coli* and fecal coliform concentrations ($R^2=0.9592$, $p<0.05$). The relationship between total and fecal coliforms, while poor, is an important comparison because of the wide use of total coliforms at the WWTF in NPDES monitoring. It is presumed that the ubiquitous nature of total coliforms and their potential to be present independent of fecal contamination contributed to the poor and erratic concentrations observed during the study, and resulted in the poor relationship. Similar results were observed in a previous study of the Exeter WWTF (Jones, 1990), and the suggestion was made to not use total coliforms as a fecal contamination indicator. The strong relationship between *E. coli* and fecal coliform concentrations is not surprising as the analytical methods are similar because they rely on the same growth media (i.e., mTEC). The fact that enterococci are not at all similar to coliforms is borne out in the poor relationships between the two groups of organisms and probably reflects differences in survival through the treatment process.

While all of the relationships between bacterial indicators were significant at the 0.05-level, the R^2 -values and standard errors indicate that the regression analyses for these comparisons should be used only as a loose guideline when calculating unknown bacterial concentrations. As an example, if the total coliform concentration of a WWTF sample was 100 cfu per 100 ml, it would be possible to estimate the fecal coliform concentration based on the following equation (Table 6): $\log(\text{fecal coliform}) = 0.6909 (\pm 0.30) * \log(\text{total coliform}) - 0.8567 (\pm 0.65)$. Inserting the total coliform concentration of 100 into the equation and accounting for the standard error in the parameters, it is possible to estimate a fecal coliform concentration ranging between 0.19 and 59 cfu per

100 ml. This suggests the ratio for TC:FC ranges from 1.7 to 526. In fact, the ratios for actual paired data ranged from 2.1 to 860. The large amount of uncertainty associated with these calculations must be taken into account when using these equations to estimate concentrations of one organism from measured concentrations of another organism. In fact, the large uncertainty associated with these calculations strongly argues against the use of these equations. The paired ratio data did show that TC was always >FC, *E. coli* and enterococci, and that FC was always $\geq E. coli$. It is worth noting that poor correlations between *E. coli*, fecal coliforms and total coliforms in wastewater effluent have been observed in other studies (Elmund et al., 1999).

Variability in Effluent Quality

Indicator organisms and major N species were collected on a near monthly basis from March 2002 to April 2003. Clearly there was monthly variability in concentrations of indicator organisms and major N species (Table 7). The range of monthly concentrations of indicator organisms varied by several orders of magnitude at several treatment facilities. For example, *E. coli* concentrations ranged from less than 1.5 to 373 cfu per 100 ml at the Exeter WWTF. Monthly nutrient data were less variable. Nutrient concentrations tended to vary by a factor of 2 or less between months at a given WWTF, as opposed to the order-of-magnitude variations observed for the indicator organisms. There were, however, exceptions. For example, ammonium concentrations varied by over 2 orders of magnitude at the Hampton and Portsmouth WWTFs.

The detection of the different bacterial indicators in effluent samples was widely variable. The number of samples in which indicator bacteria were analyzed were relatively equal, ranging from 77 for total coliforms to 83 for *E. coli* (Table 7). However, the number of samples in which the indicators were below detection limit ranged from 11 for total coliforms to 53-58 for the other three indicators. This resulted in a frequency of detection of 86% for total coliforms, and less than 33% for the other three indicators. Thus, the treatment processes at the WWTFs were relatively effective in reducing bacterial indicators to non-detectable levels, except for total coliforms which, as previously stated, can be present in the absence of fecal contamination

To look at short-term variability 1-day and 5-day studies were conducted at both Newmarket and Durham WWTFs. Hourly variability of bacterial indicators was especially evident during the August 22, 2002 sampling event with concentrations varying by over an order of magnitude at both Newmarket and Durham WWTFs (Table 8). In contrast, nutrient concentrations varied by only a factor of 2 or less. It should be noted that concentrations observed at Durham during this sampling event could have been influenced by maintenance activities, which were performed that afternoon. In contrast, results from samples taken at Newmarket and Durham on April 25, 2003 showed very little variability in the effluent over a period of one day and concentrations for all species were significantly reduced when compared to results from the August 22,

2002 sampling event (Table 9). Similar variability in bacterial indicators and nutrients was also observed at each plant over the course of one week (Table 10).

Chronic Loading of Nutrients from WWTFs

Nutrient loading calculations were possible with the data collected during the study. Wastewater treatment facility daily discharge data were obtained from each WWTF (with the exception of Newfields) for the days on which nutrient samples were collected. These data were used to calculate the loading in tons per year for each COC (i.e., TDN, NH_4^+ -N, NO_3^- -N, DON, DOC) over the course of this study to the NH Seacoast (Table 11). Loading estimates for Newfields WWTF were not determined because discharge data were unavailable. It is unlikely that this data gap significantly influences the accuracy of the loading estimates because Newfields does not discharge on a regular basis and does not discharge more than 1 MGD.

Average loading for each WWTF was calculated for the study period and totaled in an effort to estimate the total loading for the year to the NH Seacoast. (On days in which DON concentrations were BDL at a WWTF, we assumed loading was zero for this COC). Based on the loading data, NH_4^+ -N was the most significant N species being discharged into the Great Bay Estuary on a monthly basis. Of the 7 major WWTFs within the Great Bay Estuary, the Portsmouth WWTF had the greatest loading of TDN, NH_4^+ -N, DON and DOC, however, the plant is near the mouth of the Piscataqua River and therefore only a portion of the nutrients are transported into the upper portions of the Great Bay Estuary. Most of the nutrients discharged by Portsmouth are most likely transported to Portsmouth Harbor and even the Atlantic Ocean. For the whole NH Seacoast, including Hampton Harbor, the Hampton WWTF is the most significant source of NO_3^- -N in estuarine waters (Table 11, Figure 4).

Intensive hourly and daily sampling at two WWTFs (Newmarket and Durham) was completed in an effort to understand short-term variability in nutrient loading. Calculations were made as previously described except for the fact nutrient loading was reported in pounds per day. Similar to the monthly samples, NH_4^+ -N was the most significant N species being discharged from Newmarket and Durham WWTFs on an hourly and daily basis (Table 12). No clear temporal trends were detected in nutrient loading at either WWTF (Figure 5). However, TDN, NH_4^+ -N, NO_3^- -N and DON loading showed minimal variability during the daily and weekly sampling events. There was some variability observed in DOC loading, especially at Newmarket.

These data represent an important source of information because they have allowed for the quantification of chronic nutrient loading from WWTFs. To our knowledge, the collection and analysis of multiple nutrient samples over an extended period of time at NH Seacoast WWTFs has not been previously performed. To improve upon the accuracy and precision of loading calculations, it would be necessary to increase sample size and frequency. It is worth noting, however, that the nutrient loading rates calculated during

this study are consistent with rates from earlier studies where sampling was less frequent (NHEP 2000).

Few past (Jones and Langan, 1994; Mitnik and Valleau, 1996) and no recent studies have documented impacts and fate of WWTF-discharged nutrients to NH surface waters. With increasing development and human population increases, the potential for impairment is not well understood. Further field studies on effluent loading rates and the fate and effects of discharged nutrients in receiving waters would help to address this potential issue. Such work would require assessment of all nutrient sources for any area around a WWTF, including urban stormwater, agricultural runoff, tributary and river freshwater loading, etc., in order to attribute water quality impacts to any single source.

Estimation of In-Stream Bacterial Concentrations

The erratic occurrence of detectable bacteria, in contrast to the constant occurrence of detectable nutrients, made it impractical to calculate bacterial loading. Rather, estimations of in-stream bacterial concentrations following discharge from the WWTFs were made. Using WWTF-specific dilution factors, bacterial indicator concentrations observed during each effluent sampling event were used to estimate in-stream bacteria concentrations following discharge to receiving waters for those dates. The chief operators of each WWTF provided dilution factors as reported on their respective NPDES permits. Based on the dilution factors, in-stream estimations of bacterial concentration were calculated as follows

$$C_T = \frac{Q_1 C_1 + Q_2 C_2}{Q_1 + Q_2} \quad (1)$$

where C_T is in-stream bacterial indicator concentration (cfu per 100 ml), Q_1 is WWTF discharge (liters per second), C_1 is bacterial concentration (cfu per 100 ml) in WWTF effluent, Q_2 is stream discharge (liters per second), C_2 is in-stream bacterial concentration (cfu per 100 ml). Assuming the in-stream bacterial concentration is zero, equation 1 can be reduced to

$$C_T = \frac{Q_1 C_1}{Q_1 + Q_2} \quad (2)$$

We can further simplify equation 2 by noting that each plant's dilution factor is equal to Q_2/Q_1 . Incorporating this identity into equation 2 and simplifying yields

$$C_T = \frac{C_1}{(1 + \text{dilution factor})} \quad (3)$$

Although elevated bacterial indicator concentrations (i.e., in exceedance of NPDES standards) did occur in some WWTF effluent during some monitoring events, none of the estimated indicator concentrations exceeded maximum contaminant level (MCL) concentrations for New Hampshire surface waters following dilution (Table 13). Based on the sampling results reported here, it appears that following dilution of WWTF effluent into the respective receiving waters, discharges of bacteria from WWTFs do not represent a significant threat to water quality (assuming no regrowth or resuscitation of injured cells). It should also be noted that the dilution factors used to estimate in-stream bacterial concentrations have been established for low flow conditions in the receiving waters around the WWTFs. As such, the in-stream bacterial concentrations represent a “worst-case” scenario. That is, because actual dilution of WWTF effluent was likely greater than what was calculated using the dilution factors, in-stream bacterial concentrations caused by WWTF discharges would typically be lower than the concentrations reported here.

Compilation and Inventory of Sewer Infrastructure

In addition to point sources, nonpoint sources such as exfiltration from leaky sewer infrastructure can be a significant source of bacteria and nutrients to the Seacoast region (Jones and Langan, 1994). To help the State prioritize areas where they should direct their sampling efforts to determine the impact of leaking sewer pipes we compiled information on sewer infrastructure location, age, composition, and distance to surface water bodies.

Surveys pertaining to the sewer infrastructure for Dover, Durham, Exeter, Hampton, Newington, Newfields, Newmarket, Portsmouth, Seabrook, Kittery and South Berwick were distributed and collected from May 2003 to August 2003 in an effort to collect specific sewer infrastructure attributes. Surveys were supplied to the appropriate personnel for each municipality, including WWTF operators, city environmental coordinators or DPW representatives. Data requested included contact information for each town, the number and location of pump stations, the number and location of combined sewer overflows (CSOs), age of infrastructure and future upgrades or improvements (Table 14).

Based on these surveys, Kittery has the most pump stations associated with its infrastructure, while Newfields and Newington have the fewest (Table 14). With the exception of Exeter, Portsmouth and Kittery, no locations have CSOs associated with their sewer infrastructure. Exeter, Portsmouth and Kittery have 2, 3 and 3 CSOs, respectively. Based on the information provided, Dover and Portsmouth have the most extensive plans for infrastructure upgrades.

Relative Risk Assessment

We assessed relative risk of impairment due to leaking sewer infrastructure for each municipality based on age of infrastructure, amount of infrastructure in critical areas (i.e. within predefined distances of surface water bodies) and the proximity of critical infrastructure to shellfish growing beds. The locations of critical infrastructure and length of sewer infrastructure for 10 of the 11 municipalities studied were identified using a combination of GIS information and sewer plans supplied by local municipalities. GIS coverages identifying sewer infrastructure were obtained from NHDES for Dover, Durham, Exeter and Portsmouth. As part of this project GIS coverages were created for Hampton, Seabrook, Newmarket, Newfields, Kittery and South Berwick using sewer infrastructure plans supplied by either the respective WWTF or Department of Public Works (DPW). Data from the town of Newington were not available from either the WWTF or DPW and therefore could not be analyzed. Coverages created with sewer infrastructure plans were not ground-truthed and should only be relied upon to identify approximate sewer locations.

Upon completion of the sewer infrastructure GIS coverages, critical infrastructure - defined as infrastructure within 150 or 300 feet of a surface water body - was identified around all contiguous water bodies for each respective municipality using the buffer tool in ArcView™ GIS (Figures 6 through 15). The length of pipe within each of these buffers was estimated using the measuring tool in ArcView™ (Table 15). The number of critical infrastructure stream and/or river crossings was also enumerated for each municipality. Given our focus on water quality concerns in shellfish beds we determined that the distance between critical infrastructure and shellfish beds should be considered in any risk assessment. In other words, the closer a municipality's critical infrastructure is to shellfish beds the greater the likelihood that exfiltration from this infrastructure will adversely impact the water quality in the shellfish beds. As a result the shortest distances between infrastructure within the 300-foot buffer and shellfish beds were determined for each municipality using a GIS coverage that included the 2002 shellfish bed locations (NHFG, 2002). Based on these data and the age of infrastructure and the number of CSOs within a town, a relative risk value of low, medium or high was determined to identify infrastructure (by municipality) that may pose a threat to water quality in shellfish beds (Table 16).

Based on the analysis of each town's infrastructure, the town of Newfields represents an unlikely source of surface water contamination based on facility size, discharge volume and sporadic discharges. Minimal amounts of infrastructure are located within a 300-foot of surface water and are over a mile from the nearest shellfish bed location. The towns of Exeter and Kittery also represent a low threat to shellfish bed quality from exfiltration due to the relative distance between infrastructure and shellfish beds. However, the overall risk value for the town of Exeter should be considered medium to high due to the presence of two CSOs that overflow during extreme weather events. A moderate to high risk value for Exeter is further supported by the number of times overflows from Exeter

have resulted in shellfish bed closures (Table 5) but it should be noted that this elevated risk is not due to the potential of impairment due to exfiltration.

The towns of Newmarket and South Berwick were assigned a relative risk value of medium based on the distances from shellfish beds, the number of infrastructure water crossings and the age of infrastructure. Although the shortest distance between infrastructure and shellfish bed locations was over 3 miles for South Berwick, it was concluded that the age of this infrastructure should be considered a source of concern. Upgrades of this infrastructure have taken place, but it is not possible to rule out the risk posed by the presence of aged pipe material. The town of Durham was assigned a medium to high-risk value due to the proximity of infrastructure to shellfish beds (<1.0 mile) and the large number of infrastructure surface water crossings throughout the town, as well as the age of the sewer pipes.

The towns of Dover, Hampton, Portsmouth and Seabrook were all assigned high relative risk values. Dover, Hampton and Seabrook are in close proximity to shellfish beds and have between 29 and 55 infrastructure surface water crossings within the respective town boundaries. However, Seabrook infrastructure is much newer than the other two towns, which could lower this risk value. Portsmouth infrastructure is not as close to shellfish beds, but the age of infrastructure is of particular concern as well as the presence of three CSOs. In addition, some of the infrastructure, such as Deer St. pump station, is located adjacent to surface waters and has been the cause of shellfish bed closures. It should be noted that efforts are underway by the City of Portsmouth to upgrade all aged infrastructure and to remove CSOs.

Infrastructure Site Investigation

Site investigations were conducted in an effort to evaluate infrastructure locations identified during the aforementioned GIS analysis. Investigations were only conducted at those locations assigned a high relative risk value (Table 16). During the site investigations, visual and olfactory observations were made to determine the condition of infrastructure. The locations of critical infrastructure, including infrastructure stream crossing points, were determined using GIS coverages generated during this study and appropriate NH town maps. Due to accessibility and time constraints we may have overlooked some locations. As a result, there may exist locations in which exfiltration is occurring but was not identified as part of this study.

Infrastructure investigations were conducted for the towns of Hampton and Seabrook on September 5, 2003. All critical infrastructure locations identified for Hampton were visited except for infrastructure that crosses the Tide Mill Creek salt marsh (north of Rt. 101). With the exception of infrastructure located west of Ashworth Avenue, most infrastructure was not observable and belowground. Infrastructure west of Ashworth Avenue is located in portions of salt marsh near an extensive residential area. Sewer manholes were easily visible in this area. Investigations conducted for the town of

Seabrook resulted in similar findings in that no observable problems were identified. Sewer pipes were visible under the Rt. 286 bridge, but at no other location. At no time during the investigation at Hampton or Seabrook were there any signs of exfiltration or other problems. Given the location of infrastructure relative to residential areas in many of these areas, it is likely that any obvious problems would be quickly identified and reported.

On October 10, 2003 additional infrastructure investigations were performed for the cities of Portsmouth and Dover and the town of Durham. Infrastructure in these towns was predominately below paved surfaces and not observable. Infrastructure locations associated with river crossings were more easily observed. None of the observed sewer infrastructure crossings exhibited any signs of exfiltration or other problems, although in some cases they were in close proximity to surface water.

Sewer infrastructure around North Mill Pond in Portsmouth was identified at Bartlett Avenue and Maplewood/Vaughn Avenues. Visible sewer infrastructure was also observed at a bridge crossing out to Pierce Island and the Portsmouth WWTF. Investigations were also performed around South Mill Pond in Portsmouth. Although no visible crossings were identified, an on-going sewer replacement project was underway to remove the associated combined sewer overflow currently in place. An additional crossing was also noted at the Rt. 1/Sagamore Creek crossing in Portsmouth, but could not be accessed from the shore.

Extensive sewer infrastructure is located in a residential area of Dover Point in the City of Dover. No direct observations were possible from land. Sewer infrastructure was observed directly in Canney Brook at Spur Road just west of Rt. 16. Multiple river crossings are also located along Burr Brook near Hough Road in Dover. Burr Brook is culverted and not in close proximity to the sewer pipe and is not likely impacted by sewer infrastructure. There was evidence of sewer repairs in this area, however. Sewer pipe infrastructure was also observed crossing the Cocheco River (associated with River Street Pump Station). All other sewer crossing locations along 6th Street, Washington Street and Rt. 155 appeared to be relatively new with no signs of exfiltration.

Much of the infrastructure associated with the town of Durham and the University of New Hampshire appears to be below pavement or in areas that were not accessible during this study. The site that was investigated was at the mouth of Beards Creek near Rt. 4. A previous study had shown evidence of exfiltration of bacteria and freshwater into tidal waters at this site on one date, but was not observed on several other dates (Jones and Langan, 1994) and no signs (visual or olfactory) of exfiltration were observed during the site visit.

The site investigations were conducted on only one day in each community. Thus, the findings are only a snapshot of current conditions. The transient nature of exfiltration and other possible infrastructure problems suggests that more observations would be needed to adequately assess this issue, an effort well beyond the scope of this project. There remains concern for the infrastructure in several areas, especially the two largest

Seacoast cities, Dover and Portsmouth. Other studies have documented problems associated with both sewage and stormwater infrastructure and impacts to surface waters in these and other areas, including Exeter and Durham (Jones, 2003; Jones and Gaudette, 2001; Jones, 1998; NHDES, 1997; Jones and Langan, 1996). Thus, in contrast to the infrequent bacterial problems and the lack of recent evidence for nutrient problems from WWTFs, it appears that infrastructure problems may pose the greater immediate threat to surface water quality.

SUMMARY AND CONCLUSIONS

The primary goal of this project was to collect and compile preliminary data and information that will help guide future efforts by the State to improve water quality in the NH Seacoast. A summary of the major findings and some conclusions drawn from this study include:

1. There is a significant increase in flow and bacterial concentrations in effluent when large magnitude (>4") rainfall events occur. However, regression analysis between daily high flows from two WWTFs and precipitation yielded poor to moderate relationships for conditions associated with smaller rainfall events. There was, however, a clear relationship between peak discharges and time of year. Of the 36 high-flow events for Dover WWTF, 34 occurred in the months of March and April. Similarly, 19 of the 21 high-flow events for Hampton WWTF also occurred in the months of March and April. These high flows are likely due to increased soil moisture caused by snowmelt, spring rains, and low evapotranspiration. This in turn leads to infiltration of subsurface water into infrastructure leading to the WWTFs. No significant relationship was found between FC concentrations and high-flow daily plant discharge at either WWTF. These preliminary analyses suggest that the quantity and quality of WWTF effluent is not strongly correlated with precipitation. That is not to say that significant precipitation does not lead to increased WWTF discharge (see for example Exeter, Table 5). Rather, high flows from WWTFs can occur with or without significant weather-related events.
2. Forty-nine events of hydraulic overloading and other untreated effluent discharges were reported to NHDES Shellfish Program from January 1, 2000 to April 14, 2003. Most of these events involved relatively minor discharges and only 13 of these events resulted in shellfish bed closures. Weather-related events resulted in a total of 6 closures during this period of time, all of which were due, in at least part, to permitted CSO discharges by the Town of Exeter. Three closures were caused by human error. The remaining 4 closures were caused by mechanical failure. Water quality data available from various monitoring programs supported the shellfish bed closure decisions, including the decisions to not close beds following less significant discharges. Thus, a mixture of weather, human and mechanical factors have been causes of WWTF discharge-related closures of shellfish beds in New Hampshire.

3. Examination of the bacterial indicator ratios indicates that the only significant relationship is the log – log relationship between *E. coli* and fecal coliform concentrations. Other comparisons between bacterial indicators exhibited poor relationships, similar to what has been reported in the literature (Elmund et al., 1999). The large amount of uncertainty associated with these calculations must be taken into account when using these equations to relate concentrations of one organism, say fecal coliforms, to measured concentrations of another organism, say enterococci.
4. The high frequency of detection of total coliforms compared to other indicators suggests that it is a poor indicator of fecal contamination and may not accurately reflect treatment process effectiveness. The poor relationships for indicator ratios involving total coliforms is further evidence of total coliforms being a poor indicator of fecal contamination.
5. Variability in concentrations of indicator organisms and major N species was observed at all time scales tested (monthly, daily, and hourly). Monthly concentrations of indicator organisms varied by several orders of magnitude at several treatment facilities. Nutrient concentrations were more apt to only vary by a factor of 2 or less between months. Given the observed variability in concentrations and the erratic occurrence of detection for most of the bacterial indicators, accurate estimates of bacterial loading to Great Bay will be difficult to calculate unless a larger number of samples are taken so that the variability at different temporal scales (e.g. hourly, daily, monthly, etc.) can be quantified.
6. Based on this study, NH_4^+ -N loading is the most significant N species being discharged into the Great Bay Estuary. Of the 7 major WWTFs within the Great Bay Estuary, Portsmouth WWTF had the highest loading rates for TDN, NH_4^+ -N, DON and DOC whereas the Dover WWTF had the highest loading rate for NO_3^- -N. However, the Portsmouth WWTF is near the mouth of the Piscataqua River and therefore only a portion of the nutrients is transported back into upper portions of the Great Bay Estuary. For the whole NH Seacoast, the Hampton WWTF had the highest loading rate for NO_3^- -N to estuarine waters.
7. No estimates or measurements of nutrient concentrations in receiving waters were made, and no other recent studies have focused on WWTF nutrient discharges. Assessments of nutrient, dissolved oxygen and chlorophyll *a* concentrations in receiving waters along with nutrients in effluents are needed to document the fate of WWTF-borne nutrients and to determine if effluent discharges are impacting receiving waters.
8. Although occurrences of elevated bacterial indicator concentrations occurred occasionally in WWTF effluent throughout the study none of the estimated indicator concentrations exceeded maximum contaminant level (MCL) concentrations for New Hampshire surface waters following dilution. Based on the modeling results and effluent sample analysis findings reported here, it

appears that following dilution of WWTF effluent into the respective receiving waters, discharges of bacteria from WWTFs do not represent a significant threat to water quality (assuming no regrowth or resuscitation of injured cells).

9. Sewer infrastructure was assessed using a combination of GIS coverages and municipal resources in an effort to evaluate sources of potential contamination and to identify sources of concern. Based on this analysis, it was determined that Dover, Hampton, Portsmouth and Seabrook represent the greatest potential risk from leaking infrastructure to estuarine quality and shellfish harvesting areas. The significance of the threat was based upon age and quantity of infrastructure, proximity to surface waters and shellfish areas, and the number of combined sewer overflows. Durham, Newmarket and Kittery were all assigned a medium threat value. Exeter represents a low risk from leaking infrastructure due to the great distance from critical infrastructure to shellfish beds (approximately 6 miles). However, the presence of 2 CSOs in Exeter has been shown to affect shellfish bed closures but does not indicate a threat due to leaking infrastructure. It must be noted that these rankings are qualitative and based on subjective metrics. However, we believe that these rankings will help the State prioritize sampling efforts to quantify the impacts of infrastructure problems (exfiltration, infiltration, CSOs, cross-connections) on water quality in shellfish beds.
10. Site investigations were performed at Dover, Hampton, Portsmouth, Seabrook and Durham in an effort to identify any current problems with infrastructure. Based on visual and olfactory observations, no sources of contamination were observed at any of the locations. Sampling of surface waters adjacent to these critical areas under conditions conducive to possible exfiltration will need to be conducted to confirm these one-time qualitative assessments.
11. In general, the treatment of effluent discharged from WWTFs is at present relatively effective at minimizing water quality impacts from bacteria, while impacts from effluent nutrients is largely undocumented. However, several different concerns have been raised by this study about sewage and stormwater infrastructure including CSOs, infiltration during springtime, and age of pipes. Evidence of problems with cross connections and exfiltration has been reported in previous studies. Thus, to address the most pressing sewage-related issues related to estuarine water quality, focus should be on upgrading aged infrastructure in urban areas.

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TABLES

Table 1: Progress in shellfish growing water classification.

Data Source	Dates Included	Shellfish Growing Water Conditions
NHEP Technical Characterization Report	1960 1975 1990 1998	<ul style="list-style-type: none"> <li data-bbox="680 375 1885 516">• 1960: Only a small portion of eastern Great Bay Estuary was open for shellfish harvesting near the shore between Fabyan and Pierce Points. No other areas were suitable for shellfish harvesting due to the presence of chronic pollution by raw sewage. No reports outlining conditions in Hampton/Seabrook Harbor were available at this time. <li data-bbox="680 526 1885 776">• 1975: Large portions of Great Bay Estuary were considered suitable for harvest, including eastern Great Bay Estuary between Nannie Island and Birch Point, two areas near the western shoreline around Footman and Vols islands, the lower tidal portions of the Oyster and Bellamy Rivers, Little Harbor and southern portions of the Back Channel, outer Portsmouth Harbor, the northern half of Hampton Harbor and lower portions of some tributaries, Rye Harbor and the whole NH Atlantic coast. During this time, shellfish classification was based on a standard of <70 total coliforms per 100 ml. <li data-bbox="680 786 1885 959">• 1990: Large portions of Great Bay Estuary associated with the Lamprey and Squamscott River and upper Little Bay were considered unclassified and closed to shellfish harvesting. Central and eastern sections of Great Bay Estuary were approved for shellfish harvesting. Shellfish harvesting in the entire Hampton Harbor estuary was prohibited after NHDHHS closed Hampton and Little Harbors in March 1989. <li data-bbox="680 969 1885 1360">• 1998: Approved shellfish harvesting areas were extended northward into Little Bay, leaving much of Little Bay with an approved classification, with the exception of Oyster River east of Fox Point. Areas of Great Bay Estuary near the confluence of the Lamprey and Squamscott Rivers were reclassified as restricted and prohibited. The eastern portions of the Great Bay Estuary were reclassified as approved with the exception of areas south and west of Pierce Point in Greenland Bay. Little Harbor was reclassified as an approved harvesting area due to improved water quality (in 2001), but is dependent upon usage of the Wentworth Marina and the performance of the Portsmouth WWTF. Portions of Hampton/Seabrook Harbor were reclassified to conditionally approved; harvesting is limited by rainfall events and WWTF performance and closed during warm months (June – October).

Data Source	Dates Included	Shellfish Growing Water Conditions
NHDES Shellfish Program Annual Reports	2000 2001	<ul style="list-style-type: none"> • 1999: The NHDES Shellfish Program was initiated in 1999 with the purpose of classifying shellfish growing waters for the State of New Hampshire. Previously, the NHDHHS was responsible for classification. No annual report was submitted for this year. • 2000: The first NHDES Shellfish Program annual report was submitted in June 2001 for the year 2000. Of the 13,718 acres of estuarine waters in the Seacoast area, it was noted that 36.3% of estuarine waters were open for harvesting and 14.3% were closed due to poor water quality and/or proximity to WWTFs. The remaining 49.4% of the area was unclassified. • 2001: The second NHDES Shellfish Program annual report was submitted in April 2002 for the year 2001. During this time, the percent of open and closed estuarine harvesting areas increased to 37.8% and 18.7%, respectively. The percent of unclassified estuarine waters decreased to 43.5%.

Acronyms:

NHEP: New Hampshire Estuaries Project

GBE: Great Bay Estuary

NHDHHS: New Hampshire Department of Health and Human Services

WWTF: Wastewater Treatment Facility

NHDES: New Hampshire Department of Environmental Services

Table 2: Long term and on-going bacterial indicator monitoring programs in the NH Seacoast region.

Long Term Monitoring Programs	Sample Parameters	Monitoring Locations	Monitoring Frequency	Data Maintenance Location(s)	Contact Information
GBNERR/JEL, NHCP Ambient Monitoring Program	FC EC EN	4 locations in Great Bay Estuary	One sample per month at low and high tides	Jackson Estuarine Laboratory 85 Adams Pt. Rd. Durham, NH	Dr. Steve Jones (JEL/UNH) 603-862-2175 shj@cisunix.unh.edu
NHDES Shellfish Program	FC	60 – 75 locations near shellfish beds – Great Bay Estuary, Hampton/Seabrook Harbors, Atlantic Coast, Little Harbor	9 – 12 samples per year; approximately monthly sampling	NHDES Shellfish Program 360 Corporate Dr. Pease Tradeport Portsmouth, NH	Chris Nash Shellfish Program Manager 603-430-7900 cnash@des.state.nh.us
GBCW	FC	21 locations in Great Bay Estuary	Monthly sampling from April to November	GBCW, Kingman Farm/UNH Durham, NH	Ann Reid GBCW Coordinator 603-749-1565 ann.reid@unh.edu
NPDES Permit Monitoring	TC FC EC	Coastal WWTFs	Data recorded from DMRs provided by individual WWTFs	NHDES 29 Hazen Drive Concord, NH	Phil Trowbridge NHEP Coastal Scientist 603-271-8872
NHDES – Beach Program	EC EN	18 public beaches	Weekly sampling during open season	NHDES 29 Hazen Drive Concord, NH	Jody Connor NHDES Limnology Center 603-271-3414

Long Term Monitoring Programs	Sample Parameters	Monitoring Locations	Monitoring Frequency	Data Maintenance Location(s)	Contact Information
NHDES Ambient Program	EC EN	40 - 50 sites around Great Bay Estuary watershed	Not performed every year	NHDES 29 Hazen Drive Concord, NH	NHDES Water Division (603) 271-3503
National Coastal Assessment Program	TC FC EC	13 sites in Great Bay and Hampton/Seabrook estuaries	April - December	Jackson Estuarine Laboratory 85 Adams Pt. Rd. Durham, NH	Dr. Steve Jones (JEL/UNH) 603-862-2175 shj@cisunix.unh.edu

Acronyms:

GBNERR: Great Bay National Estuarine Research Reserve

JEL: Jackson Estuarine Laboratory

NHCP: New Hampshire Coastal Program

FC: fecal coliform

EC: *Escherichia coli*

EN: enterococci

TC: total coliform

UNH: University of New Hampshire

NHDES: New Hampshire Department of Environmental Services

GBCW: Great Bay Coast Watch

NPDES: National Pollutant Discharge Elimination System

DMR: daily monitoring report

Table 3. Plant discharge, fecal coliform concentrations, and precipitation totals for high-flow events at the Hampton WWTF for the period of March 1, 2001 to April 30, 2002.

Date	Plant Discharge (MGD)	Fecal Coliform (CFU/100 ml)	1-day precipitation total (in)	3-day precipitation total (in)	5-day precipitation total (in)
3/14/2001	2.61	5	0.1	0.82	1.7
3/22/2001	11.49	2850	4.52	4.52	4.52
3/23/2001	3.2	44	0.67	5.19	5.19
3/24/2001	4.11	15	0	5.19	5.19
3/25/2001	3.43	7	0	0.67	5.19
3/31/2001	4.04	5	0.24	2.02	2.06
4/1/2001	2.9472	13	0	2.02	2.02
8/18/2001	2.62	5	0	0.04	0.04
12/16/2001	2.66	5	0	0.93	0.93
3/27/2002	2.7227	9	0.88	1.34	1.34
3/28/2002	2.59	5	0	1.19	1.34
3/29/2002	2.63	5	0	0.88	1.34
3/30/2002	2.71	ND*	0.11	0.11	1.3
3/31/2002	2.64	5	0	0.11	0.99
4/1/2002	2.9	27	0.88	0.99	0.99
4/2/2002	2.64	5	0	0.88	0.99
4/3/2002	2.63	11	0.1	0.98	1.09
4/4/2002	2.69	5	0.33	0.43	1.31
4/27/2002	2.61	1	0	1.28	1.35
4/28/2002	2.78	1	0.55	1.83	1.83
4/29/2002	2.95	1	0.18	0.73	2.01

*Fecal coliform concentrations were not recorded in the MOR for 3/30/2002

Table 4. Plant discharge, fecal coliform concentrations, and precipitation totals for high flow events at the Dover WWTF for the period of March 1, 2000 to March 31, 2002. (Data for April 2000 were not available)

Date	Plant Discharge (MGD)	Fecal Coliform* (CFU/100 ml)	1-day precipitation total (in)	3-day precipitation total (in)	5-day precipitation total (in)
3/1/2000	4.328	ND	0	0.18	0.21
3/12/2000	5.131	ND	0.6	1.62	1.77
3/13/2000	4.374	ND	0	1.61	1.77
3/17/2000	4.634	ND	0.71	1.03	1.03
3/28/2000	5.71	ND	1.4	1.4	1.4
3/29/2000	4.413	ND	0.1	1.5	1.5
12/17/2000	6.475	2	1.69	1.92	2.57
12/18/2000	4.588	8	0.01	1.92	2.58
3/19/2001	4.596	4	0	0	0
3/20/2001	4.624	8	0	0	0
3/21/2001	5.656	2	0.03	0.03	0.03
3/22/2001	16.8	30.8	4.34	4.37	4.37
3/23/2001	9.283	4	0.13	4.5	4.5
3/24/2001	7.417	8	0	4.47	4.5
3/25/2001	6.196	2	0	0.13	4.5
3/26/2001	5.487	4	0	0	4.47
3/27/2001	5.333	2	0	0	0.13
3/28/2001	4.966	8	0	0	0
3/29/2001	4.969	7	0	0	0
3/30/2001	6.888	8	1.78	1.78	1.78
3/31/2001	6.863	2	0.02	1.8	1.8
4/1/2001	5.56	2	0	1.8	1.8
4/2/2001	4.982	2	0	0.02	1.8
4/3/2001	4.768	9	0	0	1.8
4/4/2001	4.862	4	0	0	0.02
4/5/2001	5.014	2	0	0	0
4/6/2001	4.881	2	0.07	0.07	0.07
4/7/2001	4.649	2	0	0.07	0.07
4/8/2001	4.647	2	0.13	0.2	0.2
4/9/2001	4.733	2	0.06	0.19	0.26
4/10/2001	4.475	2	0	0.19	0.26
4/12/2001	5.016	2	0.53	0.53	0.72
4/13/2001	4.685	2	0.01	0.54	0.6
4/14/2001	4.624	2	0	0.54	0.54
3/26/2002	4.636	2	0.89	1	1
3/27/2002	5.165	11	0.47	1.47	1.47

* ND - Fecal coliform concentrations were not recorded in the MOR for these dates.

Table 5: Summary of WWTF-related discharges, associated causes and result. Data were compiled from NHDES Shellfish Program Inter-Department Communication letters and pager memos maintained by NHDES Shellfish Program.

Date of Occurrence	Shellfish Area(s) Affected	Municipalities involved	Explanation of Occurrence	Event Classification¹	Shellfish Bed Closure
01/01/2000	NA	Seabrook	<ul style="list-style-type: none"> • Overflow of untreated sewage from an unnamed pump station 	Mechanical Failure	No
01/11/ 2000	NA	Exeter	<ul style="list-style-type: none"> • Discharge of 12,000 gallons from Clemson Pond 	ND	No
02/01/2000	NA	Seabrook	<ul style="list-style-type: none"> • Disconnected sewer line 	Infrastructure/ Human Error	No
02/07/2000	NA	Exeter	<ul style="list-style-type: none"> • Discharge of 150 gallons of untreated sewage due to blocked sewer line 	Infrastructure Failure	No
02/14/2000	NA	Exeter	<ul style="list-style-type: none"> • Discharge of 100 gallons of untreated sewage from Clemson Pond 	ND	No
02/15/2000	NA	Exeter	<ul style="list-style-type: none"> • Discharge of 18,000 gallons of untreated sewage from Spring Street CSO 	Mechanical Failure ²	No
03/09/2000	NA	Seabrook	<ul style="list-style-type: none"> • Improperly connected sewer line 	Human Error	No
03/13/2000	NA	Exeter	<ul style="list-style-type: none"> • Discharge of 5,000 gallons of untreated sewage caused by blocked sewer and manhole overflow 	Infrastructure Failure	No
04/12/2000	NA	Seabrook	<ul style="list-style-type: none"> • Blocked sewer line 	Infrastructure Failure	No

Date of Occurrence	Shellfish Area(s) Affected	Municipalities involved	Explanation of Occurrence	Event Classification¹	Shellfish Bed Closure
04/22/2000	Hampton/Seabrook Harbor Great Bay Upper Little Bay Lower Little Bay	Exeter Newmarket Dover	<ul style="list-style-type: none"> Discharge of untreated sewage from collection systems and pump stations 	Weather Event - Rainfall in excess of 3 inches	Yes
04/28/2000	NA	Exeter	<ul style="list-style-type: none"> Discharge of untreated sewage from Clemson Pond CSO and Jay Hill manhole 	Infrastructure/ Mechanical Failure	No
05/15/2000	NA	Seabrook	<ul style="list-style-type: none"> Disconnected sewer line 	Infrastructure/ Human Error	No
07/25/2000	NA	Seabrook	<ul style="list-style-type: none"> Improperly connected sewer line 	Human Error	No
08/10/2000	NA	Seabrook	<ul style="list-style-type: none"> Pump station overflow 	Mechanical Failure ³	No
09/27/2000	NA	Dover	<ul style="list-style-type: none"> Discharge of 4,000 gallons of untreated sewage 	Infrastructure Failure	No
10/03/2000	NA	Seabrook	<ul style="list-style-type: none"> Disconnected sewer line 	Infrastructure Failure	No
11/11/2000	NA	Exeter	<ul style="list-style-type: none"> Discharge of untreated sewage from blocked sewer and manhole overflow 	Infrastructure Failure	No
11/13/2000	Great Bay Upper Little Bay Lower Little Bay	Portsmouth	<ul style="list-style-type: none"> Discharge of partially treated wastewater 	Human Error ⁴	Yes
11/14/2000	NA	Seabrook	<ul style="list-style-type: none"> Improperly connected sewer line 	Human Error	No
11/21/2000	NA	Exeter	<ul style="list-style-type: none"> Discharge of untreated sewage from ruptured sewer line 	Infrastructure Failure	No

Date of Occurrence	Shellfish Area(s) Affected	Municipalities involved	Explanation of Occurrence	Event Classification¹	Shellfish Bed Closure
12/17/2000	NA	Exeter	<ul style="list-style-type: none"> Discharge of untreated sewage from Spring Street CSO 	Weather Event – Rainfall of 1.69 inches	No
12/18/2000	NA	Exeter	<ul style="list-style-type: none"> Discharge of untreated sewage from riverbend manhole and an unnamed CSO 	Weather Event – Related to preceding days rain/snowfall	No
01/06/2001	NA	Hampton	<ul style="list-style-type: none"> Discharge of untreated sewage from broken pipe at plant 	Infrastructure Failure	No
01/19/2001	NA	Seabrook	<ul style="list-style-type: none"> Discharge of untreated sewage due to blocked sewer line 	Infrastructure Failure	No
01/29/2001	NA	Seabrook	<ul style="list-style-type: none"> Discharge of untreated sewage due to blocked sewer line 	Infrastructure Failure	No
02/06/2001	NA	Seabrook	<ul style="list-style-type: none"> Discharge of untreated sewage due to cracker sewer line 	Infrastructure Failure	No
03/22/2001	Hampton/Seabrook Harbor Upper Little Bay Lower Little Bay Atlantic Coast Great Bay	Exeter Newmarket Dover Portsmouth	<ul style="list-style-type: none"> Discharge of untreated sewage from collection systems and pump stations 	Weather Event - Rainfall in excess of 3 inches	Yes
03/27/2001	NA	Exeter	<ul style="list-style-type: none"> Discharge of untreated sewage from Jady Hill manhole and unnamed pump station 	Infrastructure/ Mechanical Failure	No
03/28/2001	NA	Seabrook	<ul style="list-style-type: none"> Discharge of untreated sewage due to cracked sewer line 	Infrastructure Failure	No

Date of Occurrence	Shellfish Area(s) Affected	Municipalities involved	Explanation of Occurrence	Event Classification¹	Shellfish Bed Closure
03/30/2001	NA	Exeter	<ul style="list-style-type: none"> Discharge of untreated sewage from Clemson Pond and unnamed CSOs 	Weather Event – Rainfall of 1.78 inches	No
04/18/2001	Hampton/Seabrook Harbor	Hampton	<ul style="list-style-type: none"> Discharge of approximately 90,000 gallons of untreated sewage from secondary clarifier Discharge of approximately 150,000 gallons of partially treated sewage from outfall pipe. 	Mechanical Failure	Yes
04/19/2001	NA	Seabrook	<ul style="list-style-type: none"> Discharge of untreated sewage due to sewer main rupture 	Infrastructure Failure	No
06/09/2001	NA	Exeter	<ul style="list-style-type: none"> Discharge of untreated sewage from unnamed pump stations 	Mechanical Failure ⁵	No
06/18/2001	Great Bay Upper Little Bay Lower Little Bay	Exeter	<ul style="list-style-type: none"> CSO overflow in excess of 250,000 gallons 	Weather Event – Rainfall of nearly 3 inches	Yes
06/30/2001	NA	Exeter	<ul style="list-style-type: none"> Discharge of untreated sewage from unnamed pump stations 	Mechanical Failure	No
07/10/2001	NA	Exeter	<ul style="list-style-type: none"> Discharge of untreated sewage from Spring Street CSO 	Weather Event/ Infrastructure Failure	No
07/16/2001	NA	Hampton	<ul style="list-style-type: none"> Discharge of effluent with elevated TC concentrations 	Mechanical Failure ⁶	No
07/24/2001	NA	Seabrook	<ul style="list-style-type: none"> Discharge of untreated sewage due to vandalized pump station 	Human Error	No

Date of Occurrence	Shellfish Area(s) Affected	Municipalities involved	Explanation of Occurrence	Event Classification¹	Shellfish Bed Closure
07/24/2001	NA	Hampton	<ul style="list-style-type: none"> Discharge of effluent with elevated TC concentrations 	Mechanical Failure	No
10/17/2001	Great Bay Upper Little Bay Lower Little Bay	Portsmouth	<ul style="list-style-type: none"> Significant discharge of raw sewage from Deer Street pump station (unknown volume) 	Mechanical Failure	Yes
04/14/2002	Great Bay Upper Little Bay Lower Little Bay	Exeter	<ul style="list-style-type: none"> CSO overflow in excess of 140,000 gallons 	Weather Event – Rainfall >2 inches Mechanical Failure	Yes
01/04/2003	None	Dover	<ul style="list-style-type: none"> Flooding of Mill Street pump station due to extremely high tide experienced in the Bellamy River 	NA	No
01/05/2003	Lower Little Bay	Dover	<ul style="list-style-type: none"> Mill Street pump station release of approximately 66,000 gallons of untreated sewage 	Human Error	Yes
01/10/2003	Upper Little Bay Great Bay	Dover	<ul style="list-style-type: none"> Release of approximately 250,000 gallons of untreated sewage from Charles Street pump station 	Mechanical Failure	Yes
02/04/2003	Hampton/Seabrook Harbor	Hampton	<ul style="list-style-type: none"> Discharge of 26,000 gallons of unchlorinated effluent 	Mechanical Failure	Yes
03/21/2003	Great Bay Little Bay	Exeter	<ul style="list-style-type: none"> Intermittent discharge from Spring Street and Water Street CSOs 	Weather Event – Rainfall not reported	Yes

Date of Occurrence	Shellfish Area(s) Affected	Municipalities involved	Explanation of Occurrence	Event Classification¹	Shellfish Bed Closure
03/23/2003	Little Harbor	Portsmouth	<ul style="list-style-type: none"> Discharge of approximately 3.8 million gallons of treated but unchlorinated effluent from the WWTF 	Mechanical Failure Human Error ⁷	Yes
03/31/03	Great Bay Little Bay	Exeter	<ul style="list-style-type: none"> Discharge from Spring Street and Water Street CSOs 	Weather Event – 0.94 inches of rain/snow	Yes ⁸
04/14/2003	NA	Durham	<ul style="list-style-type: none"> Broken 4-inch force main resulting in 6,000 gallons of untreated sewage released 	Infrastructure Failure	No ⁹

Notes:

- ¹: Event classification divided into four categories to describe reason for reporting, including weather events, mechanical failure, infrastructure failure and/or human error.
- ²: It is unclear why this event occurred as no reason was provided, but is assumed to be mechanical in nature.
- ³: Overflow was caused by an electrical failure.
- ⁴: Effluent was not treated as chlorine supply ran out following the Veterans Day holiday.
- ⁵: Assumed to be mechanical failure and/or human error as no extreme weather conditions were reported.
- ⁶: Treatment process failed to decrease coliform concentrations.
- ⁷: Chlorine pumps did not activate (alarms were not recognized by operator resulting in excessive discharge).
- ⁸: Closure already in place and extended.
- ⁹: Closure already in place.

Acronyms:

NA: not applicable

ND: not determined

WWTF: wastewater treatment facility

CSO: combined sewer overflow

Table 6: Regression analysis data obtained from comparisons between bacterial indicator concentrations.

Indicator Comparison^a	N^b	R²-value	Regression Equation^c	p-value
A	29	0.4843	$\log(\text{EC}) = 0.725 (\pm 0.30) * \log(\text{TC}) - 1.0296 (\pm 0.66)$	2.77E-05
B	34	0.4138	$\log(\text{FC}) = 0.691 (\pm 0.30) * \log(\text{TC}) - 0.8567 (\pm 0.65)$	4.07E-05
C	19	0.4246	$\log(\text{EN}) = 0.532 (\pm 0.32) * \log(\text{TC}) - 0.6762 (\pm 0.69)$	0.002505
D	19	0.4929	$\log(\text{EN}) = 0.599 (\pm 0.31) * \log(\text{EC}) - 0.2217 (\pm 0.31)$	0.000805
E	22	0.4269	$\log(\text{EN}) = 0.519 (\pm 0.28) * \log(\text{FC}) - 0.2342 (\pm 0.28)$	0.000976
F	32	0.9592	$\log(\text{EC}) = 0.936 (\pm 0.07) * \log(\text{FC}) - 0.1213 (\pm 0.08)$	2.16E-22

Notes:

^a: Indicator comparison explanation provided in Figure 3 caption.

^b: Indicator comparisons consisted of different sample sizes due to the presence of TNTC and BDL on several sample dates. Comparisons were only made for sample dates that had countable concentrations of bacteria.

^c: Values in parentheses represent standard error.

Acronyms:

FC: fecal coliform

EC: *Escherichia coli*

EN: enterococci

TC: total coliform

Table 7: Monthly sample data from 11 WWTFs for bacterial indicators and nutrients.

Durham WWTF									
Analysis	03/21/02	04/17/02	05/21/02	06/18/02	08/01/02	08/21/02	09/18/02	11/25/02	12/19/02
EC	101	BDL ¹	BDL ²	5	1.5	30	1	2	BDL ⁵
FC	NA	BDL ¹	BDL ²	7	2	32.5	1.5	2.5	BDL ⁵
EN	NA	3	BDL ²	BDL ⁴	10	TNTC	2	BDL ⁵	BDL ⁵
TC	210	NA	90	55	100	150	185	185	40
TDN (mg N/L)	NA	16.64	15.00	16.86	13.55	15.26	18.95	ND	NS
NO ₃ ⁻ (mg N/L)	NA	5.60	17.82	12.72	4.49	2.30	10.88	5.98	NS
NH ₄ ⁺ (mg N/L)	NA	11.55	1.22	2.59	9.40	10.89	5.28	0.87	NS
DON (mg N/L)	NA	BDL ⁶	BDL ⁶	1.54	BDL ⁶	2.06	8.07	BDL ⁶	NS
DOC (mg C/L)	NA	12.89	7.88	10.49	8.44	15.41	16.42	11.95	NS
Dover WWTF									
Analysis	03/21/02	04/17/02	05/22/02	06/19/02	08/07/02	08/21/02	09/19/02	11/25/02	12/19/02
EC	6	2	BDL ²	4	2.5	15	0.5	10.5	5.5
FC	NA	3	2	7	3	64.5	1	11.5	9.5
EN	NA	15	BDL ²	BDL ⁴	6.5	3.5	1.5	1	7.5
TC	30	NA	95	15	100	TNTC	35	215	175
TDN (mg N/L)	NA	17.43	4.97	16.26	22.55	20.15	21.29	15.64	NS
NO ₃ ⁻ (mg N/L)	NA	1.89	5.45	8.57	10.00	10.43	3.12	0.63	NS
NH ₄ ⁺ (mg N/L)	NA	17.80	0.00	10.97	11.11	9.58	10.97	7.66	NS
DON (mg N/L)	NA	BDL ⁶	BDL ⁶	BDL ⁶	BDL ⁶	BDL ⁶	18.16	15.00	NS
DOC (mg C/L)	NA	13.25	5.60	5.07	9.07	14.20	14.58	14.00	NS

Exeter WWTF

Analysis	03/21/02	04/18/02	05/21/02	06/18/02	08/07/02	08/20/02	09/18/02	11/25/02	12/19/02
EC	ND	BDL ¹	BDL ²	BDL ⁴	3	BDL ⁵	BDL ⁵	373	BDL ⁵
FC	NA	BDL ¹	BDL ²	BDL ⁴	3	BDL ⁵	BDL ⁵	400	BDL ⁵
EN	NA	BDL ¹	BDL ²	BDL ⁴	3.5	0.5	BDL ⁵	52	0.5
TC	400	NA	130	55	130	BDL ³	BDL ³	6000	0
TDN (mg N/L)	NA	12.86	11.68	16.00	16.61	13.16	10.76	14.24	NS
NO ₃ ⁻ (mg N/L)	NA	3.09	2.38	4.49	3.13	5.29	8.21	2.76	NS
NH ₄ ⁺ (mg N/L)	NA	5.00	11.76	13.00	13.87	9.00	1.16	8.99	NS
DON (mg N/L)	NA	4.77	BDL ⁶	0.00	BDL ⁶	BDL ⁶	2.54	11.47	NS
DOC (mg C/L)	NA	10.63	10.31	14.11	9.72	13.07	22.30	23.48	NS

Hampton WWTF

Analysis	03/21/02	04/17/02	05/22/02	06/18/02	08/01/02	08/20/02	09/18/02	11/25/02	12/19/02
EC	NA	BDL ¹	BDL ²	6	BDL ⁵	BDL ⁵	2.5	2	0.5
FC	NA	1	BDL ²	13	1	0.5	3	2.5	1
EN	NA	BDL ¹	BDL ²	BDL ⁴	1.5	1.5	1	1.5	BDL ⁵
TC	NA	NA	10	140	5	430	65	260	30
TDN (mg N/L)	NA	16.61	17.63	10.61	18.83	28.10	25.05	17.47	NS
NO ₃ ⁻ (mg N/L)	NA	12.10	15.01	4.66	15.08	7.53	22.28	14.87	NS
NH ₄ ⁺ (mg N/L)	NA	0.01	0.02	0.01	0.04	0.05	0.86	1.74	NS
DON (mg N/L)	NA	4.50	2.60	5.94	3.71	20.52	BDL ⁶	BDL ⁶	NS
DOC (mg C/L)	NA	8.28	4.15	3.72	6.61	4.15	15.42	12.34	NS

Kittery WWTF

Analysis	03/21/02	04/17/02	05/22/02	06/20/02	08/01/02	08/21/02	09/19/02	11/25/02	12/19/02	4/17/03
EC	NS	NS	BDL ²	1	13	52	14	NS	295	265
FC	NS	NS	BDL ²	1	31.5	115	18	NS	300	425
EN	NS	NS	BDL ²	BDL ⁴	BDL ⁵	BDL ⁵	4.5	NS	149	200
TC	NS	NS	625	690	1100	940	265	NS	TNTC	5125
TDN (mg N/L)	NS	NS	14.94	9.23	8.60	6.91	3.42	NS	NS	NS
NO ₃ ⁻ (mg N/L)	NS	NS	6.67	5.93	3.06	3.33	5.90	NS	NS	NS
NH ₄ ⁺ (mg N/L)	NS	NS	12.45	1.38	0.06	0.04	0.96	NS	NS	NS
DON (mg N/L)	NS	NS	BDL ⁶	1.92	5.49	3.53	BDL ⁶	NS	NS	NS
DOC (mg C/L)	NS	NS	8.42	6.19	5.79	8.26	11.64	NS	NS	NS

Newington WWTF

Analysis	03/21/02	04/17/02	05/22/02	06/19/02	08/01/02	08/21/02	09/18/02	11/25/02	12/19/02
EC	ND	BDL ¹	BDL ²	BDL ⁴	BDL ⁵	BDL ⁵	0.5	BDL ⁵	0.5
FC	NA	BDL ¹	BDL ²	2	BDL ⁵	BDL ⁵	0.5	BDL ⁵	0.5
EN	NA	2	38	BDL ⁴	1.5	BDL ⁵	2	BDL ⁵	0.5
TC	84	NA	BDL ³	40	20	BDL ³	40	60	20
TDN (mg N/L)	NA	21.79	15.61	19.28	14.90	1.99	3.87	15.58	NS
NO ₃ ⁻ (mg N/L)	NA	0.16	6.43	11.34	0.34	0.72	2.29	0.86	NS
NH ₄ ⁺ (mg N/L)	NA	21.30	10.72	7.54	13.37	0.14	0.98	15.72	NS
DON (mg N/L)	NA	0.33	BDL ⁶	0.40	BDL ⁶	1.14	1.58	14.70	NS
DOC (mg C/L)	NA	22.93	9.93	10.30	9.62	10.42	18.32	20.79	NS

Newfields WWTF

Analysis	03/21/02	04/18/02	05/21/02	06/19/02	08/07/02	08/21/02	09/18/02	11/25/02	12/19/02
EC	NS	BDL ¹	BDL ²	BDL ⁴	NS	NS	BDL ⁵	NS	NS
FC	NS	BDL ¹	BDL ²	BDL ⁴	NS	NS	BDL ⁵	NS	NS
EN	NA	11	BDL ²	BDL ⁴	NS	NS	BDL ⁵	NS	NS
TC	NS	NA	BDL ³	2055	NS	NS	20	NS	NS
TDN (mg N/L)	NA	16.71	14.05	16.89	NS	NS	NA	NS	NS
NO ₃ ⁻ (mg N/L)	NA	7.83	3.64	2.21	NS	NS	NA	NS	NS
NH ₄ ⁺ (mg N/L)	NA	9.29	15.63	18.29	NS	NS	NA	NS	NS
DON (mg N/L)	NA	BDL ⁶	BDL ⁶	BDL ⁶	NS	NS	NA	NS	NS
DOC (mg C/L)	NA	10.39	9.80	9.60	NS	NS	NA	NS	NS

Newmarket WWTF

Analysis	03/21/02	04/18/02	05/21/02	06/18/02	08/07/02	08/21/02	09/18/02	11/25/02	12/19/02
EC	36	BDL ¹	BDL ²	2	BDL ⁵	TNTC	3.5	BDL ⁵	BDL ⁵
FC	NA	BDL ¹	BDL ²	6	0.5	TNTC	6	BDL ⁵	BDL ⁵
EN	NA	BDL ¹	BDL ²	BDL ⁴	6	13.5	24.5	BDL ⁵	0.5
TC	761	NA	316	70	70	620	1165	255	70
TDN (mg N/L)	NA	20.46	18.60	10.66	12.21	17.31	19.06	13.65	NS
NO ₃ ⁻ (mg N/L)	NA	4.79	2.59	0.06	5.38	5.80	3.90	1.49	NS
NH ₄ ⁺ (mg N/L)	NA	11.54	18.30	16.99	6.87	8.04	14.88	10.54	NS
DON (mg N/L)	NA	4.13	BDL ⁶	BDL ⁶	BDL ⁶	3.47	15.15	12.16	NS
DOC (mg C/L)	NA	20.91	10.25	15.15	15.38	16.81	22.95	22.56	NS

Portsmouth WWTF

Analysis	03/21/02	04/17/02	05/22/02	06/19/02	08/01/02	08/21/02	09/18/02	11/25/02	12/19/02
EC	220	BDL ¹	BDL ²	BDL ⁴	BDL ⁵	34	0.5	0.5	BDL ⁴
FC	NA	5	BDL ²	6	BDL ⁵	81	0.5	0.5	BDL ⁴
EN	NA	BDL ¹	16	BDL ⁴	BDL ⁵	BDL ⁵	BDL ⁵	BDL ⁵	BDL ⁴
TC	410	NA	185	245	285	1110	80	5	40
TDN (mg N/L)	NA	16.54	7.05	11.07	16.88	18.83	21.40	16.01	NS
NO ₃ ⁻ (mg N/L)	NA	0.23	0.17	0.00	0.03	0.03	0.68	0.22	NS
NH ₄ ⁺ (mg N/L)	NA	14.04	8.73	9.85	11.87	10.61	19.84	11.29	NS
DON (mg N/L)	NA	2.27	BDL ⁶	1.22	4.97	8.18	20.69	15.78	NS
DOC (mg C/L)	NA	36.54	12.09	16.91	25.63	67.07	57.35	43.37	NS

South Berwick WWTF

Analysis	03/21/02	04/17/02	05/22/02	06/19/02	08/07/02	08/21/02	09/19/02	11/25/02	12/19/02
EC	NS	NS	NS	BDL ⁴	BDL ⁵	BDL ⁵	NS	NS	BDL ⁵
FC	NS	NS	NS	BDL ⁴	BDL ⁵	BDL ⁵	NS	NS	BDL ⁵
EN	NS	NS	NS	BDL ⁴	BDL ⁵	BDL ⁵	NS	NS	BDL ⁵
TC	NS	NS	NS	5.00	5	BDL ³	NS	NS	40
TDN (mg N/L)	NS	NS	NS	8.89	8.51	5.64	NS	NS	NS
NO ₃ ⁻ (mg N/L)	NS	NS	NS	3.06	2.98	3.04	NS	NS	NS
NH ₄ ⁺ (mg N/L)	NS	NS	NS	8.12	3.81	2.21	NS	NS	NS
DON (mg N/L)	NS	NS	NS	BDL ⁶	1.72	BDL ⁶	NS	NS	NS
DOC (mg C/L)	NS	NS	NS	4.03	8.32	11.84	NS	NS	NS

Seabrook WWTF

Analysis	03/21/02	04/17/02	05/22/02	06/18/02	08/01/02	08/20/02	9/18/02	11/25/02	12/19/02
EC	ND	BDL ¹	BDL ²	BDL ⁴	BDL ⁵	BDL ⁵	2.5	1	BDL ⁵
FC	NA	1	BDL ²	BDL ⁴	BDL ⁵	BDL ⁵	3	2	BDL ⁵
EN	NA	BDL ¹	BDL ²	BDL ⁴	BDL ⁵	BDL ⁵	0.5	0.5	BDL ⁵
TC	4	NA	5	BDL ³	BDL ³	BDL ³	15	175	5
TDN (mg N/L)	19.1	12.34	16.46	1.34	5.19	10.53	7.46	11.05	NS
NO ₃ ⁻ (mg N/L)	6.02	8.21	14.12	0.20	6.42	6.49	9.19	8.74	NS
NH ₄ ⁺ (mg N/L)	17	0.015	1.94	0.56	0.01	0.01	0.003	0.803	NS
DON (mg N/L)	13.06	4.12	0.40	0.58	BDL ⁶	4.03	BDL ⁶	2.314	NS
DOC (mg C/L)	6.84	7.54	9.45	5.89	7.40	4.79	11.843	12.522	NS

Notes and acronyms:

¹ < 1.5 CFUs per 100 ml

² < 2 CFUs per 100 ml

³ < 5 CFUs per 100 ml

⁴ < 1 CFUs per 100 ml

⁵ < 0.5 CFUs per 100 ml

⁶ DON values below 10% detection limit

EC - Escherichia coli per 100 ml; FC - fecal coliform per 100 ml; EN - enterococci per 100 ml; TC - total coliform per 100 ml

TDN - total dissolved nitrogen; NO₃⁻ - nitrate; NH₄⁺ - ammonium; DON - dissolved organic nitrogen

DOC - dissolved organic carbon; NA - not analyzed; NS - not sampled; ND - not determined; BDL - below detection limit

TNTC: too numerous to count

Table 8: One-day intensive sampling study at Newmarket (A) and Durham (B) WWTFs (August 22, 2002).

A. Newmarket WWTF				
Analysis	Time			
	0915	1100	1300	1500
EC	TNTC ³	TNTC ³	BDL ¹	0.5
FC	TNTC ³	TNTC ³	0.5	2.5
EN	BDL ¹	BDL ¹	4.0	2.5
TC	TNTC ⁴	1,350.0	45.0	15.0
TDN	15.24	16.32	20.86	15.95
NO3-N	5.12	4.66	2.93	2.70
NH4-N	5.95	8.94	9.51	7.85
DON	4.17	2.72	8.42	5.40
DOC	15.78	23.17	11.63	17.32

B. Durham WWTF				
Analysis	Time			
	0910	1100	1300	1500
EC	13.0	2.5	TNTC ³	TNTC ³
FC	34.5	3.0	TNTC ³	TNTC ³
EN	2.0	BDL ¹	BDL ¹	1.0
TC	2,280.0	245.0	860.0	1,015.0
TDN	13.34	8.72	15.63	15.79
NO3-N	0.46	0.58	0.36	0.29
NH4-N	9.93	8.95	9.73	10.94
DON	2.95	BDL ²	5.54	4.56
DOC	10.36	11.53	13.90	10.20

Notes and Acronyms:

¹: < 0.5 cfu per 100 ml

²: DON values below 10% detection limit

³: > 250 cfu per 100 ml

⁴: > 2500 cfu per 100 ml

EC: *Escherichia coli*

FC: fecal coliform

EN: enterococci

TC: total coliform

NA: not analyzed

NS: not sampled

ND: not determined

BDL: below detection limit

TNTC: too numerous to count

Table 9: One-day intensive study at Newmarket (A) and Durham (B) WWTFs (April 25, 2003).

A. Newmarket WWTF				
Analysis	Time			
	0905	1100	1300	1500
EC	BDL ¹	BDL ¹	BDL ¹	BDL ¹
FC	BDL ¹	BDL ¹	BDL ¹	BDL ¹
EN	BDL ¹	BDL ¹	BDL ¹	BDL ¹
TC	12	19	17	17

B. Durham WWTF				
Analysis	Time			
	0850	1050	1250	1450
EC	10	4	1	1
FC	22	4	BDL ¹	BDL ¹
EN	21	BDL ¹	BDL ¹	BDL ¹
TC	290	37	35	68

Notes and Acronyms:

¹: < 0.5 cfu per 100 ml

EC: *Escherichia coli*

FC: fecal coliform

EN: enterococci

TC: total coliform

BDL: below detection limit

Table 10: Five-day intensive sampling a Newmarket (A) and Durham (B) WWTFs (August 19, 2002 through August 23, 2002).

A. Newmarket WWTF					
Analysis	Date				
	08/19/02	08/20/02	08/21/02	08/22/02	08/23/02
EC	BDL ¹	2.5	TNTC	TNTC	BDL ¹
FC	BDL ¹	2.5	TNTC	TNTC	BDL ¹
EN	19.5	5.5	13.5	BDL ¹	1.0
TC	45.0	35.0	620.0	1,350.0	40.0
TDN	15.71	17.76	17.31	16.32	11.87
NO3-N	6.09	5.99	5.80	4.66	5.58
NH4-N	10.05	9.28	8.04	8.94	6.18
DON	BDL ²	2.49	3.47	2.72	0.10
DOC	10.31	16.87	16.81	23.17	15.40

B. Durham WWTF					
Analysis	Date				
	08/19/02	08/20/02	08/21/02	08/22/02	08/23/02
EC	2.0	14.5	30.0	3.0	6.5
FC	2.0	16.5	32.5	3.0	8.0
EN	8.0	16.5	TNTC	BDL ¹	BDL ¹
TC	135.0	50.0	150.0	245.0	125.0
TDN	11.20	12.46	15.26	8.72	15.79
NO3-N	5.74	4.12	2.30	0.58	0.30
NH4-N	5.03	6.75	10.89	8.95	13.44
DON	BDL ²	1.59	2.06	BDL ³	2.04
DOC	10.03	8.21	15.41	11.53	14.14

Notes and Acronyms:

¹: < 0.5 cfu per 100 ml

²: DON values below 10% detection limit

EC: *Escherichia coli*

FC: fecal coliform

EN: enterococci

TC: total coliform

NA: not analyzed

NS: not sampled

ND: not determined

BDL: below detection limit

TNTC: too numerous to count

Table 11: Estimated annual nutrient loading from WWTF effluent.

WWTF Identification	Nutrient Constituent ^{1,2}				
	TDN	NO ₃ ⁻ -N	NH ₄ ⁺ -N	DON	DOC
Durham (n=7) ³	20.37	13.79	8.34	2.42	17.98
Dover (n=7)	61.24	20.56	35.86	17.30	40.16
Exeter (n=7)	24.50	7.10	18.00	2.73	24.20
Hampton (n=7)	77.41	51.24	1.31	23.50	29.78
Kittery (n=7)	13.47	7.79	5.43	2.79	12.04
Newington (n=7)	2.15	0.52	1.62	0.40	2.37
Newmarket (n=7)	16.58	3.53	12.90	4.90	17.90
Portsmouth (n=7)	104.90	1.32	85.20	49.99	247.00
South Berwick (n=3)	3.14	1.25	2.02	0.19	3.25
Seabrook (n=8)	17.33	12.11	4.60	5.30	13.40
Estimated Annual WWTF Nutrient Loading	341.10 (±10.90) ⁴	119.21 (±7.88)	175.28 (±9.73)	109.51 (±11.86)	408.09 (±13.25)

Notes:

- ¹: Values are expressed in tons per year.
- ²: Below detection values obtained during sampling events were changed to 0 in order to calculate an average loading value for each constituent.
- ³: Values in parentheses indicate the number of samples used to determine nutrient loading.
- ⁴: Values in parentheses represent the standard error for the estimated nutrient loading to the NH Seacoast in tons per year.

Table 12: Nutrient-loading data collected during one and five day sampling events at Newmarket and Durham. Values are expressed in pounds per day.

Time	Newmarket 1-Day Intensive Study					Durham 1-Day Intensive Study				
	TDN	NO ₃	NH ₄	DON	DOC	TDN	NO ₃	NH ₄	DON	DOC
900	83.92	28.21	32.74	22.96	86.89	60.11	2.06	44.74	13.31	46.68
1100	89.89	25.69	49.24	14.97	127.63	39.28	2.62	40.33	0.00	51.94
1300	114.90	16.15	52.39	46.35	64.05	70.41	1.61	43.86	24.95	62.63
1500	87.82	14.85	43.24	29.73	95.38	71.15	1.29	49.31	20.55	45.98
Daily Average	94.13	21.22	44.40	28.51	93.49	60.24	1.90	44.56	14.70	51.81
Date	Newmarket 5-Day Intensive Study					Durham 5-Day Intensive Study				
	TDN	NO ₃	NH ₄	DON	DOC	TDN	NO ₃	NH ₄	DON	DOC
08/19/02	86.51	33.52	55.36	0.00	56.76	51.38	26.36	23.09	0.00	46.03
08/20/02	93.34	31.47	48.77	13.10	88.70	71.75	23.72	38.87	9.16	47.26
08/21/02	95.34	31.96	44.26	19.13	92.55	86.59	13.08	61.80	11.71	87.45
08/22/02	89.89	25.69	49.24	14.97	127.63	39.28	2.62	40.33	0.00	51.94
08/23/02	62.38	29.36	32.51	0.51	80.98	63.24	1.21	53.85	8.18	56.65
Weekly Average	85.50	30.40	46.03	9.54	89.32	62.45	13.40	43.59	5.81	57.87

Table 13: Estimated in-stream bacterial indicator concentrations (cfu per 100 ml) following discharge from WWTF to receiving waters. All values were below NH surface water standards¹.

Durham WWTF

Analysis	03/21/02	04/17/02	05/21/02	06/18/02	08/01/02	08/21/02	09/18/02	11/25/02	12/19/02	4/17/03
EC	41.94	BDL	BDL	2.08	0.63	12.50	0.42	0.83	BDL	NS
FC	NA	BDL	BDL	2.92	0.83	13.54	0.63	1.04	BDL	NS
EN	NA	1.25	BDL	BDL	4.17	CND ²	0.83	BDL	BDL	NS
TC	87.50	NA	37.50	22.92	41.67	62.50	77.08	77.08	16.67	NS

Dover WWTF

Analysis	03/21/02	04/17/02	05/22/02	06/19/02	08/07/02	08/21/02	09/19/02	11/25/02	12/19/02	4/17/03
EC	0.06	0.02	BDL	0.04	0.02	0.15	0.00	0.10	0.05	NS
FC	NA	0.03	0.02	0.07	0.03	0.64	0.01	0.11	0.09	NS
EN	NA	0.15	BDL	BDL	0.06	0.03	0.01	0.01	0.07	NS
TC	0.30	NA	0.94	0.15	0.99	CND ²	0.35	2.13	1.73	NS

Exeter WWTF

Analysis	03/21/02	04/18/02	05/21/02	06/18/02	08/07/02	08/20/02	09/18/02	11/25/02	12/19/02	4/17/03
EC	BDL	BDL	BDL	BDL	0.11	BDL	BDL	14.24	BDL	NS
FC	NA	BDL	BDL	BDL	0.11	BDL	BDL	15.27	BDL	NS
EN	NA	BDL	BDL	BDL	0.13	0.02	BDL	1.98	0.02	NS
TC	15.27	NA	4.96	2.10	4.96	BDL	BDL	229.01	BDL	NS

Hampton WWTF

Analysis	03/21/02	04/17/02	05/22/02	06/18/02	08/01/02	08/20/02	09/18/02	11/25/02	12/19/02	4/17/03
EC	NA	BDL	BDL	6.00	BDL	BDL	2.50	2.00	0.50	NS
FC	NA	1.00	BDL	13.00	1.00	0.50	3.00	2.50	1.00	NS
EN	NA	BDL	BDL	BDL	1.50	1.50	1.00	1.50	BDL	NS
TC	NA	NA	10.00	140.00	5.00	430.00	65.00	260.00	30.00	NS

Kittery WWTF

Analysis	03/21/02	04/17/02	05/22/02	06/20/02	08/01/02	08/21/02	09/19/02	11/25/02	12/19/02	4/17/03
EC	NS	NS	BDL	0.02	0.20	0.80	0.22	NS	4.54	4.08
FC	NS	NS	BDL	0.02	0.48	1.77	0.28	NS	4.62	6.54
EN	NS	NS	BDL	BDL	BDL	BDL	0.07	NS	2.29	3.08
TC	NS	NS	9.62	10.62	16.92	14.46	4.08	NS	CND ²	78.85

Newington WWTF

Analysis	03/21/02	04/17/02	05/22/02	06/19/02	08/01/02	08/21/02	09/18/02	11/25/02	12/19/02	4/17/03
EC	BDL	BDL	BDL	BDL	BDL	BDL	0.00	BDL	0.00	NS
FC	NA	BDL	BDL	0.02	BDL	BDL	0.00	BDL	0.00	NS
EN	NA	0.02	0.38	BDL	0.01	BDL	0.02	BDL	0.00	NS
TC	0.83	NA	BDL	0.40	0.20	BDL	0.40	0.59	0.20	NS

Newmarket WWTF

Analysis	03/21/02	04/18/02	05/21/02	06/18/02	08/07/02	08/21/02	09/18/02	11/25/02	12/19/02	4/17/03
EC	0.64	BDL	BDL	0.04	BDL	CND ²	0.06	BDL	BDL	NS
FC	NA	BDL	BDL	0.11	0.01	CND ²	0.11	BDL	BDL	NS
EN	NA	BDL	BDL	BDL	0.11	0.24	0.44	BDL	0.01	NS
TC	13.60	NA	5.64	1.25	1.25	11.07	20.80	4.55	1.25	NS

Portsmouth WWTF

Analysis	03/21/02	04/17/02	05/22/02	06/19/02	08/01/02	08/21/02	09/18/02	11/25/02	12/19/02	4/17/03
EC	4.31	BDL	BDL	BDL	BDL	0.67	0.01	0.01	BDL	NS
FC	NA	0.10	BDL	0.12	BDL	1.59	0.01	0.01	BDL	NS
EN	NA	BDL	0.31	BDL	BDL	BDL	BDL	BDL	BDL	NS
TC	8.04	NA	3.63	4.80	5.59	21.76	1.57	0.10	0.78	NS

South Berwick WWTF

Analysis	03/21/02	04/17/02	05/22/02	06/19/02	08/07/02	08/21/02	09/19/02	11/25/02	12/19/02	4/17/03
EC	NS	NS	NS	BDL	BDL	BDL	NS	NS	BDL	NS
FC	NS	NS	NS	BDL	BDL	BDL	NS	NS	BDL	NS
EN	NS	NS	NS	BDL	BDL	BDL	NS	NS	BDL	NS
TC	NS	NS	NS	0.12	0.12	BDL	NS	NS	0.93	NS

Seabrook WWTF

Analysis	03/21/02	04/17/02	05/22/02	06/18/02	08/01/02	08/20/02	9/18/02	11/25/02	12/19/02	4/17/03
EC	BDL	BDL	BDL	BDL	BDL	BDL	0.03	0.01	BDL	NS
FC	NA	0.01	BDL	BDL	BDL	BDL	0.04	0.02	BDL	NS
EN	NA	BDL	BDL	BDL	BDL	BDL	0.01	0.01	BDL	NS
TC	0.05	NA	0.06	BDL	BDL	BDL	0.18	2.08	0.06	NS

Notes and Acronyms:

¹ Values were compared to NH surface water MCL standards as follows: 88 *E. coli*/100ml for Freshwater A Beach; 104 enterococci/100ml for tidal recreational waters; and >43 fecal coliforms/100ml for approved shellfish harvesting area. No standards are available for total coliforms.

² Value reported was TNTC following sampling.

NA: not analyzed

NS: not sampled

BDL: below detection limit

CND: could not be determined

EC: *E. coli* per 100 ml

FC: fecal coliform per 100 ml

EN: enterococci per 100 ml

TC: total coliform per 100 ml

Table 14: Sewer infrastructure details according to town indicating the number and location of pump stations and combined sewer overflows for each town.

Town	Contact Information	No. of PSTs	Location of PSTs	No. of CSOs	Location of CSOs	Future Plans
Durham	Max Driscoll Durham WWTF Chief Operator 868-2274	3	<ul style="list-style-type: none"> • Dover Rd. (Route 108) • Old Concord Rd. • Oyster River Rd. 	0	NA	Miscellaneous Projects
Dover	Dean Peschel City of Dover Environmental Project Manager 516-6094	20	<ul style="list-style-type: none"> • Leighton • Wentworth • Boston Harbor • Varney • Spruce Lane • Mosl Rd. • Crosby • Middle School • Charles • Mill Street • Brickyard • Mt. Pleasant • River Street • Coheco River • Hampshire • Watson • Country Farm • Clay Hill • Cran Brook • Strafford Farms 	0	NA	Upgrade Charles St. PST, Upgrade UV system at WWTF (2004), Upgrade discharge outlet structure (2003), and SCADA system distribution completion.

Town	Contact Information	No. of PSTs	Location of PSTs	No. of CSOs	Location of CSOs	Future Plans
Exeter	Scott Butler Exeter WWTF Chief Operator 773-6157	9	<ul style="list-style-type: none"> • 279 Water St. • 9 River Woods Dr. • 109 Court St. • 19 Colcord Pond Dr. • 16 Langdon Ave. • 21 Webster Ave. • 2 Westside Dr. • 38A Riverbend Cr. • 1 Prentise Wy. 	2	<ul style="list-style-type: none"> • End of Spring Street and Water Street • 277 Water Street 	Maintenance as needed
Hampton	Dave Spainhower Hampton DPW 926-3202	8	<ul style="list-style-type: none"> • Highlands • Merritt Indus Dr. • High Street West • High Street East • Kingshighway • Winnucunnet Rd. • Church Street • Campton Street 	0	NA	Sewer system upgrades

Town	Contact Information	No. of PSTs	Location of PSTs	No. of CSOs	Location of CSOs	Future Plans
Seabrook	Phil Maltais Seabrook WWTF Chief Operator 474-8012	19	<ul style="list-style-type: none"> • 61 B Street • 56 Dows Lane • 156 Batchelder Rd. • 356A Walton Road • 61 Causeway Street • 31 Worthley Ave. • 24 Mill Lane • 15 Riley Road • 34 Stard Road • 82 Ledge Road • 23 Folly Mill Terr. • 30 Old New Boston Road • 657 Ocean Blvd. • River Street • River Street • 265 Route 107 • 70 Rocks Road • 447 Route 286 • 31 Centennial Street 	0	NA	No plans; maintenance as needed
Newington	Denis Messier Newington WWTF Plant Operator 431-4111	2	<ul style="list-style-type: none"> • Paul Brook behind Simplex • River Road 	0	NA	No plans at this time. Proposals to flush and video system likely.

Town	Contact Information	No. of PSTs	Location of PSTs	No. of CSOs	Location of CSOs	Future Plans
Newmarket	Ron Bloom Newmarket WWTF Technician 659-8810	4	<ul style="list-style-type: none"> • Packers Fall Road • Cedar Street • Salmon Street • Bay Road 	0	NA	Upgrade of old sewer infrastructure; Dover Road
Newfields	Peter Helfach Newfields WWTF Chief Operator 778-8213	2	<ul style="list-style-type: none"> • Piscassic Road • Swamscott Road 	0	NA	Maintenance as needed
Portsmouth	Paula Annia Portsmouth WWTF Chief Operator 427-1553	20	<ul style="list-style-type: none"> • Atlantic Ave. • Constitution Dr. • Deer St. • Gosling Rd. • Griffin Pk. • Heritage Rd. • Lafayette Rd. • Leslie Dr. • Marcy St. • Marsh Ln. • Mechanic St. • Mill Pond Wy. • Northwest • Rye Ln. • Tucker's Cove 	3	<ul style="list-style-type: none"> • South Mill Pond • River by Salt Pile 	Separation of storm water system from sewer system and pump station upgrades.

Town	Contact Information	No. of PSTs	Location of PSTs	No. of CSOs	Location of CSOs	Future Plans
			<ul style="list-style-type: none"> • West Rd. • Woodlands I • Woodlands II • Corporate Rd. • Brackett Rd (under construction) 			

Town	Contact Information	No. of PSTs	Location of PSTs	No. of CSOs	Location of CSOs	Future Plans
Kittery	Steve Tapley Kittery WWTF Chief Operator 207-439-4646	21	<ul style="list-style-type: none"> • Trefethen Ave. • Williams Ave • Stoddard St. • Water St. • Rice Ave. • Oak Terrace • Dennett Rd. • Mill Pond Rd. • Moore St. • Rogers Rd. Ext. • Sterling Rd. • Badgers Island • Route 1 across from Ox Point Dr. • Eliot Rd. • Adams Ln. • Whipple Rd. • Tilton Ave. • Old Ferry Ln. • Newson Ave. • Rose Ln. • Rte. 1 just prior to Haley Rd. 	3	<ul style="list-style-type: none"> • Moore St. • Corner of Pleasant St. and Water St. • Rice Ave. 	Extensions of sewer infrastructure northeast of Back Channel and Piscataqua River and north of Interstate 95. Maintenance as needed, including televising sewer lines.

Town	Contact Information	No. of PSTs	Location of PSTs	No. of CSOs	Location of CSOs	Future Plans
South Berwick	Harold (Skip) S. Berwick WWTF Chief Operator 207-384-0091	6	<ul style="list-style-type: none"> • Beaver Dam Rd. • Marshwood High School Rt. 236 • Old Mill Rd. • Quarry Dr. • Academy St./ Brattle St. • Liberty Street 	0	NA	Reconstruction of sewers on Berwick Rd., Grant St., Park St., Webster St., and Pleasant St. in the next 3 to 5 years.

Acronyms:

WWTF: wastewater treatment facility

PST: pump station

CSO: combined sewer overflow

NA: not applicable

Table 15. Sewer infrastructure attributes for each municipality.

Durham, NH	Buffer Width		Crossing Description
	River (Age of Infrastructure)	150 ft	
Oyster River (1955) ^a	5,173	10,048	1 at Beards Creek/Dover Road
College Brook (1948)	9,640	15,529	1 at north of where Main Street crossed College Brook 2 in College Woods north of utility road 7 before and after College Road 2 north of Mill Road (underground) 2 before Mill Pond Road
Reservoir Brook (1948)	7,598	14,390	1 north of Edgewood Road 11 prior to entering Beards Creek
Littlehole Creek (1965)	6,661	8,078	1 at headwaters 4 north of Edgewood Road 1 north of Bagdad Road 4 north of entering Beard Creek
Beards Creek (1965)	5,231	7,455	4 in the ponded section of Beards Creek before entering Oyster River 1 at Bagdad Road
Total Infrastructure Length (ft)	34,303	55,500	
Total Infrastructure Length (miles)	6.5	10.5	
Total Number of Crossings	42		

Notes:

^a: Infrastructure type includes PVC, transite and/or clay along the associated waterbodies.

^b: A 1.73 acre oyster bed is located 3,000 feet from nearest sewer infrastructure and 6,000 feet from the nearest infrastructure river crossing. More extensive networks of oyster and clam beds are 14,000 feet downstream from infrastructure.

Dover, NH	Buffer Width		Crossing Description
	River (Age of Infrastructure)	150 ft	
Jackson Brook (1992) ^a	300	716	1 at Country Farm Road
Indian Brook (1992)	1,737	3,018	1 at Sixth Street
Berry Brook (2002)	4,730	9,908	9 crossings along length of the brook, including: 2 at Sixth Street, 1 at Hough Street, 1 at Ash Street, 1 at Roosevelt Avenue
Unnamed Tributary #1 of Cocheco River (1973)	1,847	4,777	1 west of Spaulding Turnpike 1 at Washington Street 1 at Fourth Street
Unnamed Tributary #2 of Cocheco River (1973)	3,171	6,761	4 crossings along length of the tributary
Cocheco River (1973)	18,079	34,777	10 along length of river through downtown area
Unnamed Tributary #1 of Bellamy River (1973)	2,542	5,317	6 crossings along length of tributary
Knox Marsh Brook (1973)	529	1,007	1 crossing at Knox Marsh Road
Unnamed Tributary #2 of Bellamy River (1973)	509	1,957	1 after Knox Marsh Road
Varney Brook (1973)	9,913	20,577	12 crossings along length of brook - double piping along majority of brook
Canney Brook (1973)	5,780	6,882	1 crossing at Middle Road
Unnamed Tributary #3 of Bellamy River (1970)	1,810	3,912	1 at Garrison Road 1 down stream of Garrison Road
Unnamed Tributary #4 of Bellamy River (1970)	0	355	none
Bellamy River (1973; 1991 ^b)	12,227	23,288	1 at Durham Road 1 before end of first impoundment on the Bellamy River

Dover, NH River (Age of Infrastructure)	Buffer Width		Crossing Description
	150 ft	300 ft	
			1 at Bellamy Road
Piscataqua River (NA)	4,845	13,609	none
Johnson Creek (1990)	1,841	6,550	1 crossing after Hoyts Pond
Total Infrastructure Length (ft)	69,860	143,411	
Total Infrastructure Length (miles)	13.2	27.2	
Total Number of Crossings	55		

Notes:

^a: Infrastructure type includes PVC, transite and/or clay along the associated waterbodies.

^b: portions of infrastructure located near Boston Harbor were improved in 1991.

^c: Several oyster beds are downstream from downtown Dover, including Dover Point/Boston Harbor Flat #50 (16.69 acres), which runs parallel to 2,100 feet of infrastructure and is at points only 30 feet from the infrastructure. Several infrastructure river crossings are located 9,000 feet upstream from four oyster beds in the Bellamy/Piscataqua confluence. Infrastructure within the Cocheco River is approximately 17,000 feet from the Piscataqua River oyster bed (9.99 acres).

Exeter, NH River (Age of Infrastructure)	Buffer Width		Crossing Description
	150 ft	300 ft	
Unnamed Tributary #1 of Exeter River - South of Route 111 (1962) ^a	680	1,414	1 along length of tributary
Unnamed Tributary #1 of Scamen Brook (1962)	415	905	1 at Kingston Road
Unnamed Tributary #2 of Scamen Brook (1962)	558	1,382	1 at Kingston Road
Scamen Brook (1962)	408	793	1 downstream of Tamarina Lane 1 before Court Street 1 at Court Street
Exeter River (1962)	4,896	10,602	1 prior to mouth of the Little River/Scamen Brook
Squamscott River (1962)	5,107	7,707	5 downstream of High Street
Unnamed/unidentified Tributary #1 of The Cove (Hampton Fall Road) (1962)	212	1,032	None
Unnamed Tributary #2 of The Cove (1962)	1,030	4,190	3 upstream of Hampton Falls Road
Unnamed/unidentified Tributary #3 of The Cove (Hampton Fall Road) (1962)	485	1,316	1 below headwaters
Unnamed/unidentified Tributary #4 of The Cove (Drinkwater Road) (1962)	140	1,613	None
Tributary of Norris Brook (1962)	0	260	None
Norris Brook (1962)	625	1,531	2 below headwaters
Wheelright Creek/Dearborne Brook (1962)	2,891	4,943	1 along Portsmouth Avenue 2 downstream of Portsmouth Avenue

Exeter, NH River (Age of Infrastructure)	Buffer Width		Crossing Description
	150 ft	300 ft	
Total Infrastructure Length (ft)	17,447	37,688	
Total Infrastructure Length (miles)	3.3	7.1	
Total Number of Crossings	21		

Notes:

^a: Cast iron piping used through out infrastructure system.

^b: The nearest distance between infrastructure and shellfish beds (Misc. Squamscott River Flat - 83.19 acres) is approximately 25,000 feet.

Hampton, NH River (Age of Infrastructure)	Buffer Width		Crossing Description
	150 ft	300 ft	
Line Swamp/Old River headwaters (1990) ^a	2,786	6,080	6 throughout wetland area
Drakes River (1986)	1,196	2,031	1 at Towle Farm Road
Unnamed Tributary of Drakes River (1986)	978	1,778	2 prior to Exeter Hampton Road
Garland Brook/Little River Swamp (1989)	1,350	4,141	1 at Huckleberry Lane
Meadow Pond (1962)	5,597	12,239	1 after intersection of Seaview Avenue and Smith Avenue 1 at High Street crossing 1 along High Street and unnamed tributary of Meadow Pond 1 at an unnamed tributary 2 before Tide Mill Creek at Winnicunnet Road
Old Mill Pond (1962)	158	732	1 before High Street Crosses mouth of Pond
Tide Mill Creek (1964)	13,802	29,029	8 before first major branch in Tide Mill Creek 2 in an unnamed tributary of Tide Mill Creek 2 west of Ashworth Avenue
Atlantic Ocean (1935 with some upgrades/extensions)	4,843	17,160	None
Total Infrastructure Length (ft)	30,710	73,190	
Total Infrastructure Length (miles)	5.8	13.9	
Total Number of Crossings	29		

Notes:

^a: Cast iron piping used through out infrastructure system.

^b: Extensive infrastructure located west of Ashworth Ave. is at points approximately 850 feet from the nearest shellfish beds (Willow Flat - 28.65 acres). Eight infrastructure crossings occur throughout Tide Mill Creek and the associated wetland and are 8,600 feet upstream from the nearest shellfish beds.

Kittery, ME River (Age of Infrastructure)	Buffer Width		Crossing Description
	150 ft	300 ft	
Spinney Creek (1968-69) ^a	434	1,347	None
Spruce Creek (approx. 1935)	3,394	8,301	1 at Route 1 1 at headwaters of Gerry Cove
Chickering Creek (1996)	162	593	1 prior to entering Spruce Creek
Piscataqua River (1968-69)	7,104	14,207	1 at Back Channel
Total Infrastructure Length (ft)	11,094	24,448	
Total Infrastructure Length (miles)	2.1	4.6	
Total Number of Crossings	4		

Notes:

^a: The majority of infrastructure (60-65%) is PVC and lesser amounts are asbestos and clay (20-25% and 5-10%, respectively).

^b: The nearest distance between infrastructure and shellfish beds (Wentworth Clam Flat - 19.70 acres) is approximately 14,000 feet, located northeast of Back Channel and Piscataqua River.

Newmarket, NH River (Age of Infrastructure)	Buffer Width		Crossing Description
	150 ft	300 ft	
Piscassic River (1969; 1980s) ^a	2,493	6,004	1 at Ladyslipper Drive 1 at Follets Brook before entering Piscassic River 1 at Packers Falls Road
Moonlight Brook (1980s)	3,778	9,286	11 along length of brook including one at headwaters and several road crossings.
Lamprey River (1980s; 1990s)	1,892	5,601	1 at dam after Route 108 crossing
Total Infrastructure Length (ft)	8,163	20,891	
Total Infrastructure Length (miles)	1.5	4.0	
Total Number of Crossings	15		

Notes:

^a: A combination of piping materials used throughout infrastructure system, including PVC, transite, clay and cast iron. Piping older than 1969 is clay.

^b: The nearest distance between infrastructure and shellfish beds is approximately 1,200 feet. Extensive infrastructure is located 8,800 feet from shellfish beds (28.50 acres) and Moonlight Brook, which has 10 infrastructure crossings throughout. An infrastructure crossing at the Lamprey River tidal dam is 9,800 feet from shellfish beds.

Newfields, NH River (Age of Infrastructure)	Buffer Width		Crossing Description
	150 ft	300 ft	
Squamscott River (1982) ^a	8	563	None
Total Infrastructure Length (ft)	8	563	
Total Infrastructure Length (miles)	0.0	0.1	
Total Number of Crossings	0		

Notes:

^a: PVC piping used throughout infrastructure system.

^b: The nearest distance between infrastructure and shellfish beds is approximately 8,000 feet.

Portsmouth, NH River (Age of Infrastructure)	Buffer Width		Crossing Description
	150 ft	300 ft	
Berrys Brook (1960) ^a	1,515	2,575	1 in ponded section below headwaters.
Unnamed Tributary #1 of Berrys Brook (1960)	351	1,414	None
Unnamed Tributary #2 of Berrys Brook (1960)	437	765	None
Unnamed Tributary #3 of Berrys Brook (1960)	769	2,793	2 downstream of headwaters.
Sagamore Creek (1950 w/ upgrades)	5,765	11,265	1 at Lafayette Road crossing. 2 along tributary at north of Elwyn Road.
Unnamed Tributary of Piscataqua River (1960)	6,379	9,632	4 along length of tributary; including 3 sections of pipe approximately 1000 feet in length submerged in wetland area associated with a trailer park.
Hodgson Brook (1800 w/ upgrades)	954	2,829	1 at Route 1 Bypass.
North Mill Pond (1800 w/ upgrades)	8,811	21,022	1 at Bartlett Street at beginning of pond. 1 at Maplewood crossing near mouth of pond 1 at Market Street crossing at mouth of pond.
South Mill Pond (1800 w/ upgrades)	7,508	9,360	2 along Parrot Avenue along northwestern shore of pond.
Piscataqua River (1800 w/ upgrades)	10,240	20,529	1 on road to Pierce Island.
Total Infrastructure Length (ft)	42,729	82,184	
Total Infrastructure Length (miles)	8.1	15.6	
Total Number of Crossings	17		

^a: The infrastructure dating back to the 1800s is predominantly clay. Infrastructure installed in 1950 and 1960 is concrete with upgrades to PVC. Infrastructure installed in the 1800s are currently undergoing upgrades to PVC.

^b: The nearest distance between infrastructure and shellfish beds is approximately 7,000 feet, between Pleasant Street and Pierce Island to the Triangle and Wentworth Flats (3.19 and 19.70 acres, respectively). Infrastructure near the headwaters of the Sagamore Creek is approximately 12,000 feet from a network of shellfish beds (36.95 acres).

Seabrook, NH River (Age of Infrastructure)	Buffer Width		Crossing Description
	150 ft	300 ft	
Hampton Falls River (1996) ^a	2,355	5,146	1 at Mill Lane crossing 1 at Route 107 crossing 1 at Stard Road crossing
Browns River (1996)	1,485	3,234	4 crossings in headwaters
Mill Creek (1996)	2,832	5,916	2 at Causeway Road 2 at Centennial Avenue 1 in an unnamed tributary
Cains Brook (1996)	9,138	18,201	1 at Batchelder Road 2 at Route 1 crossing 2 on unnamed tributary of Cains Brook
Unnamed Tributary #1 of Blackwater River (1996)	0	632	1 along Route 286
Unnamed Tributary #2 of Blackwater River (1996)	1,295	3,428	1 along Route 286
Unnamed Tributary #3 of Blackwater River (1996)	936	3,562	1 along Route 286
Unnamed Tributary #4 of Blackwater River (1996)	1,438	3,410	4 south of South Main Street
Blackwater River (1996)	13,178	18,103	2 along Route 286 3 along Ocean Blvd.
Atlantic Ocean (1996)	598	1,760	0
Total Infrastructure Length (ft)	33,255	63,392	
Total Infrastructure Length (miles)	6.3	12.0	
Total Number of Crossings	29		

^a: Infrastructure type is PVC.

^b: The nearest distance between infrastructure and shellfish beds (Middle Ground Flat - 47.45 acres) is 370 feet, located north of River Street. Extensive infrastructure is located around the perimeter of the Blackwater River and associated salt marsh with numerous infrastructure crossings. The infrastructure crossing at the Blackwater River and Route 286 is approximately 6,400 feet upstream from a Misc. Blackwater River Flat (7.30 acres).

South Berwick, ME River (Age of Infrastructure)	Buffer Width		Crossing Description
	150 ft	300 ft	
Drisscol Brook (1900 - 1970) ^a	922	2,635	2 at road crossings before entering Salmon Falls River
Salmon Falls River (1900 - 1970; with upgrades in 1999)	819	2,498	0
Unnamed Tributary #1 of Great Works River (1987)	3,968	9,342	7 along length of tributary through a residential development
Unnamed Tributary #2 of Great Works River (1987)	1,698	2,676	3 before entering Great Works River
Unnamed Tributary #3 of Great Works River (NR)	852	1,727	2 before entering Great Works River
Great Works River* (1982)	1,631	7,299	1 at Route 236 1 at Brattle Street *pump station within 150 ft of Great Works River at Brattle Street
Total Infrastructure Length (ft)	9,890	26,177	
Total Infrastructure Length (miles)	1.9	5.0	
Total Number of Crossings	16		

^a: Infrastructure older than 1972 consists of clay pipe. All infrastructure constructed since 1982 consists of PVC piping.

^b: The nearest distance between infrastructure and shellfish beds (Misc. Salmon Falls Flat - 39.26 acres) is approximately 18,000 feet.

Table 16: Relative risk based upon important sewer infrastructure attributes.

Town	Amount of Critical Infrastructure ^a	Number of Infrastructure River/Stream Crossings	Approximate Shortest Distance to Shellfish Beds	Age of Infrastructure	Number of CSOs	Relative Risk
Durham	55,500	42	3,000 ft	1955-1965	0	MEDIUM/HIGH ^b
Dover	143,411	55	30 ft	1973-1991	0	HIGH
Exeter	37,688	21	25,000 ft	1962	2	LOW ^c
Hampton	73,190	29	850 ft	1964	0	HIGH
Kittery	24,448	4	14,000 ft	1968-1969	0	LOW
Newington ^d	NA	NA	NA	NA	NA	ND
Newmarket	20,891	15	8,800 ft ^e	1980-1990	0	MEDIUM
Newfields	563	0	8,000 ft	1982	0	LOW
Portsmouth	82,184	17	7,000 ft	1800 w/ upgrades	3	HIGH
Seabrook	63,392	29	370 ft	1996	0	HIGH
S. Berwick	82,184	16	18,000 ft	1900-72; 1999 upgrades	0	MEDIUM ^f

Notes and Acronyms:

^a: Reported as feet of infrastructure within a 300-foot buffer.

^b: Durham was considered medium/high because of the number of infrastructure river crossings and the relative distance of infrastructure from shellfish beds.

^c: The presence of two CSOs in Exeter should be considered a source of risk, but does not necessarily indicate a threat due to leaking infrastructure.

^d: Infrastructure data for the town of Newington were not available and could not be analyzed.

^e: The shortest distance between infrastructure and shellfish beds was actually 1,200 feet. However, this value was not used because it was a very small portion of the Newmarket's sewer infrastructure (Figure 1F).

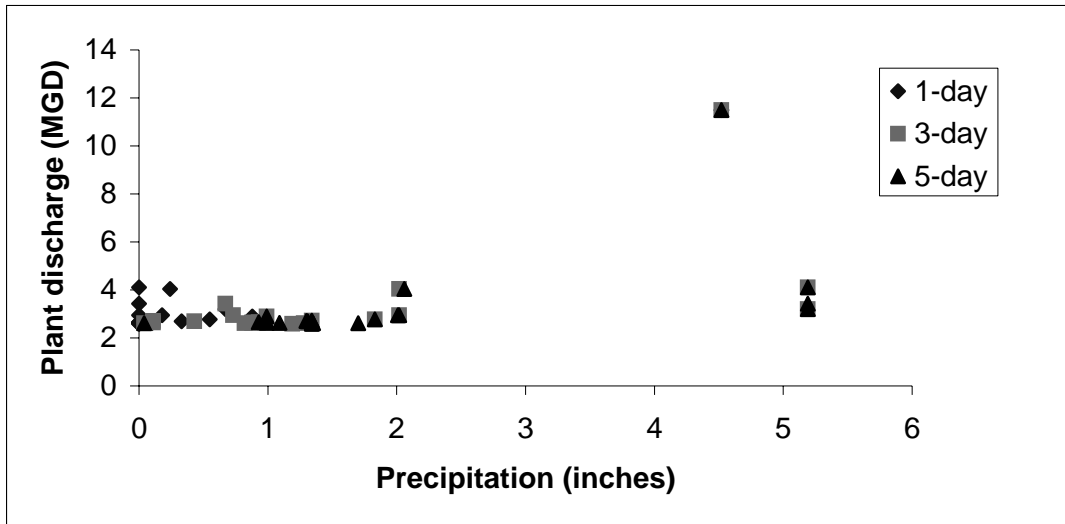
^f: Although the distance of infrastructure from shellfish beds is greater than three miles, the potential presence of aged sewer pipes could represent a source of surface water contamination.

NA: not available

ND: not determined

FIGURES

A.



B.

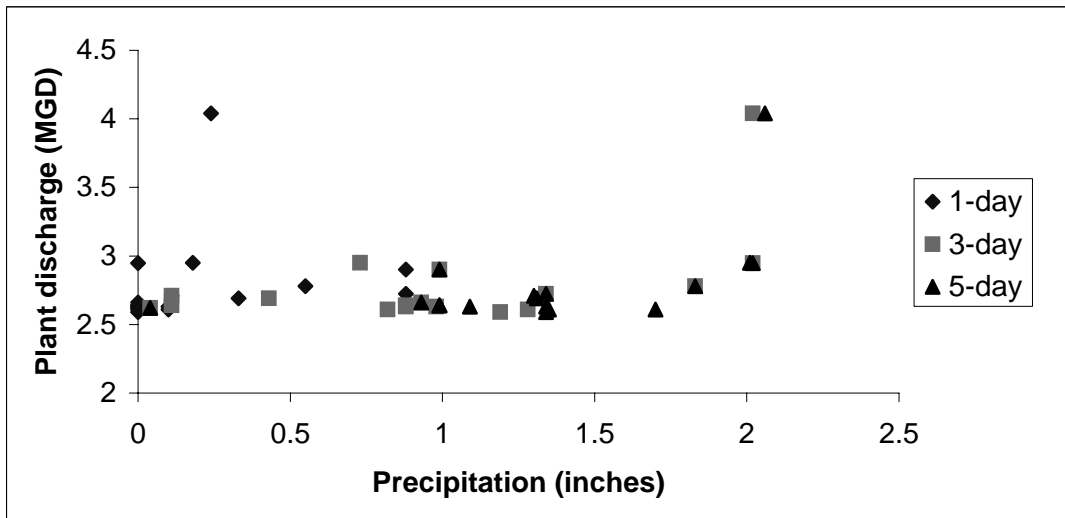
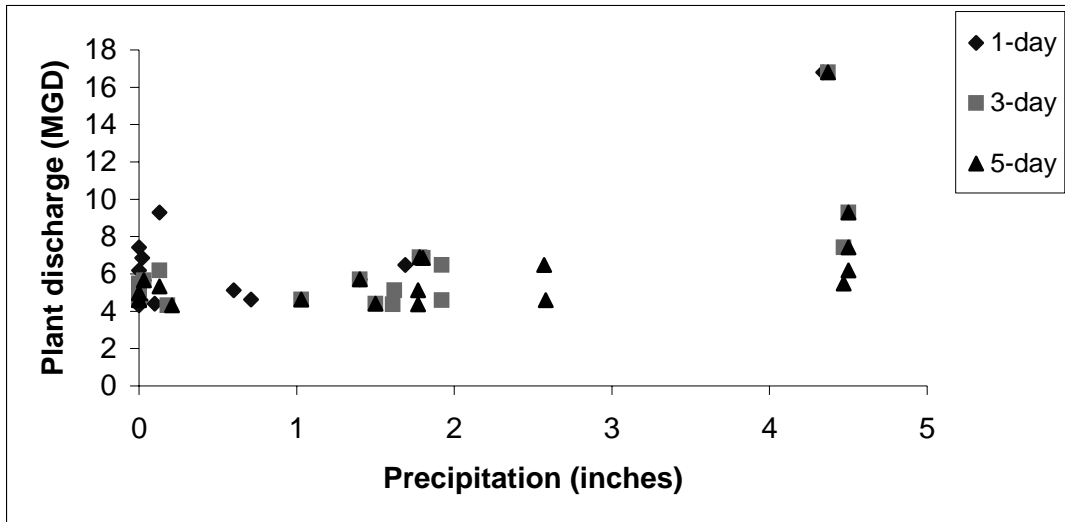


Figure 1. Hampton WWTF high-flow discharge versus 1-day, 3-day, and 5-day precipitation totals. Figure shows data with A) and without B) extreme event recorded on March 22, 2001. No strong relationship exists between high-flow discharge and total precipitation. Linear regressions show that no significant linear relationship exists between high-flow discharge and 1-day precipitation ($R^2 = 0.033$). However, a mild relationship was observed between plant discharge and 3-day ($R^2 = 0.30$) and 5-day ($R^2 = 0.28$) precipitation totals. (Data from March 22, 2001 through March 26, 2001 were treated as outliers and not included in the regression analyses)

A.



B.

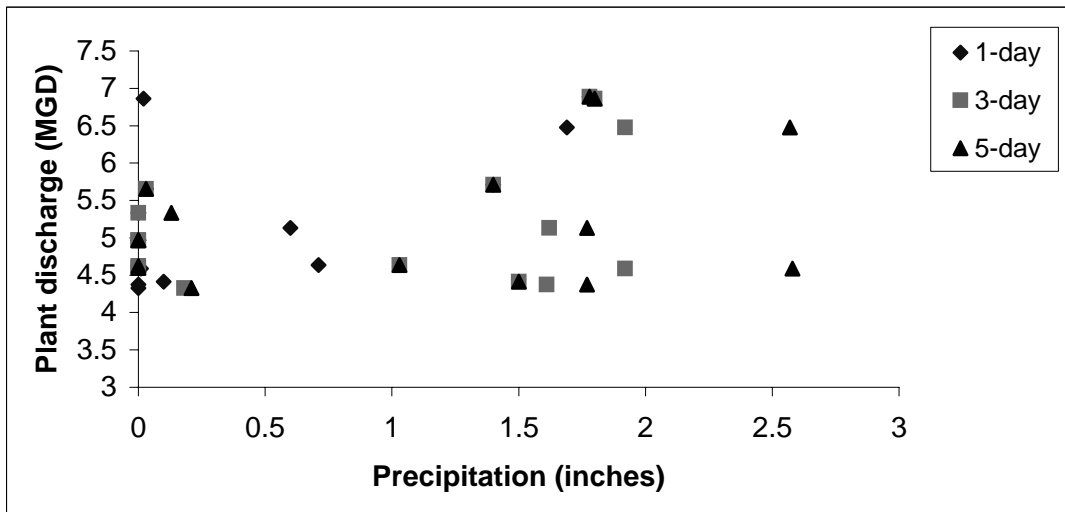


Figure 2. Dover WWTF high-flow discharge versus 1-day, 3-day, and 5-day precipitation totals. Figure shows data with A) and without B) extreme event recorded on March 22, 2001. No strong relationship exists between high-flow discharge and total precipitation. Linear regressions show that a moderate linear relationship exists between plant discharge and 1-day precipitation ($R^2 = 0.39$). Relationships between high-flow discharge and 3-day ($R^2 = 0.16$) and 5-day ($R^2 = 0.13$) precipitation totals were not as strong. (Data from March 22, 2001 through March 26, 2001 were treated as outliers and not included in the regression analyses)

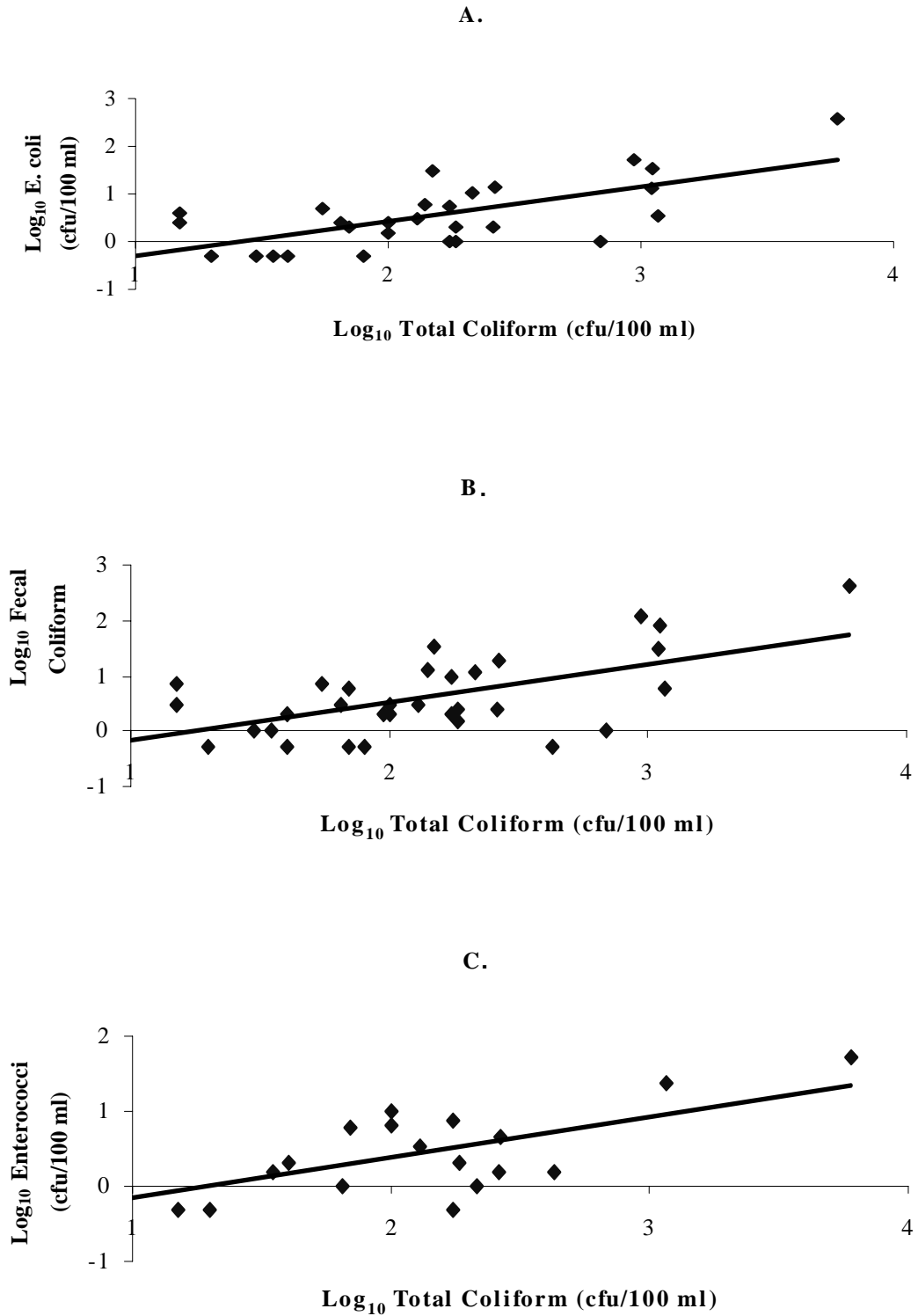
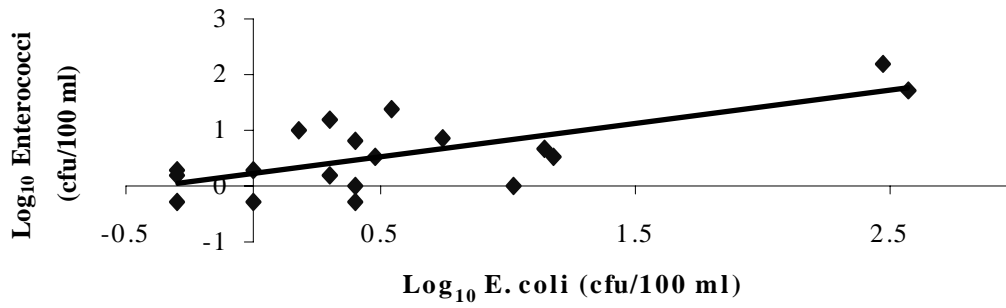
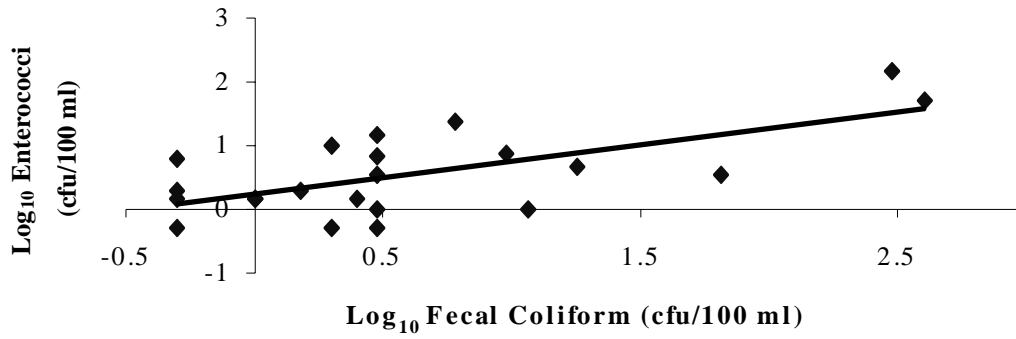


Figure 3: Regression analysis comparing total coliform concentrations with (A) *E. coli*, (B) fecal coliform and (C) enterococci concentrations from 11 WWTFs. Indicator concentrations were log₁₀ transformed.

D.



E.



F.

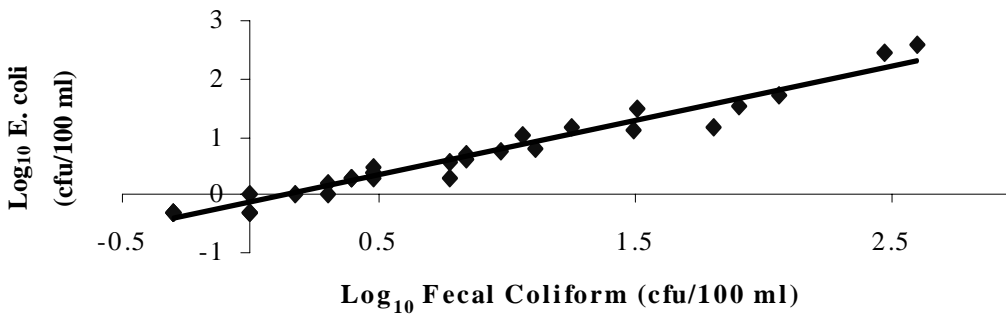


Figure 3 (continued): Regression analysis comparing (D) E. coli and enterococci, (E) fecal coliform and enterococci and (F) fecal coliform and E. coli concentrations from 11 WWTFs. Indicator concentrations were log_{10} transformed.

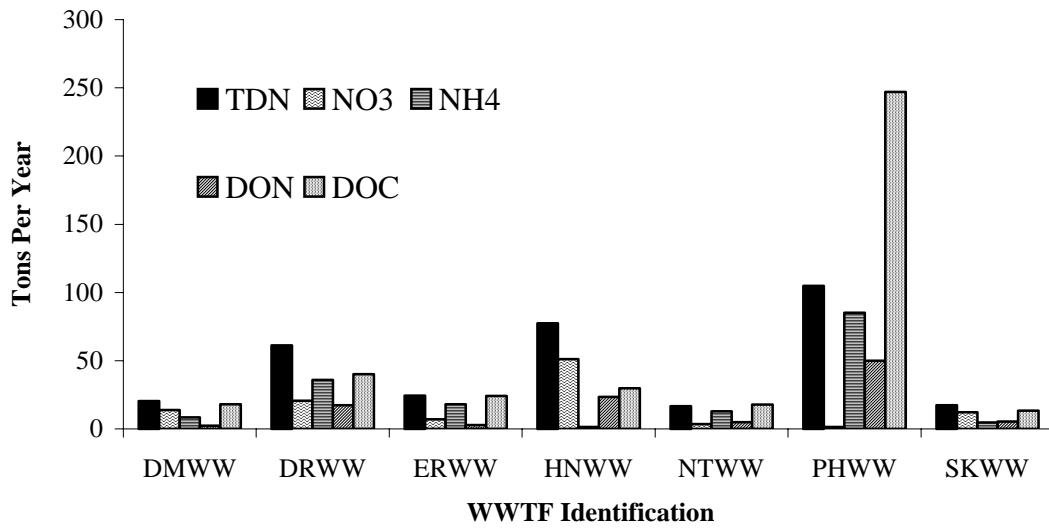


Figure 4: Nutrient loading at seven WWTFs. Loading is expressed as tons per year.

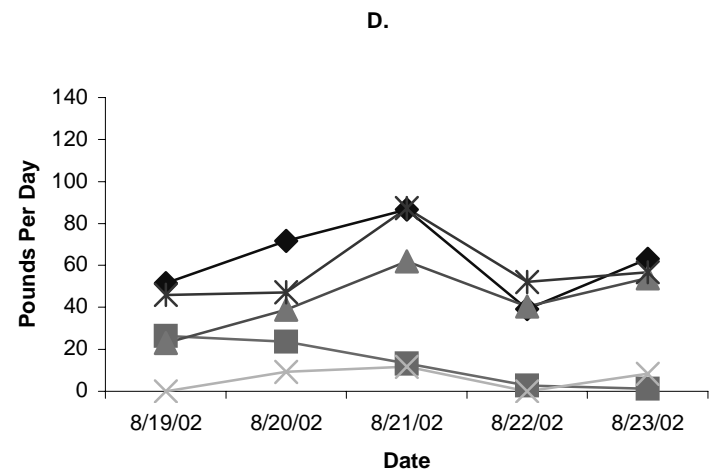
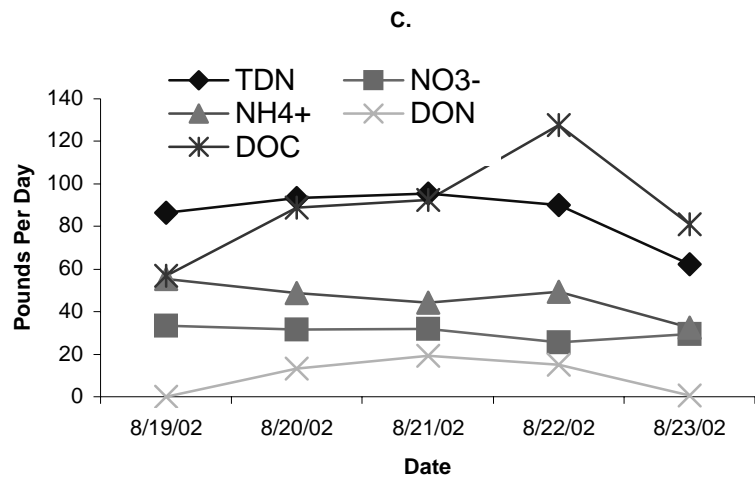
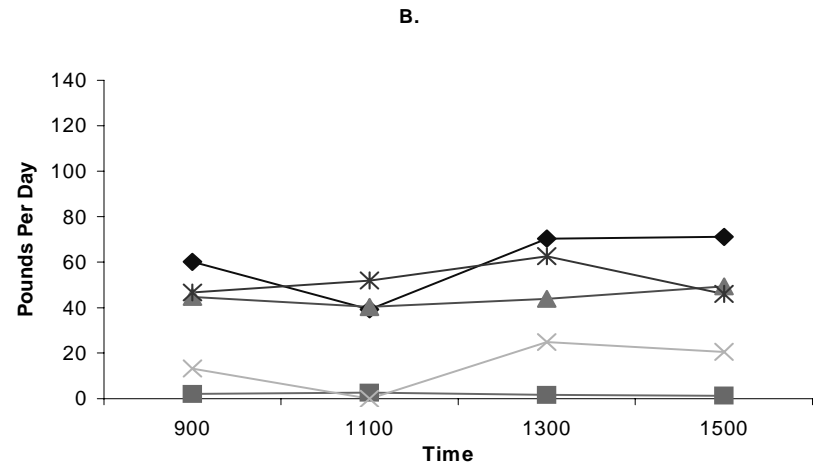
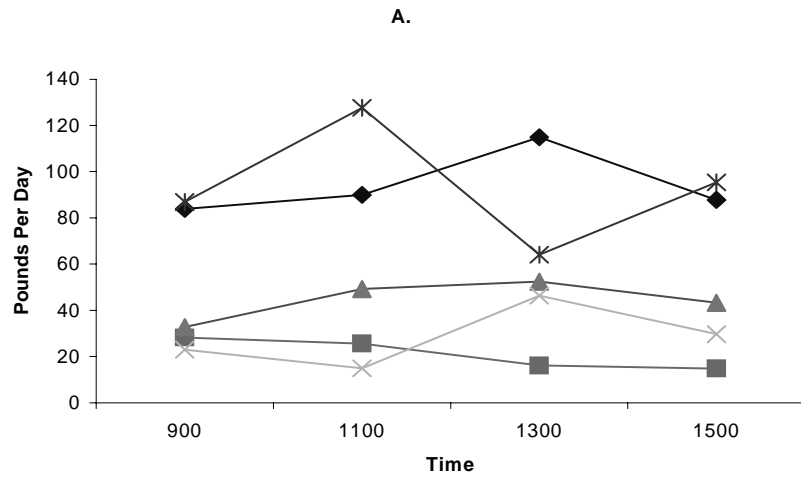


Figure 5: Daily and weekly variability in nutrient loading measurements at two subject WWTFs. (A) One day loading at NTWW, (B) one day loading at DMWW, (C) five day loading at NTWW and (D) five day loading at DMWW

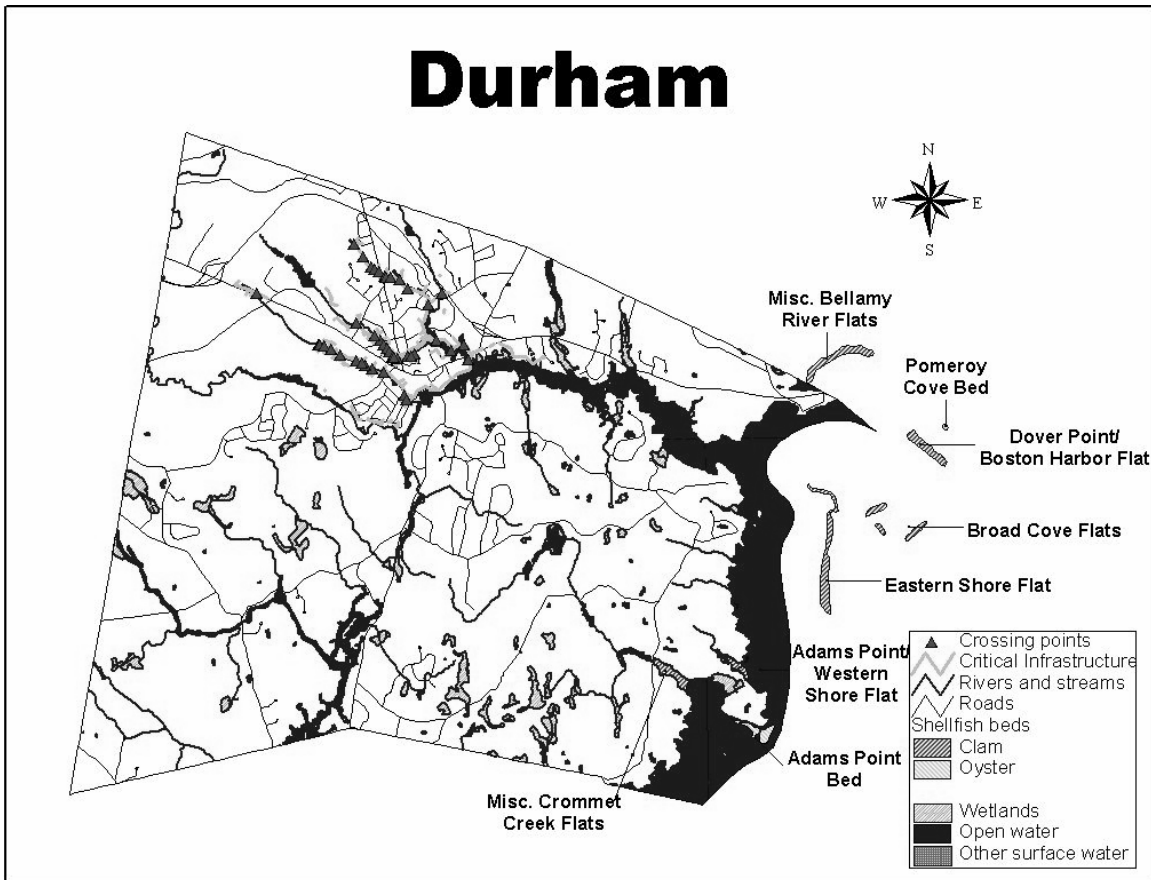


Figure 6: Sewer infrastructure map for Durham, NH showing critical infrastructure areas, including locations in which sewer lines cross surface water bodies.

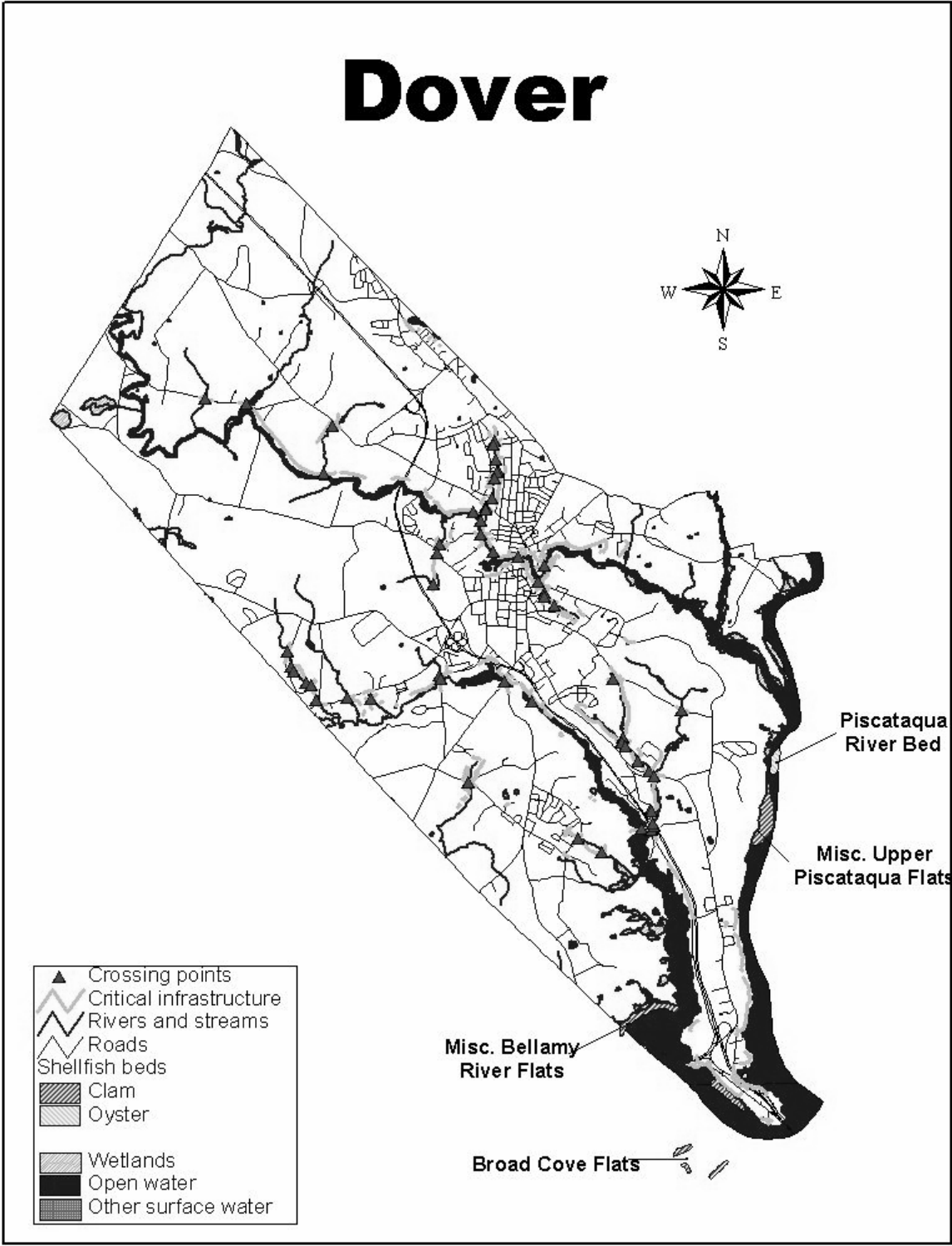


Figure 7: Sewer infrastructure map for Dover, NH showing critical infrastructure areas, including locations in which sewer lines cross surface water bodies.

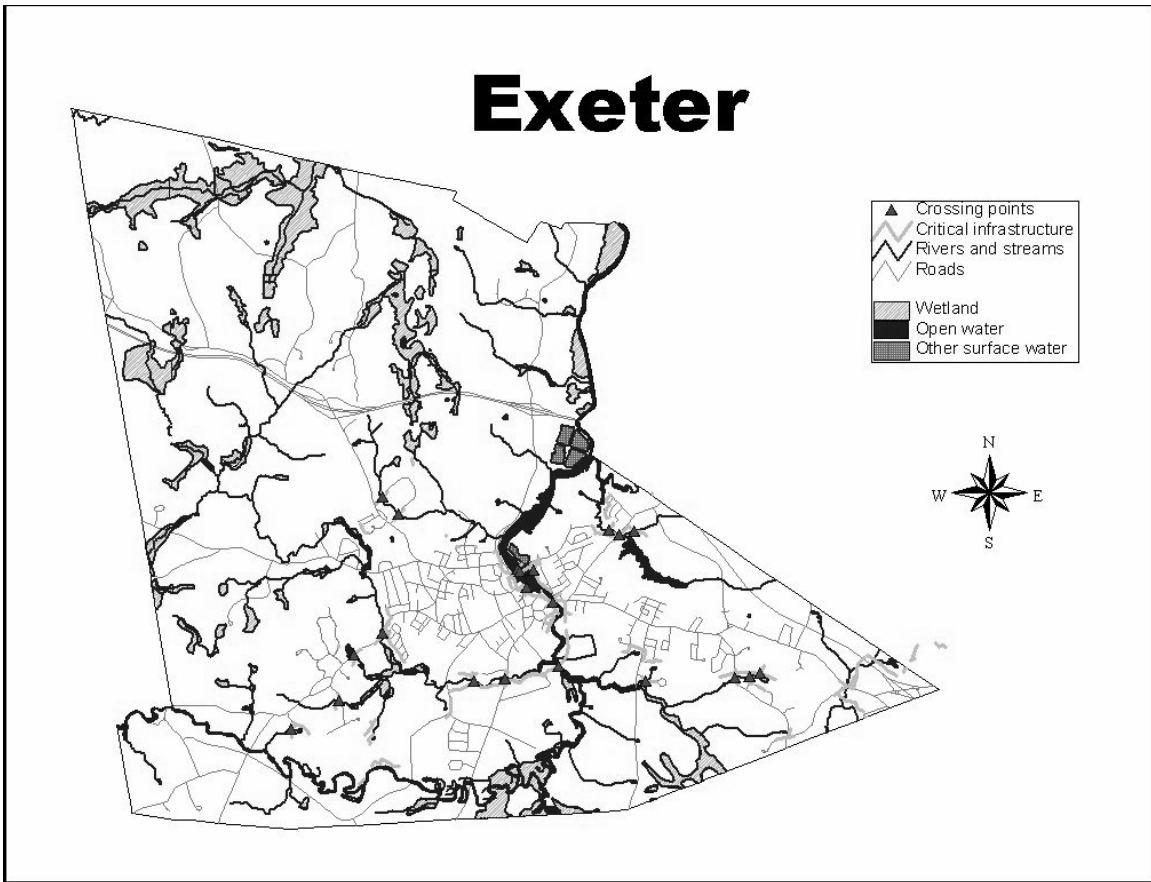


Figure 8: Sewer infrastructure map for Exeter, NH showing critical infrastructure areas, including locations in which sewer lines cross surface water bodies.

Hampton

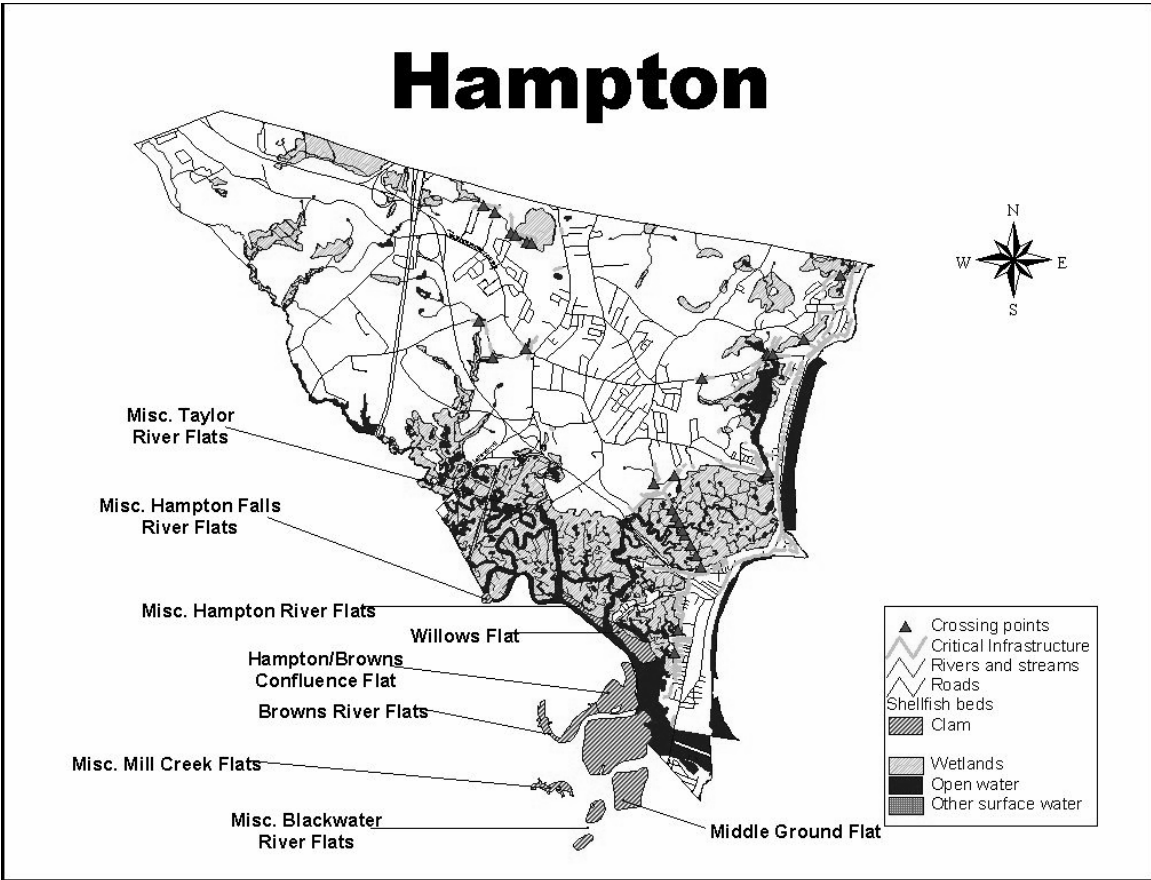


Figure 9: Sewer infrastructure map for Hampton, NH showing critical infrastructure areas, including locations in which sewer lines cross surface water bodies.

Kittery

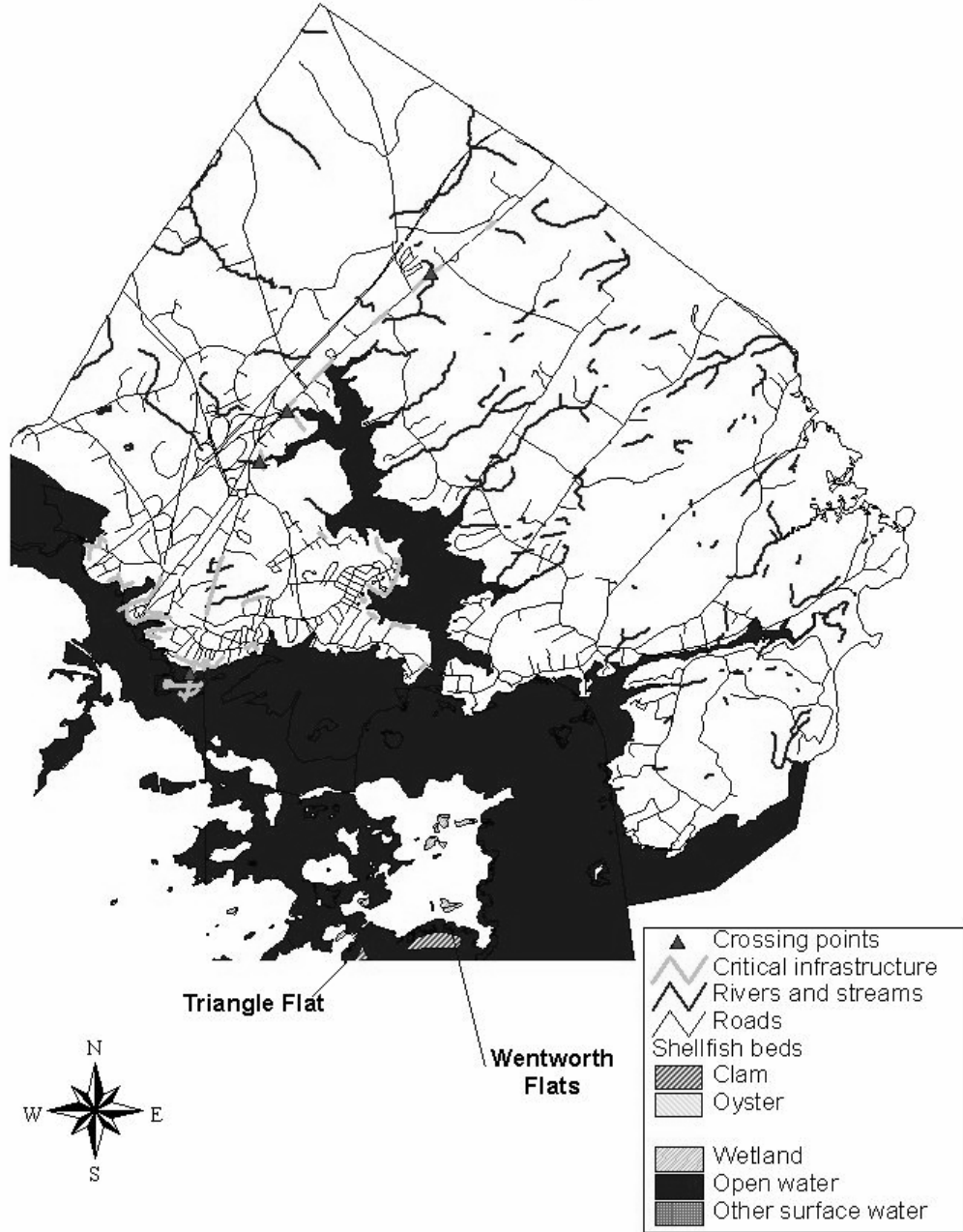


Figure 10: Sewer infrastructure map for Kittery, ME showing critical infrastructure areas, including locations in which sewer lines cross surface water bodies.

Newfields

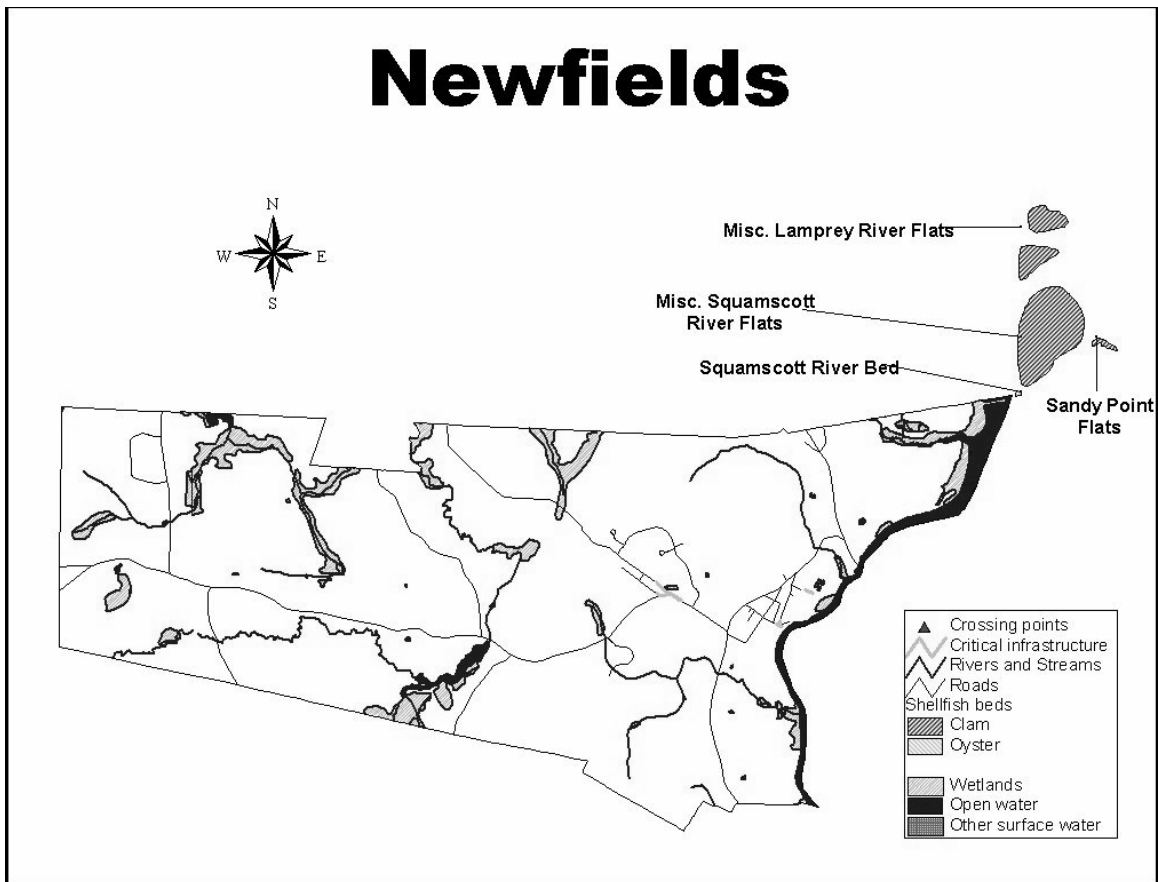


Figure 11: Sewer infrastructure map for Newfields, NH showing critical infrastructure areas.

Newmarket

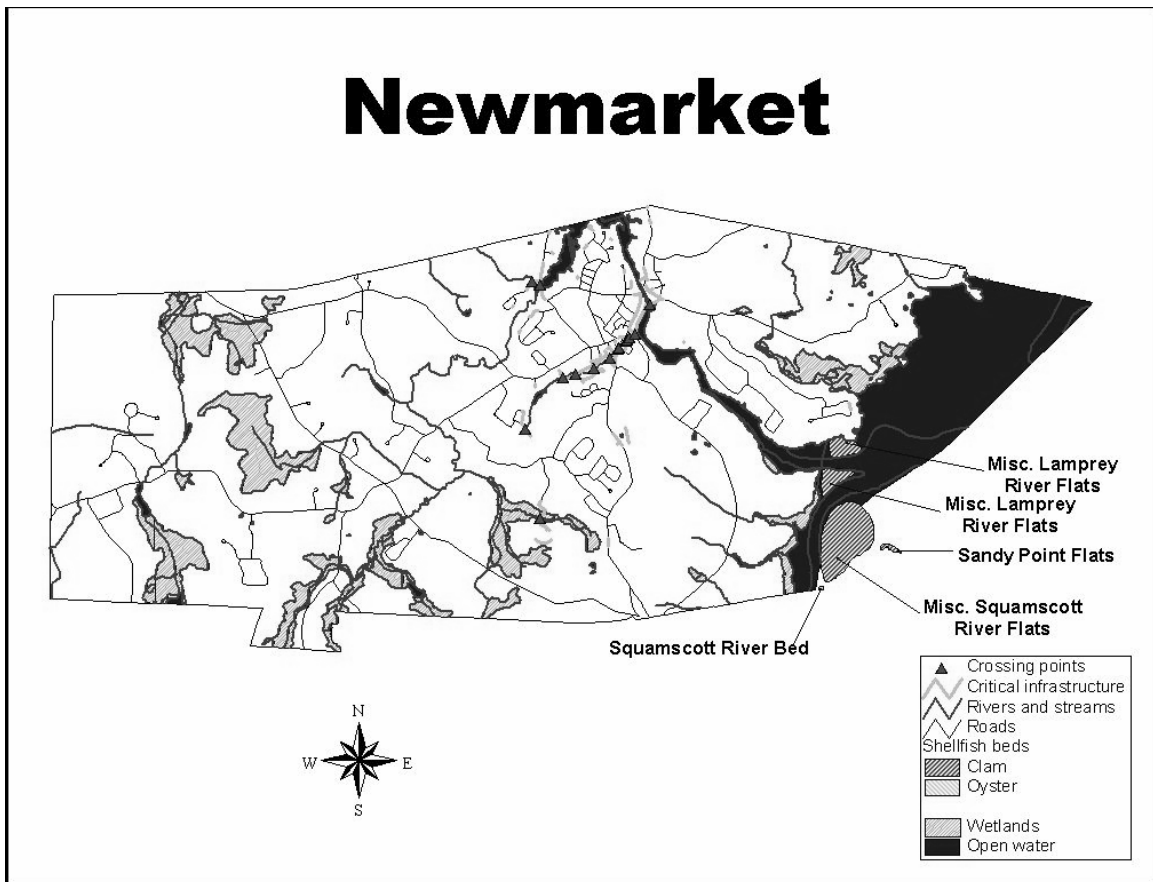


Figure 12: Sewer infrastructure map for Newmarket, NH showing critical infrastructure areas, including locations in which sewer lines cross surface water bodies.

Portsmouth

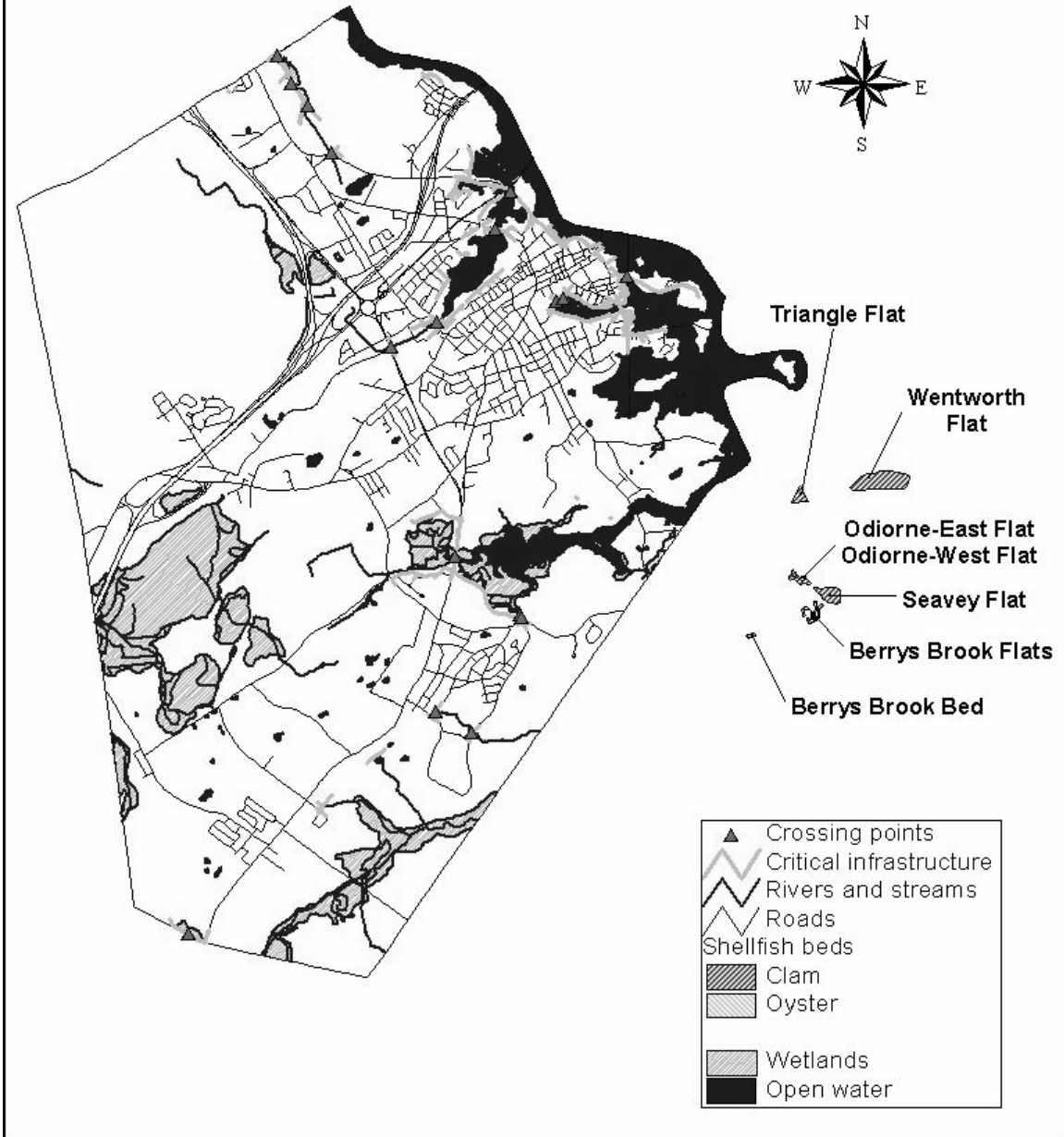


Figure 13: Sewer infrastructure map for Portsmouth, NH showing critical infrastructure areas, including locations in which sewer lines cross surface water bodies.

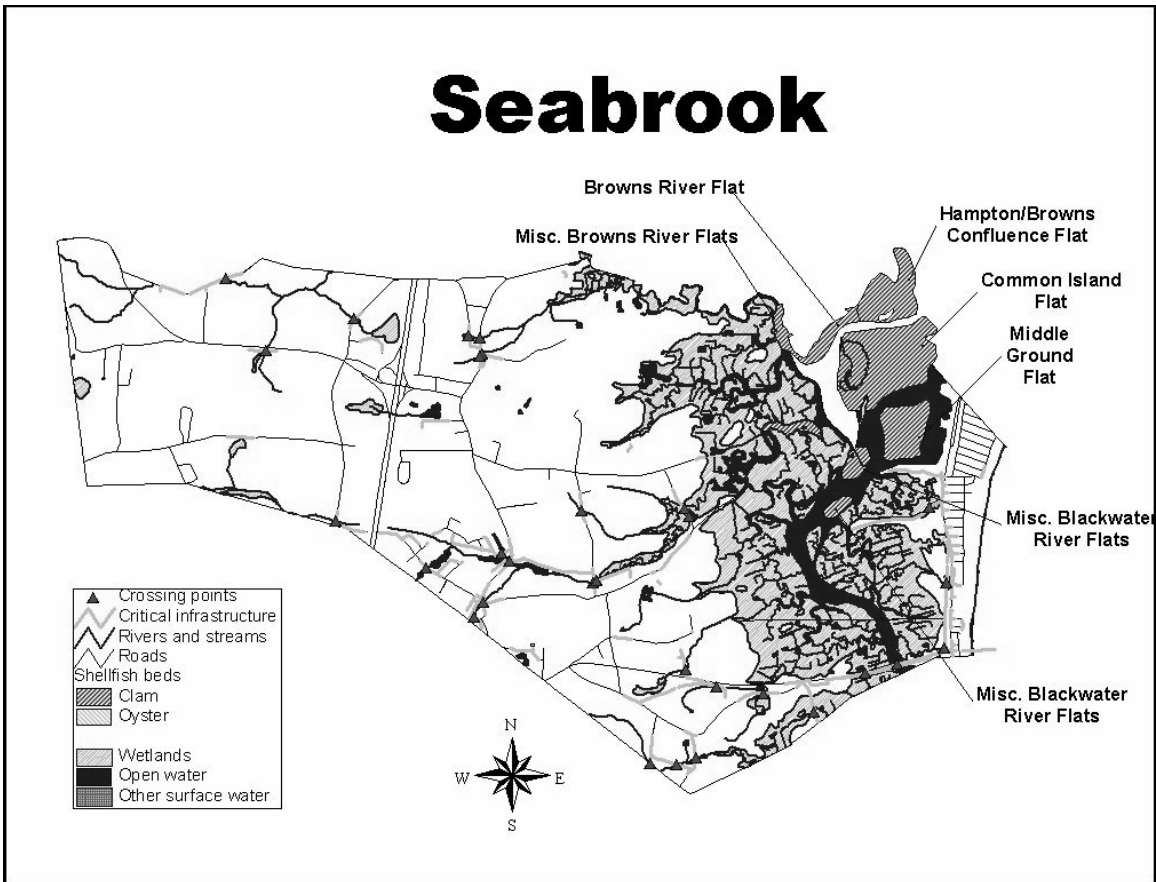


Figure 14: Sewer infrastructure map for Seabrook, NH showing critical infrastructure areas, including locations in which sewer lines cross surface water bodies.

South Berwick

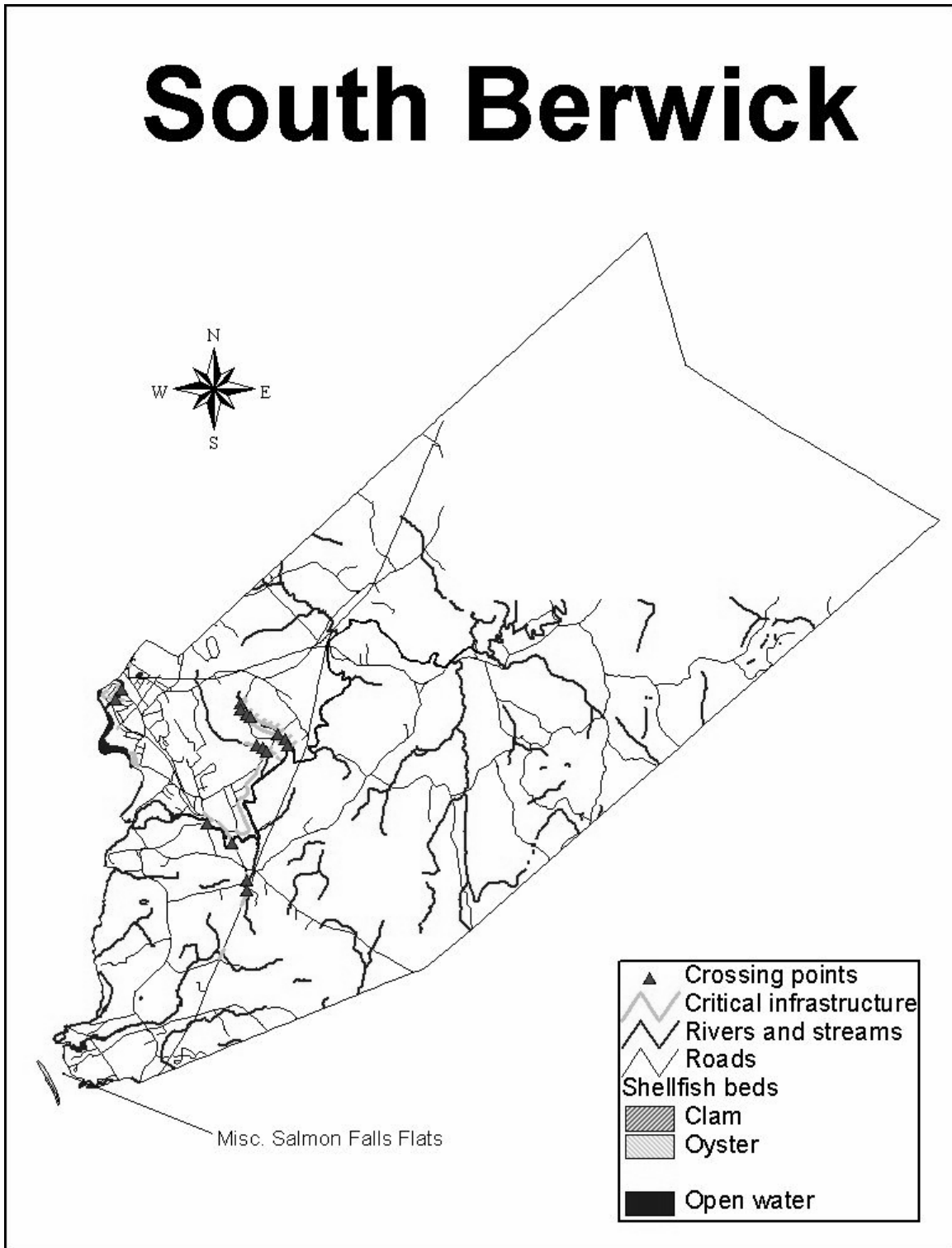


Figure 15: Sewer infrastructure map for South Berwick, ME showing critical infrastructure areas, including locations in which sewer lines cross surface water bodies.