EXHIBIT N

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05/09/2005 11:04 PM

To Damien Houlihan/R1/USEPA/US@EPA
cc
bcc
Subject Portsmouth Comments from CCA

History: This message has been replied to.

Damien :

Many thanks to the EPA for the hearing on the Portsmouth 301 H Wavier --- It was conducted in a very professional manner .

As we discussed my comments on N2 loading fom the Portsmouth Plant can be found in the following report : **Evaluation of Effects of Wastewater Treatment Discharge On Estuarine Water Quality** Dec 2003 by Dr. Stephen Jones and Dr. Bolster Jackson Lab University of New Hampshire . It is available on line at www.coastalclear.org ----- go to related studies on the link and the report will come up . Pages 2 and page 19 cite Nutrient loading from the Portsmouth Plant ----largest impact in the Estuary .

Best regards
Peter Whelan

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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

Submitted by

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UNIVERSITY of NEW HAMPSHIRE

NEW HAMPSHIRE DEPARTMENT OF Environmental Services

NewHampshire EstuariesProject

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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. NH_4^+-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, 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 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 NO_3^--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 Valleau, 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 (fecal coliform) = 0.6909 (±0.30) * log (total coliform) – 0.8567 (±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 paried 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 that 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

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

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

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

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

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

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-feet 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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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