Monitoring Nantucket Harbor

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Abstract

Monitoring and maintaining the quality of Nantucket Harbor is the responsibility of the Nantucket Department of Natural Resources. The goal of this project was to compile all available data on water quality regarding Nantucket Harbor, make observations in trends regarding the harbor's health, and make recommendations to better record and communicate information on water quality. This goal was met by analyzing nitrates and nitrogen inputs into the harbor and addressing the need for more detailed monitoring of water quality factors.

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Executive Summary

Water pollution is one major problem that the island of Nantucket has had to face, particularly in recent years. Nantucket Harbor is vital to the economic and social well-being of the island – it is a source of shellfish and other seafood, it attracts tourists on the ferries, and its beaches are a major attraction for many of the island's visitors.

Nitrogen is considered to be a limiting factor in water quality, and subsequently is the subject of many of Nantucket's nutrient related studies (Curly, 2002). There are three major forms in which nitrogen occurs in aquatic systems. These forms are ammonia, nitrate, and various other organic compounds, with the focus of many testing sites on Nantucket being nitrate (Curly, 2002). Due to what is known as the nitrogen cycle, nitrogen in a healthy system will naturally occur in low quantities. As part of this cycle, nitrogen is converted by bacteria into forms usable by plants, which then utilize the nitrogen to make food through photosynthesis. When the plants die and decompose, the cycle can start anew, but problems can occur when the loading of nutrients such as nitrogen are added to a system faster than they can be integrated through these processes.

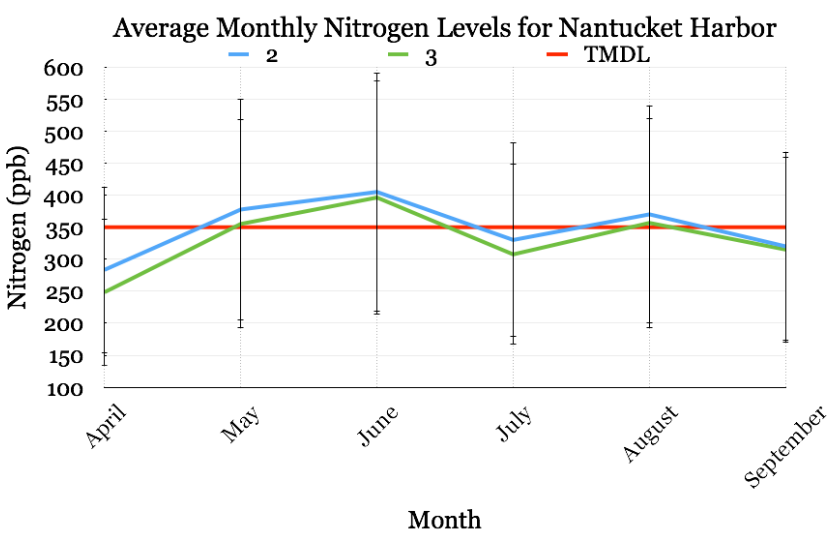
Nitrogen can be loaded into Nantucket Harbor by natural processes such as rainfall, the changing of tides, or the deposition of nitrogen from the atmosphere to water. The nitrogen loading over which people on the island have an influence include the surface runoff of nitrogen-rich fertilizer, faulty septic systems leeching into groundwater, and other agricultural additives that are washed through the island watershed into the harbor.

The Total Maximum Daily Load (TMDL) for total nitrogen is the amount of nitrogen in mg/L that can be released into the harbor that will not have adverse effects on the health of the harbor, and should be considered a threshold for which Nantucket needs to strive (Howes, 2009). In 2009, the Mass Estuaries Project determined that the TMDL for total nitrogen in Nantucket Harbor should be 0.35mg/L (Howes, 2009). In the same year, they also measured the nitrogen concentration in the harbor and determined it to be 0.34 – 0.41 mg/L at the head of the harbor, 0.34 mg/L at the Quaise Basin and 0.30 – 0.34 mg/L at the Town Basin (Howes, 2009). The nitrogen levels at each part of the harbor are either extremely close to or over the TMDL threshold. The harbor's small ecosystem makes it sensitive to even the slightest nitrogen concentration changes so being even slightly over the TMDL is a threat to the health of the harbor (Howes, 2009).

During our initial research we planned to analyze all of the water quality data that was located at the Nantucket Department of Natural Resources. However, it soon became apparent that this was not possible to do within our time constraints. After consulting with Dr. Sarah Oktay, we decided to narrow our project scope, focusing on nitrates because they come from human sources and are therefore the most easily regulated source of nitrogen that flows into the harbor.

With this new direction we were able to gather the nitrate data through the Department of Natural Resources and organize it into quantitative data and contextual information. We then entered that data into spreadsheets and analyzed it to determine if there were any clear trends in the water quality in the harbor.

The first graph we made compared all 16 years of data that was collected at the eight different sampling stations around the harbor. Since the data was sparse and inconsistent, trends were hard to identify. We then focused on stations 2 (Quaise Basin) and 3 (head of the harbor)



because they have the slowest flushing rates, and therefore the most consistent data. Trends were easier to identify on this graph and showed fluctuations in nitrates during the spring and summer months. When the total nitrogen was compared at the same stations with the TMDL for the harbor, we observed that a peak in

June greatly exceeded the TMDL. Next, we calculated the percentage of total nitrogen of which nitrates composed during June. We observed values of 6.6% for station 2 and 7.8% for station 3. By removing the percentage of total nitrogen that nitrates compose we saw that the value drops to a level that is very close to the TMDL for both stations. From the data we concluded that the TMDL could eventually be met in the harbor by reducing the amount of nitrates flowing into the harbor due to human influence.

Based on our analysis of the data we developed recommendations of how to continue monitoring and tracking the water quality trends in the harbor. One of our more important recommendations was to take water quality samples for analysis more frequently, and use more consistent sampling methods in order to show concentration data trends with higher resolution. To properly monitor the water quality, as well as the other bodies of water on Nantucket, we recommended that the town hire a full time employee to take these samples and analyze the data. Additionally, we recommended the Department of Natural Resources consider the use of several automatic water sampling buoy systems, which would enable continuous sampling and analysis. We also recommended a future study in which researchers observe just how much of the nitrate concentrations can be realistically reduced by human practices. Lastly, we recommended that the town ArcGIS database be continuously updated. Taken together, our recommendations will make it easier to help organize harbor quality data, as well as make this data easily accessible to both researchers and the public.

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1.0 Introduction

Every year, 1.2 trillion gallons of industrial waste, storm water, and untreated sewage are discharged into United States water. Polluted water can have detrimental effects including beach closures, damage to aquatic plants and animals, and contamination of clean drinking water. An estimated 40% of rivers in the United States are too polluted for aquatic life to survive (EPA).

One of the main sources of water pollution in the United States is runoff from fertilizers that contain nutrients, such as nitrogen and phosphorous, that promote plant growth. However, due to over-fertilization of primarily industrial crops, the runoff contains excess levels of nutrients that are not absorbed by the ground or crops. The runoff nutrients contribute to excessive plant growth, which reduces the oxygen concentration in the water, and creates an environment where it is difficult for fish and native aquatic plants to survive. For example, every year 15% of the fertilizer applied to crops in the Mississippi River Basin ends up in the Gulf of Mexico, which creates a nearly-8,000 square mile "dead zone" where organisms cannot survive (EPA).

Water pollution is a major problem that the island of Nantucket has had to face, particularly in recent years. The island, measuring about forty-nine square miles, is home to about 15,000 year-round residents yet in the summer the population increases to about 60,000 due to the influx of tourists (Town of Nantucket). This dramatic rise in the number of people on the island naturally affects the amount of waste and pollutants that go into Nantucket's waters.

If the harbor and the water bodies that flow into the harbor are contaminated, then the shellfish population and quality will be negatively affected and the shellfish economy will suffer. Additionally, polluted water affects not only Nantucket's ecosystems and shellfish industry but also the health of the island's residents. The island has only one source of groundwater that is used for drinking water, domestic use, and agriculture purposes. If this aquifer were to be compromised, there is no alternative source of fresh water for the island to use.

The island of Nantucket plays host to several governmental departments and independent organizations concerned about threats to the local water quality. For instance, the Nantucket Shellfish Association, Inc., a non-profit organization, was formed to ensure that the community has a sturdy, diverse economic base in commercial and recreational shellfish harvesting. The Massachusetts Estuaries Project is active on the island as well. Its mission is to protect the tourism and property revenues on which the local economy relies. When pollutants, which cause excessive growth of algae and invasive sea vegetation, damage the natural beauty of the landscape, these revenues are at risk.

Currently, Nantucket's water quality is not irreversibly damaged or even in a critical situation, but with the island's population increasing to four times its year-round population each summer, there is an urgent need for a process by which concerned social organizations can make educated, well-supported decisions on pollution reduction programs.

The goal of this project was to aid the Nantucket Department of Natural Resources in establishing long term sustainability recommendations for Nantucket Harbor by creating a water quality database dedicated to openly accessible information. By placing all current data within this database, we established a process that will help in studying pollution trends in the harbor.

2.0 Background

2.1 A Brief History

The island of Nantucket was first discovered by English explorer Bartholomew Gosnold in 1602. At that time the island was a colony of New York until it became a colony of Massachusetts in 1692 (Oldham, 2013). The first settlers came from Massachusetts and New Hampshire in 1659 and lived alongside about 3000 Wampanoag natives. In the 1690's Nantucket started to change from a community of small farms to a community engaged in whaling from small boats and by 1715, deep sea whaling had begun (Oldham, 2013). The island eventually became the whaling capitol of the world. In the span of 30 years starting in the 1830's, however, Nantucket's economy was "brought to its knees" (Oldham, 2013). Whaling journeys had become increasingly expensive, the whaling boats could not get past a sandbar that had formed at the opening of the harbor, and the American Civil War took many of the men away to fight for the Union army (Oldham, 2013). Nantucket was ultimately saved by the income of summer visitors and eventually became one of the most popular tourist destinations on the east coast (Oldham, 2013). The bay scallop industry was also a factor in the revival of Nantucket as scalloping became a central part of the economy; it now brings in about 2 million dollars each winter during times of peak harvest.

2.2 Harbor Significance

Nantucket Harbor is vital to the economic and social well-being of the island – it is a source of shellfish and other seafood, it attracts tourists on the ferries, and its beaches are a major attraction for many of the island's visitors. The harbors of Nantucket have been providers of shellfish, in particular bay scallops, since the 1800's; before then, scallops were used merely as bait for cod fishing (Balling, 2009). Later in the 19th century, scallops had become a popular delicacy and Nantucket residents began to harvest the abundant bay scallops and sell them off-island.

Unfortunately, as a result of changes in water quality, the habitat conditions and prolificacy of the shellfish have changed over time. Some fishermen say that “bay scallops [used to be] so plentiful...that you had no way to avoid stepping on them when you entered the water” (Herr & Dutra, 2012). Now, bay scallops are not nearly as abundant as they once were. In the 1980 season, commercial scallopers brought in 120,000 bushels of scallops, but in 2007 they brought in an all-time low of 3,860 bushels (Balling, 2009). 2008’s harvest was back up to 17,000 bushels, and 2009’s harvest was back down to 9,000, showing the fluctuation of the harbor’s scallop population (Balling, 2009). Despite the changes in the population of shellfish, Nantucket’s bay scallop fisheries remain an integral part in the island’s economy. Not only do they provide shellfish for the residents, visitors, and businesses of the island, they are one of the few reliable sources of bay scallops for the United States. Nantucket’s bay scallop fishery, although “less predictable and productive than it once was,” is still a consistent provider of bay scallops to the rest of the country (Herr & Dutra, 2012).

Nantucket’s economy has also relied heavily on its visitors since the late 19th century. At the peak of the summer there can be up to 60,000 people on the island, but the year-round population of the island is around 15,000 (Town of Nantucket). This number fluctuates due to the transient nature of the population; even some “permanent residents” spend extended portions of the year off-island. Many local businesses on the island are open only during “tourist season,” which is considered to be Memorial Day to Labor Day, so they rely on the island’s summer visitors to frequent their establishments and keep them in business. Additionally, up to 89% of the taxpayers on the island are non-resident property owners and are on-island only during the summer season (Christiansen, 2007).

2.3 Watershed Dynamics

Nantucket, although only forty-nine square miles, has 28 lakes and ponds, twelve of which are over 10 acres (Nantucket Island Watershed, 2008). The island is described as having an “isolated hydrology,” meaning that the water on the island itself is the only source of water that Nantucket has (Nantucket Island Watershed, 2008). Nantucket receives an annual precipitation of about forty-four inches (Nantucket Land Council, 2013). Twenty-five inches of those forty-four inches cycle back into the atmosphere through evaporation; one inch becomes surface runoff into lakes, ponds, and oceans, and eighteen inches are estimated to seep into the soil and resupply the groundwater (Nantucket Land Council, 2013).

A watershed is defined as an area of land where water flows from high to low elevations and eventually drains into a pond or harbor. Watersheds can receive water from surface runoff, from streams, or from water that has seeped into the soil and flows underground (Nantucket Land Council, 2013). Figure 1 shows the different watershed zones around and near Nantucket Harbor. The zones closer to the harbor, represented by solid blue, drain into the harbor faster than the gridded zones surrounding the harbor that are farther away. It is important to keep these areas as healthy as possible for the sake of the health of the harbor as well as the general health of the people on the island.

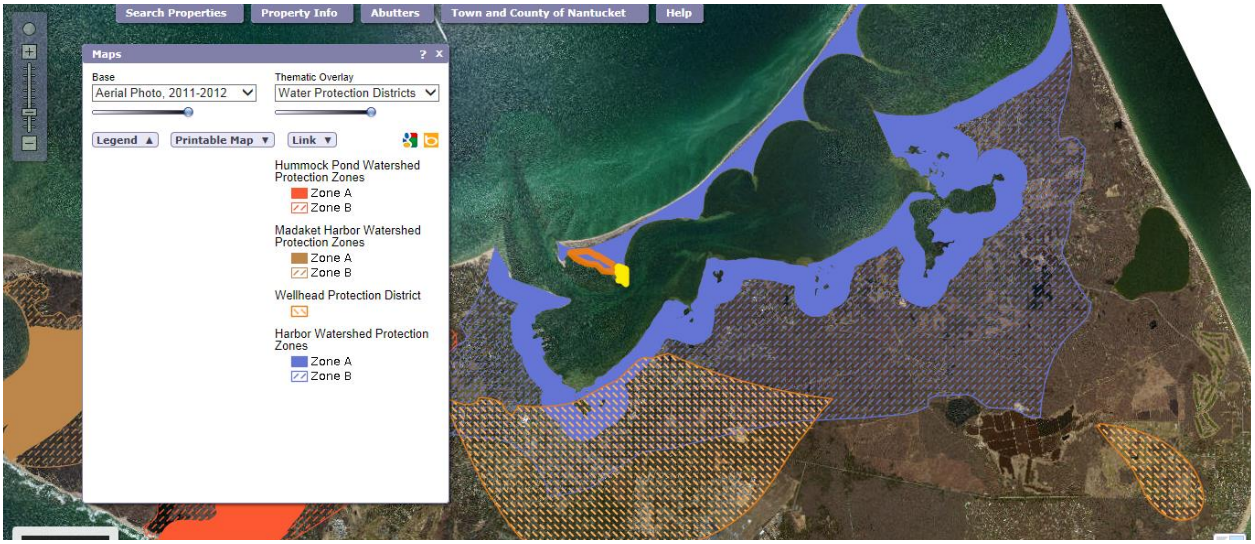

Figure 1: Watersheds around and near Nantucket harbor (http://www.mapgeo.com/NantucketMA/)

2.4 Nutrient Inputs to Nantucket Harbor

The quality of an aquatic system is defined by the measured concentrations of primary pollutants or pollutant indicators. A commonly used example of this is the ratio between nitrogen and phosphorus in a body of water such as Nantucket Harbor. A ratio of 16 parts nitrogen to 1 part phosphorus is ideal for the growth of plant life. Because nitrogen makes up a significantly larger portion of this ratio, its availability in the harbor has a wide range of effects on the harbor's life systems. For this reason, nitrogen in particular is considered to be a limiting factor in water quality, and subsequently is the subject of much of Nantucket's nutrient related studies (Curly, 2002).

There are three major forms in which nitrogen occurs in aquatic systems. These forms are ammonia, nitrate, and various other organic compounds, with the focus of many testing sites on Nantucket being nitrate (Curly, 2002). Due to what is known as the nitrogen cycle, nitrogen in a healthy system will naturally occur in low quantities. As part of this cycle, nitrogen is converted by bacteria into forms usable by plants, which then utilize the nitrogen to make food through photosynthesis. When the plants die and decompose, the cycle can start anew, but problems begin to occur when the loading of nutrients such as nitrogen are added to a system faster than they can be integrated through these processes.

Nitrogen can be loaded into Nantucket Harbor by uncontrollable, natural processes such as rainfall, the changing of tides, or the deposition of nitrogen from the atmosphere to water. Although there is little that can be done to affect these natural processes, approximately 17 percent of nitrogen entering the harbor system is due to human influence (Curly, 2002). The loadings of nitrogen over which people on the island have an influence include the surface runoff of nitrogen-rich fertilizer, faulty septic systems leeching into groundwater, and other agricultural additives being washed through the island watershed into the harbor.

Excess nitrogen loading into the Nantucket Harbor system causes algae blooms to take place. These blooms use nitrogen that would be otherwise available to plants natural to the system, and they reduce light to plants such as eelgrass that grow at the bottom of the harbor. When these algae die and sink, they are decomposed by bacteria that consume dissolved oxygen in the water supply to grow, eat and multiply, which furthers the imbalance of the system. Under the duress of constant loading of excess nitrogen, the system enters a eutrophic state. Eutrophication describes the occurrence in which the dissolved oxygen, specifically near the floor of the water column, is used up, and chemical reactions in the floor sediment releasing more organic nitrogen back into the system (Curly, 2002).

2.5 Impacts of Nitrogen Loading in Nantucket Harbor

There are many negative effects of the Nantucket Harbor remaining in a eutrophic state. As outlined in §2.1, Nantucket Harbor provides commercial fishing, recreation, and aesthetic benefits. These benefits can all be negatively influenced by nitrogen loading (Figure 2).

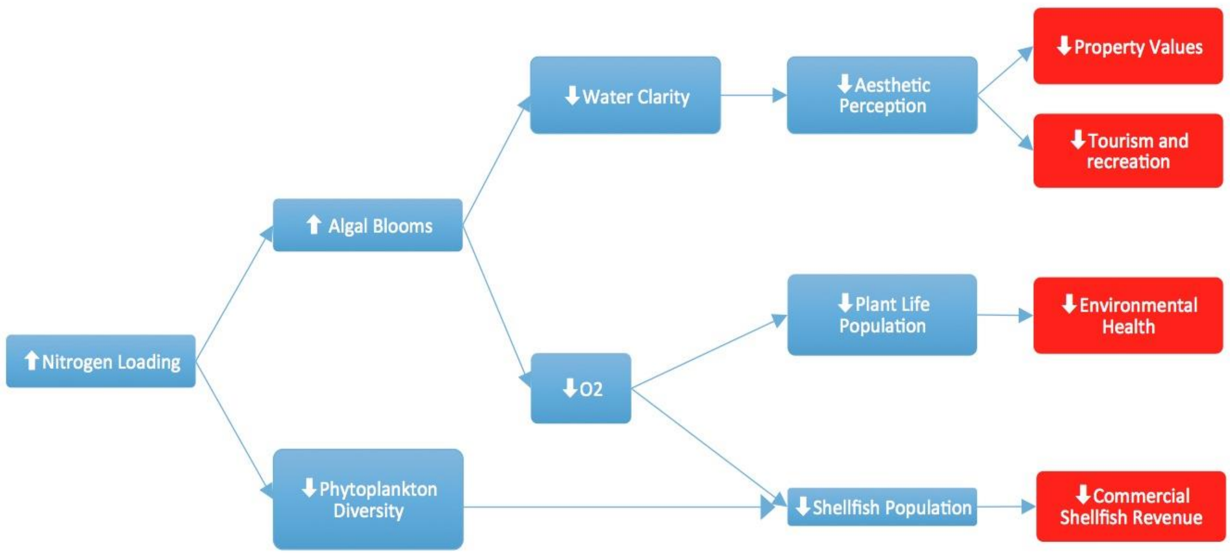

Figure 2: Flowchart describing impacts of excess nitrogen inputs

Drops in the island's shellfish population have been correlated with algal blooms occurring in the summer months (Brace, 2012). Tourists are also less likely to swim, boat, and fish during these blooms due to unfavorable appearance and perceived health risk (Dodds, 2009). As described in section 2.2, declines in tourism and shellfish population are undesirable, as tourism and shellfish are integral to Nantucket's economy.

Eutrophication negatively impacts the biosphere of Nantucket harbor through two main factors. The first factor is hypoxia, defined as bacteria using up dissolved oxygen during the process of decomposing dead algae, which is detrimental to aquatic life, causing "reduced growth rates, increased susceptibility to predation, disruption of spawning and recruitment, and in extreme cases, mortality," according to a study by the US National Science and Technology Council (NSTC 9, 2003). The second factor is the amount of eelgrass present in the harbor. Nutrient loading is a major threat to eelgrass, depriving it of oxygen and blocking out necessary sunlight (Eelgrass Fact Sheet). Scallops and other shellfish depend on eelgrass for habitat and food, and their survivability is reduced by a decrease in the eelgrass population (Curly, 2002). In the case of Nantucket Harbor, a reduction in the amount of eelgrass poses a direct threat to the local shellfish industry which relies on the famous Nantucket Bay scallop to generate revenue, both through scallop sales, and associated scalloping licenses (Herr & Dutra, 2012).

Figure 3: Algal Bloom in Nantucket Harbor Head, photographed in August 2010 by Tara Riley (Brace, 2010)

The eutrophic state of the Nantucket Harbor also has a negative economic impact through decreasing property values and tourist revenue. Nationally, eutrophication is estimated to cost the United States 2.2 billion dollars annually through revenue losses in fishing industries (Dodds, 2009). Nantucket already has problems with an algae bloom known locally as the "brown tide" which has occupied the bay and several ponds during many summer seasons. As shown, the bloom takes the form of a rust-colored streak across the affected body of water, decreasing aesthetic appeal. This impact on aesthetic appeal has a tangible effect on tourism, and similar bloom events have been found to negatively influence tourism revenue through murky water and perceived risk of toxic algae (Dodds, 2009). The increased presence of algae also causes a decrease in water clarity (NSTC 9, 2003), which has been found to strongly correlate with waterfront property values (Dodds, 2009). Finally, algae blooms are a potential threat to the Nantucket real estate market, which hosts several hundred million dollars of transactions per year (Windwalker, 2013).

2.6 Regulating Nutrient Inputs on Nantucket

2.6.1 Total Maximum Daily Load

In 2009, The Massachusetts Estuaries Project (MEP) submitted a report on Nantucket Harbor's Total Maximum Daily Loads for total nitrogen. In this report, the MEP describes the problem of excess nitrogen in the harbor, where this nitrogen comes from, what the Total Maximum Daily Load (TMDL) of total nitrogen should be in the harbor, and how the TMDL standard will be implemented (Howes, 2009).

The TMDL for total nitrogen is the amount of nitrogen in mg/L that can be released into the harbor that will not have adverse effects on the health of the harbor, and should be considered a threshold amount of nitrogen that Nantucket needs to strive for (Howes, 2009). TMDL can be presented as a loading rate (kg/day) or a concentration (mg/L). The loading rate is calculated by taking the concentration (mg/L) of nitrogen in the water and using the surface area of the body of water to convert it to kg/L. Taking the concentration of the total nitrogen represents only that one point in time and since the concentration is constantly changing in the harbor, many data points must be taken to get an accurate value for the nitrogen concentration. The complex calculation to determine the loading rate involves many assumptions and estimates about the conditions of the harbor and the surrounding areas, so working with concentrations is a more effective method for tracking trends in nitrogen. The total nitrogen measured in the harbor consists of nitrate, nitrite, Kjeldahl nitrogen, atmospheric nitrogen and background nitrogen. Of these different forms of nitrogen, nitrate is the one input easily controlled by humans since it mostly comes from human sources like fertilizer and sewage.

In 2009 the MEP determined that the TMDL[1] for total nitrogen in Nantucket harbor should be 0.35mg/L (Howes, 2009). In the same year, they also measured the current overall nitrogen concentration in the harbor and determined it to be 0.34 – 0.41 mg/L at the head of the harbor, 0.34 mg/L at the Quaise Basin and 0.30 – 0.34 mg/L at the Town Basin (Howes, 2009). The nitrogen levels at each part of the harbor are either extremely close or over the TMDL threshold. The harbor's small ecosystem makes it sensitive to even the slightest changes in its conditions so nitrogen concentrations being even slightly over the TMDL is a threat to the health of the harbor (Howes, 2009). Even though the values for the basins are technically under the threshold, they are extremely close to the limit so the harbor is still very much in danger of exceeding the TMDL (Howes, 2009). Based on the TMDL for the harbor and the current nitrogen levels the MEP recommended that Nantucket reduce the concentration of nitrogen flowing into the harbor. They suggested a variety of methods to do this including wastewater treatment, tidal flushing, storm water control and treatment and fertilizer management (Howes, 2009). Later in 2009 the EPA approved the TMDL report saying that it met all of the requirements of the Clean Water Act and 40 Code of Federal Regulations.

2.6.2 Fertilizer Best Management Practices

Fertilizer contains a considerable amount of nitrogen that can leech into Nantucket Harbor when it rains. Since the nitrogen is a limiting factor in the health of Nantucket Harbor and fertilizer is a substantial source of nitrogen, it needs to be regulated (Young, 2012). There

[1] In this report, the units mg/L and parts per billion (ppb) will be used interchangeably with appropriate scaling, because most of the harbor data is recorded in ppb while the TMDL is stated in mg/L. Thus, for example, 0.35 mg/L equals 350 ppb.

are many different ways that nitrogen from fertilizer can be reduced to meet the restrictions on nitrogen loading in the harbor. One solution is to alter the application rates and timing of when the fertilizer is applied. Grass does not use the nitrogen in the fertilizer efficiently when the ground temperature is below 55ºF (Young, 2012). Therefore, the Fertilizer Best Management Practices report recommends the fertilizer should be applied after April 15 but before October 15 and when the temperature of the soil is determined to be 55ºF or above (Young, 2012). Fertilizers also should not be applied before there is a heavy rain fall and irrigation after applying the fertilizer should only moisten the soil (Young, 2012). The application rate regulation for nitrogen on lawns is 3 lb. N/1000 ft^2 per year and for individual lawns the rate cannot exceed 1 lb. N/1000 ft^2 or 0.25 lb. N/1000 ft^2 for fast-release nitrogen (Young, 2012). In addition, the intervals between applications cannot be less than two weeks apart (Young, 2012). If these regulations are adhered to, the amount of excess nitrogen going into the harbor from fertilizer run-off will be greatly decreased.

2.6.3 Sewage Practices

Sewage run-off is another contributor to nitrogen overloading in Nantucket's harbor. Nitrogen containing waste from humans comes from the leakage from septic tanks. Septic systems make up the majority of waste-disposal methods of the island (Young, 2012). Only some of the land around Nantucket Harbor has sewers and this mainly consists of just the downtown area. The rest of the surrounding areas to the harbor have septic tanks so septic leakage is still a significant problem for the harbor. The other bodies of water on the island, such as Madaket Harbor and Hummock Pond, are also considerably threatened by septic leakage since those areas are not linked to the sewer system (Young, 2012).

There are a few measures that can be taken in order to help reduce the nutrients leeching into the ground from septic tanks: having septic tanks inspected and pumped every 3-5 years, installing water conserving devices in showers, faucets etc., and not flushing non-biodegradables down the toilet or sink and planting grass above the tank (Septic Systems/Title 5, 2012). The MassDEP website also has a more extensive list on the how to properly care for a septic system (Septic Systems/Title 5, 2012).

2.7 Monitoring Nantucket Harbor Water Quality

The Nantucket Department of Natural Resources and associated workgroups such as the Article 68 Work Group and the Shellfish and Harbor Advisory Board work year-round to organize data gathered on all of the on island bodies of water. Many groups outside of those charged directly by the island of Nantucket, including the University of Massachusetts-Dartmouth's School of Marine Science and Technology (SMAST) and the Massachusetts Department of Environmental Protection, utilize all the collected data to aid in the development of plans to mitigate pollutants in important ponds and coastal embayments around Nantucket.

Since 2004, bodies of water on and around Nantucket have been evaluated by the Massachusetts Estuaries Project (MEP), performed by SMAST, in order to discern particular total maximum daily loads for the estuarine systems of Nantucket as mentioned in section 2.6. With the help of SMAST, the Department of Natural Resources has established monitoring stations to track water quality nutrient levels on and around the island. The data that is collected is divided into monitoring stations for specific regions. These regions are Madaket Harbor, Long Pond, Nantucket Harbor, Sesachacha Pond, Hummock Pond, and Miacomet Pond, each having their own particular pollutant data that is up to date as of 2012.

The quantitative data on file in the Department of Natural Resources can be separated into two main categories – annual water quality reports, and tables of pure data. The water quality reports include a summary of the data, as well as graphs showing trends over time. Most of the reports also include tables of raw data, organized by sampling site, data, and specific parameter (such as salinity or nitrogen levels). There are also data sheets done by outsourced laboratories, again organized in tables by sampling site, date, and parameter. For the majority of nutrient data, samples were taken from the same six stations around Nantucket Harbor, with two more stations added in 2011. A map of these stations, taken from the 2012 Water Quality Report, is shown below.

Figure 4: 2012 Water Quality Report, sampling locations

2.8 Managing Water Quality Data

To date, research conducted primarily by SMAST has been used to determine the present health of all main salt ponds and estuaries and to gauge both the long term decline and/or recovery of selected water systems, establishing the groundwork for more detailed resource management efforts. By continuing to gather information from Nantucket's various testing stations, the Department of Natural Resources can continue to define trends in how different nutrients such as nitrogen are distributed around the harbor over time, and henceforth develop better management plans for the water quality of all major coastal embayments around the island.

Separate from site specific water quality information, various zoning and spatial information is maintained on Nantucket's online GIS webpage; different regions are categorized by their association to different watersheds, the island's aquifer, and sewage systems. This information alone is very informative, but can be utilized further to organize data on different estuarine systems (Town of Nantucket). By topographically associating nutrient inputs and readings throughout the Nantucket over time, researchers will be able to make more informed inferences about the human impetus behind nutrient loading.

3.0 Methodology

This project was intended to help the Nantucket Department of Natural Resources to sustain Nantucket's human and economic well-being through efficient water quality research. This was accomplished by organizing data regarding factors of water quality over which humans have influence, analyzing seasonal trends, and presenting our findings to ensure the accessibility and communicability of all data to both associated researchers, and to the Nantucket public.

Our team worked on this project from October 28th through December 19th to prototype a database that meets the needs of the Nantucket Department of Natural Resources. Our overall methodology is featured in Figure 5:

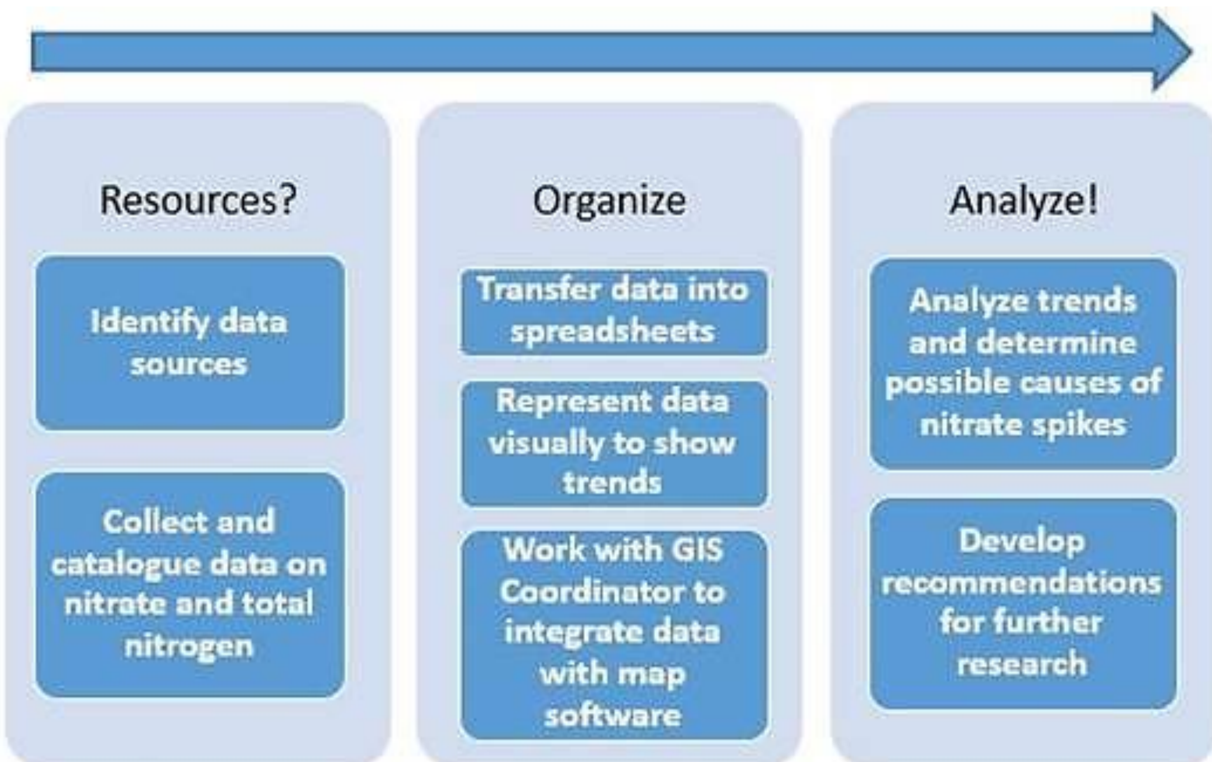

Figure 5: General overview of how we satisfied our objectives.

3.1 Identifying available resources

In order to create a database for water quality data collected by and for Nantucket's Department of Natural Resources, it was important to learn who has been involved in the research and to what capacity, what data they have, etc. While the Department of Natural Resources is an actor in the effort to maintain a clean and healthy harbor, the entirety of Nantucket's water quality data has been collected by a variety of individuals over time. This includes those working directly with the Department of Natural Resources and also independent scientists. Changing strategies in data collection over time have resulted in inefficient management of data, making it difficult to use in subsequent studies.

One goal of this project was to help create a system in order to more efficiently manage the water quality data that currently exists. In order to do this, we had to identify several factors:

- Who has collected water quality data? What parties (individual scientists, other organizations, etc.) are associated with the water quality research on the island?
- What data was present at the time? What factors in water quality (pH, metal levels, microorganisms, etc.) were collected over what time spans?
- How was the data formatted? E.g. units of measurement, temporal resolution of samples, format of computer files, etc.
- What methods were used to collect the data?
- What were the goals in collecting the data?

We addressed these questions through meetings and other correspondence with the people and organizations that are associated with water quality research on the island. By communicating with the Department of Natural Resources as well as using online resources provided by the department, we were able to locate and consult with the associated parties.

3.2 Defining the scope of our project

When we first began our project we met with our sponsors and the consultants to whom our work would be relevant. While preparing for this project last term, we had established a general overview of what the project would entail, but the purpose of this meeting was to further define the scope of the project and develop an idea of what the stakeholders' expectations were. During the meeting we learned that there were various ways in which the stakeholders felt a comprehensive, central database of water quality information could be used, in terms of verifying policies regarding fertilizer and sewage management. It became clear that in order to produce something useable for such a wide array of interests, it would be necessary to chronologically organize data for the different bodies of water around Nantucket. This chronological and regional organization of data would allow for objective analysis of trends in water quality, so that political groups such as the Article 68 work group can better understand exactly why any sort of policy would need to be implemented.

After the initial meeting, we then met with Dr. Sarah Oktay, an oceanographer who has done extensive work on water quality sampling on the island, to further narrow the scope of the project. She recommended that we choose one specific water quality parameter and one body of water to focus on for this project – trying to account for all factors (nitrogen, phosphorus, salinity, etc.) in all bodies of water on the island (all the harbors, great ponds, etc.) was not an achievable goal for a seven-week project. By choosing one single parameter, we could simultaneously perform useful analysis, while also creating an exemplary process for future studies in water quality on Nantucket.

Based on her recommendations, we decided to focus on levels of nitrates in Nantucket Harbor. We then composed a background report on the significance of nitrate (and nitrogen overall) in order to gain a better understanding of its effect on the health of Nantucket Harbor.

It was appropriate to use nitrate as the focus of our study because our process of organizing the present data can be used for other future studies, while the actual data we collected can be analyzed to show the extent of human influence over the Nantucket Harbor system. Nitrates are a form of nitrogen over which humans have a large influence; their presence in the Nantucket watershed is a result of the application of fertilizer, and leeching of septic and sewage systems. By focusing our research on nitrates, we will provide the Nantucket community with useable information about the impairment of Nantucket Harbor, while identifying that they themselves have an influence over the observed nitrate concentrations.

3.3 Organizing Information

3.3.1 Preliminary Categorization

We began the process by going through all the physical harbor data from the Department of Natural Resources and sorting the files into two categories: resources containing quantitative information, such as tables of raw data and annual water quality reports, and those containing contextual information, such as case studies and historical reports. Within these two categories, we sorted the data chronologically, then separated it into folders by decade for easier access. Once the data had been sorted, we began picking out the resources that contained nitrate data and more general nitrogen information specifically.

3.3.2 Recording Data

We used Excel to set up a spreadsheet for each of the eight sampling stations that are located in and around Nantucket Harbor. We set up three columns on each spreadsheet for the date the sample was taken, the concentration of nitrates, and the total nitrogen concentration of the sample, in units of parts per billion (ppb). As detailed in the background section, the total maximum daily load, or TMDL, is the concentration of nitrogen in total (in mg/L) that can be released into the harbor without having adverse effects on the health of the harbor. This threshold total nitrogen concentration refers to nitrogen in all its forms in the Harbor, we decided to compare the nitrate concentration to total nitrogen to determine how much of the total nitrogen is composed of nitrates, and then compare the total nitrogen levels to the TMDL.

The nitrate concentrations that were entered into the spreadsheets were primarily from the appendices of the annual water quality reports, starting from 1997's report. We made the decision to start with this report because 1997 was the year that water sampling practices and reporting were becoming regular and standardized – before 1997, there was not an annual water quality report produced each year, and collecting water samples for testing was not done on a regular schedule.

Using the tables from the reports, we entered the values from each sampling date into the tables. Not all of the sampling stations had data for each date, and there were no annual reports from 2008 or 2009 due to lack of funding for the Department of Natural Resources in those years.

4.0 Results

As we compiled the available data on nitrate and total nitrogen, we studied the most effective methods for observing meaningful data trends. Because of issues such as infrequently sampled concentrations, inconsistently sampled concentrations, and varied flushing dynamics within the harbor system, trends in nitrates varied widely. The purpose of the following results section is to describe the effect that reducing nitrate inputs will have on the total nitrogen in Nantucket Harbor during the most heavily affected season.

4.1 Observing All Nitrate Data

Our first compilation of nitrate data, found in Appendix 7.3, consists of nitrate concentrations in parts per billion (ppb), organized by the station at which the sample was collected, and the day on which the sample was collected. We used data that was recorded between 1997 and 2011, because the process of water sampling on Nantucket had very little consistency from year to year before 1997 and data for years following 2011 have been made available only through the Nantucket Department of Natural resources in the form of various graphical interpretations. Unfortunately, the post-2011 data was of no use to us, as our research process required the original data as reported by either the Department of Natural Resources, or by one of the mainland labs with which the DNR consults.

We first sought to observe a trend in nitrate concentrations over the course of an average year. We accomplished this by averaging all nitrate values for a given month at a given station, and plotting the value as a single point. At the recommendation of Jeff Carlson at the Department of Natural Resources, we attributed a standard 5% uncertainty to our data, to account for miscalculations in analyzing water quality samples. This is a conservative uncertainty, as it does not account for inconsistencies in the collection methods of water quality samples. In order to remain as consistent as possible, we chose to represent only data that was taken as a surface sample. The results of this first trend analysis can be seen in Figure 6.

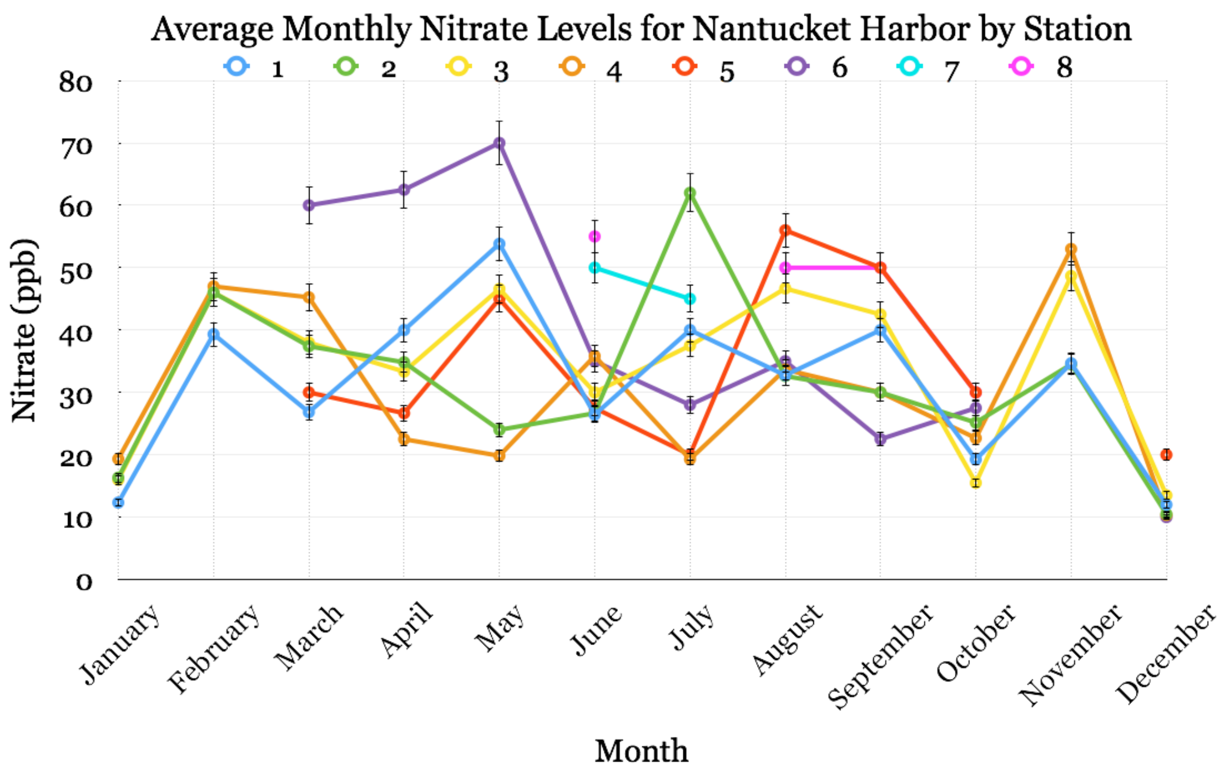

Figure 6: Average Monthly Nitrate Levels for Nantucket Harbor by Station

We observed that there is no clear trend in the nitrate concentrations between the different stations. One of the primary reasons for this is that the samples were taken infrequently, often with many weeks of no sampling in between single data points. This means that a rainfall that might increase nitrate concentrations for just a day could greatly affect our average if a sample was taken that day. Harbor areas towards the town basin specifically, seen as station 1 in Figure 4, can see rapid changes in nutrient concentrations, and would require far more frequent sampling to accurately represent. It is for this reason that we chose to narrow our focus to stations 2 and 3, located in Quaise Basin and in the head of the harbor respectively (Figure 4).

These stations represent larger bodies of water within the harbor which, because they are further from the town basin, flush significantly more slowly. Since nutrients take longer to shift location near these stations, the average monthly nitrate concentration will not depend as drastically on the precise day that it is sampled. The nitrate concentrations for an average year at stations 2 and 3 are shown in Figure 7.

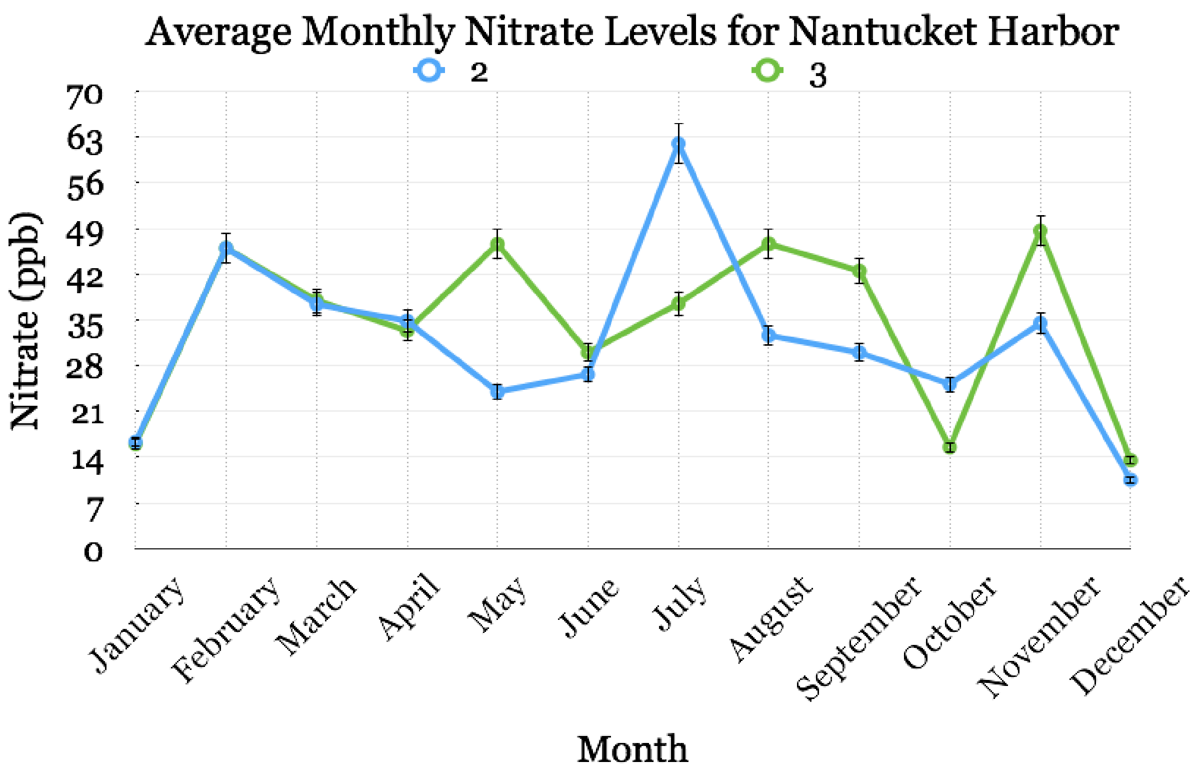

Figure 7: Average Monthly Nitrate Levels for Nantucket Harbor

The largest amount of nutrient inputs enters Nantucket Harbor during the spring and summer months. For these months, stations 2 and 3 see fairly consistent trends in nitrate concentrations. During the more heavily loaded spring and summer months, however, there are significant discrepancies in the trend of these two stations. This is most likely due to the fact that the inputs of nitrates are coming from different locations in the harbor watershed. Infrequently taken samples limit our ability to see how these inputs flow from one station to another. The fact that the time between April and September exhibits the largest changes to nitrate concentration, and these months are represented by significantly more data points than the winter months, mean that the data in these months should be examined in more detail. In order to address the significance of these changing nitrate concentrations, we must look at more than just the nitrate concentrations for these months.

4.2 Trend in Total Nitrogen

For each of the dates in our data for which we have recorded a nitrate concentration, we also have the concentration of total nitrogen. The total nitrogen value accounts for all forms of nitrogen present in the harbor, addressed in section 2.6.1. Continuing to use stations 2 and 3 as examples, we again average all total nitrogen concentrations for each month on which we have chosen to focus. The average trend for total nitrogen concentrations during the more heavily loaded months is shown in Figure 8.

For these averages, the Massachusetts Estuaries Project has defined a mean value and a standard deviation for total nitrogen concentration samples in the upper head of the harbor (station 3) and Quaise Basin (station 2). Station 3 has a mean value for total nitrogen concentration of 0.408 parts per million, and a standard deviation of 0.188 parts per million, giving a percent error of 46%. By the same process, station 2 shows a percent error of 33%. Despite the large uncertainties, the mean values used in the following figures still provide a useful representation of the concentrations of nitrogen in the harbor; however more frequent sampling and a more consistent sampling process may help in reducing these errors.

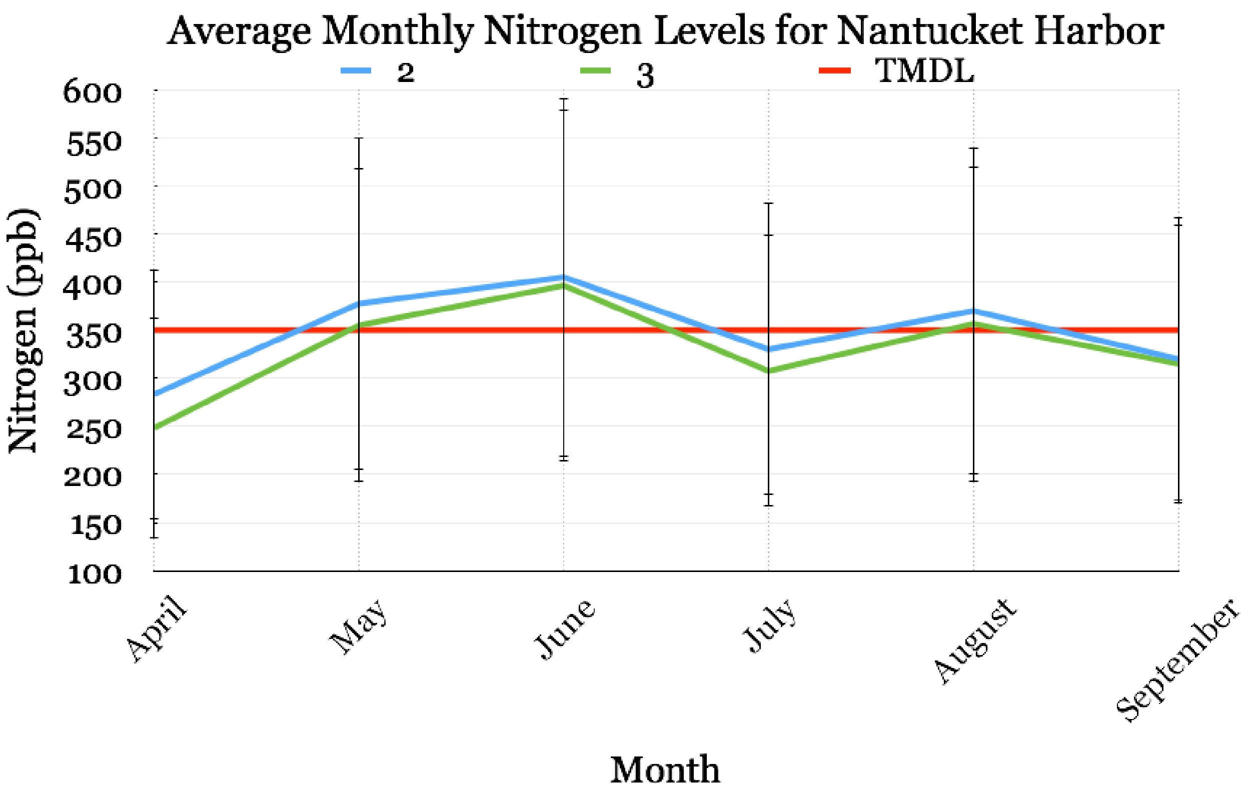

Figure 8: Average Monthly Nitrogen Levels for Nantucket Harbor

Using this figure, we compare the trend in total nitrogen concentration to the safe concentration 350 ppb, defined by the Massachusetts Estuaries Project. We see that in June, the mean of the total nitrogen concentrations for both stations 2 and 3 exhibits a local maximum, in which the total nitrogen is above the safe concentration by about 50 ppb. We found it necessary to then focus on lowering this total nitrogen in June, so that we can assure that Nantucket Harbor remains below this limit for the surrounding months.

4.3 Satisfying the Total Maximum Daily Load

We have established in §2.6 that nitrate can be loaded into the harbor through a variety of human inputs. We showed that the month of June is, on average, well above the safe concentration for total nitrogen. We then looked to show the effect that removing nitrate inputs would have on the average total nitrogen concentration in June. By bringing the total nitrogen concentration below the safe concentration, we intended to show the potential for the long term sustainability in the water quality of Nantucket Harbor. Continuing to use our example stations 2 and 3, we recorded the total nitrogen and nitrate concentrations for every June on record. By comparing the nitrate to the total nitrogen concentration, we were able to discern the average percent of the total nitrogen that nitrate contributes. These averages are represented in Figure 9 and Figure 10.

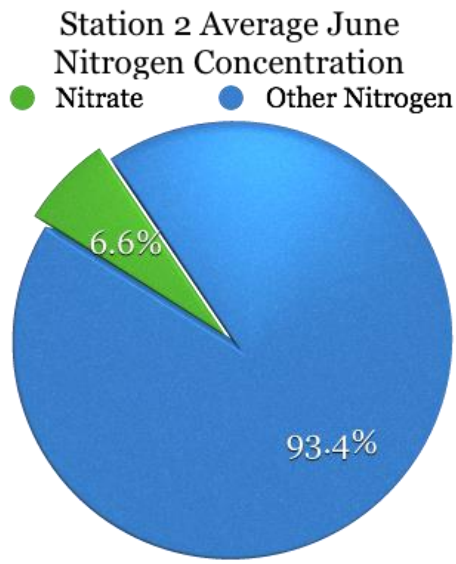

Figure 9: Station 2 June Nitrogen Breakdown

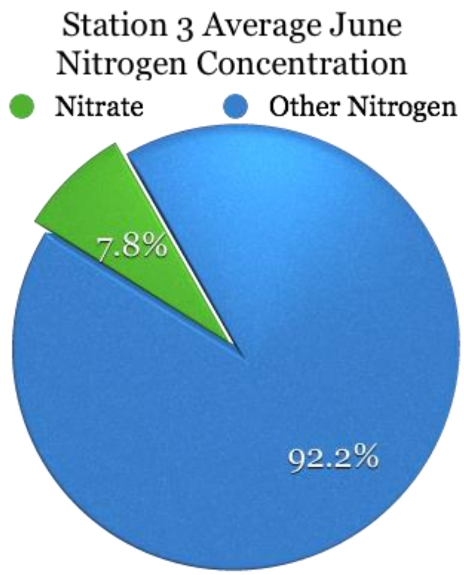

Figure 10: Station 3 June Nitrogen Breakdown

Using the data depicted in the pie charts, we can subtract the nitrate percentage for each station from the total June concentration. This analysis is shown in Figure 11 for station 2 and Figure 12 for station 3.

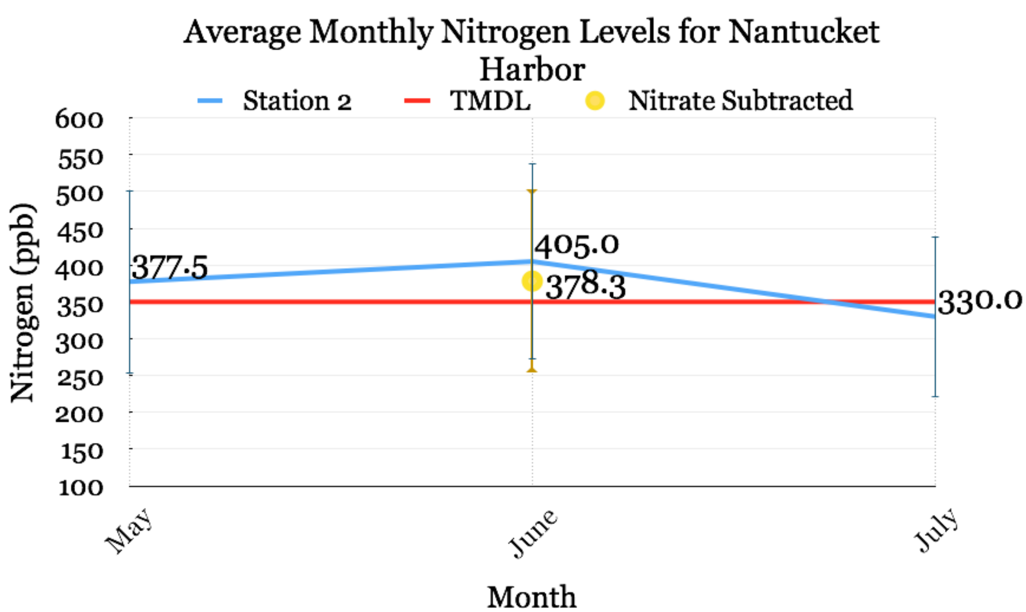

Figure 11: Nitrate Subtracted from Station 3 Average Monthly Nitrogen Levels

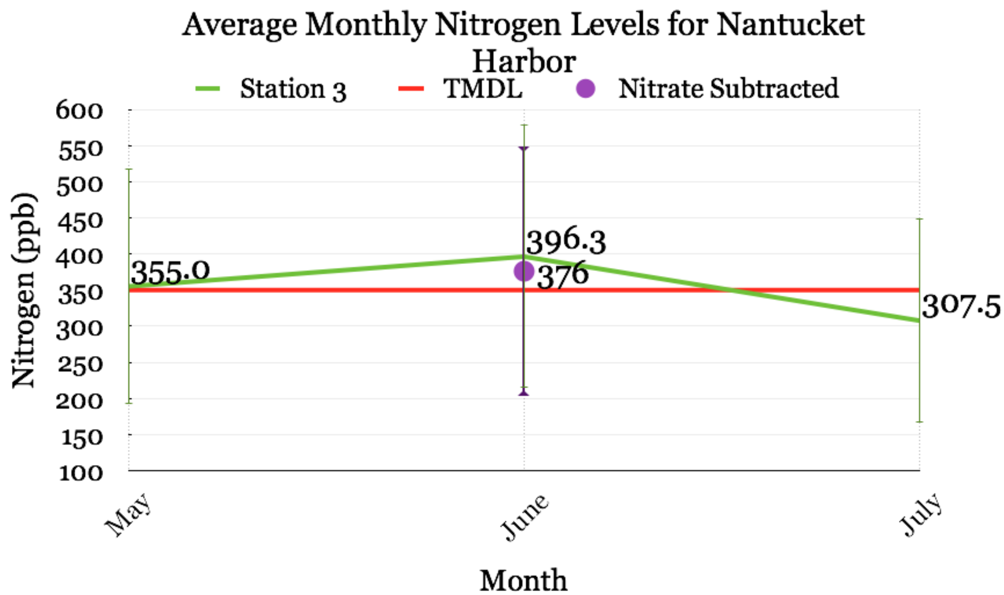

Figure 12: Nitrate Subtracted from Station 3 Average Monthly Nitrogen Levels

After subtracting the nitrate percentage from the mean values for both stations, we see that the June total nitrogen concentrations are brought significantly closer to the safe concentration defined using the TMDL. This means that for the surrounding months, a similar reduction in nitrate inputs can put Nantucket Harbor further under the TMDL limit.

5.0 Conclusion and Recommendations

The goal of this project was to help Nantucket's Department of Natural Resources improve the efficiency and effectiveness of their current water quality research and management. Our group worked with the DNR, as well as several independent scientists, to organize and analyze the water quality data on file, and understand the effect that reducing nitrate inputs would have on the harbor. This chapter describes the conclusions we drew after completing our data analysis, as well as the recommendations that we developed for the Department of Natural Resources.

5.1 Removing Nitrate Concentrations

Using the methods described in our report, we analyzed the nitrogen data and established how much of the total nitrogen in the harbor nitrate composes. From our analysis we determined that if the nitrate inputs to the harbor were to be removed, the concentration of total nitrogen would be closer to the safe concentration used to calculate the Total Maximum Daily Load (TMDL) for June, the peak month in harbor impairment. If the nitrogen concentration were to be reduced to the safe concentration for the peak month, during the surrounding months of the year the nitrogen would also be below or well below this concentration.

By remaining below this concentration, the loading rate for the harbor defined as the Total Maximum Daily Load will not be exceeded. Unfortunately, we can make no further conclusion pertaining to the trend of nitrate and total nitrogen for Nantucket Harbor. This is due to the infrequency with which the data was taken and the inconsistencies in the time, location, and method of sampling.

5.2 Recommendations

Based on the above conclusions, our group has developed recommendations for the Department of Natural Resources to help improve the efficiency and effectiveness of their water quality management efforts.

Much of the existing harbor water quality data was taken at inconsistent intervals, and was taken too infrequently to show detailed trends. Additionally, there are some inconsistencies regarding the time of day at which water samples were taken; and whether the tide is incoming or outgoing can affect the outcome of water samples. In order to increase the accuracy of the data, we recommend that water quality samples be taken more frequently and with more consistency. Having more data points leads to having higher resolution data, which enables a more detailed and accurate analysis of trends.

In order to achieve an increased frequency of water sampling, we also recommend that a new job position be created at the Department of Natural Resources dedicated to water quality sampling and analysis. Currently, water sampling is done by the Department of Natural Resources on an irregular basis. If there were a single individual responsible for taking and managing the data from water samples, data would be able to be taken much more frequently and consistently as per our first recommendation.

In our conclusions we discussed the effects of reducing or eliminating nitrate flowing into the harbor from human-controlled sources. Accordingly, we recommend that further studies be conducted to observe the feasibility of reducing nitrate inputs through good management practices.

In order to organize future data we have worked with the town GIS coordinator to compose an ArcGIS package that displays nitrate and total nitrogen concentrations, organized by sampling station. The database is to be made available through the Department of Natural Resources once the town website is updated. This database will allow for researchers to store data on nitrates in a common, easily accessible location. It will also enable interested residents to obtain more detailed data on the nutrient conditions in the harbor.

Finally, the Department of Natural Resources may want to consider the use of water quality monitoring buoys which can be placed in the harbor and which include water quality logging systems for long-term, unattended monitoring. If these sampling systems were in place, water samples could be taken continuously and provide a sufficient number of data points to help increase the resolution of the data. Additionally, if there were two buoys, one placed at the head of the harbor and one placed at Children's Beach (near the entrance of the harbor) the data collected could help identify the nutrient flow in and out of the harbor.

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7.0 Appendices

7.1 Fertilizer Application Tips For Homeowners on Nantucket

Background

A comprehensive plan to reduce nutrient contamination of our waters from excess use of fertilizers, thus meeting mandated Total Maximum Daily Loads, TMDL, of nutrients in our waters, has been released by the Town of Nantucket.

- The Board of Health will be responsible for the plan and the Department of Health will enforce it.
- It applies to professional fertilizer applicators and interested homeowners on Nantucket, excepting commercial agriculture. Landscapers will take a test to be licensed and will reapply every three years. Is your landscaper certified? Homeowners may apply for a license as well. License holders may follow the detailed but flexible guidance of the BMP.
- The comprehensive plan is based on a scientifically rigorous Best Management Practices Plan, BMP, available in the DOH office or on line as a reference.
- The BMP has been written specifically for Nantucket: Soil, topography, climate, and plants. Our soil is porous and does not hold fertilizer, which, if over applied, washes into our water sources.
- Fertilizer should be applied for plants to use as quickly and effectively as possible. Excess will harm ACK waters:
- Apply only between April 15 and Oct 15 so that plants are active, not dormant;
- Do not apply before strong rain that will wash it into water sources;
- Avoid excess irrigation;
- Avoid wetlands and other areas defined by the Conservation Commission as no-fertilize areas;
- Test the soil before applying fertilizer.

Compost –Learn More

- Special case on Nantucket: soils are different here from the mainland and need to be treated differently.
- Many of our amended lawn and garden soils have enough phosphate for plant growth, adding more might harm waters.
- Animal manures and animal-manure-based composts are rich in nitrogen and phosphate; leaf litter composts are less so and are preferred.
- Native levels of organic matter, OM, are lower here than elsewhere.
    - Compost is important to develop organic matter in soil:

        - a source of carbon and other nutrients,
        - retains moisture,
        - hosts beneficial bacteria and insects,
        - leaf litter compost is preferred,
        - while compost is important for raising OM levels, it should be applied slowly.
    - <u>Raising soil organic matter much above native levels can result in nitrogen and phosphorus leaching.</u>

<u>How to test soils, why?</u>

- Always use the same testing laboratory for consistency in results;
- Follow sampling directions on sample container;
- What is learned?
    - Texture: percentages of clay, silt, and sand,
    - Essential elements: P, K, Ca, Mg, Fe, and trace elements,
    - Organic matter,
    - Nitrogen is not exact.

<u>READ the LABELS when buying fertilizer and applying.</u>

- Labels list the ingredients as follows: Nitrogen, N, as elemental nitrogen, Phosphorus, P, as P_2O_5, and Potassium, K, as potash, K_2O.
- The label tells us in percentages how much of each is contained in a bag of fertilizer: N percent, P percent, and K percent.

<u>Guide to Fertilizer Application</u>

- Nitrogen application limits:
    - excess nitrogen affects marine life,
    - 3.0 lbs per 1000 sq ft per season,
    - At least 2 weeks apart,
    - 0.5 lbs per application,
    - No more than 0.25 lbs per 1000 sq ft of quick-release nitrogen per application,
    - Variations allowed for license holders who follow the BMP.
- Phosphate application limits:
    - Excess phosphates affect fresh water life,
    - None unless need specified by soil test,
    - If soil tests show need, new plantings and moved plantings may receive phosphate.

Effective lawn care can reduce the need for fertilizer

- Let your grass grow longer, 2 ½ to 3 inches long. The plant is healthier and can take up fertilizer more effectively. Long grass weathers the hot summer better.
- A 3-inch high lawn can take up and use nutrients up to ten times as effectively as a 2-inch lawn.
- Leave the clippings on the lawn. They equal a pound of fertilizer per 1,000 sq. ft. per year that you do not have to apply.
- Cut the grass more often. Never remove more than the top 1/3 of the length. Your lawn will be healthier.

Using native plants is a simple way to reduce nutrient inputs to our soils.

- Site planning and landscape designs incorporating or preserving native plants, which do not require fertilizer, are encouraged.
- Some native plants that work well on Nantucket:
  - Meadow grasses, including little bluestem and Pennsylvania sedge;
  - Shrubs, including bayberry, inkberry, winterberry, and blueberry;
  - Trees including red maple, tupelo, American holly, and oaks.

More information can be found in the Best Management Practices manual.

7.2 Sponsor and Mentor Biographies

Jeff Carlson – Natural Resources Coordinator

Jeff Carlson graduated from Purdue University in 200 with a B.S. in Natural Resources, and worked as an environmental permitting specialist with Nantucket Surveyors from Nov. 2000 – May 2006. Jeff has been with the Town of Nantucket from May 2006 working as the beach manager and became the Natural Resources Coordinator and head of the Natural Resources Department in 2011.

Sarah Oktay – Director of UMass Boston Nantucket Field Station

Sarah Oktay received her doctorate from Texas A&M University at Galveston in Chemical Oceanography in December 1999. Her research publications and book chapter topics described sediment movements, radioactive and stable iodine concentrations and the associated carbon loads and trace metal fluxes and concentrations in a variety of matrices from ocean water to rivers and estuaries to atmospheric, biological samples, and soils. She was a Research Associate in the Department of Earth, Environmental, and Ocean Sciences at UMass Boston starting in 2000 and continued biogeochemical research with a seminal paper on the chemical footprint of the World Trade Center ash material as found in the Hudson River. An offshoot of that work was the discovery of radioactive iodine from hospital waste in the NY/NJ estuary system. She has been on the graduate committee of 6 PhD and 4 Masters students and she has mentored over 100 undergraduate and graduate students. Her current research focuses on beach profiling and water quality parameters (septic and fertilizers) on Nantucket in addition to all ages education and outreach on environmental issues. She is the President Elect of the Organization of Biological Field Stations and an invited member of the Society of Women Geographers.

Nathan Porter – Town GIS Coordinator

Nathan Porter received a B. A. History at University of Georgia. He was a Project Manager at Information Technology Outreach Services between 1999 and 2005. He is currently the GIS Coordinator for the Town of Nantucket.

Gregg Tivnan – Assistant Town Manager

Gregg A. Tivnan, originally from Danvers, MA, attended Danvers High School, the University of Notre Dame for a degree in business and German, and Northeastern University for a Masters in Public Administration.

He worked for the City of Boston for 10 years. During this time he worked in the Mayor's Office of Budget and Management as a Management Analyst, in Boston City Council as the Assistant Director of Budget and in the Office of Homeland Security as a Project Manager. Prior to coming to Nantucket, he worked in the Governor's Executive Office of Administration and Finance as the Operations Manager for Budget Systems. He became the Assistant Town Manager of Nantucket in 2009.

He is an avid baseball fan and has been to 24 of the 30 major league ballparks, and is a former Marine Corps infantryman.

Peter Boyce – Research Associate at Maria Mitchell Association

Dr. Peter Boyce is an astronomer who turned marine biologist after retiring to Nantucket. He now is a Research Associate at the Maria Mitchell Association in charge of their Scallop Research Program. With a BA from Harvard and a PhD from Michigan, Dr. Boyce worked at Lowell Observatory and the National Science Foundation before spending a year as the science adviser to Congressman Morris K. Udall. He then served the American Astronomical Society as Executive Officer for nearly 20 years. While there, he was a pioneer in electronic publication, bringing the Society's scientific journals on line in 1995. Two years later he led the astronomy community to establish a coherent, interlinked information service which seamlessly combined the electronic journals with a database of searchable abstracts, and several worldwide astronomical data depositories. He began studying Nantucket's bay scallop population in 2003 and, since 2006 has given numerous scientific presentations in his new field.

Lee W. Saperstein – Professor Emeritus of Mining Engineering

Dr. Saperstein has a B. S. in Mining Engineering from the Montana School of Mines and a D. Phil. in engineering science from Oxford University, which he attended as a Rhodes Scholar. He has been a mining engineering faculty member at The Pennsylvania State University, the University of Kentucky, and the University of Missouri-Rolla. He was Dean of the School of Mines and Metallurgy at UMR for 11 years. He is a licensed Professional Engineer and is an expert in the environmental impacts of mining. He has also served ABET, Inc, the recognized accreditor for engineering, as its President. He is a Distinguished Member of the Society for Mining, Metallurgy, and Exploration, Inc. (SME), a Fellow of ABET and holder of its Grinter Award, and recognized as a Distinguished Alumni by Montana Tech. He retired to Nantucket in 2007.

Peter Morrison – Mentor, Applied Demographer

Dr. Morrison is retired from the RAND Corporation where he was the founding director of RAND's Population Research Center. He has taught at the RAND Graduate School, Helsinki School of Economics, and University of Pennsylvania, and mentors Worcester Polytechnic Institute student teams at the Institute's Nantucket Project Center.

Jean Grimmer – 2013 Chair, NCS Clean Harbor Award

Jean Grimmer came to Nantucket in 1998 to plan and execute the Campaign for the Nantucket Historical Association which, among other things, financed the building and renovation of the Whaling Museum on Broad Street. She went on to run the Egan Maritime Institute and its affiliates, The Shipwreck & Lifesaving Museum and Mill Hill Press as its executive director. After over eight years in that position, she started her own consulting business to assist non-profit organizations. Jean volunteers for a number of organizations including Nantucket Community Sailing which, through its annual Clear Harbor Award, is the genesis for this project.

7.3 Nitrate and Nitrogen Data Tables

Table 1: All Station 1 Data by Date

Date	NO3 (ppb)	Total Nitrogen (ppb)	NO3/Total Nitrogen
10/25/97	27	No Record	
11/27/97	24	No Record	
12/15/97	14	No Record	
1/15/98	7	No Record	
2/27/98	68	No Record	
3/17/98	16	No Record	
4/14/98	BRL	No Record	
5/19/98	13	No Record	
6/16/98	45	No Record	
7/7/98	BRL	No Record	
8/18/98	72	No Record	
9/22/98	BRL	No Record	
1/21/99	20	No Record	
3/29/99	20	No Record	
4/20/99	20	No Record	
5/30/99	10	No Record	
7/6/99	110	200	55.00%
8/3/99	60	200	30.00%
3/24/00	25	200	12.50%
5/16/00	60	500	12.00%
6/26/00	10	500	2.00%
7/24/00	10	1690	0.59%
8/25/00	10	500	2.00%
9/7/00	40	500	8.00%
10/24/00	10	500	2.00%
11/21/00	70	500	14.00%
1/25/01	10	500	2.00%
2/22/01	30	500	6.00%
3/27/01	50	100	50.00%
4/23/01	70	10	700.00%
5/29/01	110	100	110.00%
6/19/01	10	10	100.00%
7/12/01	10	100	10.00%
8/8/01	40	100	40.00%
9/10/01	60	480	12.50%
10/9/01	20	100	20.00%

11/8/01	BRL	420	
2/4/02	20	100	20.00%
3/14/02	30	450	6.67%
4/16/02	BRL	140	
5/23/02	10	570	1.75%
6/12/02	BRL	420	
7/15/02	BRL	140	
8/2/02	10	290	3.45%
10/23/02	BRL	50	
11/20/02	BRL	140	
12/18/02	BRL	140	
3/25/03	20	30	66.67%
4/30/03	20	30	66.67%
6/3/03	BRL	140	
6/26/03	20	30	66.67%
7/28/03	BRL	280	
8/25/03	20	440	4.55%
9/29/03	20	300	6.67%
10/20/03	20	440	4.55%
11/10/03	BRL	280	
12/22/03	BRL	420	
4/7/04	NR	280	
5/13/04	NR	420	
6/21/04	NR	420	
7/7/04	NR	280	
8/18/04	20	440	4.55%
9/28/04	NR	420	
11/2/04	NR	280	
11/23/04	10	290	3.45%
12/13/04	10	430	2.33%
5/18/05	120	400	30.00%
6/16/05	20	300	6.67%
7/13/05	BRL	280	
8/11/05	30	450	6.67%
9/26/05	BRL	350	
10/27/05	BRL	280	
4/20/06	120	400	30.00%
5/24/06	BRL	280	
6/19/06	30	870	3.45%
7/31/06	BRL	1900	
8/17/06	BRL	No Record	

9/13/06	BRL	120	
10/17/06	BRL	No Record	
11/30/06	BRL	11	
4/23/07	10	110	9.09%
5/22/07	BRL	300	
6/21/07	BRL	110	
7/10/07	40	240	16.67%
8/20/07	BRL	100	
9/18/07	BRL	110	
10/16/07	BRL	220	
6/9/11	50	No Record	
6/24/11	50	No Record	
7/5/11	30	No Record	
7/20/11	30	No Record	
9/14/11	BRL	No Record	

Table 2: All Station 2 Data by Date

Date	NO3 (ppb)	Total Nitrogen (ppb)	NO3/Total Nitrogen
10/25/97	31	No Record	
11/27/97	9	No Record	
12/15/97	11	No Record	
1/15/98	9	No Record	
2/27/98	72	No Record	
3/17/98	42	No Record	
4/14/98	9	No Record	
5/19/98	28	No Record	
6/16/98	40	No Record	
7/7/98	BRL	No Record	
8/18/98	91	No Record	
9/22/98	BRL	No Record	
1/21/99	30	No Record	
3/29/99	20	No Record	
4/20/99	20	No Record	
5/30/99	10	No Record	
7/6/99	60	200	30.00%
8/3/99	70	200	35.00%
3/24/00	5	200	2.50%
5/16/00	60	500	12.00%

6/26/00	10	560	1.79%
7/24/00	30	500	6.00%
8/25/00	10	500	2.00%
9/7/00	60	500	12.00%
10/24/00	10	500	2.00%
11/21/00	60	500	12.00%
1/25/01	10	500	2.00%
2/22/01	20	500	4.00%
3/27/01	30	100	30.00%
4/23/01	10	10	100.00%
5/29/01	10	100	10.00%
6/19/01	20	10	200.00%
7/12/01	20	190	10.53%
8/8/01	BRL	0	
9/10/01	30	310	9.68%
10/9/01	20	100	20.00%
11/8/01	BRL	420	
2/4/02	BRL	100	
3/14/02	BRL	420	
4/16/02	BRL	140	
5/23/02	10	570	1.75%
6/12/02	10	570	1.75%
7/15/02	BRL	280	
8/2/02	BRL	280	
10/23/02	BRL	50	
11/20/02	BRL	420	
12/18/02	BRL	140	
3/25/03	90	370	24.32%
4/30/03	60	340	17.65%
6/3/03	10	570	1.75%
6/26/03	30	870	3.45%
7/28/03	BRL	420	
8/25/03	40	460	8.70%
9/29/03	10	150	6.67%
10/20/03	10	570	1.75%
11/10/03	BRL	420	
12/22/03	BRL	280	
4/7/04	No Record	280	
5/13/04	No Record	560	
6/21/04	No	420	

	Record		
7/7/04	No Record	420	
8/18/04	30	450	6.67%
9/28/04	No Record	420	
11/2/04	No Record	280	
11/23/04	No Record	280	
12/13/04	10	430	2.33%
5/18/05	40	320	12.50%
6/16/05	BRL	280	
7/13/05	BRL	280	
8/11/05	10	570	1.75%
9/26/05	10	360	2.78%
10/27/05	BRL	420	
4/20/06	30	720	4.17%
5/24/06	BRL	280	
6/19/06	BRL	420	
7/31/06	BRL	No Record	
8/17/06	BRL	No Record	
9/13/06	BRL	No Record	
10/17/06	BRL	110	
11/30/06	BRL		
4/23/07	80	210	38.10%
5/22/07	BRL	120	
6/21/07	BRL	110	
7/10/07	150	350	42.86%
8/20/07	BRL	130	
9/18/07	BRL	180	
10/16/07	20	210	9.52%
6/9/11	50	No Record	
6/24/11	50	No Record	
7/5/11	10	No Record	
7/20/11	40	No Record	
9/14/11	60	No Record	

Table 3: All Station 3 Data by Date

Date	NO3 (ppb)	Total Nitrogen (ppb)	NO3/Total Nitrogen
10/25/97	32	No Record	

11/27/97	26	No Record	
12/15/97	17	No Record	
1/15/98	8	No Record	
2/27/98	72	No Record	
3/17/98	26	No Record	
4/14/98	20	No Record	
5/19/98	32	No Record	
6/16/98	40	No Record	
7/7/98	BRL	No Record	
8/18/98	80	No Record	
9/22/98	BRL	No Record	
1/21/99	30	No Record	
3/29/99	20	No Record	
4/20/99	20	No Record	
5/30/99	60	No Record	
7/6/99	100	200	50.00%
8/3/99	50	200	25.00%
3/24/00	62	200	31.00%
5/16/00	91	500	18.20%
6/26/00	10	840	1.19%
7/24/00	20	500	4.00%
8/25/00	10	500	2.00%
9/7/00	40	500	8.00%
10/24/00	10	500	2.00%
11/21/00	110	500	22.00%
1/25/01	10	500	2.00%
2/22/01	20	500	4.00%
3/27/01	60	100	60.00%
4/23/01	100	240	41.67%
5/29/01	10	100	10.00%
6/19/01	30	10	300.00%
7/12/01	20	100	20.00%
8/8/01	BRL	170	
9/10/01	100	100	100.00%
10/9/01	BRL	420	
11/8/01	BRL	560	
2/4/02	BRL	2020	
3/14/02	30	100	30.00%
4/16/02	20	280	7.14%
5/23/02	BRL	700	
6/12/02	20	580	3.45%

7/15/02	BRL	280	
8/2/02	BRL	420	
10/23/02	BRL	50	
11/20/02	BRL	140	
12/18/02	BRL	280	
3/25/03	30	420	7.14%
4/30/03	30	310	9.68%
6/3/03	40	460	8.70%
6/26/03	30	450	6.67%
7/28/03	BRL	280	
8/25/03	40	460	8.70%
9/29/03	10	150	6.67%
10/20/03	10	570	1.75%
11/10/03	BRL	420	
12/22/03	BRL	280	
4/7/04	No Record	280	
5/13/04	No Record	280	
6/21/04	No Record	420	
7/7/04	No Record	420	
8/18/04	70	490	14.29%
9/28/04	No Record	420	
11/2/04	No Record	420	
11/23/04	10	430	2.33%
12/13/04	10	430	2.33%
5/18/05	BRL	280	
6/16/05	BRL	280	
7/13/05	30	450	6.67%
8/11/05	BRL	560	
9/26/05	BRL	560	
10/27/05	BRL	420	
4/20/06	BRL	280	
5/24/06	BRL	420	
6/19/06	BRL	420	
7/31/06	BRL	No Record	
8/17/06	BRL	140	
9/13/06	20	No Record	
10/17/06	BRL	100	

11/30/06	BRL	No Record	
4/23/07	10	100	10.00%
5/22/07	BRL	100	
6/21/07	BRL	170	
7/10/07	30	230	13.04%
8/20/07	30	270	11.11%
9/18/07	BRL	160	
10/16/07	10	170	5.88%
6/9/11	50	No Record	
6/24/11	50	No Record	
7/5/11	30	No Record	
7/20/11	20	No Record	
9/14/11	BRL	No Record	

Table 4: All Station 4 Data by Date

Date	NO3 (ppb)	Total Nitrogen (ppb)	NO3/Total Nitrogen
10/25/97	46	No Record	
11/27/97	26	No Record	
12/15/97	11	No Record	
1/15/98	8	No Record	
2/27/98	101	No Record	
3/17/98	BRL	No Record	
4/14/98	BRL	No Record	
5/19/98	9	No Record	
6/16/98	15	No Record	
7/7/98	BRL	No Record	
8/18/98	72	No Record	
9/22/98	BRL	No Record	
1/21/99	40	No Record	
3/29/99	20	No Record	
4/20/99	20	No Record	
5/30/99	10	No Record	
7/6/99	40	200	20.00%
8/3/99	60	200	30.00%
3/24/00	81	200	40.50%
5/16/00	40	500	8.00%
6/26/00	30	590	5.08%
7/24/00	10	500	2.00%

8/25/00	10	500	2.00%
9/7/00	40	500	8.00%
10/24/00	30	500	6.00%
11/21/00	80	500	16.00%
1/25/01	10	500	2.00%
2/22/01	30	500	6.00%
3/27/01	60	100	60.00%
4/23/01	20	160	12.50%
5/29/01	20	100	20.00%
6/19/01	50	10	500.00%
7/12/01	20	100	20.00%
8/8/01	BRL	BRL	
9/10/01	BRL	BRL	
10/9/01	20	100	20.00%
11/8/01	BRL	280	
2/4/02	10	350	2.86%
3/14/02	20	100	20.00%
4/16/02	BRL	420	
5/23/02	BRL	280	
6/12/02	20	720	2.78%
7/15/02	BRL	280	
8/2/02	10	290	3.45%
10/23/02	10	50	20.00%
11/20/02	BRL	420	
12/18/02	BRL	420	
3/25/03	BRL	560	
4/30/03	20	440	4.55%
6/3/03	10	710	1.41%
6/26/03	50	470	10.64%
7/28/03	20	300	6.67%
8/25/03	40	600	6.67%
9/29/03	BRL	140	
10/20/03	20	440	4.55%
11/10/03	BRL	560	
12/22/03	10	140	7.14%
4/7/04	No Record	420	
5/13/04	No Record	280	
6/21/04	No Record	420	
7/7/04	No Record	420	

8/18/04	10	430	2.33%
9/28/04	No Record	560	
11/2/04	No Record	420	
11/23/04	No Record	420	
12/13/04	10	570	1.75%
5/18/05	30	450	6.67%
6/16/05	BRL	280	
7/13/05	10	430	2.33%
8/11/05	BRL	420	
9/26/05	BRL	420	
10/27/05	BRL	420	
4/20/06	30	590	5.08%
5/24/06	BRL	420	
6/19/06	BRL	280	
7/31/06	BRL	No Record	
8/17/06	BRL	No Record	
9/13/06	20	140	14.29%
10/17/06	BRL	110	
11/30/06	BRL	110	
4/23/07	BRL	120	
5/22/07	BRL	110	
6/21/07	BRL	150	
7/10/07	10	210	4.76%
8/20/07	BRL	100	
9/18/07	BRL	190	
10/16/07	10	180	5.56%
6/9/11	50	No Record	
6/24/11	50	No Record	
7/5/11	30	No Record	
7/20/11	20	No Record	
9/14/11	BRL	No Record	

Table 5: All Station 5 Data by Date

Date	NO3 (ppb)	Total Nitrogen (ppb)	NO3/Total Nitrogen
10/25/97	No Record	No Record	
11/27/97	No Record	No Record	
12/15/97	No Record	No Record	

1/15/98	No Record	No Record	
2/27/98	No Record	No Record	
3/17/98	No Record	No Record	
4/14/98	No Record	No Record	
5/19/98	No Record	No Record	
6/16/98	No Record	No Record	
7/7/98	No Record	No Record	
8/18/98	No Record	No Record	
9/22/98	No Record	No Record	
1/21/99	No Record	No Record	
3/29/99	No Record	No Record	
4/20/99	No Record	No Record	
5/30/99	No Record	No Record	
7/6/99	No Record	No Record	
8/3/99	No Record	No Record	
3/24/00	No Record	No Record	
5/16/00	No Record	No Record	
6/26/00	No Record	No Record	
7/24/00	No Record	No Record	
8/25/00	No Record	No Record	
9/7/00	No Record	No Record	
10/24/00	No Record	No Record	
11/21/00	No Record	No Record	
1/25/01	No Record	No Record	
2/22/01	No Record	No Record	
3/27/01	30	100	30.00%
4/23/01	40	100	40.00%
5/29/01	40	100	40.00%
6/19/01	10	10	100.00%
7/12/01	10	100	10.00%
8/8/01	20	190	10.53%
9/10/01	60	480	12.50%
10/9/01	40	260	15.38%
11/8/01	BRL	140	
2/4/02	BRL	280	
3/14/02	BRL	280	
4/16/02	BRL	280	
5/23/02	BRL	560	
6/12/02	BRL	700	
7/15/02	BRL	560	
8/2/02	BRL	700	

10/23/02	BRL	280	
11/20/02	BRL	420	
12/18/02	BRL	420	
3/25/03	BRL	280	
4/30/03	10	430	2.33%
6/3/03	20	580	3.45%
6/26/03	50	470	10.64%
7/28/03	BRL	420	
8/25/03	60	480	12.50%
9/29/03	BRL	280	
10/20/03	20	300	6.67%
11/10/03	BRL	280	
12/22/03	BRL	490	
4/7/04	No Record	280	
5/13/04	No Record	700	
6/21/04	No Record	560	
7/7/04	No Record	420	
8/18/04	40	460	8.70%
9/28/04	No Record	560	
11/2/04	No Record	420	
11/23/04	No Record	280	
12/13/04	20	300	6.67%
5/18/05	50	470	10.64%
6/16/05	30	450	6.67%
7/13/05	20	440	4.55%
8/11/05	120	820	14.63%
9/26/05	BRL	420	
10/27/05	BRL	560	
4/20/06	30	420	7.14%
5/24/06	BRL	420	
6/19/06	10	430	2.33%
7/31/06	BRL	720	
8/17/06	BRL	190	
9/13/06	30		
10/17/06	BRL	130	
11/30/06	BRL		
4/23/07	BRL	140	
5/22/07	BRL	100	
6/21/07	30	170	17.65%
7/10/07	10	210	4.76%
8/20/07	40	100	40.00%

9/18/07	BRL	150	
10/16/07	BRL	150	
6/9/11	50	No Record	
6/24/11	50	No Record	
7/5/11	30	No Record	
7/20/11	50	No Record	
9/14/11	60	No Record	

Table 6: All Station 6 Data by Date

Date	NO3 (ppb)	Total Nitrogen (ppb)	NO3/Total Nitrogen
10/25/97	No Record	No Record	
11/27/97	No Record	No Record	
12/15/97	No Record	No Record	
1/15/98	No Record	No Record	
2/27/98	No Record	No Record	
3/17/98	No Record	No Record	
4/14/98	No Record	No Record	
5/19/98	No Record	No Record	
6/16/98	No Record	No Record	
7/7/98	No Record	No Record	
8/18/98	No Record	No Record	
9/22/98	No Record	No Record	
1/21/99	No Record	No Record	
3/29/99	No Record	No Record	
4/20/99	No Record	No Record	
5/30/99	No Record	No Record	
7/6/99	No Record	No Record	
8/3/99	No Record	No Record	
3/24/00	No Record	No Record	
5/16/00	No Record	No Record	
6/26/00	No Record	No Record	
7/24/00	No Record	No Record	
8/25/00	No Record	No Record	
9/7/00	No Record	No Record	
10/24/00	No Record	No Record	
11/21/00	No Record	No Record	
1/25/01	No Record	No Record	
2/22/01	No Record	No Record	

3/27/01	30	100	30.00%
4/23/01	20	100	20.00%
5/29/01	190	200	95.00%
6/19/01	40	10	400.00%
7/12/01	20	100	20.00%
8/8/01	BRL	170	
9/10/01	50	330	15.15%
10/9/01	40	100	40.00%
11/8/01	BRL	280	
2/4/02	BRL	430	
3/14/02	50	400	12.50%
4/16/02	BRL	280	
5/23/02	BRL	560	
6/12/02	BRL	700	
7/15/02	BRL	280	
8/2/02	BRL	420	
10/23/02	BRL	140	
11/20/02	BRL	280	
12/18/02	BRL	280	
3/25/03	100	280	35.71%
4/30/03	80	360	22.22%
6/3/03	10	570	1.75%
6/26/03	40	320	12.50%
7/28/03	30	310	9.68%
8/25/03	40	290	13.79%
9/29/03	10	290	3.45%
10/20/03	10	290	3.45%
11/10/03	BRL	420	
12/22/03	BRL	630	
4/7/04	No Record	280	
5/13/04	No Record	420	
6/21/04	No Record	420	
7/7/04	No Record	420	
8/18/04	20	440	4.55%
9/28/04	No Record	420	
11/2/04	No Record	420	
11/23/04	No Record	280	
12/13/04	10	290	3.45%
5/18/05	10	290	3.45%
6/16/05	BRL	420	
7/13/05	10	290	3.45%

8/11/05	20	440	4.55%
9/26/05	10	430	2.33%
10/27/05	BRL	560	
4/20/06	140	420	33.33%
5/24/06	BRL	560	
6/19/06	10	570	1.75%
7/31/06	BRL	720	
8/17/06	BRL	200	
9/13/06	20	No Record	
10/17/06	40	150	26.67%
11/30/06	BRL	No Record	
4/23/07	10	100	10.00%
5/22/07	BRL	170	
6/21/07	BRL	130	
7/10/07	40	240	16.67%
8/20/07	60	190	31.58%
9/18/07	BRL	160	
10/16/07	20	180	11.11%
6/9/11	50	No Record	
6/24/11	50	No Record	
7/5/11	40	No Record	
7/20/11	30	No Record	
9/14/11	BRL	No Record	

Table 7: Station 7 Nitrate Data by Date

Date	**NO3 (ppb)**
6/9/11	50
6/24/11	50
7/5/11	40
7/20/11	50
9/14/11	BRL

Table 8: Station 8 Nitrate Data by Date

Date	**NO3 (ppb)**

8/20/07	50
9/18/07	50
10/16/07	30
6/9/11	20
6/24/11	90

Table 9: Station 1 Nitrate Data Arranged by Month

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2011	Avg
January	NR	7	20	NR	10	NR	NR	NR	NR	NR	NR	NR	12.3
February	NR	68	NR	NR	30	20	NR	NR	NR	NR	NR	NR	39.3
March	NR	16	20	25	50	30	20	NR	NR	NR	NR	NR	26.8
April	NR	BRL	20	NR	70	BRL	20	NR	NR	120	10	NR	48.0
May	NR	13	10	60	110	10	BRL	NR	120	BRL	BRL	NR	53.8
June	NR	45	NR	10	10	BRL	20	NR	20	30	BRL	50	26.4
July	NR	BRL	110	10	10	BRL	BRL	NR	BRL	BRL	40	30	40.0
August	NR	72	60	10	40	10	20	20	30	BRL	BRL	NR	32.8
September	NR	BRL	NR	40	60	NR	20	NR	BRL	BRL	BRL	NR	40.0
October	27	NR	NR	10	20	BRL	20	NR	BRL	BRL	BRL	NR	19.3
November	24	NR	NR	70	BRL	BRL	BRL	10	NR	BRL	NR	NR	34.7
December	14	NR	NR	NR	NR	BRL	BRL	10	NR	NR	NR	NR	12.0

Table 10: Station 2 Nitrate Data Arranged by Month

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2011	Avg
January	NR	9	30	NR	10	NR	NR	NR	NR	NR	NR	NR	16.3
February	NR	72	NR	NR	20	BRL	NR	NR	NR	NR	NR	NR	46.0
March	NR	42	20	5	30	BRL	90	NR	NR	NR	NR	NR	37.4
April	NR	9	20	NR	10	BRL	60	NR	NR	30	80	NR	34.8
May	NR	28	10	60	10	10	10	NR	40	BRL	BRL	NR	24.0
June	NR	40	NR	10	20	10	30	NR	BRL	BRL	BRL	50	26.7
July	NR	BRL	60	30	20	BRL	BRL	NR	BRL	BRL	150	50	62.0
August	NR	91	70	10	BRL	BRL	40	30	10	BRL	BRL	10	37.3
September	NR	BRL	NR	60	30	NR	10	NR	10	BRL	BRL	40	30.0
October	31	NR	NR	10	20	BRL	10	NR	BRL	BRL	20	60	25.2
November	9	NR	NR	60	BRL	BRL	BRL	NR	NR	BRL	NR	NR	34.5
December	11	NR	NR	NR	NR	BRL	BRL	10	NR	NR	NR	NR	10.5

Table 11: Station 2 Nitrogen Data Arranged by Month

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2011	Avg
January	NR	NR	NR	NR	500	NR	NR	NR	NR	NR	NR	NR	500.0
February	NR	NR	NR	NR	500	100	NR	NR	NR	NR	NR	NR	300.0
March	NR	NR	NR	200	100	420	370	NR	NR	NR	NR	NR	272.5
April	NR	NR	NR	NR	10	140	340	280	NR	720	210	NR	283.3
May	NR	NR	NR	500	100	570	570	560	320	280	120	NR	377.5
June	NR	NR	NR	560	10	570	870	420	280	420	110	NR	405.0
July	NR	NR	200	500	190	280	420	420	280	NR	350	NR	330.0
August	NR	NR	200	500	BRL	280	460	450	570	NR	130	NR	370.0
September	NR	NR	NR	500	310	NR	150	420	360	NR	180	NR	320.0
October	NR	NR	NR	500	100	50	570	NR	420	110	210	NR	280.0
November	NR	NR	NR	500	420	420	420	280	NR	NR	NR	NR	408.0
December	NR	NR	NR	NR	NR	140	280	430	NR	NR	NR	NR	283.3

Table 12: Station 3 Nitrate Data Arranged by Month

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2011	Avg
January	NR	8	30	NR	10	NR	NR	NR	NR	NR	NR	NR	16.0
February	NR	72	NR	NR	20	BRL	NR	NR	NR	NR	NR	NR	46.0
March	NR	26	20	62	60	30	30	NR	NR	NR	NR	NR	38.0
April	NR	20	20	NR	100	20	30	NR	NR	BRL	10	NR	33.3
May	NR	32	60	91	10	BRL	40	NR	BRL	BRL	BRL	NR	46.6
June	NR	40	NR	10	30	20	30	NR	BRL	BRL	BRL	50	30.0
July	NR	BRL	100	20	20	BRL	BRL	NR	30	BRL	30	25	37.5
August	NR	80	50	10	BRL	BRL	40	70	BRL	BRL	30	NR	46.7
September	NR	BRL	NR	40	100	NR	10	NR	BRL	20	BRL	NR	42.5
October	32	NR	NR	10	BRL	BRL	10	NR	BRL	BRL	10	NR	15.5
November	26	NR	NR	110	BRL	BRL	BRL	10	NR	BRL	NR	NR	48.7
December	17	NR	NR	NR	NR	BRL	BRL	10	NR	NR	NR	NR	13.5

Table 13: Station 3 Nitrogen Data Arranged by Month

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2011	Avg
January	NR	NR	NR	NR	500	NR	NR	NR	NR	NR	NR	NR	500.0
February	NR	NR	NR	NR	500	NR	NR	NR	NR	NR	NR	NR	500.0
March	NR	NR	NR	200	100	100	420	NR	NR	NR	NR	NR	205.0
April	NR	NR	NR	NR	240	280	310	280	NR	280	100	NR	248.3
May	NR	NR	NR	500	100	700	460	280	280	420	100	NR	355.0
June	NR	NR	NR	840	10	580	450	420	280	420	170	NR	396.3
July	NR	NR	200	500	100	280	280	420	450	NR	230	NR	307.5
August	NR	NR	200	500	170	420	460	490	560	140	270	NR	356.7
September	NR	NR	NR	500	100	NR	150	420	560	NR	160	NR	315.0
October	NR	NR	NR	500	420	50	570	420	420	100	170	NR	331.3
November	NR	NR	NR	500	560	140	420	430	NR	NR	NR	NR	410.0
December	NR	NR	NR	NR	NR	280	280	430	NR	NR	NR	NR	330.0

Table 14: Station 4 Nitrate Data Arranged by Month

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2011	Avg
January	NR	8	40	NR	10	NR	NR	NR	NR	NR	NR	NR	19.3
February	NR	101	NR	NR	30	10	NR	NR	NR	NR	NR	NR	47.0
March	NR	BRL	20	81	60	20	BRL	NR	NR	NR	NR	NR	45.3
April	NR	BRL	20	NR	20	BRL	20	NR	NR	30	BRL	NR	22.5
May	NR	9	10	40	20	BRL	10	NR	30	BRL	BRL	NR	19.8
June	NR	15	NR	30	50	20	50	NR	BRL	BRL	BRL	50	35.8
July	NR	BRL	40	10	20	BRL	20	NR	10	BRL	10	25	19.3
August	NR	72	60	10	BRL	10	40	10	BRL	BRL	BRL	NR	33.7
September	NR	BRL	NR	40	BRL	NR	BRL	NR	BRL	20	BRL	NR	30.0
October	46	NR	NR	30	20	10	20	NR	BRL	BRL	10	NR	22.7
November	26	NR	NR	80	BRL	BRL	BRL	NR	NR	BRL	NR	NR	53.0
December	11	NR	NR	NR	NR	BRL	10	10	NR	NR	NR	NR	10.3

Table 15: Station 5 Nitrate Data Arranged by Month

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2011	Avg
January	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	
February	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	
March	NR	NR	NR	NR	30	NR	NR	NR	NR	NR	NR	NR	30.0
April	NR	NR	NR	NR	40	10	NR	NR	NR	30	BRL	NR	26.7
May	NR	NR	NR	NR	40	NR	NR	NR	50	BRL	BRL	NR	45.0

June	NR	NR	NR	NR	10	35	NR	NR	30	10	30	50	27.5
July	NR	NR	NR	NR	10	NR	NR	NR	20	BRL	10	40	20.0
August	NR	NR	NR	NR	20	60	NR	40	120	BRL	40	NR	56.0
September	NR	NR	NR	NR	60	NR	NR	NR	BRL	30	BRL	60	50.0
October	NR	NR	NR	NR	40	20	NR	NR	BRL	BRL	BRL	NR	30.0
November	NR	NR	NR	NR	BRL	NR	NR	NR	NR	BRL	NR	NR	
December	NR	NR	NR	NR	NR	NR	NR	20	NR	NR	NR	NR	20.0

Table 16: Station 6 Nitrate Data Arranged by Month

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2011	Avg
January	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	
February	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	
March	NR	NR	NR	NR	30	50	100	NR	NR	NR	NR	NR	60.0
April	NR	NR	NR	NR	20	BRL	80	NR	NR	140	10	NR	62.5
May	NR	NR	NR	NR	190	BRL	10	NR	10	BRL	BRL	NR	70.0
June	NR	NR	NR	NR	40	BRL	40	NR	BRL	10	BRL	50	35.0
July	NR	NR	NR	NR	20	BRL	30	NR	10	BRL	40	40	28.0
August	NR	NR	NR	NR	BRL	BRL	40	20	20	BRL	60	NR	35.0
September	NR	NR	NR	NR	50	NR	10	NR	10	20	BRL	NR	22.5
October	NR	NR	NR	NR	40	BRL	10	NR	BRL	40	20	NR	27.5
November	NR	NR	NR	NR	BRL	BRL	BRL	NR	NR	BRL	NR	NR	
December	NR	NR	NR	NR	NR	BRL	BRL	10	NR	NR	NR	NR	10.0

Table 17: Station 2 June Data for Percentages

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2011	Avg
Nitrogen				560	10	570	870	420	280	420	110		405.0
Nitrate		40		10	20	10	30		BRL	BRL	BRL	50	26.7
Percentage				1.8%	200.0%	1.8%	3.4%	0.0%					6.6%
												Nitrate Subtracted:	378.3

Table 18: Station 3 June Data for Percentages

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2011	Avg
Nitrogen	NR	NR	NR	840	10	580	455	420	280	420	170	NR	396.9
Nitrate	NR	40	NR	10	30	20	35	NR	BRL	BRL	BRL	50	30.8
Percentage				1.2%	300.0%	3.4%	7.7%						7.8%
												Nitrate Subtracted:	366.0