# Madaket Harbor / Long Pond Annual Report 2006

Prepared for:
Marine and Coastal Resources Department
34 Washington St.
Nantucket, MA. 02554

Prepared by:
Keith L. Conant
Town Biologist

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Introduction:

Madaket Harbor and Long Pond make up a unique ecosystem encompassing approximately one quarter (9 sq. miles) of the surface area of Nantucket Island. These two systems are hydrologically connected via Hither Creek, and the Madaket Ditch. Historically, since the late 1600s the area was operated as a herring run, coincidentally there is now a ban on the taking of herring until January, 2009, by order of the Division of Marine Fisheries. Hither Creek is permanently closed to the taking of shellfish, and Madaket Harbor maintains a six month seasonal closure due to fecal coliform counts monitored by the DMF. As it is in the best interests of the Town of Nantucket to maintain water quality in this area, and re-open the closed beds for shell fishing, a great deal of water quality research has been done and continues to be done in this area.

The Woods Hole Oceanographic Institute conducted some of the first studies on Long Pond from 1989 – 1992, in an island wide study on fresh water ponds. They determined that the pond had become eutrophic as a result of nutrient loading, and was experiencing low oxygen events and large phytoplankton blooms. The Division of Marine Fisheries monitors fecal coliform with respects to shellfish contamination, and has conducted shoreline surveys, and circulation studies, with regards to this problem. Applied Science Associates of Rhode Island completed a computer model / circulation study of the area in 2002. Northeast Aquatic Research of Connecticut along with the Marine Department conducted two years of preliminary monitoring, ’01-‘02 to qualify for the Massachusetts Estuaries Project. This study preformed by the School for Marine Science and Technology (SMAST), also assisted by the Marine Department is to provide a nutrient threshold limit for the Madaket system; which will be regulated by The Department of Environmental Protection. Town of Nantucket’s Department of Public Works is also working with Earth Tech on a Comprehensive Wastewater Treatment Plan to remediate some of the problems associated with this system. Also the Nantucket Health Department has established a Madaket Harbor Watershed Protection District, comprised of two zones, in which all septic systems will require inspection. Zone A inspections will be required to be completed by December of 2007, and Zone B, further out in the watershed should be finished by June of 2008.

Madaket Harbor is approximately 746 acres, semi circular in shape, open to Nantucket Sound on its western edge, and open to the Atlantic on its southwest corner via a cut between Smith’s Point and Tuckernuck. The Harbor is relatively a shallow water body, 4-5 feet deep, with a deeper channel (6-9ft.) running east and north to the coastline of the Sound. There are a few deeper channels that pre date Hurricane Esther (1961), but much of the harbor has filled in as a result of the opening that was created by this storm. This condition existed until Hurricane Gloria, (1985) which closed the gap to Smith’s Pt. Because the southwest edge is open, circulation is high (flushing every 3 days), and water quality is good. Epiphytic, and macro algae are limited in presence and density, and eel grass beds are healthy.

Hither Creek is the main connector to Long Pond, as such it functions as an estuary with a noticeable salinity gradient. Approximately 40 acres, it is a narrow rectangular channel, connecting a boat yard on its northeast end to the harbor on its south west end, and serving as a safe mooring field. The depth varies from 6-9 feet, and the bottom is composed of silt, sand, and mud. Water quality suffers moderate impairment due to high bacteria, and nutrient levels; despite its flushing time of 3 tidal cycles.

Madaket Ditch connects Hither Creek to Long Pond, and runs through a 50 acre salt marsh, latticed by mosquito ditches which connect several small ponds. This area may be completely flooded during winter high tides. The ditch has depths between 2-4 feet, with little tidal variation on the pond end. The marsh acts as a nutrient sink, and intercepts an appreciable amount of nutrients from Long Pond before they reach the creek and harbor. The ditch flushes 4 times a day, but basically acts as bottle neck to Long Pond which flushes only once every 76 days at the North Head, and only once every 183 days at the southern end. So the water in the ditch basically sloshes back and forth, with some exchange occurring on the creek end.

Long Pond, because of this circulation pattern, is somewhat isolated from the whole system, and may be evaluated as having separate water quality issues. This is not to say however that Long Pond is not a contributing factor to rising nutrients in the ditch, marsh, creek, and harbor. With a length of 1.8 miles, and 79 surface acres this is the largest of the salt / brackish water ponds on the island. It is also one of the more shallow ponds, only 4-6 feet deep with no deep basins. It is relatively narrow and winding, with a few isolated coves, and one large open circular area, (the North Head); which is a little grater than half the total size. Very nearly impassable in the late summer because of the prolific pond weed, water quality is poor, and may be defined as hyper-eutrophic. The State (DEP) would list it as “severely degraded” according to their coastal water nitrogen threshold guide (Interim Report “03), and the low oxygen events may no longer support suitable habitat for desired fish species.

Water quality monitoring of the Madaket Harbor / Long Pond system has been continued in 2006 to note any changes in the harbor, and to follow trends in the pond’s decline. Sampling includes temperature, dissolved oxygen, salinity, water transparency, and water quality constituents (nitrogen and phosphorus). Initially the plan was to sample just 4 sites in the harbor, but because the pond is connected, and a sampling regime had been established, and 2 sites were added to include the pond. The sampling locations are as follows; **Site 1:** Hither Creek, **Site 2:** Jackson’s Pt., **Site 3:** Warren’s Landing, **Site 4:** Eel Pt., **Site 5:** Massasoit Bridge, **Site 6:** Long Pond / Madaket Ditch Culvert. These sites are located on **Map# 1**.

Monitoring Results:

**Appendix A:** contains all physical and chemical data taken for 2006. **Appendix B:** contains the averages of A, and graphs of that data. **Appendix C:** contains average monthly rainfall data for 2006, as collected by the Nantucket Water Company.

Average Temperatures and Average Dissolved Oxygen:

Temperature and dissolved oxygen are as relevant to the Madaket Harbor / Long Pond system as they are to Nantucket Harbor. These are vital physical parameters that will affect the flora, and fauna in the ecosystem. As these two conditions affect one another, they can be combined and discussed together. Because these water bodies are shallow, they are relatively isothermic throughout the water column. Temperatures and D. O. levels vary at different sites because of the size of the water body, fresh water inputs from the watershed, and varying conditions in the Sound and the Atlantic. Higher temperatures decrease the solubility of oxygen in water. Dissolved oxygen is lowered by this process, it is further lowered by the process known as biological oxygen demand, generated from respiration and the consumption of oxygen by bacteria. Dissolved oxygen levels above 5 mg/l are a desirable condition for most aquatic species. Some species have a wide range of tolerances and may not be stressed until D.O. levels drop below 3 mg/l. Anoxic conditions exist when D.O. levels drop to 1 mg/l and below. Most fish, shellfish, and benthic organisms can not survive anoxic conditions for any length of time. A eutrophic state will also begin to occur as nutrients are released from benthic soils during anoxic events, and nitrogen is recycled into the water column. The resultant affect of these conditions are the blooms of phytoplankton, epiphytic and macro algae; which eventually die increasing nutrients, decreasing oxygen, and decreasing habitat (i.e. eel grass).

The summer of 2006 showed relatively normal temperatures and dissolved oxygen levels for Madaket Harbor; (Sites 2-4). Because of the open flushing, Madaket Harbor temperatures did not rise as high as Nantucket Harbor temperatures. However in Hither Creek and Long Pond, (Sites 1, 5, and 6) recorded temperatures that were higher during the July sampling round. The highest temperature recorded was 27.7 $^{o}$C at the Massasoit Bridge in July. Higher temperatures would be expected in shallow water bodies with little circulation. When combined with a nutrient rich condition, dissolved oxygen levels often plummet into periods of hypoxia, and anoxia. Site 1, 5, and 6 experienced the worst of these conditions, exhibiting a hyper-eutrophic state in July. These conditions persisted into August for Sites 1, and 5. Because of an abundant growth of pond weeds, Long Pond experienced super saturated levels of dissolved oxygen in October and November. The D.O. at Site 5 on the bottom was 11.84 mg/l for the November sampling period. Photosynthesis is responsible for this during the day. It follows and would be expected however that respiration, the opposing condition occurring at night would be just as severe, resulting in anoxia. In 2005 the D.O. conditions at Site 5, and 6 were worse though temperatures were not as high. In 2006 a stratified layer in the water column was again recreated in July. Borderline anoxic D.O. levels of 2.34 mg/l and 2.29 mg/l were taken on the bottom during this sampling round (Appendix A). The surface D.O. conditions at these two sites at this time were 7.58 mg/l and 5.72 mg/l respectively. The consumption of decaying pond weed and phytoplankton, by bacteria creates this stratified anoxic condition. The re-release of nutrients into the water column during anoxic periods increases the frequency of these conditions, however ultimately responsible for this is the excessive nutrient loading comes from the watershed. This will be discussed further in the section on nutrients.

Figure 1: Average Temperatures 2006

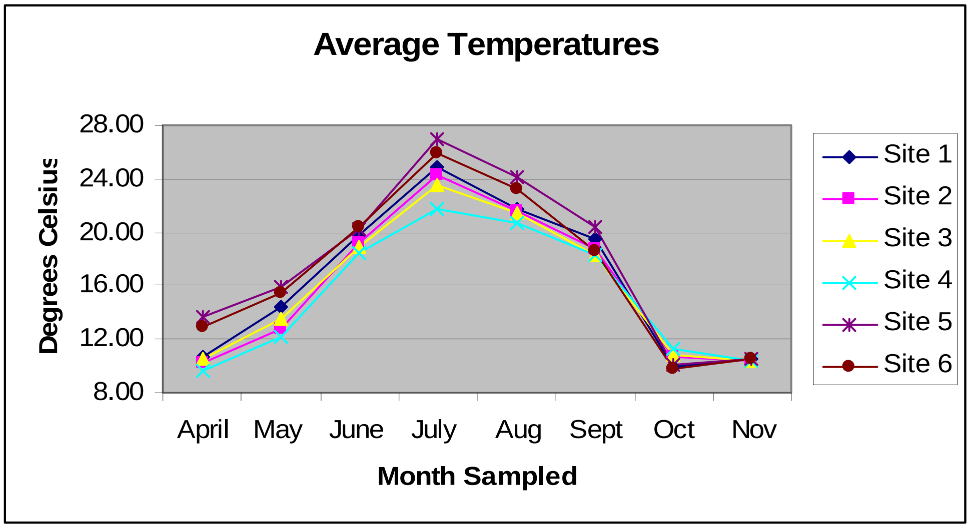
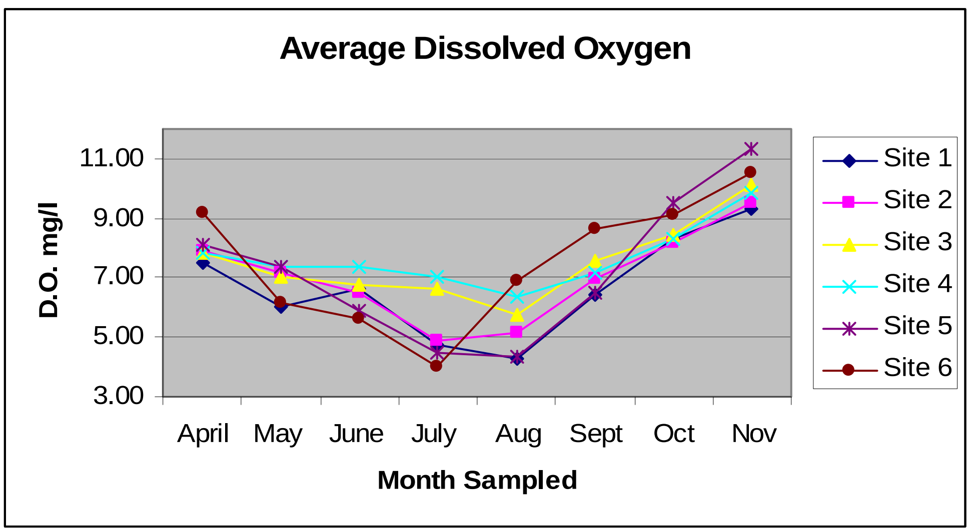



Figure 2: Average Dissolved Oxygen 2006



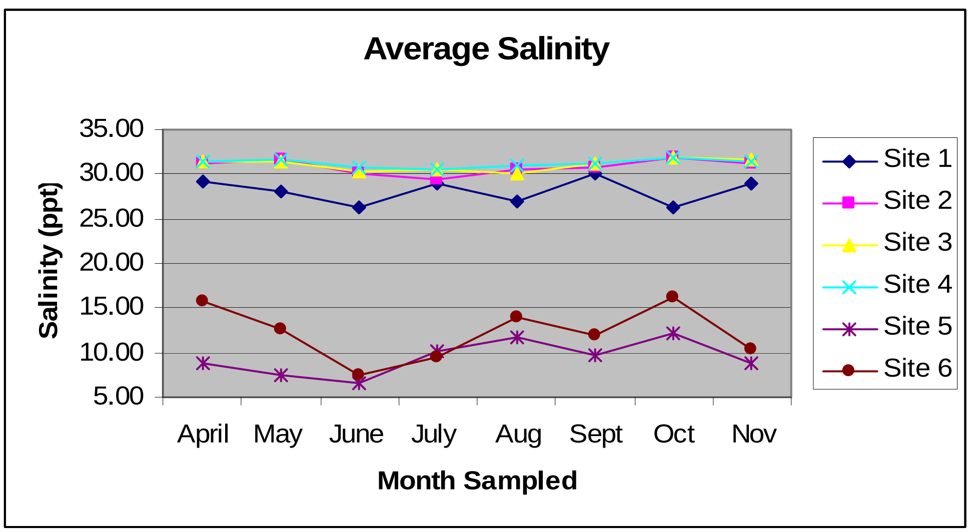

Salinity:

Average salinity in Madaket Harbor is usually around 30 ppt (parts per thousand), average salinity in the open ocean is closer to 32 ppt. Salinity is important with respects to stratification, and biodiversity. As previously discussed the harbor is well mixed, the only area of exception to this is Hither Creek. Because of the exchange with Long Pond through the Madaket Ditch, occurring in relatively small amounts, the salinity gradients in the creek vary widely from the open harbor. Stratification does occur here, and surface salinities have been measured as low as 15.8 ppt, Site 1, June sampling event 2006. Though relatively shallow, the difference between top and bottom may be as much as 14.2 ppt. Salinity and temperature stratifications may adversely affect dissolved oxygen concentrations, especially if there is an oxygen deficiency in the fresh water input.

Long Pond like Madaket Harbor is fairly well mixed, and salinity in any particular water column is largely the same. Variations in salinity occur over the long expanse of the pond, and are affected by tidal forces, as well as fresh water inputs. Site 5, at the southern end of the pond, is usually very fresh, (<10 ppt.). However the August sampling round recorded 8 ppt. at the surface, and 14.2 ppt. at the bottom. This was more than a 4 ppt. difference between top and bottom recorded in the 2005 data, a relatively dry summer. When combined with rainfall data, which showed high precipitation from May through July, this data would suggest that the salt water wedge was far reaching despite the extremely high level of rainfall for those months. This would also suggest that the freshness of the pond, not the volume, may be determined by accumulated rainfall. Site 5, and 6 also showed lower salinities during this time period, the most notable drop in salinity occurred in June following an increase in precipitation during that time frame.

Different species of aquatic animals often require different salinities at different stages in their life cycles. As such many of these species can sustain variations of salinity ranges. This is best done as adults, however as juveniles, and as larvae, many species have definite salinity requirements. For example winter flounder in their early life cycle prefer salinities around 4 ppt., and herring require almost completely fresh water; as do many anadromous fish species. Oysters may live in salinities as low as 5 ppt. Other shellfish such as bay scallops, have salinity requirements that are much higher (25 ppt for normal development). Further, the larvae of bay scallops can not survive a drop in salinity below 28 ppt.

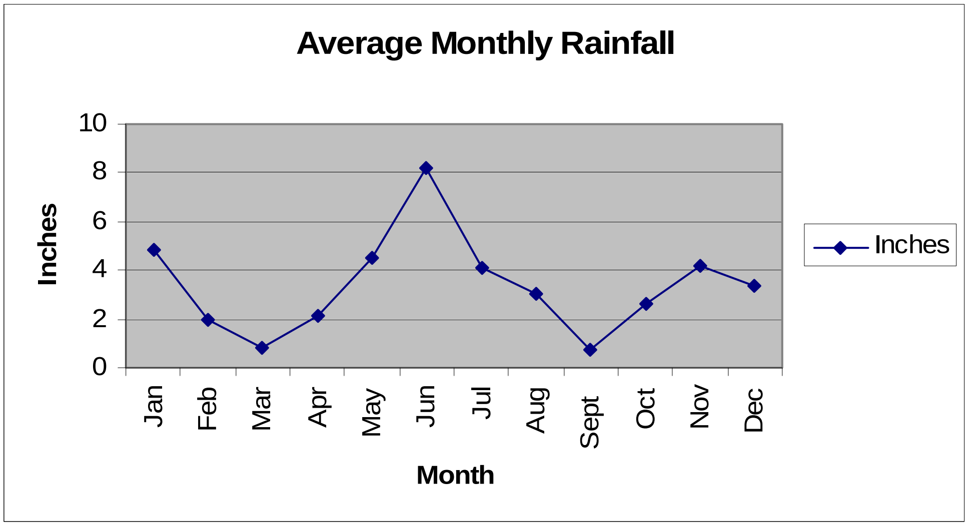
Figure 3: Average Salinity 2006



Rainfall:

Rainfall data corresponds well with salinity changes in Long Pond, and may also be linked to some of the nutrient loading which will be discussed later. A major reduction in salinity as the result of precipitation may also cause a shift in plant communities, which may further dictate changes in nutrient uptake and availability. This will be discussed further in the section on nutrients.

Figure 4: Average Monthly Rainfall 2006



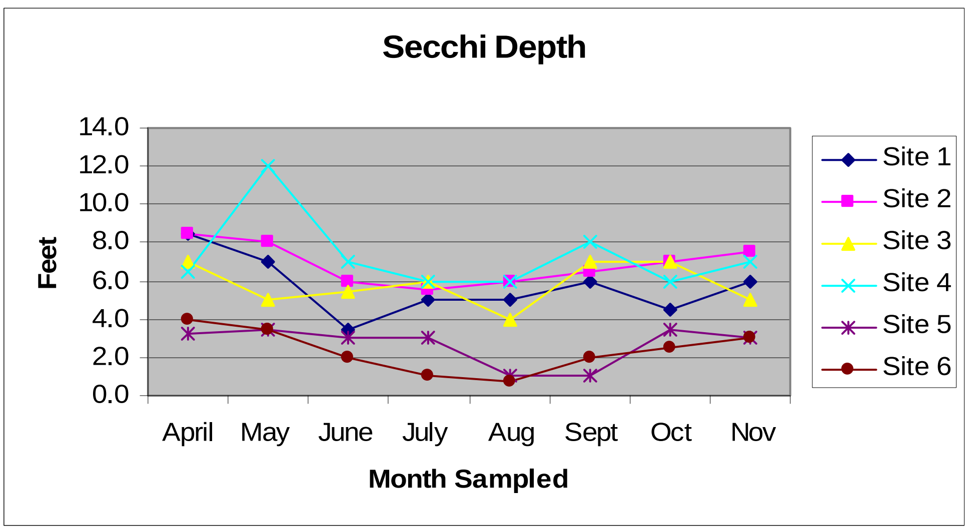

Secchi Depth:

Secchi depth is an approximate measurement of light penetration into the vertical water column. The recorded depth is roughly half the depth that sunlight will reach below the surface of the water. Below this depth photosynthesis is not possible, so a record of this information will provide a rough estimate of potential eel grass habitat. Water transparency is also largely a factor of phytoplankton production, as such it is an indicator of nutrients available in the water column. Generally there are two periods of maximum water clarity prior to and following two major blooms of phytoplankton. Usually these occur during the spring, and at the end of the fall or the onset of winter as water temperatures warm and cool dictating a change in phytoplankton communities.

The microscopic algae known as diatoms, make up the base of primary production in the marine ecosystem. They provide the base of a food web upon which all other marine animals exist, and are normally the dominant species. However, if there is an excessive amount of nutrients and sufficient fresh water inputs in a system, the development of a dinoflagellate community may evolve. In 2005 Nantucket experienced a "Red Tide", the toxic and potentially lethal dinoflagellate *Alexandrium tamerense* closed shellfish beds from 6/2 to 7/5. This was the first known incident for Nantucket, which participates in phytoplankton monitoring for the Division of Marine Fisheries.

Because Madaket Harbor, and Long Pond are shallow water bodies, secchi depths may not always accurately reflect water transparency. In 2006 the shoals around Eel Pt. moved sufficiently enough to change the depth at the sampling station. In order to get an accurate judgment, secchi depth must be compared with total depth. The Hither Creek station usually has the least amount of light penetration, and this is the result of a combination of problems. The most naturally occurring contributor is increased turbidity from rainfall. This in conjunction with a silt bottom, and boat traffic in a localized area bring down light penetration considerably. High nutrient concentrations may also come from associated watersheds with rainfall, which will negatively affect closed systems with poor circulation. This will affect Hither Creek as well as the stations in Long Pond, where secchi depths almost never reach the bottom; even in these most shallow locations. Conversely, at the three harbor stations where water quality is good, and the harbor is open to regular flushing with sea water, secchi depths almost always reach the bottom. Coincidentally the majority of secchi depths were lowest in July and August following the heavy rains in June.

Figure 5: Secchi Depth 2006




Nutrients:

Nitrogen:

Nitrogen is the limiting nutrient in marine ecosystems, the quantity of which will dictate the health of any particular water body. Nitrogen does not usually accumulate in Madaket Harbor, primarily because of its open shape, and high rate of circulation. However in August, October, and November of 2006 elevated levels of nitrogen were measured in the samples taken from Jackson's Pt. The effects of nitrogen are more prevalent in some areas than others. Total nitrogen includes both organic and inorganic components. For many years, ammonia or $NH_3$ was the only component (Below the Reportable Limit) in Madaket Harbor / Long Pond system. For additional costs in the laboratory analysis the detectable limit was lowered to 20 ppb in order to accurately determine the influence of ammonia with respects to total nitrogen, and to note any trends or changes. The Department of Environmental Protection for Massachusetts uses some standard classifications based on nitrogen thresholds to describe the health of many marine ecosystems. Madaket Harbor falls between the SA/SB category; and remains in good condition throughout the summer months. These standards can be found in the Estuaries Project Interim Report '03.

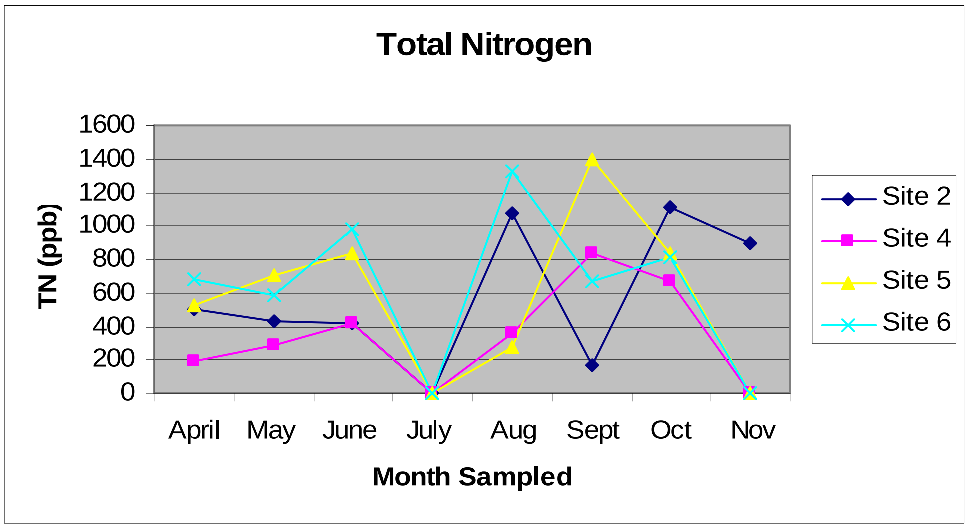
Total nitrogen levels in Madaket Harbor were relatively good throughout the summer. In July all sites show a dramatic decrease in TN, and this may be due to the excessive rainfall in June (Appendix C). Nitrogen is none the less still in the system, and can be seen in the ammonia analysis. The Kjeldhal nitrogen TKN, also a component of organic nitrogen shows values in July less than 500 ppb, and this is because the reportable limit for analysis was set at 100 ppb TKN. This reportable limit for TKN may need to be lowered in order to get a more accurate result, in addition the values that are given, do not chart compatibly in (Figure 6). However at Site 2 the level of nitrogen increases dramatically in August to 1,070 ppb TN, and remains high through the sampling period. In September and October Site 4 shows measured levels of TN in the impairment range. If the higher values at Site 2 were consistent throughout the harbor, State standards would classify these waters as being impaired. However this condition does not develop until August, and doesn't last through October. These higher TN levels are probably the result of inputs from anthropogenic uses in the watershed of this system. Because Madaket Harbor is flushed so regularly, and is connected to the open Atlantic, it remains in good to fair condition; and may be classified as a mesotrophic water body.

Hither Creek was sampled for physical parameters throughout the summer. The creek was not sampled for chemical constituents, because it was determined that the two stations, Jackson's Pt. (Site 2) and the Madaket Ditch / Long Pond culvert (Site 6), included and covered a broader range of the system. This is because the waters in the creek represent the waters flowing back and forth between these two sites during tidal cycles. In addition, the creek is known to be an impaired water body, and is permanently closed to shell fishing. This condition is expected to continue, and is probably the cause for rising nutrient levels in the harbor. The Hither Creek station, and a North Head station may be added to the sampling regime next year. This may be done in order to confirm the areas involvement in nutrient loading, and to follow declining water quality trends.

Long Pond and its various coves, have the capacity because of circulation patterns to trap nitrogen, and exhibit eutrophic conditions. Combine this with a high level of nutrient loading from anthropogenic uses in the watershed, the internal recycling of nutrients, and the result is a severely degraded water body. Nitrogen may not be the most limiting nutrient in Long Pond, as it is closer to a fresh water system, than a salt water one. However it is consistently brackish, and TN levels are so high that the salinity level may not be the most important factor. The values for 2006 were not as high as the values in 2005. This may be the result of the freshening of the pond in May, June, and July; which would have changed the dominant plant communities based on salinity regimes.

This would in turn cause a shift in the uptake of preferred nutrients, there by making the Long Pond System an even more phosphorous limiting water body. Shifts in plant communities may be occurring because of salinity changes. This will then increase nutrients from decaying plant matter, and increase nutrient uptake from the opposing limiting plant species in a cyclical pattern that increase nutrient recycling. Site 5 at the southern end in September measured TN at 1,400 ppb, anything above 800 ppb is considered to be hyper-eutrophic. These levels are so high that even if the system were completely fresh, they would have an adverse affect. Long Pond is at such an impaired level, that it must be exporting nutrients to the ditch, the marsh, the creek, and the harbor. For this reason it must continue to be monitored, with plans for remediation forthcoming.

Figure 6: Total Nitrogen 2006




Phosphorous:

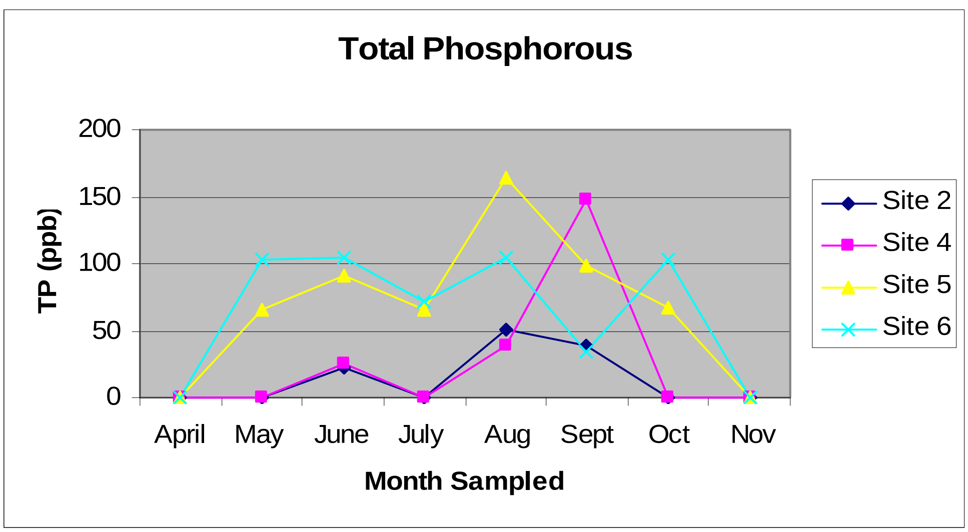
Phosphorous is a limiting nutrient in fresh water, but it is of relative concern to the marine ecosystem. Phosphorous in over abundance can affect the type of phytoplankton species that will be dominant in any system, because the preferred nitrogen to phosphorous ratio which is 16:1, will dictate the type of phytoplankton communities that will be dominant in any system. Blue green algae, dinoflagelates, and nuisance pond weeds are usually associated with high nutrient ratios out of balance. The level of total phosphorous becomes a problem when values around 50 ppb and above become prevalent. This level would indicate a eutrophic condition, which also would be associated with excessive undesirable plant growth, and anoxic events. A value of 25 ppb TP would be representative of a good/fair mesotrophic system with corresponding nitrogen values around 400 ppb. Phosphorous, like nitrogen is naturally occurring, and would be expected at certain levels based on the geology of any given area. However, the influx of phosphorous from fertilizers, detergents, and septic systems will load a system; and upset the preferred balance.

Loading usually begins in the spring, and lasts through to the end of the summer, when levels are highest. This is most likely related to the seasonal fluctuation of residents on Island, which does not peak until late June. The Madaket Harbor stations recorded fairly low TP levels for most of the summer, and for a marine system this is representative of good water quality. Site 2, and 4 did reach higher levels in August, and September, with Site 4 at 148 ppb TP in September. Only two of these recorded values were above 50 ppb, which would only indicate a limited level of impairment.

The Hither Creek station is predominantly a salt water system, and was discontinued for nutrient sampling so that the stations in Long Pond could be added in 2005. The creek is considered an impaired water body, and this condition will most likely continue, based upon the conditions at other stations. Next year this station, along with a station at the north head may be added to monitoring. This will help to determine if TP loading to the creek is localized, or if Long Pond is exporting it's overabundance of phosphorous.

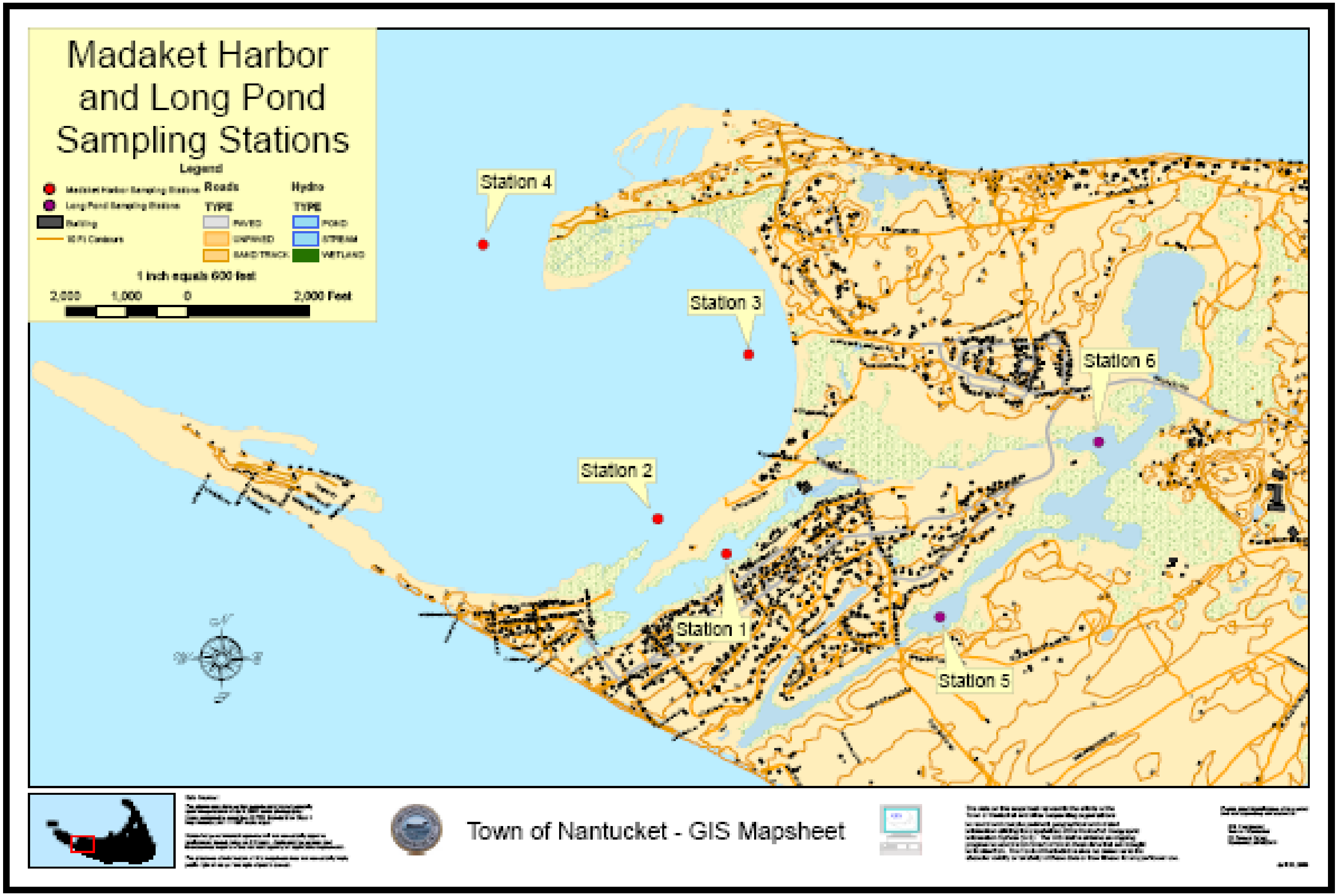
Total Phosphorous in Long Pond was already at a eutrohic level by the second sampling round in May. TP remained consistently high throughout the summer, and would have had a greater effect because of the increased freshening of the pond; as previously discussed in the section on nitrogen. The sampling rounds in April and November were the only two that showed values below the reportable limit. Undoubtedly the high level of precipitation over the summer increased the amount of runoff, increasing the level of phosphorous being carried from the watershed to the pond. The highest recorded level of TP was in August at Site 5 at 164 ppb. A value that is three times higher than needed to create a eutrophic condition. Long Pond exists in a state of significant impairment, showing signs of severe degradation at times according to State classification standards.

Figure: 7 Total Phosphorous 2006



Conclusion:

The Madaket Harbor / Long Pond ecosystem is a very important component in Nantucket's overall health, as it makes up one quarter of the island. The harbor remains in good/fair condition, primarily because of its shape and rapid flushing time. Despite this however it is closed to shell fishing for half the year. This is in large part due to the water quality in Hither Creek, and Long Pond; which may be the most severely degraded water body on the island. The Comprehensive Wastewater Treatment Plan, and Earth Tech are looking for alternative methods to remediate waste water in the area. In conjunction with this effort, the Health Department will be coordinating inspections of septic systems in the area, with a final completion date in June 2008. The Massachusetts Department of Environmental Protection Estuaries Project should have received in June of 2006, a nitrogen and bacteria loading threshold report from the School for Marine Science and Technology; which should be under a final review at this time. However, the impact and benefit from these combined efforts will undoubtedly take some time to come into effect. The good news is that the work is in progress. In the mean time the Marine Dept. will continue with its monitoring regime, and play an active role in preserving, and protecting this system. Sampling procedures will be expanded upon next year. A qualitative focus will look at macro algae coverage in the harbor. Chlorophyll sampling will commence in 2007 for the stations where chemical constituents are also gathered, which will better quantify the level of nutrients occurring in this system.



Madaket Harbor and Long Pond Sampling Stations
Legend
Roads
Hydro
TYPE
TYPE
1 inch equals 600 feet
2,000
1,000
0
2,000 Feet
Station 4
Station 3
Station 2
Station 1
Station 6
Station 5
Town of Nantucket - GIS Mapsheet

Appendix
A

Madaket Harbor / Long Pond 2006

Site 1 Hither Creek
Site 2 Jackson's Pt.
Site 3 Warren's Landing
Site 4 Eel Pt.
Site 5 Massasoit Bridge
Site 6 Long Pond / Madaket Ditch Culvert

Temperature ºC

| Site 1 | 4/26/2006 | 5/23/2006 | 6/20/2006 | 7/19/2006 | 8/16/2006 | 9/28/2006 | 10/31/2006 | 11/29/2006 |
|---|---|---|---|---|---|---|---|---|
| 0 | 11.7 | 13.7 | 19.5 | 25.1 | 21.7 | 19.4 | 9.9 | 10.5 |
| 3 | 10.7 | 13.9 | 20.2 | 24.7 | 22.2 | 19.8 | 9.7 | 10.4 |
| 6 | 10.3 | 14.6 | 19.7 | 24.8 | 22.3 | 19.5 | 10 | 10.5 |
| 8 | 10.2 | 15.2 | 19.6 | 24.8 | 20.6 | | | |

| Site 2 | 4/26/2006 | 5/23/2006 | 6/20/2006 | 7/19/2006 | 8/16/2006 | 9/28/2006 | 10/31/2006 | 11/29/2006 |
|---|---|---|---|---|---|---|---|---|
| 0 | 10.8 | 12.9 | 19.2 | 24.4 | 22 | 18.8 | 10.8 | 10.4 |
| 3 | 10.2 | 12.9 | 19.3 | 24.4 | 21.7 | 18.7 | 10.7 | 10.4 |
| 6 | 10.1 | 12.8 | 19.1 | 24.3 | 21.5 | 18.6 | 10.7 | 10.4 |
| 8 | 10.1 | 12.6 | 19.1 | 24.2 | 21.4 | | 10.7 | 10.4 |

| Site 3 | 4/26/2006 | 5/23/2006 | 6/20/2006 | 7/19/2006 | 8/16/2006 | 9/28/2006 | 10/31/2006 | 11/29/2006 |
|---|---|---|---|---|---|---|---|---|
| 0 | 10.7 | 13.5 | 18.8 | 24.1 | 21.5 | 18.3 | 11 | 10.5 |
| 3 | 10.7 | 13.5 | 19.1 | 23.5 | 21.5 | 18.3 | 10.9 | 10.4 |
| 6 | 10.4 | 13.5 | 18.6 | 22.8 | 21.5 | 18.3 | 10.9 | 10.4 |
| 7 | 10.4 | | | | | | 10.8 | |

| Site 4 | 4/26/2006 | 5/23/2006 | 6/20/2006 | 7/19/2006 | 8/16/2006 | 9/28/2006 | 10/31/2006 | 11/29/2006 |
|---|---|---|---|---|---|---|---|---|
| 0 | 9.7 | 12.3 | 18.5 | 21.9 | 20.8 | 18.3 | 11.3 | 10.4 |
| 3 | 9.7 | 12.4 | 18.5 | 21.8 | 20.7 | 18.3 | 11.3 | 10.4 |
| 6 | 9.6 | 12.2 | 18.5 | 21.8 | 20.7 | 18.3 | 11.3 | 10.3 |
| 9 | | 12.1 | 18.5 | | | 18.3 | 11.3 | 10.3 |
| 12 | | 12.1 | | | | | | |

| Site 5 | 4/26/2006 | 5/23/2006 | 6/20/2006 | 7/19/2006 | 8/16/2006 | 9/28/2006 | 10/31/2006 | 11/29/2006 |
|---|---|---|---|---|---|---|---|---|
| 0 | 14.1 | 15.8 | 19.8 | 25.6 | 23.5 | 20.2 | 10.4 | 10.8 |
| 2 | 13.1 | 15.9 | 20.5 | 27.7 | 24.3 | 20.5 | 9.8 | 10.4 |
| 4 | | 15.9 | 20.6 | 27.4 | 24.5 | | | 10.4 |

| Site 6 | 4/26/2006 | 5/23/2006 | 6/20/2006 | 7/19/2006 | 8/16/2006 | 9/28/2006 | 10/31/2006 | 11/29/2006 |
|---|---|---|---|---|---|---|---|---|
| 0 | 13 | 15.6 | 20.4 | 25.8 | 23.3 | 18.6 | 9.9 | 10.7 |
| 3 | 13 | 15.3 | 20.4 | 25.9 | 23.1 | 18.5 | 9.7 | 10.4 |
| 4 | 12.9 | 15.3 | 20.4 | | 23.1 | | | 10.4 |

Dissolved Oxygen mg/l

| Site 1 | 4/26/2006 | 5/23/2006 | 6/20/2006 | 7/19/2006 | 8/16/2006 | 9/28/2006 | 10/31/2006 | 11/29/2006 |
|---|---|---|---|---|---|---|---|---|
| 0 | 7.4 | 6.87 | 7.74 | 5.61 | 4.91 | 6.11 | 9.16 | 9.34 |
| 3 | 7.42 | 6.63 | 6.21 | 5.35 | 4.44 | 6.86 | 8.04 | 9.67 |
| 6 | 7.58 | 5.52 | 6.34 | 4.86 | 3.53 | 6.23 | 7.66 | 8.85 |
| 8 | 7.72 | 4.94 | 6.09 | 3.07 | | | | |

| Site 2 | 4/26/2006 | 5/23/2006 | 6/20/2006 | 7/19/2006 | 8/16/2006 | 9/28/2006 | 10/31/2006 | 11/29/2006 |
|---|---|---|---|---|---|---|---|---|
| 0 | 7.92 | 7.16 | 6.3 | 5.64 | 5.35 | 6.85 | 8.25 | 9.35 |
| 3 | 7.89 | 7.15 | 6.29 | 5.42 | 5.23 | 6.98 | 8.26 | 9.49 |
| 6 | 7.87 | 7.12 | 6.56 | 4.88 | 5.27 | 6.91 | 8.14 | 9.49 |
| 8 | 8.04 | 7.15 | 6.55 | 4.3 | 5.02 | | 8.04 | 9.52 |

| Site 3 | 4/26/2006 | 5/23/2006 | 6/20/2006 | 7/19/2006 | 8/16/2006 | 9/28/2006 | 10/31/2006 | 11/29/2006 |
|---|---|---|---|---|---|---|---|---|
| 0 | 7.74 | 6.82 | 6.97 | 6.03 | 5.67 | 7.6 | 8.36 | 9.77 |
| 3 | 7.76 | 7.11 | 6.63 | 6.26 | 5.62 | 7.54 | 8.34 | 9.76 |
| 6 | 7.84 | 7.19 | 6.75 | 7.68 | 6.06 | 7.6 | 8.45 | 10.74 |
| 7 | 7.94 | | | | | | 8.51 | |

| Site 4 | 4/26/2006 | 5/23/2006 | 6/20/2006 | 7/19/2006 | 8/16/2006 | 9/28/2006 | 10/31/2006 | 11/29/2006 |
|---|---|---|---|---|---|---|---|---|
| 0 | 7.84 | 7.46 | 7.31 | 7.03 | 6.31 | 7.14 | 8.25 | 9.79 |
| 3 | 7.84 | 7.3 | 7.33 | 7.03 | 6.38 | 7.11 | 8.28 | 9.82 |
| 6 | 7.86 | 7.33 | 7.36 | 7 | 6.29 | 7.12 | 8.26 | 9.83 |
| 9 | | 7.34 | 7.37 | | | 7.2 | 8.33 | 9.84 |
| 12 | | 7.31 | | | | | | |

| Site 5 | 4/26/2006 | 5/23/2006 | 6/20/2006 | 7/19/2006 | 8/16/2006 | 9/28/2006 | 10/31/2006 | 11/29/2006 |
|---|---|---|---|---|---|---|---|---|
| 0 | 8.17 | 7.41 | 7.41 | 7.58 | 7.34 | 6.25 | 9.91 | 10.27 |
| 2 | 8.05 | 7.34 | 5.39 | 3.52 | 3.09 | 6.71 | 9.09 | 11.81 |
| 4 | | 7.4 | 4.96 | 2.34 | 2.63 | | | 11.84 |

| Site 6 | 4/26/2006 | 5/23/2006 | 6/20/2006 | 7/19/2006 | 8/16/2006 | 9/28/2006 | 10/31/2006 | 11/29/2006 |
|---|---|---|---|---|---|---|---|---|
| 0 | 9.34 | 6.37 | 5.64 | 5.72 | 7.51 | 8.72 | 9.11 | 10.79 |
| 3 | 9.21 | 6.05 | 5.72 | 2.29 | 6.91 | 8.62 | 9.05 | 10.35 |
| 4 | 8.96 | 6.01 | 5.59 | | 6.22 | | | 10.39 |

Salinity
ppt.

| Site 1 | | 4/26/2006 | 5/23/2006 | 6/20/2006 | 7/19/2006 | 8/16/2006 | 9/28/2006 | 10/31/2006 | 11/29/2006 |
|---|---|---|---|---|---|---|---|---|---|
| | 0 | 28 | 25 | 15.8 | 26.8 | 20.1 | 28.6 | 19.6 | 26.3 |
| | 3 | 28.7 | 26.2 | 29.6 | 29.1 | 30.2 | 30.6 | 27.6 | 30.2 |
| | 6 | 29.8 | 30.5 | 30 | 29.7 | 30.6 | 30.9 | 31.6 | 30.7 |
| | 8 | 30 | 30.9 | 30 | 29.9 | | | | |

| Site 2 | | 4/26/2006 | 5/23/2006 | 6/20/2006 | 7/19/2006 | 8/16/2006 | 9/28/2006 | 10/31/2006 | 11/29/2006 |
|---|---|---|---|---|---|---|---|---|---|
| | 0 | 31.1 | 31.7 | 29.5 | 28 | 30.1 | 30.5 | 31.7 | 30.7 |
| | 3 | 31.4 | 31.8 | 29.9 | 30 | 30.6 | 31 | 31.7 | 31.4 |
| | 6 | 31.3 | 31.7 | 30.4 | 30 | 30.8 | 31.1 | 31.9 | 31.5 |
| | 8 | 31.3 | 31.6 | 30.4 | 30 | 30.8 | 30.1 | 31.9 | 31.5 |

| Site 3 | | 4/26/2006 | 5/23/2006 | 6/20/2006 | 7/19/2006 | 8/16/2006 | 9/28/2006 | 10/31/2006 | 11/29/2006 |
|---|---|---|---|---|---|---|---|---|---|
| | 0 | 31.3 | 31.4 | 30 | 30.4 | 29.8 | 31.2 | 32 | 31.5 |
| | 3 | 31.3 | 31.4 | 30.4 | 30.6 | 29.9 | 31.2 | 32 | 31.6 |
| | 6 | 31.4 | 31.4 | 30.5 | 30.4 | 30.8 | 31.2 | 31.9 | 31.7 |
| | 7 | 31.4 | | | | | | 31.9 | |

| Site 4 | | 4/26/2006 | 5/23/2006 | 6/20/2006 | 7/19/2006 | 8/16/2006 | 9/28/2006 | 10/31/2006 | 11/29/2006 |
|---|---|---|---|---|---|---|---|---|---|
| | 0 | 31.4 | 31.6 | 30.7 | 30.5 | 31 | 31.3 | 31.9 | 31.4 |
| | 3 | 31.4 | 31.6 | 30.7 | 30.5 | 31 | 31.3 | 31.9 | 31.4 |
| | 6 | 31.4 | 31.8 | 30.7 | 30.5 | 31 | 31.3 | 31.9 | 31.4 |
| | 9 | | 31.7 | 30.7 | | | 31.3 | 31.9 | 31.4 |
| | 12 | | 31.6 | | | | | | |

| Site 5 | | 4/26/2006 | 5/23/2006 | 6/20/2006 | 7/19/2006 | 8/16/2006 | 9/28/2006 | 10/31/2006 | 11/29/2006 |
|---|---|---|---|---|---|---|---|---|---|
| | 0 | 8.3 | 6.5 | 5.8 | 7.3 | 8.2 | 8.9 | 11.1 | 8.7 |
| | 2 | 9.3 | 7.7 | 6.9 | 11.4 | 13 | 10.3 | 13.1 | 8.7 |
| | 4 | | 8.1 | 6.9 | 11.7 | 14.2 | | | 8.9 |

| Site 6 | | 4/26/2006 | 5/23/2006 | 6/20/2006 | 7/19/2006 | 8/16/2006 | 9/28/2006 | 10/31/2006 | 11/29/2006 |
|---|---|---|---|---|---|---|---|---|---|
| | 0 | 14.9 | 12 | 7.3 | 9 | 12.8 | 11.9 | 16.2 | 10 |
| | 3 | 16.2 | 12.7 | 7.4 | 10 | 14.2 | 12.1 | 16.2 | 10.5 |
| | 4 | 16.3 | 13 | 7.4 | | 14.6 | | | 10.6 |

Secchi ft.

| | 4/26/2006 | 5/23/2006 | 6/20/2006 | 7/19/2006 | 8/16/2006 | 9/28/2006 | 10/31/2006 | 11/29/2006 |
|---|---|---|---|---|---|---|---|---|
| Site 1 | 8.5 | 7 | 3.5 | 5 | 5 | 6 | 4.5 | 6 |
| Site 2 | 8.5 | 8 | 6 | 5.5 | 6 | 6.5 | 7 | 7.5 |
| Site 3 | 7 | 5 | 5.4 | 6 | 4 | 7 | 7 | 5 |
| Site 4 | 6.5 | 12 | 7 | 6 | 6 | 8 | 6 | 7 |
| Site 5 | 3.2 | 3.5 | 3 | 3 | 1 | 1 | 3.5 | 3 |
| Site 6 | 4 | 3.5 | 2 | 1 | 0.7 | 2 | 2.5 | 3 |

Nitrate NO3 (ppb)

| | 4/26/2006 | 5/23/2006 | 6/20/2006 | 7/19/2006 | 8/16/2006 | 9/28/2006 | 10/31/2006 | 11/29/2006 |
|---|---|---|---|---|---|---|---|---|
| Site 2 | 80 | 10 | BRL | BRL | 30 | <10 | 380 | BRL |
| Site 4 | BRL | 10 | BRL | 10 | BRL | 30 | BRL | BRL |
| Site 5 | 100 | 30 | BRL | 20 | BRL | <10 | BRL | BRL |
| Site 6 | 262 | 30 | BRL | BRL | BRL | <10 | BRL | BRL |

Kjeldhal Nitrogen TKN (ppb)

| | 4/26/2006 | 5/23/2006 | 6/20/2006 | 7/19/2006 | 8/16/2006 | 9/28/2006 | 10/31/2006 | 11/29/2006 |
|---|---|---|---|---|---|---|---|---|
| Site 2 | 420 | 420 | 420 | ND | 1,004 | 170 | 730 | 900 |
| Site 4 | 140 | 280 | 420 | ND | 360 | 810 | 670 | <100 |
| Site 5 | 420 | 700 | 840 | ND | 280 | 1,400 | 840 | <100 |
| Site 6 | 420 | 560 | 980 | ND | 1,320 | 670 | 810 | <100 |

Total Nitrogen TN
(ppb)

| | 4/26/2006 | 5/23/2006 | 6/20/2006 | 7/19/2006 | 8/16/2006 | 9/28/2006 | 10/31/2006 | 11/29/2006 |
|---|---|---|---|---|---|---|---|---|
| Site 2 | 500 | 430 | 420 | <500 | 1,070 | 170 | 1,110 | 900 |
| Site 4 | 190 | 290 | 420 | <500 | 360 | 840 | 670 | <100 |
| Site 5 | 520 | 710 | 840 | <500 | 280 | 1,400 | 840 | <100 |
| Site 6 | 680 | 590 | 980 | <500 | 1,320 | 670 | 810 | <100 |

Ammonia NH3 (ppb)

| | 4/26/2006 | 5/23/2006 | 6/20/2006 | 7/19/2006 | 8/16/2006 | 9/28/2006 | 10/31/2006 | 11/29/2006 |
|---|---|---|---|---|---|---|---|---|
| Site 2 | 29 | 160 | ND | 130 | 60 | 90 | 140 | 80 |
| Site 4 | ND | 48 | ND | 110 | 120 | 110 | 30 | 80 |
| Site 5 | ND | 120 | ND | 86 | 120 | 50 | 50 | 80 |
| Site 6 | 70 | 120 | ND | 140 | 230 | 100 | 40 | 110 |

Total Phosphorous TP (ppb)

| | 4/26/2006 | 5/23/2006 | 6/20/2006 | 7/19/2006 | 8/16/2006 | 9/28/2006 | 10/31/2006 | 11/29/2006 |
|---|---|---|---|---|---|---|---|---|
| Site 2 | BRL | BRL | 23 | BRL | 51 | 39 | BRL | BRL |
| Site 4 | BRL | BRL | 25 | BRL | 39 | 148 | BRL | BRL |
| Site 5 | BRL | 65 | 91 | 65 | 164 | 98 | 67 | BRL |
| Site 6 | BRL | 103 | 105 | 72 | 104 | 35 | 103 | BRL |

ND = below detectable limit
BRL = below reportable limit

Appendix B

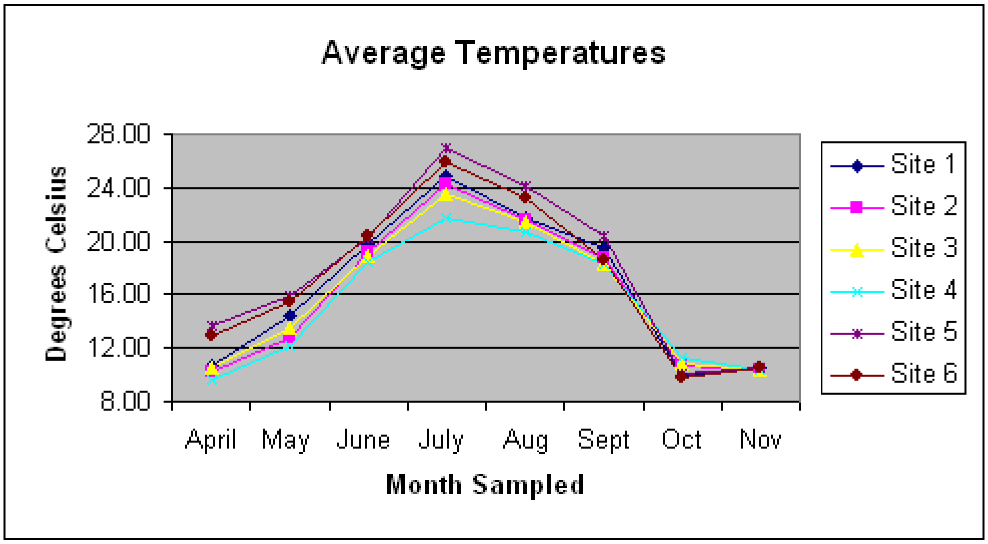
Average Physical and Chemical Parameters

Madaket Harbor / Long Pond 2006

| | |
|---|---|
| Site 1 | Hither Creek |
| Site 2 | Jackson's Pt. |
| Site 3 | Warren's Landing |
| Site 4 | Eel Pt. |
| Site 5 | Massasoit Bridge |
| Site 6 | Long Pond / Madaket Ditch Culvert |

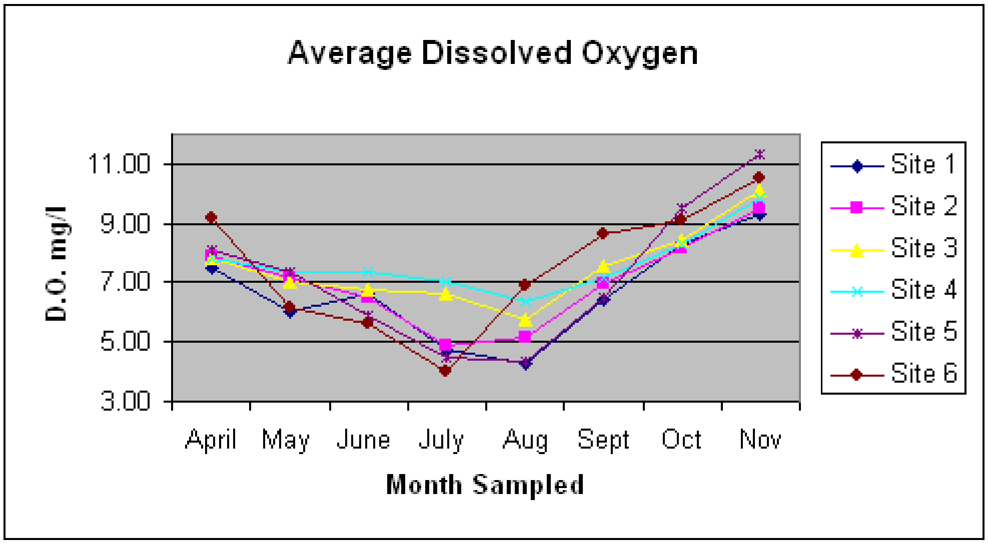
Average Temperatures ºC

| | April | May | June | July | Aug | Sept | Oct | Nov |
|---|---|---|---|---|---|---|---|---|
| Site 1 | 10.73 | 14.35 | 19.75 | 24.85 | 21.70 | 19.57 | 9.87 | 10.47 |
| Site 2 | 10.30 | 12.80 | 19.18 | 24.33 | 21.65 | 18.70 | 10.73 | 10.40 |
| Site 3 | 10.55 | 13.50 | 18.83 | 23.47 | 21.50 | 18.30 | 10.90 | 10.43 |
| Site 4 | 9.67 | 12.22 | 18.50 | 21.80 | 20.70 | 18.30 | 11.30 | 10.33 |
| Site 5 | 13.60 | 15.87 | 20.30 | 26.90 | 24.10 | 20.35 | 10.10 | 10.53 |
| Site 6 | 12.97 | 15.40 | 20.40 | 25.85 | 23.17 | 18.55 | 9.80 | 10.50 |



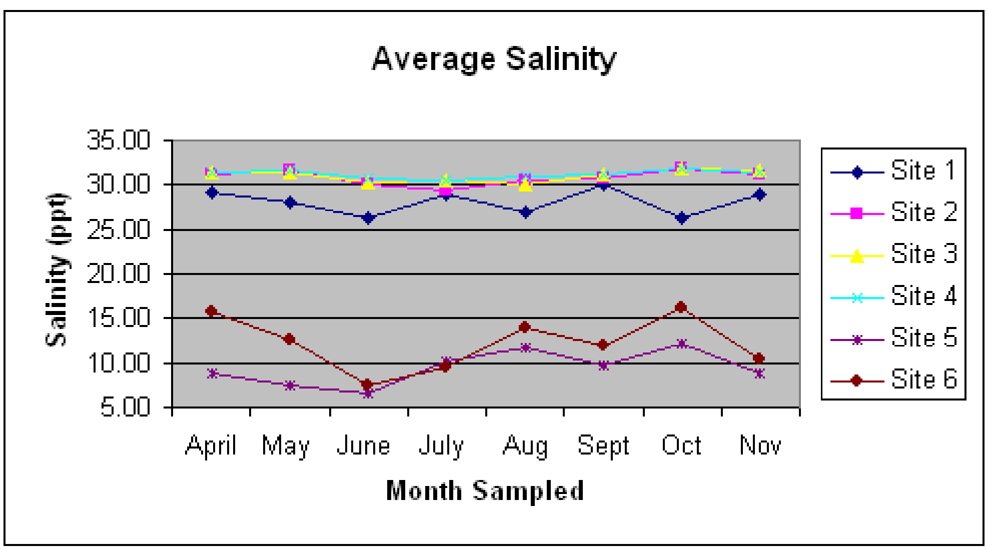

Average Dissolved Oxygen
mg/l

| | April | May | June | July | Aug | Sept | Oct | Nov |
|---|---|---|---|---|---|---|---|---|
| Site 1 | 7.53 | 5.99 | 6.60 | 4.72 | 4.29 | 6.40 | 8.29 | 9.29 |
| Site 2 | 7.93 | 7.14 | 6.47 | 4.87 | 5.17 | 6.95 | 8.15 | 9.50 |
| Site 3 | 7.82 | 7.04 | 6.78 | 6.66 | 5.78 | 7.58 | 8.42 | 10.09 |
| Site 4 | 7.85 | 7.35 | 7.34 | 7.02 | 6.33 | 7.14 | 8.28 | 9.82 |
| Site 5 | 8.11 | 7.38 | 5.92 | 4.48 | 4.35 | 6.48 | 9.50 | 11.31 |
| Site 6 | 9.17 | 6.14 | 5.65 | 4.01 | 6.88 | 8.67 | 9.08 | 10.51 |



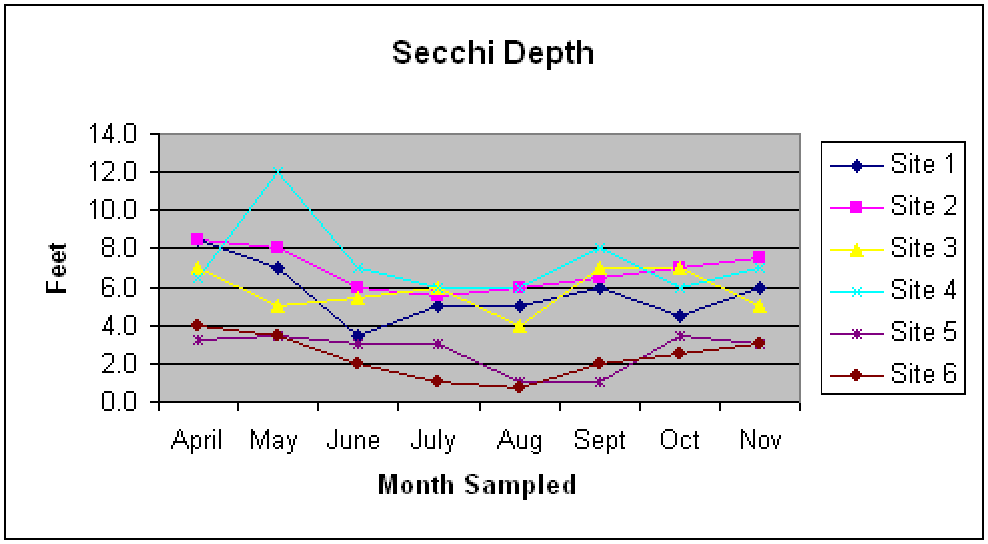

Average Salinity ppt.

| | April | May | June | July | Aug | Sept | Oct | Nov |
|---|---|---|---|---|---|---|---|---|
| Site 1 | 29.13 | 28.15 | 26.35 | 28.88 | 26.97 | 30.03 | 26.27 | 29.07 |
| Site 2 | 31.28 | 31.70 | 30.05 | 29.50 | 30.58 | 30.68 | 31.80 | 31.28 |
| Site 3 | 31.35 | 31.40 | 30.30 | 30.47 | 30.17 | 31.20 | 31.95 | 31.60 |
| Site 4 | 31.40 | 31.66 | 30.70 | 30.50 | 31.00 | 31.30 | 31.90 | 31.40 |
| Site 5 | 8.80 | 7.43 | 6.53 | 10.13 | 11.80 | 9.60 | 12.10 | 8.77 |
| Site 6 | 15.80 | 12.57 | 7.37 | 9.50 | 13.87 | 12.00 | 16.20 | 10.37 |



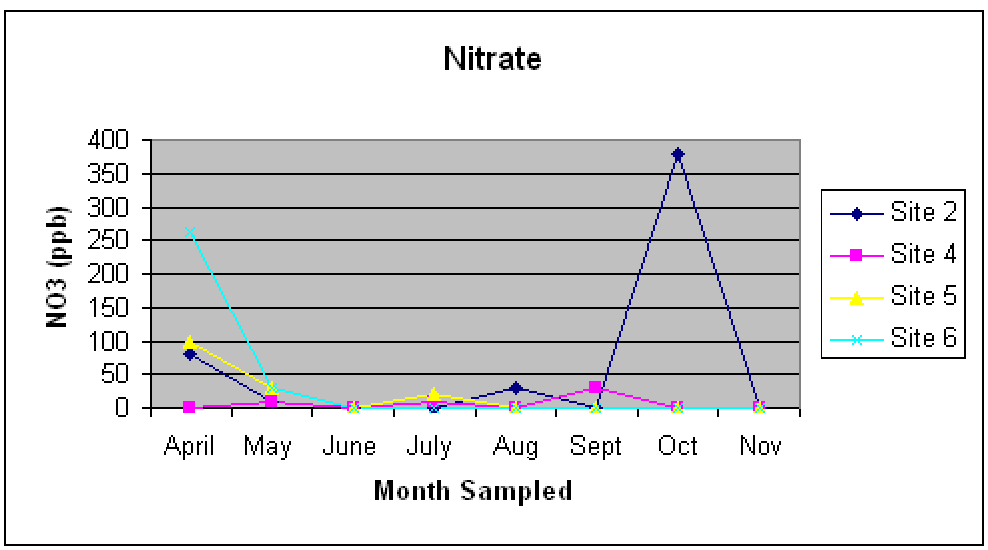
Secchi
ft.

| | April | May | June | July | Aug | Sept | Oct | Nov |
|---|---|---|---|---|---|---|---|---|
| Site 1 | 8.5 | 7.0 | 3.5 | 5.0 | 5.0 | 6.0 | 4.5 | 6.0 |
| Site 2 | 8.5 | 8.0 | 6.0 | 5.5 | 6.0 | 6.5 | 7.0 | 7.5 |
| Site 3 | 7.0 | 5.0 | 5.4 | 6.0 | 4.0 | 7.0 | 7.0 | 5.0 |
| Site 4 | 6.5 | 12.0 | 7.0 | 6.0 | 6.0 | 8.0 | 6.0 | 7.0 |
| Site 5 | 3.2 | 3.5 | 3.0 | 3.0 | 1.0 | 1.0 | 3.5 | 3.0 |
| Site 6 | 4.0 | 3.5 | 2.0 | 1.0 | 0.7 | 2.0 | 2.5 | 3.0 |



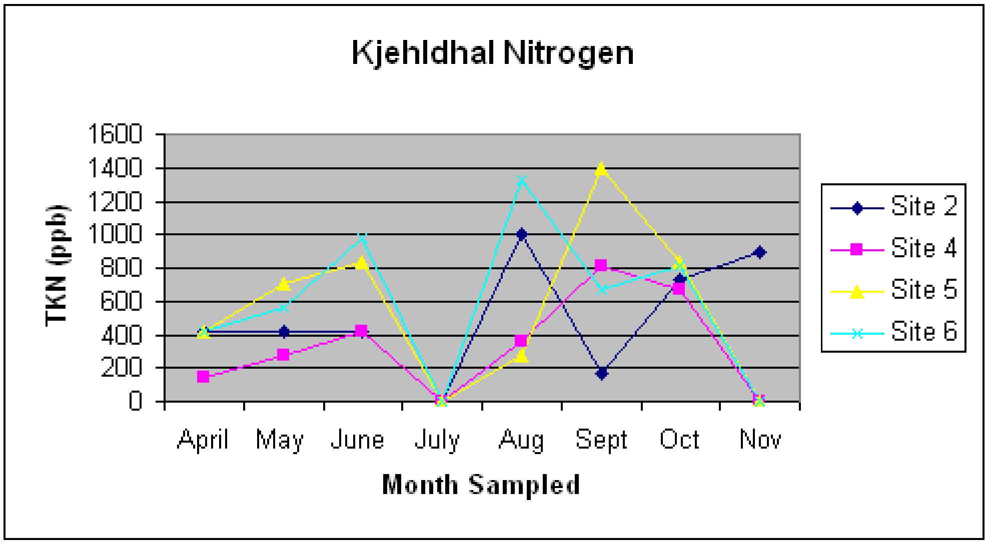

Nitrate NO3 (ppb)

| | April | May | June | July | Aug | Sept | Oct | Nov |
|---|---|---|---|---|---|---|---|---|
| Site 2 | 80 | 10 | BRL | BRL | 30 | <10 | 380 | BRL |
| Site 4 | BRL | 10 | BRL | 10 | BRL | 30 | BRL | BRL |
| Site 5 | 100 | 30 | BRL | 20 | BRL | <10 | BRL | BRL |
| Site 6 | 262 | 30 | BRL | BRL | BRL | <10 | BRL | BRL |



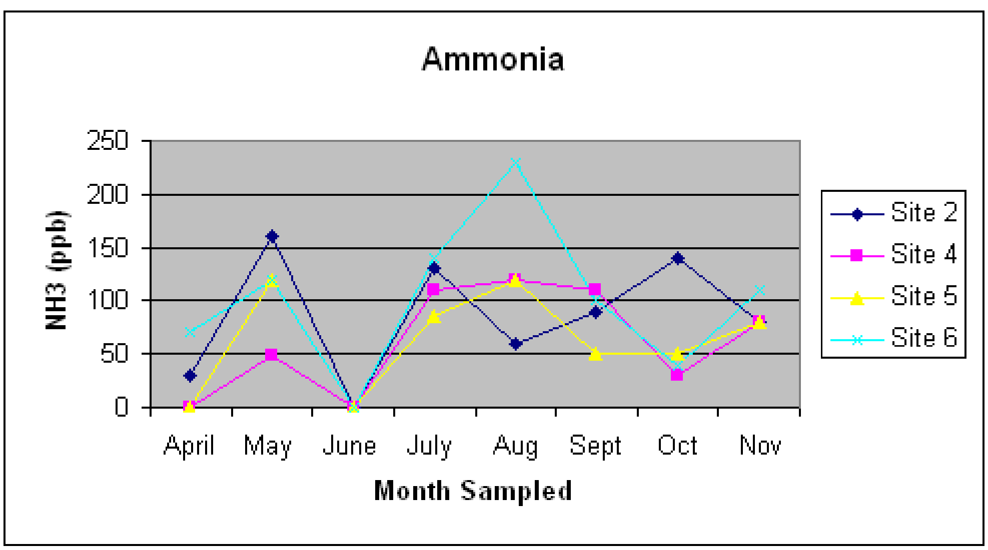
Kjeldhal Nitrogen TKN (ppb)

| | April | May | June | July | Aug | Sept | Oct | Nov |
|---|---|---|---|---|---|---|---|---|
| Site 2 | 420 | 420 | 420 | ND | 1,004 | 170 | 730 | 900 |
| Site 4 | 140 | 280 | 420 | ND | 360 | 810 | 670 | <100 |
| Site 5 | 420 | 700 | 840 | ND | 280 | 1,400 | 840 | <100 |
| Site 6 | 420 | 560 | 980 | ND | 1,320 | 670 | 810 | <100 |



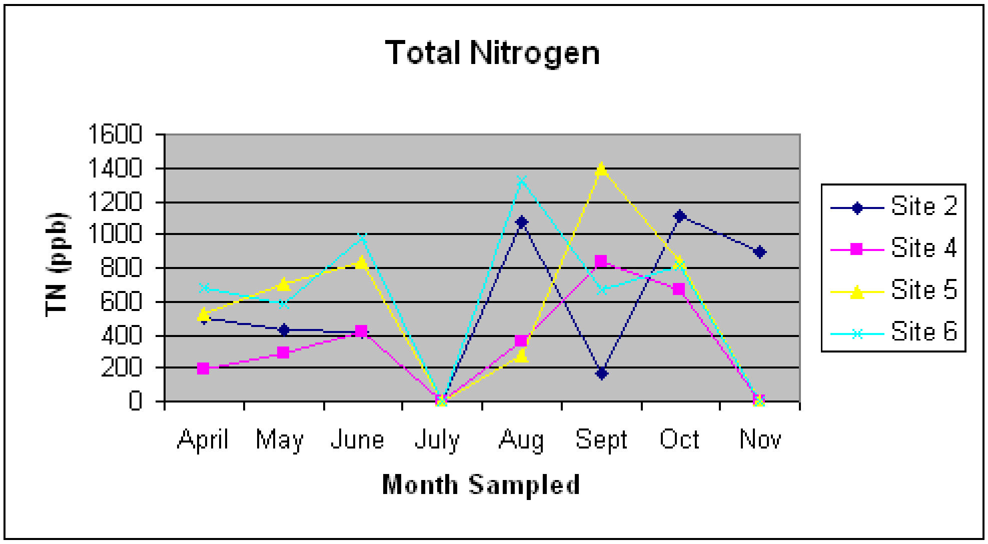

Ammonia NH3 (ppb)

| | April | May | June | July | Aug | Sept | Oct | Nov |
|---|---|---|---|---|---|---|---|---|
| Site 2 | 29 | 160 | ND | 130 | 60 | 90 | 140 | 80 |
| Site 4 | ND | 48 | ND | 110 | 120 | 110 | 30 | 80 |
| Site 5 | ND | 120 | ND | 86 | 120 | 50 | 50 | 80 |
| Site 6 | 70 | 120 | ND | 140 | 230 | 100 | 40 | 110 |



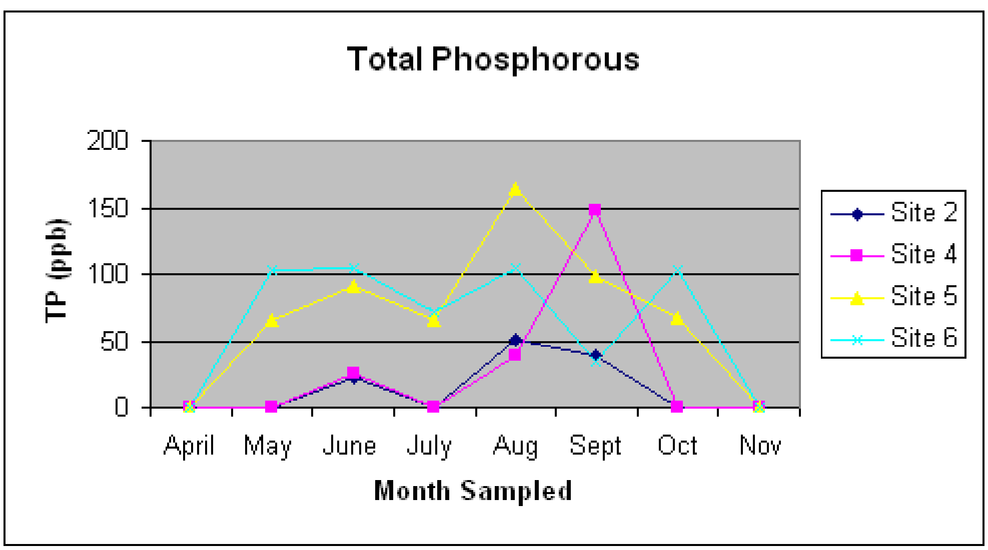
Total Nitrogen TN (ppb)

| | April | May | June | July | Aug | Sept | Oct | Nov |
|---|---|---|---|---|---|---|---|---|
| Site 2 | 500 | 430 | 420 | <500 | 1070 | 170 | 1110 | 900 |
| Site 4 | 190 | 290 | 420 | <500 | 360 | 840 | 670 | <100 |
| Site 5 | 520 | 710 | 840 | <500 | 280 | 1400 | 840 | <100 |
| Site 6 | 680 | 590 | 980 | <500 | 1320 | 670 | 810 | <100 |




Total Phosphorous TP (ppb)

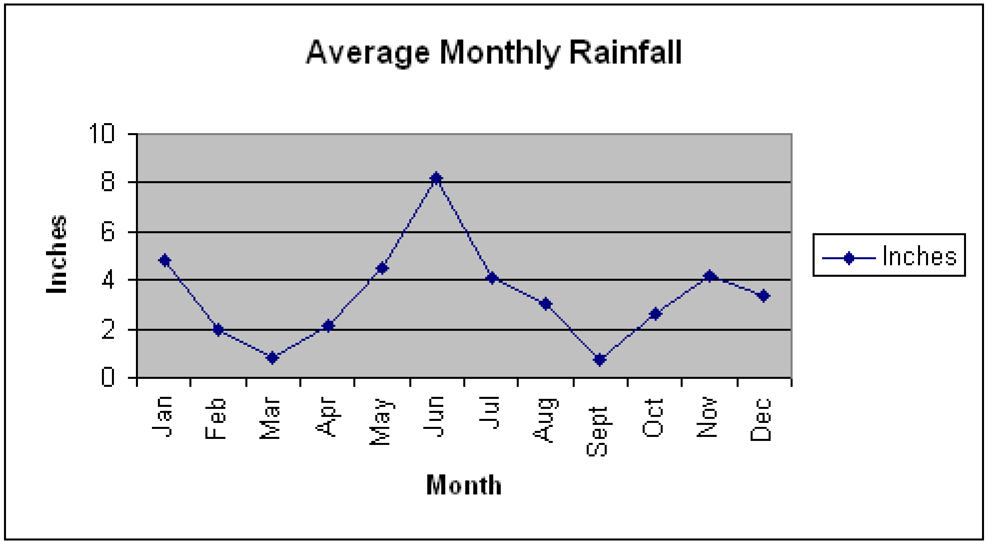
| | April | May | June | July | Aug | Sept | Oct | Nov |
|---|---|---|---|---|---|---|---|---|
| Site 2 | BRL | BRL | 23 | BRL | 51 | 39 | BRL | BRL |
| Site 4 | BRL | BRL | 25 | BRL | 39 | 148 | BRL | BRL |
| Site 5 | BRL | 65 | 91 | 65 | 164 | 98 | 67 | BRL |
| Site 6 | BRL | 103 | 105 | 72 | 104 | 35 | 103 | BRL |



Appendix C

Average Monthly Rainfall
2006

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Inches | 4.86 | 1.98 | 0.85 | 2.13 | 4.5 | 8.23 | 4.07 | 3.05 | 0.76 | 2.6 | 4.19 | 3.32 |




Total Rainfall: 40.54 "