Madaket Harbor / Long Pond
Annual Report
2007

Prepared for:
Marine and Coastal Resources Department
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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 shellfishing, 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. The 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 enabled a closure of the gap to Smith’s Pt. via drifting sand bars. 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.

On April 15th 2007, a severe Nor’ Easter breached Smith’s Pt., recreating Esther’s Island at approximately the same location. Initially the opening was 50 to 60 yards wide, and an average depth of 15 feet reported by local fishermen. A great deal of erosion occurred at New Smith's Pt., and the west end of the island this year. Many homes were moved back from the eroding shoreline, with a couple being lost to the ocean. The breach stayed open to Madaket Harbor, changing currents, and filling in harbor flats with deposited sands from long shore drift. Currently the breach remains open, 60 to 70 yards wide, with an unknown depth. Presently a large spit has formed on the inside of the harbor running roughly west to northeast in a crescent shape off Esther's. Exposed at low tide, it is approximately 500 yards long, and 20 yards wide; and has buried vast areas of adjacent eel grass beds. For photographs see Nantucket GIS maps with 2007 aerial photos The result may be an improvement in water quality, offset however by a net loss in habitat. It remains unclear how long the opening will last, as it may take a storm of equal severity to close the breach. Or, it may take even more time for spits to form up large enough, to slow currents well enough to close the gap via accretion.

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 also serves 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 elevated 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. This means that 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 2007 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, 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 2007.

Appendix B: contains the averages of A, and graphs of that data.

Appendix C: contains average monthly rainfall data for 2007, 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 for several reasons; the size of the system, fresh water inputs from the watershed, eutrophic conditions in some places, 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 nitrogenand phosphorous are recycled back 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 2007 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) temperatures were higher during the July sampling round. The highest temperature recorded was 25.6 ºC at the Massasoit Bridge in July (Appendix A). This is approximately 2 ºC cooler than last year. Higher temperatures are expected in shallow water bodies with little circulation. When combined with a nutrient rich condition, dissolved oxygen levels often drop into periods of hypoxia, and anoxia. Because of cooler water temperatures this year, Site 1 was the only location where near hypoxic D.O. recordings were taken in July at 5.43 mg/l (Appendix A). Because of an abundant growth of pond weeds, Long Pond experienced similar, but higher levels of dissolved oxygen in July and August. The D.O. at Site 5 on the bottom was 6.16 mg/l for the July 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 drive the D.O. in the opposite direction, resulting in hypoxia or anoxia. In 2005 the D.O. conditions at Site 5, and 6 were worse, with higher average temperatures for June, July, and August. 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, 2006). The surface D.O. conditions at these two sites in 2006 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; which was limited in 2007 by the reduced precipitation. This will be discussed further in the section on nutrients.

Figure 1: Average Temperatures 2007

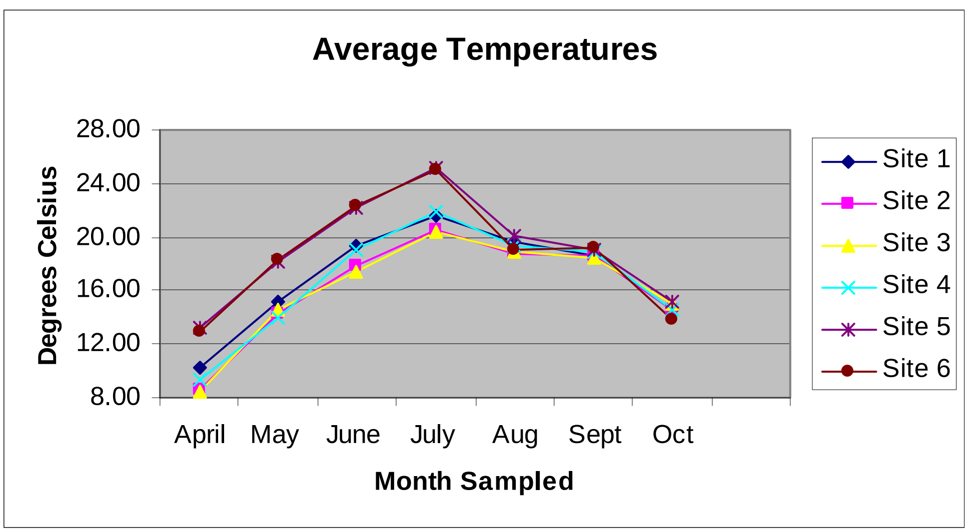
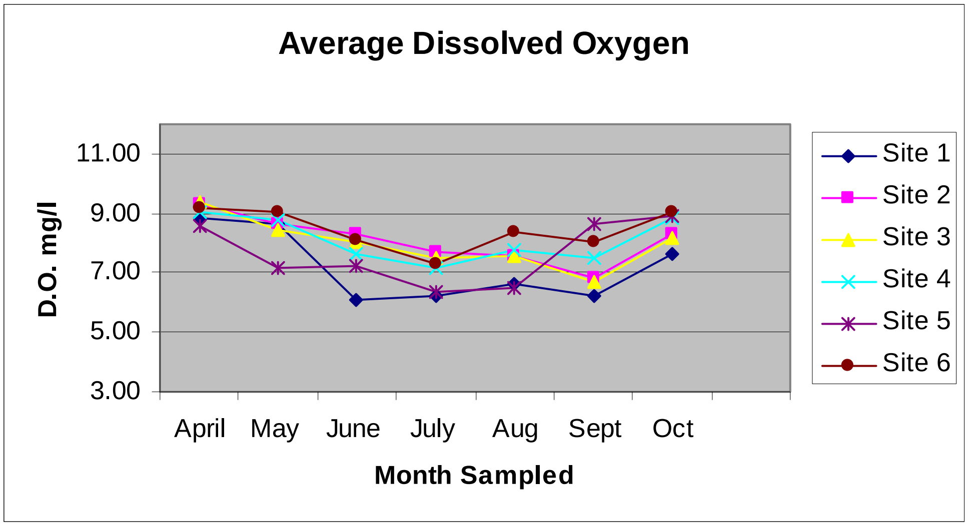


Figure 2: Average Dissolved Oxygen 2007



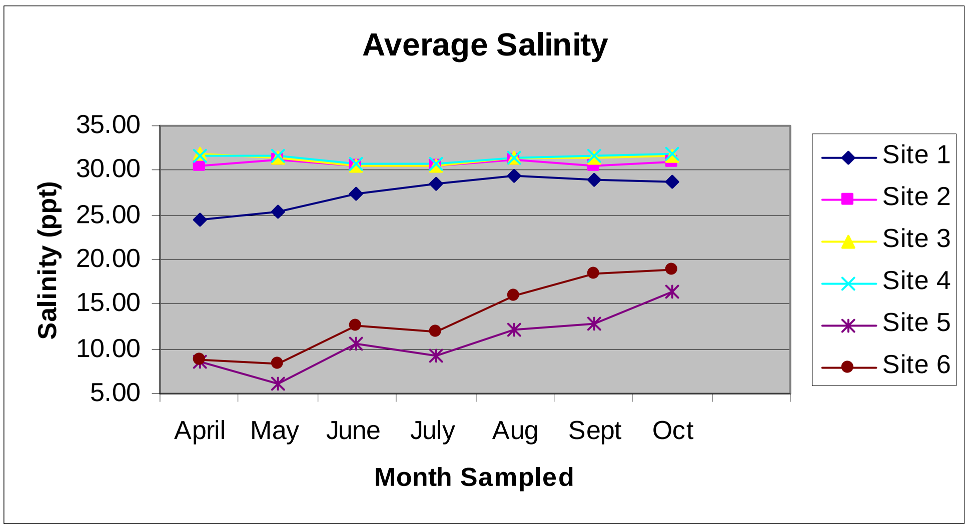
Salinity:

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 fresh and salt water exchange occurring in relatively small amounts between Long Pond and Madaket Harbor through the Madaket Ditch, the salinity gradients in the creek vary widely. Stratification does occur here, and surface salinities have been measured as low as 10.6 ppt, Site 1, April sampling event 2007 (Appendix A). Though relatively shallow, the difference between top and bottom may be as much as 21.1 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 more fresh, (<10 ppt.). The lack of precipitation in 2007 most likely caused a large increase in pond salinity for the August, September, and October sampling rounds. The October sampling round recorded 13.8 ppt. at the surface, and 17.8 ppt. at the bottom at Site 5 (Appendix A). This was a 4 ppt. difference between top and bottom recorded in the 2007 data. When combined with rainfall data, this data would suggest that the salt water wedge was far reaching because the extremely low level of rainfall for the summer months. This would also suggest that the freshness of the pond, not the volume, may be determined by accumulated rainfall. Site 5, and 6 for example showed a slight drop in salinity during the May time period, as precipitation increased. However salinity steadily increased through to the end of the sampling period as precipitation remained low during that time frame (Figure 3, and 4).

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 for spawning; 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 at a salinity level below 28 ppt.

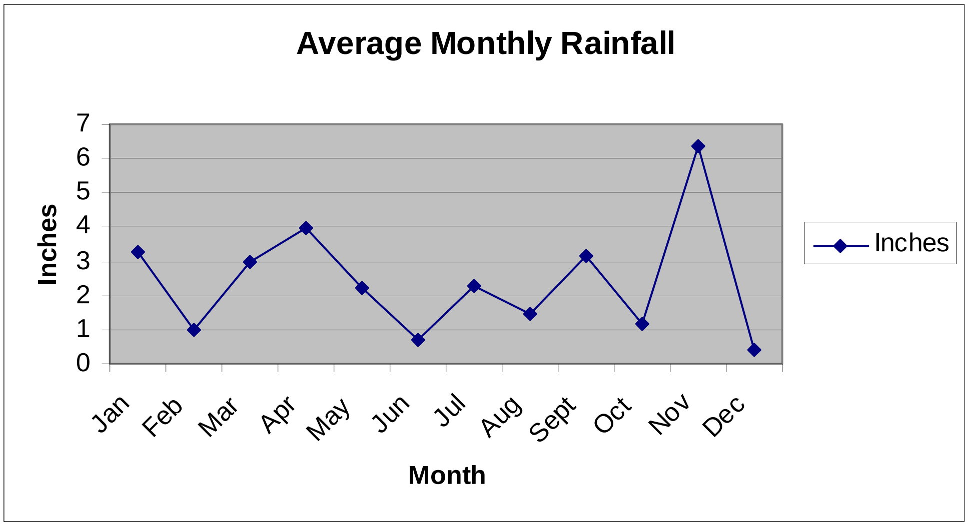
Figure 3: Average Salinity 2007



Rainfall:

Rainfall data corresponds well with salinity changes in Long Pond. According to Horsley, Witten, and Hegemann 1990, the average annual rainfall for Nantucket is 43.7" per year. The total rainfall for 2007 was 28.89", with incomplete data for December. The accumulated precipitation for the summer of 2007 was one of the lowest on record. This was seen directly in the steadily increasing trend toward more saline conditions in the southern end of long pond. The movement of nutrients through groundwater was also greatly affected; and considerably reduced compared to last year. Changes in salinity in the southern end of Long Pond as the result of precipitation may also cause a shift in plant communities. This may further dictate changes in nutrient uptake and availability, which will be discussed further in the section on nutrients.

Figure 4: Average Monthly Rainfall 2007



*December Rainfall Incomplete
Rainfall Data Collected by Wannacomet Water Company

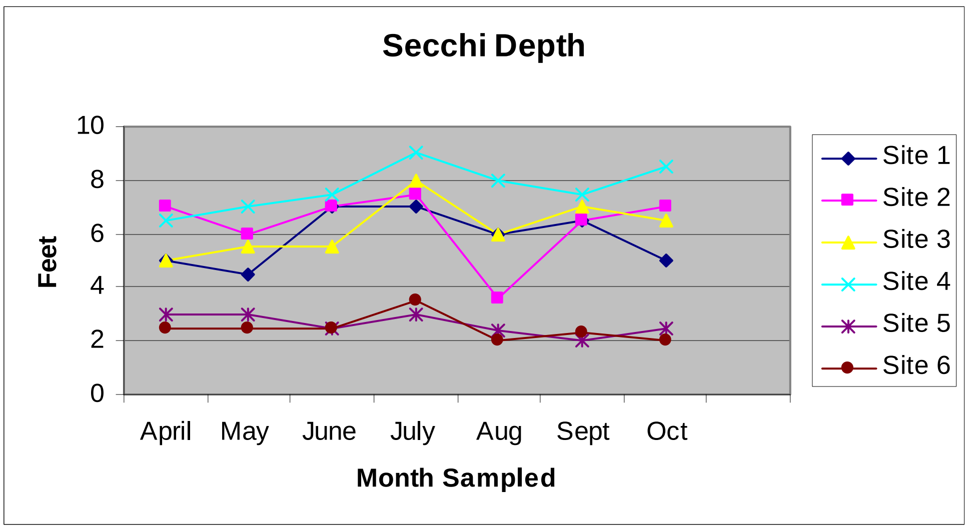
Secchi Depth:

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 2007 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 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. Note, the August secchi sampling at Site 2 was off location due to a buoy misplacement and high winds, and does not reflect a drop in water clarity.

Figure 5: Secchi Depth 2007



Nutrients:

Nitrogen:

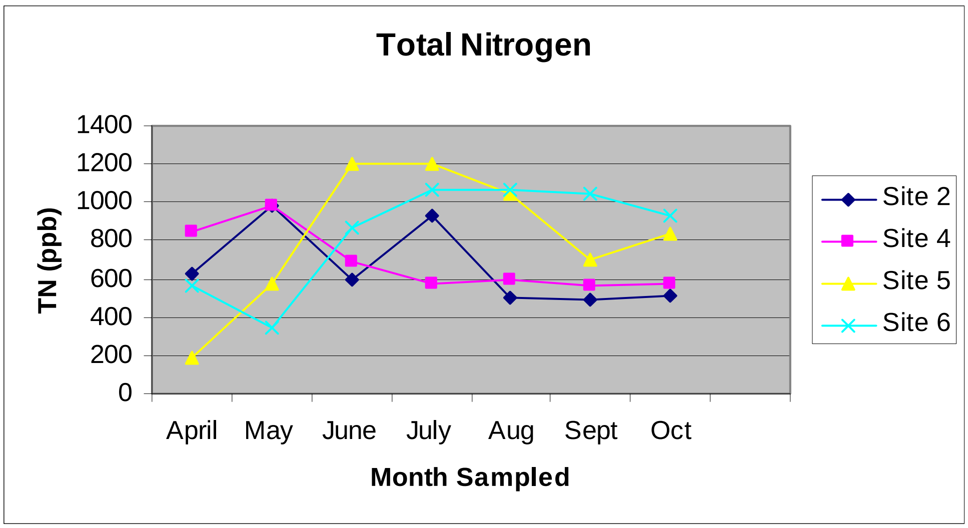
Nitrogen is the limiting nutrient in marine ecosystems, the quantity of which will dictate the health of any particular water body. Nitrogen does not usually accumulate in Madaket Harbor, primarily because of its open shape, and high rate of circulation. However in May and July of 2007 elevated levels of total nitrogen were measured in the samples taken from Jackson's Pt. They were also high (above 700 ppb TN) at Eel Pt., during April and May (Appendix A, and Figure 6). The effects of nitrogen are more prevalent in some areas than others. Total nitrogen includes both organic and inorganic components. Kjeldhal nitrogen (TKN) consists of ammonia (NH_3), and organic nitrogen (ON). Nitrate (NO_3) an inorganic component of nitrogen is usually associated with atmospheric deposition, septic systems and fertilizers, and is readily available for uptake from primary producers. Due to the lack of precipitation, and ground water flow it was seldom detected above threshold limits that are suggestive of eutrophication (70 ppb NO_3) in the Madaket Harbor / Long Pond system. 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. TN levels were also down compared to 2006 for the system as a whole. This is most likely attributable to the lack of precipitation, cooler temperatures, higher D.O. levels, and the new cut at Esther’s Island. However NH3, and ON levels were still high throughout much of the sampling period for all stations (Appendix A). This suggests a high rate of internal recycling of organic materials, especially in the Long Pond part of the system. High NH3 levels above 50 ppb may also indicate a large septic input. As many homes in this area have septic systems close to the groundwater table, it becomes highly probable that they are negatively influencing their associated water body. The highest nitrogen readings in Madaket Harbor come from organic components in May, at 850 ppb and 860 ppb ON at Sites 2 and 4 respectively (Appendix A). This may be due warming temperatures and associated biological activity. Madaket Harbor is slightly affected by Hither Creek and Long Pond, but because it 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 in the eutrophication of this water body. The TN values for 2007 were not as high as the values in 2006; both of which were also lower than 2005. This may be the result of some improvements or changes in uses in the watershed. An increasing saline condition in the pond because of a lack of precipitation, may also 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 nitrogen limiting water body in 2007. An example would be a decrease in phragmities reeds, as a result of an increase in salinity. Shifts in plant communities because of salinity changes, will then increase nutrients from decaying plant matter. An increase in nutrient uptake from the opposing, and emergent limiting plant species will follow, in a cyclical pattern that ultimately increases nutrient loading and recycling. Site 5 at the southern end in June and July measured TN at 1,200 ppb (Appendix A). TN levels above 800 ppb are considered to be thresholds for a hyper-eutrophic state. 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 2007



Phosphorous:

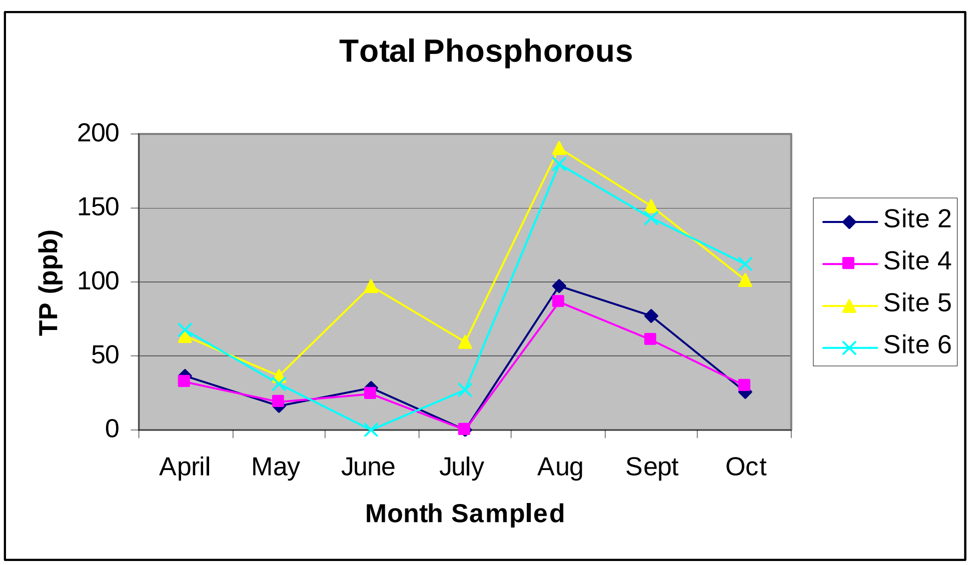
Phosphorous is a limiting nutrient in fresh water, but it is of relative concern to the marine ecosystem. Phosphorous in over abundance can affect the type of phytoplankton species that will be dominant in any system. The preferred nitrogen to phosphorous ratio is 16:1 respectively. Blue green algae, 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 greater become prevalent. This level would indicate a eutrophic condition, which also would be associated with anoxic events, and potential fish kills. 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 begin to 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 (Figure 7). Though a lower peak level was recorded this year than last year, the time period of the increase was the same. As this time period coincides with peak activity on the Island, it may be reason to believe that these peaks are related to anthropogenic sources. The limited occurrence with values not greater than double the threshold limit (50 ppb TP), 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 continued uses in the area. Next year this station, along with a station at the north head may be added to the chemical analysis 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.

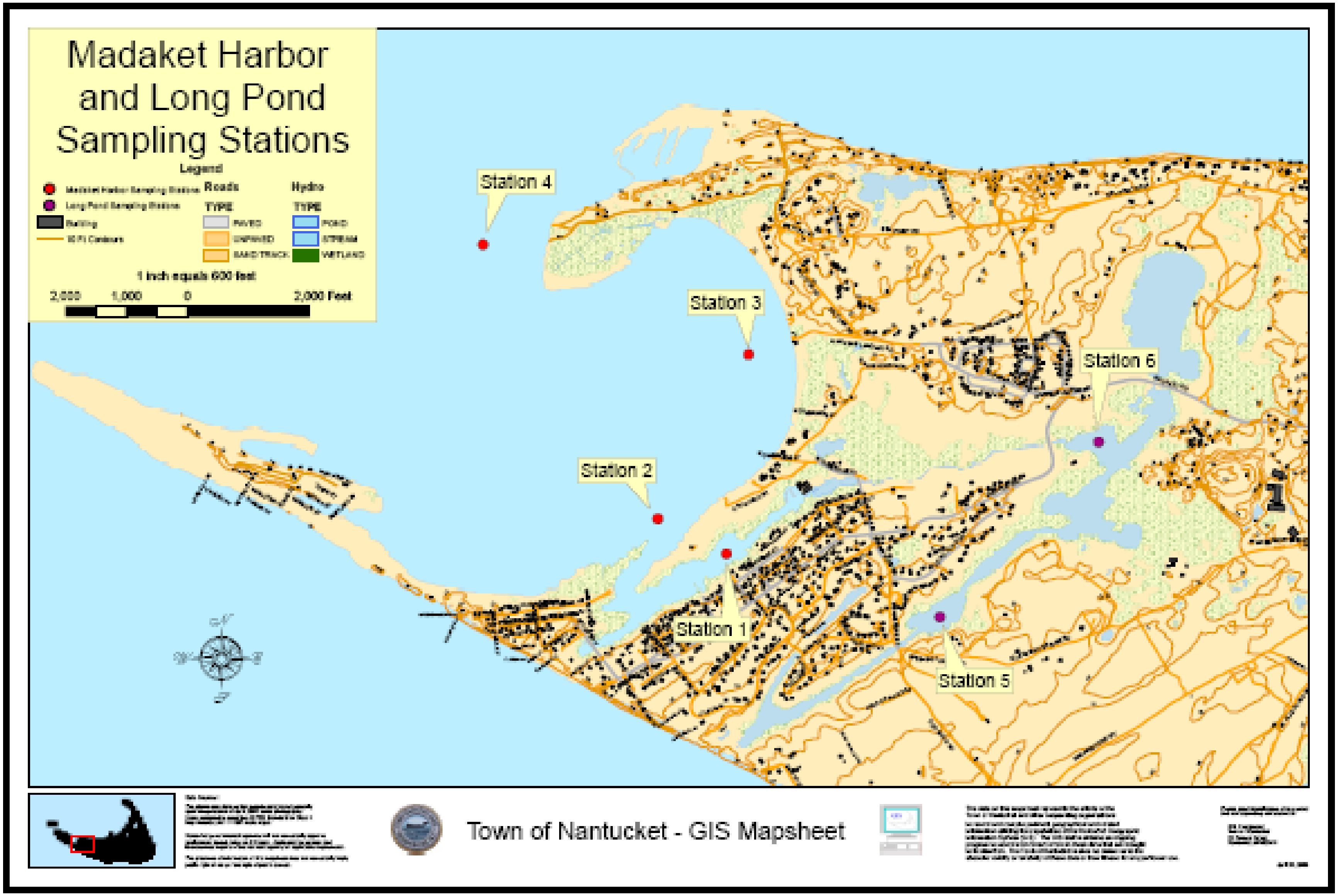
Total Phosphorous in Long Pond has been high, or at a eutrohic level in past years of sampling. TP started at an elevated level in April, then dropped off, not showing eutrophic levels again, until the June sampling round at Site 5 (Figure7). Both stations peaked in August at 190 and 180 ppb TP, at Sites 5 and 6 respectively. Though they dropped off following the August round, they were high throughout the duration of the sampling period. The sampling round in June at Site 6 was the only recording that showed a value below the reportable limit. The low level of precipitation over the summer decreased the amount of runoff, decreasing the speed at which phosphorous is carried from the watershed to the pond. Values in August were nearly four times higher than needed to exhibit 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 2007



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 a TMDL report in June of 2006 for review. The TMDL is a nitrogen and bacteria loading threshold report from the School for Marine Science and Technology, which should quantify the limit of nitrogen these systems can sustain in order to avoid creating an impaired condition. However, the impact and benefit from these combined efforts will undoubtedly take some time to come into effect. 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 may look at macro algae coverage in the harbor. And chlorophyll sampling will commence in 2008 for the stations where chemical constituents are currently being gathered. Hopefully these efforts will better quantify the level of nutrients occurring in this system, and help define the level of remediation necessary to improve water quality conditions.


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 6
Station 2
Station 1
Station 5
Town of Nantucket - GIS Mapsheet

Appendix A

Madaket Harbor / Long Pond 2007

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	4/24/2007	5/23/2006	6/25/2007	7/11/2007	8/22/2007	9/20/2007	10/17/2007
0	12.1	16.2	20.3	22.7	19.7	18.2	13
3	9.8	14.8	19.8	21.6	19.7	18.5	15.1
6	8.9	14.5	18.6	21.1	19.6	18.7	15.3
8			18.5	20.8		18.7	15.1

Site 2	4/24/2007	5/23/2006	6/25/2007	7/11/2007	8/22/2007	9/20/2007	10/17/2007
0	9.8	14.3	18	20.7	18.7	18.5	14.4
3	8.3	14.2	17.9	20.5	18.7	18.5	14.4
6	8.2	14.2	17.9	20.4	18.7	18.6	14.5
8	7.8		17.9	20.3		18.6	14.7

Site 3	4/24/2007	5/23/2006	6/25/2007	7/11/2007	8/22/2007	9/20/2007	10/17/2007
0	8.4	14.6	17.5	20.4	18.9	18.5	15
3	8.4	14.6	17.5	20.3	18.9	18.5	15
6	8.4	14.6	17.4	20.3	18.9	18.5	14.9
7				20.3	18.8	18.5	14.9

Site 4	4/24/2007	5/23/2006	6/25/2007	7/11/2007	8/22/2007	9/20/2007	10/17/2007
0	9.4	14.5	19.1	21.9	19.3	19	14.6
3	9.4	14.4	19.1	21.9	19.3	19	14.5
6	9.4	14.4	19.1	21.9	19.3	19	14.5
9		14.4	19.1	21.8	19.4	18.9	14.5
12							

Site 5	4/24/2007	5/23/2006	6/25/2007	7/11/2007	8/22/2007	9/20/2007	10/17/2007
0	13.1	18.4	21.9	24.8	20.1	19.2	14.7
2	13.3	18.3	22.6	25.6	20.2	19	15.5
4	13.3	17.9					15.5

Site 6	4/24/2007	5/23/2006	6/25/2007	7/11/2007	8/22/2007	9/20/2007	10/17/2007
0	13	18.3	22.4	25	19	19.5	13.9
3	13	18.3	22.3	25	19	19	13.8
4	13	18.3		24.9			13.8

Dissolved Oxygen
mg/l

Site 1	4/24/2007	5/23/2006	6/25/2007	7/11/2007	8/22/2007	9/20/2007	10/17/2007
0	9.16	9.01	6.79	6.75	6.84	6.36	7.92
3	8.46	8.84	5.79	6.54	6.8	5.33	6.89
6	8.85	8.17	6.06	6.07	6.19	6.22	8.16
8			5.81	5.43		6.86	7.58

Site 2	4/24/2007	5/23/2006	6/25/2007	7/11/2007	8/22/2007	9/20/2007	10/17/2007
0	9.01	8.65	8.25	7.83	7.46	6.41	8.41
3	9.37	8.62	8.27	7.76	7.55	6.69	8.41
6	9.39	8.63	8.3	7.7	7.56	6.94	8.4
8	9.5		8.3	7.6		6.87	8.14

Site 3	4/24/2007	5/23/2006	6/25/2007	7/11/2007	8/22/2007	9/20/2007	10/17/2007
0	9.37	8.36	7.98	7.43	7.61	6.75	8.2
3	9.38	8.39	8.02	7.36	7.58	6.76	8.18
6	9.48	8.55	8.14	7.53	7.59	6.79	8.17
7				7.59	7.5	6.35	8.18

Site 4	4/24/2007	5/23/2006	6/25/2007	7/11/2007	8/22/2007	9/20/2007	10/17/2007
0	9.05	8.75	7.75	7.17	7.81	7.6	8.77
3	8.99	8.73	7.7	7.15	7.75	7.6	8.76
6	9.05	8.78	7.74	7.17	7.77	7.61	8.84
9		8.84	7.37	7.13	7.82	7.2	8.88
12							

Site 5	4/24/2007	5/23/2006	6/25/2007	7/11/2007	8/22/2007	9/20/2007	10/17/2007
0	8.81	7.68	7.09	6.59	6.52	8.61	8.34
2	8.47	7.14	7.35	6.16	6.45	8.74	9.49
4	8.45	6.61					8.97

Site 6	4/24/2007	5/23/2006	6/25/2007	7/11/2007	8/22/2007	9/20/2007	10/17/2007
0	9.12	9.37	8.11	7.48	8.45	8.33	9.28
3	9.2	8.99	8.07	7.4	8.26	7.81	8.97
4	9.19	8.84		7.07			8.93

Salinity ppt.

Site 1	4/24/2007	5/23/2006	6/25/2007	7/11/2007	8/22/2007	9/20/2007	10/17/2007
0	10.6	14.2	20.8	22.8	28.8	24.3	21.1
3	31.4	31	28.7	30.2	28.8	29.2	30.9
6	31.7	31.2	30.2	30.5	30.6	31.2	31.6
8			30.3	30.5		31.3	31.5

Site 2	4/24/2007	5/23/2006	6/25/2007	7/11/2007	8/22/2007	9/20/2007	10/17/2007
0	26.8	31	30.5	30.5	31.3	28.4	30.7
3	31.7	31.4	30.5	30.5	31.3	31	30.7
6	31.9	31.4	30.5	30.5	31.3	31.4	31.1
8	31.9			30.5		31.4	31.3

Site 3	4/24/2007	5/23/2006	6/25/2007	7/11/2007	8/22/2007	9/20/2007	10/17/2007
0	31.9	31.5	30.5	30.6	31.4	31.5	31.7
3	31.9	31.5	30.5	30.5	31.4	31.5	31.7
6	31.9	31.5	30.5	30.6	31.3	31.5	31.7
7				30.5	31.3	31.5	31.7

Site 4	4/24/2007	5/23/2006	6/25/2007	7/11/2007	8/22/2007	9/20/2007	10/17/2007
0	31.7	31.6	30.8	30.7	31.4	31.6	31.8
3	31.7	31.6	30.8	30.7	31.5	31.6	31.8
6	31.7	31.6	30.8	30.7	31.5	31.6	31.8
9		31.6	30.8	30.7	31.5	31.7	31.8
12							

Site 5	4/24/2007	5/23/2006	6/25/2007	7/11/2007	8/22/2007	9/20/2007	10/17/2007
0	8.1	5.7	10.2	8.7	12.2	12.3	13.8
2	8.6	6	11	9.9	12.3	13.5	17.7
4	9.1	6.5					17.8

Site 6	4/24/2007	5/23/2006	6/25/2007	7/11/2007	8/22/2007	9/20/2007	10/17/2007
0	8.9	7.9	12.7	11.9	15.9	17.9	18.9
3	8.9	8.4	12.7	12.1	15.9	18.9	19
4	8.9	8.6		12			19

Secchi
ft.

	4/24/2007	5/23/2006	6/25/2007	7/11/2007	8/22/2007	9/20/2007	10/17/2007
Site 1	5	4.5	7	7	6	6.5	5
Site 2	7	6	7	7.5	3.6	6.5	7
Site 3	5	5.5	5.5	8	6	7	6.5
Site 4	6.5	7	7.5	9	8	7.5	8.5
Site 5	3	3	2.5	3	2.4	2	2.5
Site 6	2.5	2.5	2.5	3.5	2	2.3	2

Nitrate NO_3 (ppb)

	4/24/2007	5/23/2006	6/25/2007	7/11/2007	8/22/2007	9/20/2007	10/17/2007
Site 2	BRL	BRL	40	20	10	BRL	20
Site 4	10	BRL	60	10	40	BRL	10
Site 5	10	BRL	40	10	BRL	BRL	BRL
Site 6	BRL	BRL	30	20	20	BRL	20

Kjeldhal Nitrogen TKN (ppb)

	4/24/2007	5/23/2006	6/25/2007	7/11/2007	8/22/2007	9/20/2007	10/17/2007
Site 2	630	980	560	910	490	490	490
Site 4	840	980	630	560	560	560	560
Site 5	180	570	980	1,190	1,050	700	840
Site 6	560	350	840	1,050	1,050	1,050	910

Ammonia NH3 (ppb)

	4/24/2007	5/23/2006	6/25/2007	7/11/2007	8/22/2007	9/20/2007	10/17/2007
Site 2	440	130	110	80	190	50	60
Site 4	380	120	140	100	90	50	40
Site 5	160	90	120	130	230	80	50
Site 6	170	70	110	160	410	60	60

Organic Nitrogen TKN-NH3=ON
(ppb)

	4/24/2007	5/23/2006	6/25/2007	7/11/2007	8/22/2007	9/20/2007	10/17/2007
Site 2	190	850	450	830	300	440	450
Site 4	460	860	490	460	470	510	520
Site 5	20	480	860	1,060	820	620	790
Site 6	390	280	730	890	640	990	850

Total Nitrogen TN
(ppb)

	4/24/2007	5/23/2006	6/25/2007	7/11/2007	8/22/2007	9/20/2007	10/17/2007
Site 2	630	980	600	930	500	490	510
Site 4	850	980	690	570	600	560	570
Site 5	190	570	1,200	1,200	1,050	700	840
Site 6	560	350	870	1,070	1,070	1,050	930

Total Phosphorous TP (ppb)

	4/24/2007	5/23/2006	6/25/2007	7/11/2007	8/22/2007	9/20/2007	10/17/2007
Site 2	36	16	28	BRL	97	77	26
Site 4	33	19	24	BRL	87	61	30
Site 5	63	37	97	60	190	151	101
Site 6	67	31	BRL	27	180	143	112

ND = below detectable limit
BRL = below reportable limit

Appendix B

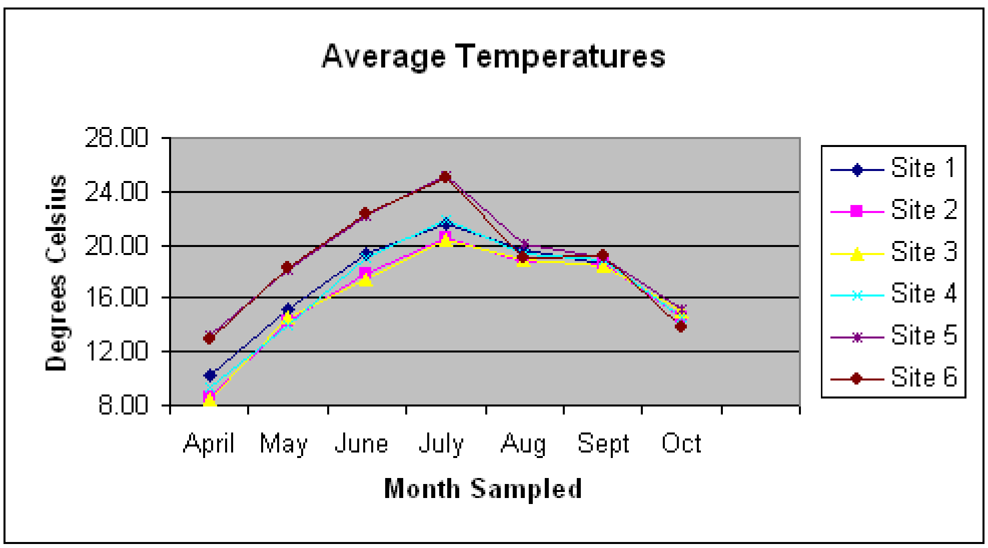
Average Physical and Chemical Parameters

Madaket Harbor / Long Pond 2007

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

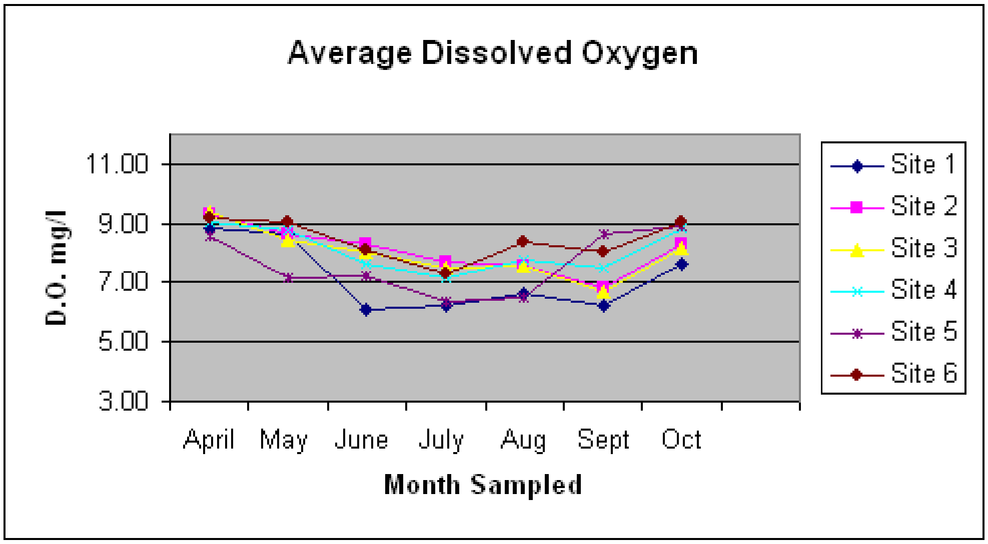
Average Temperatures ºC

	April	May	June	July	Aug	Sept	Oct
Site 1	10.27	15.17	19.30	21.55	19.67	18.53	14.63
Site 2	8.53	14.23	17.93	20.48	18.70	18.55	14.50
Site 3	8.40	14.60	17.47	20.33	18.88	18.50	14.95
Site 4	9.40	13.96	19.10	21.87	19.33	18.97	14.50
Site 5	13.23	18.20	22.25	25.20	20.15	19.10	15.23
Site 6	13.00	18.30	22.35	24.97	19.00	19.25	13.83



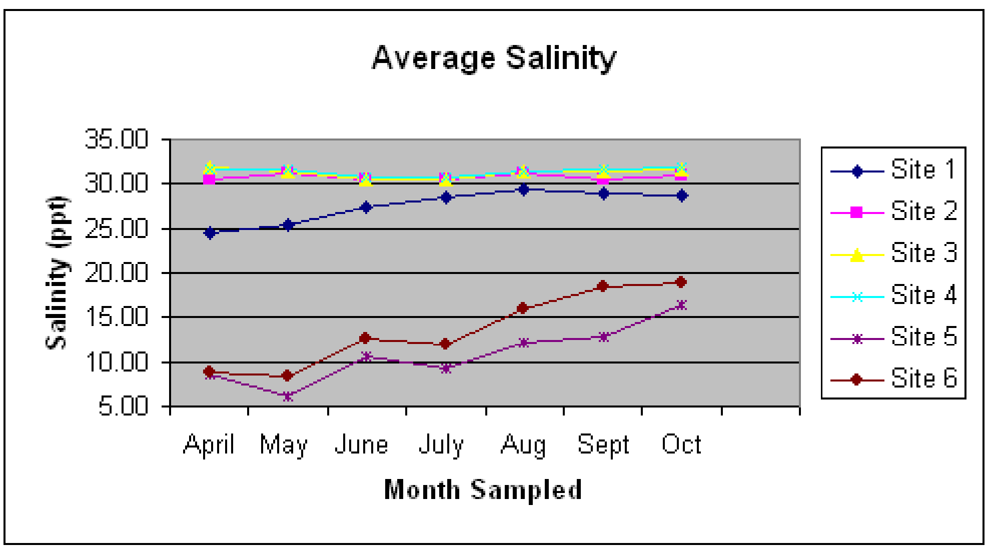
Average Dissolved Oxygen
mg/l

	April	May	June	July	Aug	Sept	Oct
Site 1	8.82	8.67	6.11	6.20	6.61	6.19	7.64
Site 2	9.32	8.63	8.29	7.69	7.56	6.83	8.32
Site 3	9.41	8.43	8.05	7.48	7.57	6.66	8.18
Site 4	9.03	8.78	7.64	7.16	7.79	7.50	8.81
Site 5	8.58	7.14	7.22	6.38	6.49	8.68	8.93
Site 6	9.17	9.07	8.09	7.32	8.36	8.07	9.06



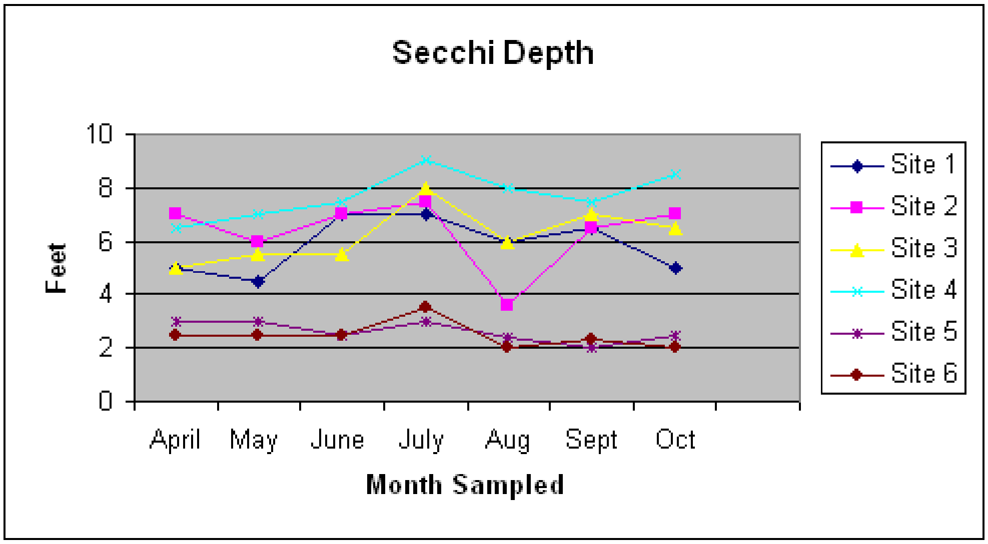
Average Salinity ppt.

	April	May	June	July	Aug	Sept	Oct
Site 1	24.57	25.47	27.50	28.50	29.40	29.00	28.78
Site 2	30.58	31.27	30.50	30.50	31.30	30.55	30.95
Site 3	31.90	31.50	30.50	30.55	31.35	31.50	31.70
Site 4	31.70	31.60	30.80	30.70	31.48	31.63	31.80
Site 5	8.60	6.07	10.60	9.30	12.25	12.90	16.43
Site 6	8.90	8.30	12.70	12.00	15.90	18.40	18.97



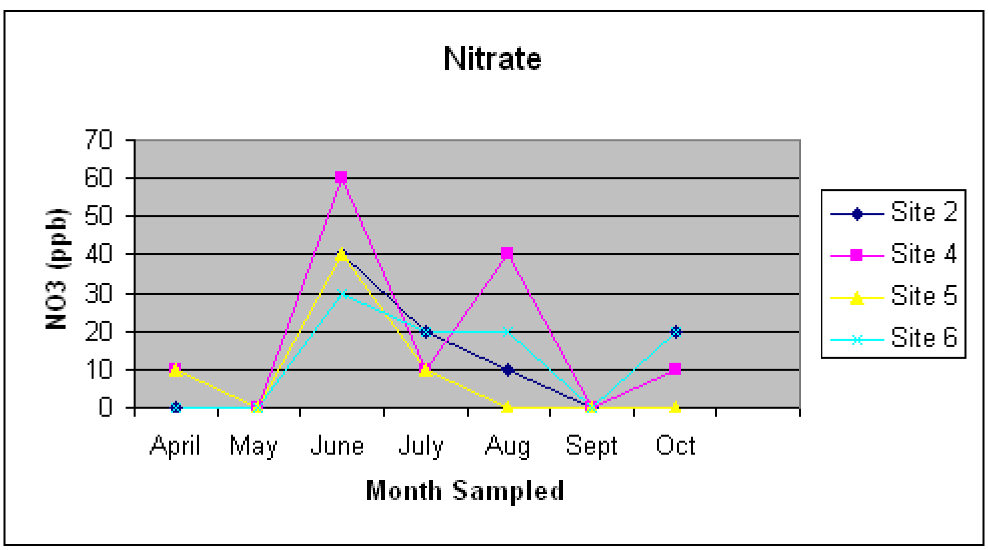
Secchi
ft.

	April	May	June	July	Aug	Sept	Oct
Site 1	5	4.5	7	7	6	6.5	5
Site 2	7	6	7	7.5	3.6	6.5	7
Site 3	5	5.5	5.5	8	6	7	6.5
Site 4	6.5	7	7.5	9	8	7.5	8.5
Site 5	3	3	2.5	3	2.4	2	2.5
Site 6	2.5	2.5	2.5	3.5	2	2.3	2



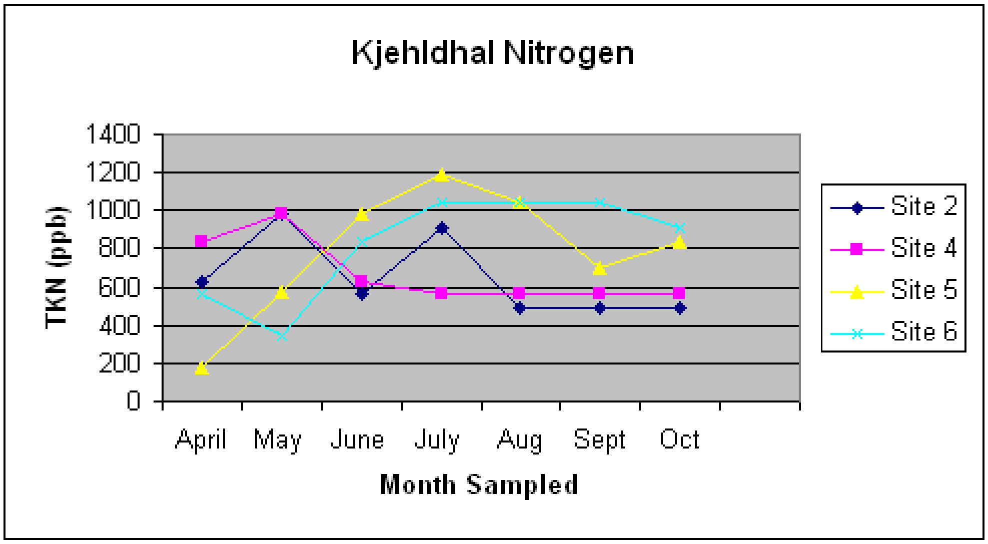
Nitrate NO3 (ppb)

	April	May	June	July	Aug	Sept	Oct
Site 2	BRL	BRL	40	20	10	BRL	20
Site 4	10	BRL	60	10	40	BRL	10
Site 5	10	BRL	40	10	BRL	BRL	BRL
Site 6	BRL	BRL	30	20	20	BRL	20



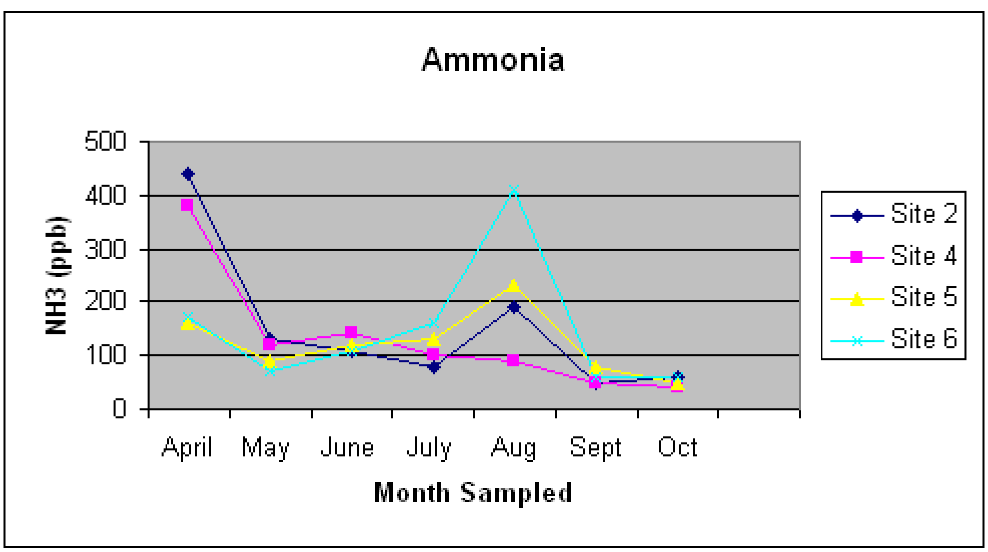
Kjeldhal Nitrogen TKN (ppb)

	April	May	June	July	Aug	Sept	Oct
Site 2	630	980	560	910	490	490	490
Site 4	840	980	630	560	560	560	560
Site 5	180	570	980	1,190	1,050	700	840
Site 6	560	350	840	1,050	1,050	1,050	910



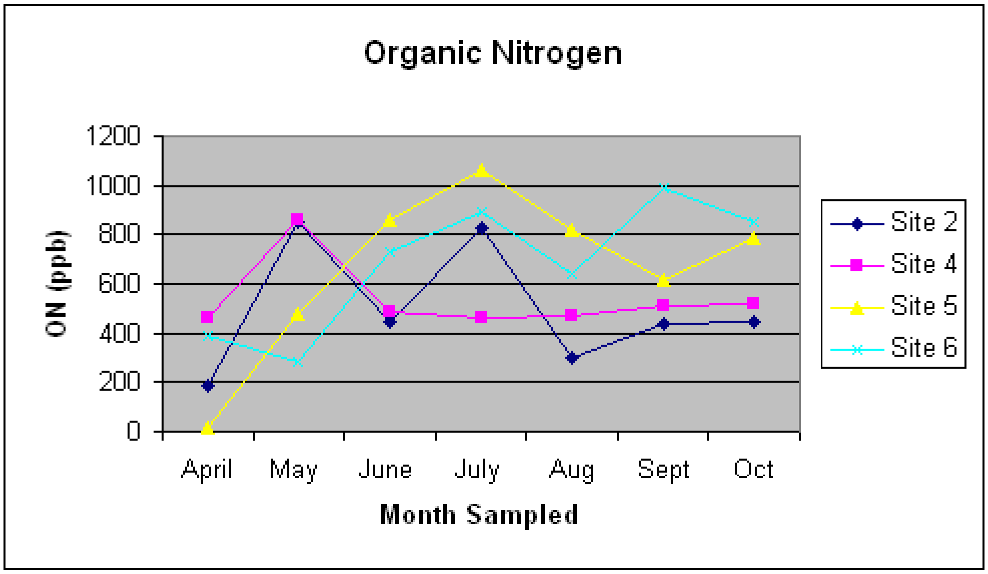
Ammonia NH3 (ppb)

	April	May	June	July	Aug	Sept	Oct
Site 2	440	130	110	80	190	50	60
Site 4	380	120	140	100	90	50	40
Site 5	160	90	120	130	230	80	50
Site 6	170	70	110	160	410	60	60



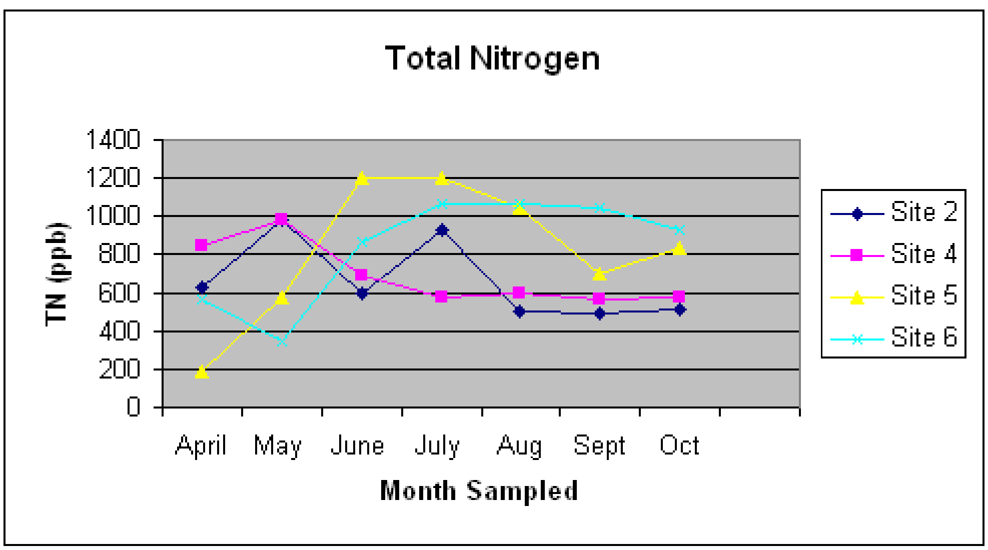
Organic Nitrogen TKN-NH3=ON (ppb)

	April	May	June	July	Aug	Sept	Oct
Site 2	190	850	450	830	300	440	450
Site 4	460	860	490	460	470	510	520
Site 5	20	480	860	1,060	820	620	790
Site 6	390	280	730	890	640	990	850



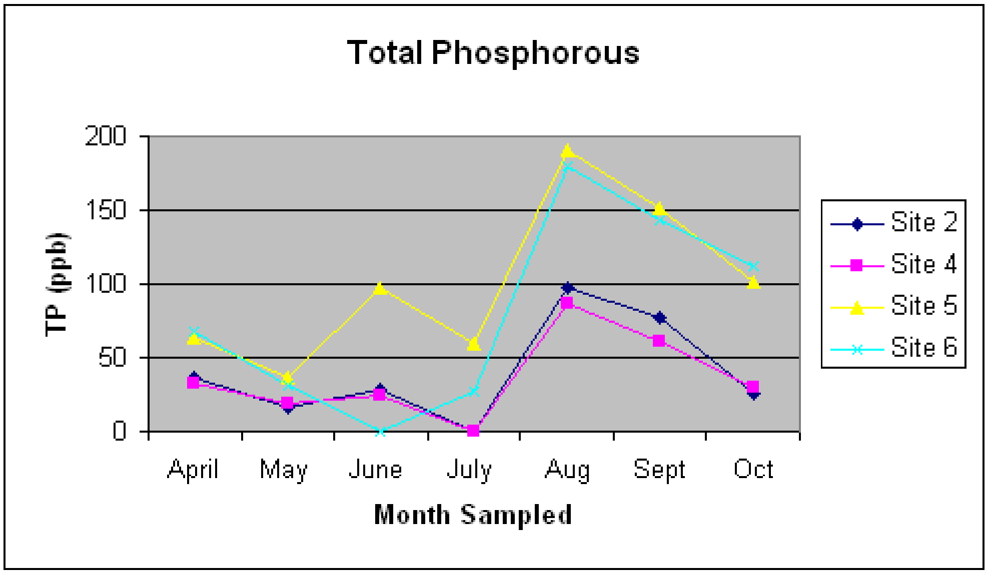
Total Nitrogen TN (ppb)

	April	May	June	July	Aug	Sept	Oct
Site 2	630	980	600	930	500	490	510
Site 4	850	980	690	570	600	560	570
Site 5	190	570	1,200	1,200	1,050	700	840
Site 6	560	350	870	1,070	1,070	1,050	930



Total Phosphorous TP (ppb)

	April	May	June	July	Aug	Sept	Oct
Site 2	36	16	28	BRL	97	77	26
Site 4	33	19	24	BRL	87	61	30
Site 5	63	37	97	60	190	151	101
Site 6	67	31	BRL	27	180	143	112

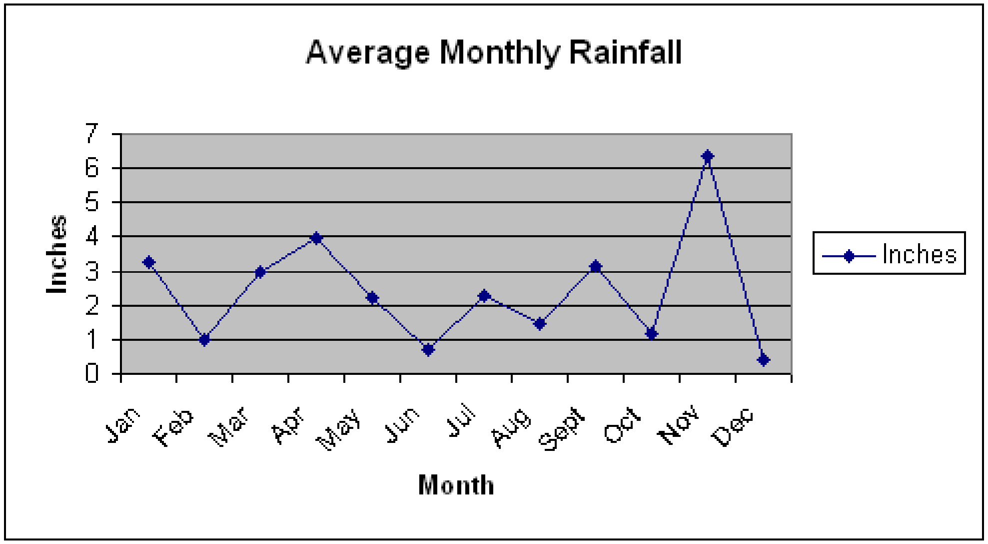


ND = below detectable limit
BRL = below reportable limit

Appendix C

Average Monthly Rainfall
2007

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Inches	3.27	0.97	2.98	3.95	2.23	0.7	2.29	1.45	3.13	1.16	6.36	0.4



Total Rainfall: 28.89 "

December Rainfall Incomplete
Rainfall Data Collected by Wannacomet Water Company