III. CHAPTER 2

Nitrate leaching of turfgrass sites with different types of fertilizer and variable site properties

i. Introduction

Turfgrass covers 25% of the land in Suffolk County, Long Island, New York (Koppelman et al., 1984). Turfgrass is used in landscaping of golf courses, school playing fields, parks and a large majority of residential yards and business complexes. The sandy soils of Long Island do not naturally support healthy turfgrass systems. The quartz dominated soils of Long Island provide low abundance of the major nutrients needed for plant growth, such as calcium, potassium, nitrogen and phosphate. With the onset of acid rain since the 1950's (pH≈4.3) Ca and K ions have been displaced by H^+ and Al^{3+} (Boguslavsky, 2000). Turfgrass growing on Long Island suffers from low pH and lack of nutrients. In order to maintain healthy, green turfgrass systems nutrients must be added in the form of fertilizers, primarily nitrogen, phosphorus and potassium. To compensate for the low concentrations of Ca and Mg in these acidic soils lime must also be applied to maintain a proper soil pH and provide Ca and Mg. Most grasses grown on Long Island originated in northern Europe (Stewart, 1999) where there is about as much precipitation in the summers as Long Island, but summers are usually much cooler. In Suffolk County a high proportion of home owners irrigate during the summer to maintain green lawns. The Suffolk County Water Authority, the sole provider of potable water to Suffolk County, estimates 30% of the water served to their customers is used for irrigating lawns (Written communication, Michael Stevenson, Suffolk County Water Authority, 2003).

Nitrogen applied as fertilizer may be: utilized and stored in the plant; stored as organic nitrogen in the soil; volatilized as ammonia, nitrogen gas or nitrous oxide; lost in runoff; or leached to the groundwater as nitrate. The amount of nitrogen partitioned between these pools is influenced by properties such as the form of nitrogen, availably rate of nitrogen during the growing season, applied fertilizer rate, removing or not removing grass clippings, soil texture, soil moisture, soil temperature, season, turfgrass type and turfgrass age (Petrovic, 1990). On Long Island volatilization, or denitrification, and runoff are small pools of the nitrogen applied to fertilizers compared to leaching. In his review Petrovic (1990) reported denitrification to be significant on fine-textured, saturated, warm soils. These are not the type of soils found on Long Island. As a result it is not surprising that oxygen and nitrogen isotope data of groundwater from the Northport area (Bleifuss et al., 2000) and other locations in Long Island (Leamond et al., 1992; Stackelberg, 1995) suggest that denitrification is not an important process in the aquifer supplying water to Suffolk County. Petrovic (1990) reports results of previous studies that suggest that turfgrass ecosystems result in soils with high infiltration and little run off. Runoff can be significant during establishment of the turfgrass but infiltration increases as turfgrass shoot density increases (Easton and Petrovic, 2004). A mass balance study, Easton and Petrovic (2004) reported nitrogen loss as elevated in the leachate compared with run off when water soluble N sources are used. Thus on Long Island, in turfgrass systems, nitrogen is stored in the turf and soil or leaches below the root zone to the water table.

Studies have shown that increases in $N\text{-}NO_3$ leaching is a function of (1) soil texture (2) application rate of fertilizer (3) infiltration (4) turfgrass age and (5) the seasons (Bergstrom and Johansson, 1991; Easton and Petrovic, 2004; Engelsjord and Singh, 1997; Geron et al., 1993; Hummel and Waddington, 1984; Petrovic, 1990; Roy et al., 2000; Schuchman, 2001; Shaddox and Sartain, 2001; Starr and Deroo, 1981; Wong et al., 1998). Quantifying and understanding nitrate leaching is essential to keep concentrations in groundwater below the Environmental Protection Agency drinking water standard of 10 ppm nitrogen as nitrate. Locally golf courses in the Peconic Estuary have agreed to meet a 2 ppm of total N in groundwater to minimize the impact to the estuary (EPA, 2004).

The objective of this study was to determine the difference in concentration of nitrate in soil water below the root zone (about 1m) for plots treated with (1) traditional chemical fertilizers and (2) natural organic fertilizers. Most studies of turfgrass systems have similar plots and change only one variable to determine a specific effect on nitrate leaching. While it is difficult to compare different fertilizer treatment on different sites the goal of this study was to understand the current turfgrass environment on Long Island which included sites of variable characteristics. Besides this complication noticeable patters were recognized within the sites. Infiltration rate, turfgrass age, thatch thickness, grain size, porosity and soil natural organic matter was determined for eight sites receiving natural organic fertilizer, traditional chemical fertilizer or no fertilizer. A leaching index was calculated as infiltration rate over thatch thickness to better compare the sites.

Soil water samples were collected from lysimeters and analyzed for $N\text{-}NO_3$. Comparisons were made between (1) the two plots treated with traditional chemical fertilizer, (2) two plots at the same location: one treated with traditional chemical fertilizer and the other with natural organic fertilizer and (3) plots treated with natural organic fertilizer of similar turfgrass age. All sites were compared to the plot receiving no treatment and to average monthly precipitation data for the first year of this study.

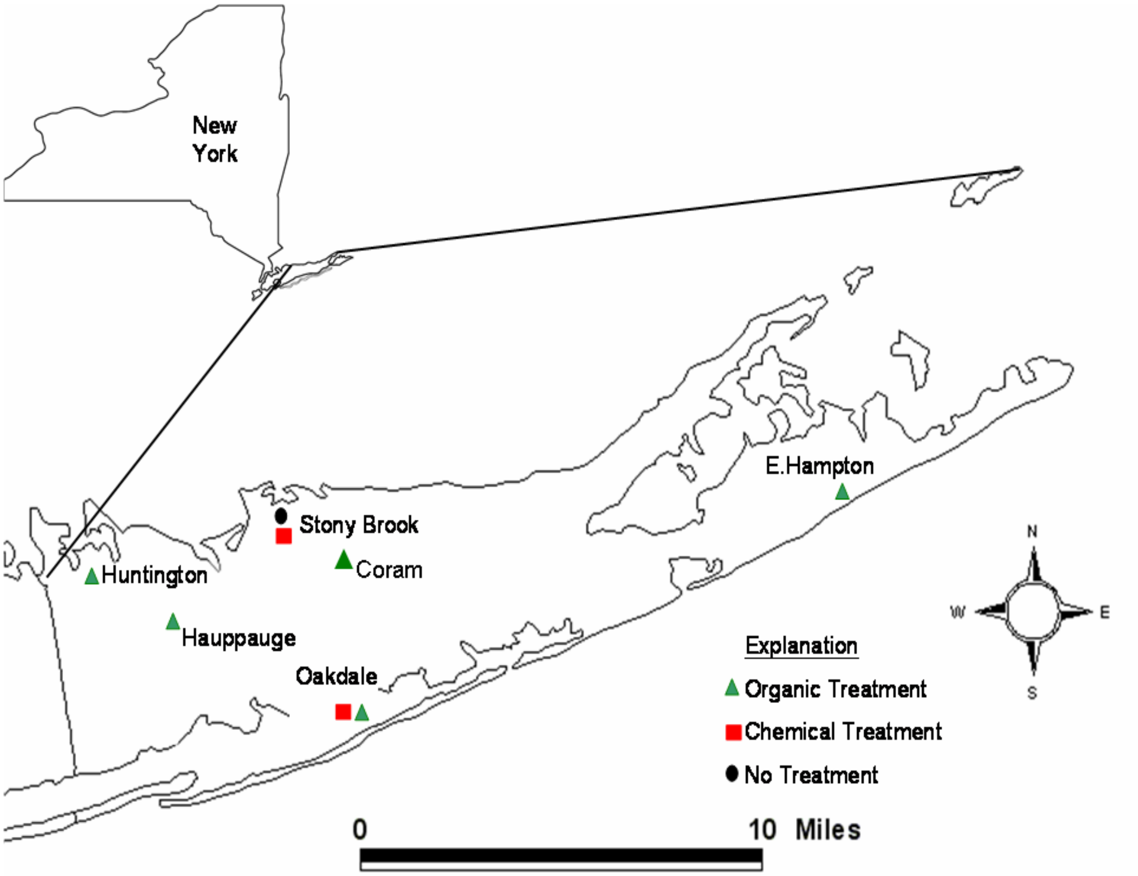

Figure 12 Locations of turfgrass sites in Suffolk County, Long Island, New York.

ii. Methods

To evaluate the long term effects of various lawn maintenance procedures lysimeters (soil water samplers) have been installed in maintained lawns at eight locations (see Figure 12) to depths up to 150cm, on Suffolk County Water Authority property and on the Stony Brook University campus. Two of these locations are undergoing traditional chemical turfgrass treatment, five are undergoing natural organic treatment and one site receives no treatment. Traditional chemical sites are treated by either Scotts® brand fertilizers or LESCO® Brand. Treatment of Scotts® brand fertilizers utilizes a company promoted 5-bag program (www.scotts.com) and began in 2000 by Schuchman (2001) on new sod. The other sites are on more established lawns. Treatment using LESCO® Brand fertilizers commenced in 2003 with a granular grade fertilizer and is applied according to the recommendations of LESCO, Inc. service center in Port Jefferson Station, NY. Urea is a slow release fertilizer. The LESCO brand, on average, has a higher percentage of urea nitrogen than does the Scotts brand. Natural organic treatment started in spring of 2002, and is maintained by a natural organic landscaper, Eco-Logical Organic Landscape, utilizing athletic turf mix, compost, lime

Table 8 Fertilizers

[1] Scott's Brand Fertilizers [2] Lesco Brand Fertilizers. Nutrient data reported in %

Site	Treatment	Application times	N applied (kg-N ha^{-1})	Fertilizer Type	N-P-K	S	Ammoniacal nitrogen	Urea nitrogen	Other water soluble nitrogen
Oakdale	Chemical[1]	May-03	75	Scotts Turf Builder with Halts	30-3-4	8.50	6.30	13.00	9.80
		Jun-03	70	Scotts Turf Builder w/weed control	28-3-3	11.00	9.00	10.40	7.90
		Jul-03	70	Scotts Turf Builder w/insect control	28-3-8	8.80	0.60	27.40	
		Sep-03	70	Scotts Turf Builder	29-3-4	7.00	5.30	13.10	9.70
		Oct-03	55	Scotts Winterizer	22-3-14	10.00	5.70	8.90	6.80
Stony Brook	Chemical[2]	Mar-03	50	Lesco brand Pre-M	19-3-7	2.90	1.15	17.85	
		May-03	50	Lesco brand Pre-M	19-3-7	2.90	1.15	17.85	
		Jul-03	35	Lesco brand Pre-M	19-3-7	2.90	1.15	17.85	
		Oct-03	50	Lesco brand Pre-M	19-3-7	2.90	1.15	17.85	
All others	Organic	May-03	0	Compost					
		May-03	28	Pro-Grow	5-3-4	present			1.5
		Jul-03	0	Compost					
		Aug-03	0	Compost					
		Sep-03	0	Compost					
		Oct-03	28	Healthy Turf	8-1-9	present			1.5

and a granular fertilizer of either Pro-Grow manufactured by North County Natural organic s or Healthy Turf by Plant Health Care. Through the summer compost is used as needed and not spread evenly throughout the lawns. The total nitrogen concentrations of the compost are generally less than 1% (Oral communication, Chris Rerrare, Eco-Logical Organic Landscape, July 2004). Lime is applied in spring or summer in amounts depending on the soil pH. Pro-Grow is added at a rate of 17kg N/ha and Healthy Turf is added as 28kg N/ha. Application rate varies for the chemical sites and is reported in the plots. Fertilizer regimes are representative of typical applications on Long Island (Table 8).

Lysimeters were installed at the Stony Brook University and the Oakdale chemical site by Schuchman (2001). All other sites were established in the fall or winter of 2002. Details of lysimeter installation are described by Schuchman (2001). A 15-cm diameter hole was dug to 5cm below the desired depth using a hand auger and a post-hole digger. A larger 12-cm hole was then dug around the borehole to a depth of 20-cm. This hole was sized to fit the plastic sprinkler box, which covers and encloses the unit beneath grade. Silica sand or <2mm local sandy soil was used as a filter media to surround the lysimeter suction cup, a depth of approx. 20cm. Local <2mm soil, was then backfilled and compacted until approx. 20cm before the surface where a 5cm layer of bentonite was used to inhibit water flow directly down the disturbed hole. Native soil was then filled to the surface.

Soil water samples from lysimeters were acquired monthly, filtered in the field, stored in acid-rinsed polypropylene bottles and frozen until analyzed. Nitrogen-nitrate concentrations were measured at the Marine Sciences Research Center, SUNY Stony

Brook on a Lachat's QuickChem8500 Flow Injection Analysis System using Method 10-107-04-1-J which measures concentrations between 0.1 and 10 ppm nitrogen as nitrate. Samples with concentrations above 10 ppm where diluted and re run. In this method nitrate is quantitatively reduced to nitrite by passage of the sample through a column containing copper coated cadmium. The nitrate (reduced nitrate plus original nitrite) is determined by diazotizing with sulfanilamide dihydrochloride followed by coupling with N-(1-naphthyl) ethylenediamine dihydrochloride. The resulting water soluble dye has a magenta color which is read at 520 nm. Our analysis had an accuracy of 5%. See Appendix 1 for these results.

Bulk density samples were extracted vertically using a core 5.0 cm in diameter. The most consistent and accurate bulk density estimates for soils were made from cores obtained with an AMS soil core sampler from Forestry Suppliers (Jackson, MS) in which internal rings can be disassembled to obtain intact samples. Samples were then air-dried to a constant weight. After air-drying, samples were oven-dried for 48 hours at 60°C. Bulk density is calculated as the oven dry soil weight divided by the sample volume. Porosity is calculated as

$$(1-\frac{\rho_b}{\rho_s})\times 100 = \% \qquad \text{eq. 1}$$

Where ρ_b is the bulk density of the sample and ρ_s is the density of the grains which are dominantly quartz and minor feldspar, 2.65g cm^{-3}. Volumetric water content is calculated as the mass of water loss in the soil sample from field weight to oven dried divided by the oven dried soil mass multiplied by the bulk density and water density (0.988g/cm^3) and reported as a fraction. Bulk density, porosity and volumetric water content for all samples are reported in Appendix 2.

The bulk density samples were used for particle size analysis. Refer to Appendix 3 for all particle size data and Figure 14 for soil texture classifications. At least 20g of <2mm grain-size was needed for analysis. Grain size distribution was determined on a sonic sifter separator for the >50µm (sand) fraction and a Sedigraph on the <50µm (clay and silt) fraction. Classification of size fractions are according to the United States Department of Agriculture. Preparation of samples included removing the gravel portion (>2mm) by dry sieving and removing organic material by adding H_2O_2 and heating for no more than 1 hour on a hot plate to evaporate the H_2O_2. Samples were deflocculated by adding a 5% Calgon solution and placed in an ultrasonic bath for five minutes. Separation of the coarse and fine fractions was accomplished by wet sieving.

Dry sieving was done using an ATM Model L3P Sonic Sifter Separator with specially designed 3" (75mm) diameter acrylic-framed sieves and a patented oscillating air column for five minutes. The weight percentage of the sediment retained in each sieve is then determined. Grain size distribution of silt and clay was determined with a Sedigraph. Appling Stokes Law and using an X-Ray beam, the Sedigraph monitors the rate at which particles settle and are removed from the monitored volume. Results yielded were in table form presenting mass % finer vs. grain size. The mass % finer is applied directly to the amount of clay and silt fraction of the sample.

Infiltration rates were determined from a single infiltrometer method (Bouwer, 1986). In this method a 12” diameter thin walled (1/8” thick), 12” long steel cylinder was pressed 3” into the soil. The cylinder was then filled with water. The time and water level was recorded incrementally until steady state was reached. Infiltration measurements were determined at each site once. Repeated measurements were taken at the Stony Brook and Huntington sites to see how infiltration varied over time. Measurements at Stony Brook ranged between 30% and at Huntington the reproducibility was 70%. Although site variability was great the data show relative differences between the sites i.e. high vs. low infiltration rates. Since this study was only interested in the relative difference in infiltration modeling was not performed. Infiltration rates are reported in Table 9.

Thatch thickness was measured at three sides of an undisturbed soil core for three samples at each site. Thatch is a tightly intermingled layer of dead and living stems and roots that develop between the growing turf plants and the soil surface. The average of these nine measurements is reported in Table 9. Soil organic matter (SOM) was determined based on a combustion method (Faithfull, 2002), for the top 15 cm of each profile, reported as SOM/g of soil in Table 9. In this method 20 grams of soil is oven dried at 105^{o}C for 24 hours and weighed then combusted in a furnace at 400^{o}C for 24 hours and weighed. At 400^{o}C the soil organic matter is pyrolyzed without significantly affecting the clay mineral water content. Therefore the difference in weight between the oven-dried soil and the combusted soil is the soil organic matter weight. Turfgrass age was determined from the date Suffolk County Water Authority purchased their buildings but could in fact be older, except for Stony Brook and Oakdale natural organic where exact ages were known. Approximate ages are reported in Table 9.

Precipitation values reported in the plots are monthly totals reported by CLIMOD (CLImate statistics by a dynamical MODel) (Figure 15) which is in central Long Island. All sites except Stony Brook are watered with an automatic sprinkler system. Stony Brook only receives water in conjunction with fertilizer treatment as the recommendations for applying fertilizer is to "water it in." The other sites are watered twice per week providing infiltration of 1.5-2" per week in accordance with the recommendations on the Suffolk County Water Authority web site (www.scwa.com, Oral communication, Micheal DeBlasi, SCWA, August, 2004).

iii. Results

Site properties including depth to groundwater, soil type based on the Soil Survey of Suffolk County (Warner, 1975), treatment type, if sprinklers are present, infiltration rate, age of turfgrass, thatch thickness and soil natural organic matter (SOM) are reported in Table 9.

Table 9 Summary of site properties. [1] Scott's Brand Fertilizers [2] Lesco Brand Fertilizers.

Site	Ground water Depth	Soil Survey Classification	Treatment Type (sprinklers)	Infiltration Rate	Turfgrass Age	Thatch thickness	Soil Organic Matter in Upper 15cm
	(m)			(cm/min)	(yrs)	(cm)	(SOM/g soil)
Coram	18	Carver and Plymouth sands	Organic (yes)	0.30	8	1.42	0.0355
E. Hampton	2	Bridgehampton silt loam	Organic (yes)	0.10	22	1.33	0.0799
Hauppauge	11	Haven loam	Organic (yes)	0.55	23	0.62	0.0561
Huntington	9	Riverhead and Haven soils	Organic (yes)	1.55	10	0.83	0.0696
Oakdale	2	Cut and fill land	Organic (yes)	1.05	6	0.17	0.0245
Oakdale	2	Cut and fill land	Chemical[1] (yes)	0.40	47	0.42	0.0594
Stony Brook	14	Riverhead and Haven soils	Chemical[2] (no)	0.20	4	0.17	0.0341

Depth to groundwater is greatest at Coram and least at E. Hampton and Oakdale. Due to capillary pressure a shallow groundwater table may draw down soil water at a faster rate than other sites (Tindall et al., 1999). High nitrate concentrations in soil water collected below the root zone for sites with a shallow water table are of greater concern than sites with a deeper water table due to less time for dilution and dispersion of the contaminant before reaching the water supply. Soil survey classifications were mapped by Warner (1975) although the sites may have been altered since then due to development. Most sites are classified as a sandy soil except for East Hampton and Hauppauge which are loam in texture. Infiltration rate is the fastest at Huntington and Oakdale natural organic and the slowest at East Hampton. Timing of fertilizer application is reported in Table 8. Coram and East Hampton have the thickest thatch layers and Stony Brook and Oakdale organic have the thinnest. The Oakdale chemical site is the oldest turfgrass site while Stony Brook is the youngest. The Stony Brook control is not listed in this table because all properties are the same as the chemical plot, except age of turfgrass.

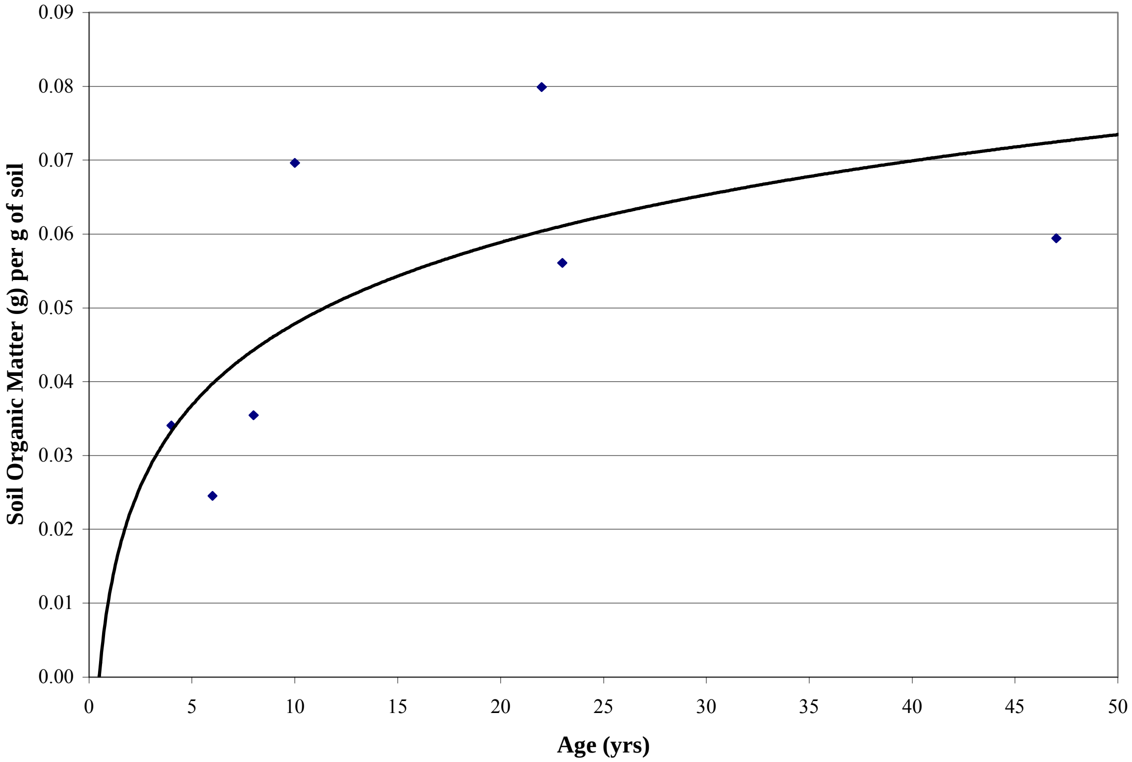

Figure 13 Soil organic matter vs. turfgrass age

The Stony Brook control is over 40 years old. East Hampton has the most soil natural organic matter per gram of soil in the upper 15cm of the soil profile and Oakdale organic has the least. Soil organic matter increases as a function of age (Figure 13), as soil organic matter increases more of the nitrogen applied to the turf will be stored in the organic matter (Petrovic, 1990). Once a new equilibrium is established the soil is no longer able to store any of the applied nitrogen.

Soil texture classification for all sites is plotted on a ternary diagram in Figure 14. Classifications are according to the U.S. Department of Agriculture. Most of the sites are sandy although East Hampton and Hauppauge show increased proportions of clay and silt. Sandy soils generally have a rapid infiltration rate and are more prone to leaching than fine textured soils, although this varies as a function of organic matter content and percent clay (Bergstrom and Johansson, 1991).

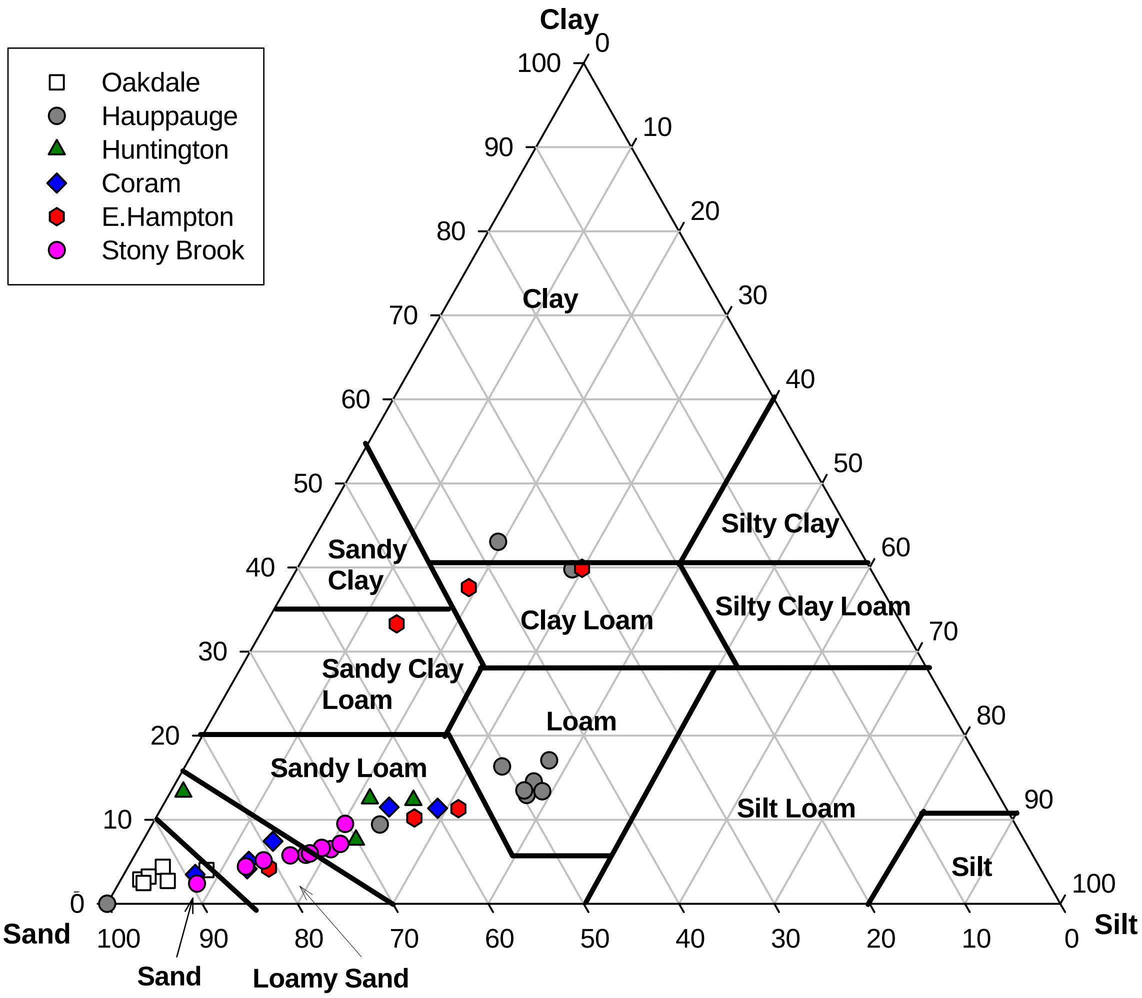

Figure 14 Soil Texture Classification
Ternary diagram classifying grain size distribution for all sites at multiple depths. Texture according to the U.S. Department of Agriculture

Nitrate concentrations in soil water collected below turfgrass sites in this study are influenced by turfgrass age (which is a function of soil organic matter), thatch thickness and infiltration rate. Increased infiltration rates increase movement of water through the soil profile and thus can increase nitrate leaching since nitrate moves at the same rate as soil water. Dry thatch may limit infiltration due to difficulty in wetting (Turgeon, 2001).

In this case more thatch could decrease nitrate leaching. Thatch has also been shown to be well-aerated with poor nutrient and water-holding properties (Turgeon, 2001). Higher concentrations of nitrate in soil water collected in this study generally correspond with a thin thatch layer. Soil organic matter increases with increasing turfgrass age, as soil organic matter increases more of the nitrogen applied to the turf will be stored in the organic matter (Petrovic, 1990). In this case older sites, with increased soil organic matter, will increase nitrate leaching.

Since this study evaluates sites with variable site conditions different leaching indices were calculated in order to better compare the sites. In this way one could compare one single value rather than evaluate all the site conditions to evaluate nitrate leaching between sites. A leaching index was calculated 1) as infiltration rate multiplied by soil organic matter and 2) as infiltration rate over thatch thickness. A larger value indicates a greater chance for nitrate leaching. These leaching indices are not meant to suggest nitrate absorbance, as with pesticide leaching indices, but only to be uses for better site comparison.

Table 10 Leaching Indices

Site	Treatment Type	Infiltration Rate multiplied by Soil Organic Matter (x10^{-2})	Infiltration rate over thatch thickness
Huntington	Organic	10.8	1.9
Hauppauge	Organic	3.1	0.9
Oakdale	Organic	2.6	6.2
Oakdale	Chemical[1]	2.4	1.0
Coram	Organic	1.1	0.2
E. Hampton	Organic	0.8	0.1
Stony Brook	Chemical[2]	0.7	1.2

The sites are examined in detail in Figures 15 to 20. First I will compare all eight sites as a general overview. Figure 15 is a plot of precipitation and nitrate concentration in soil water at all eight sites from January 2003 to December 2003. The black line is the Stony Brook control site where no fertilizer was applied and is shown on Figures 15, 17-

20 as reference. The control site, established in the late sixties, is probably leaching decayed organic matter in high concentrations due to the higher amount of rain than

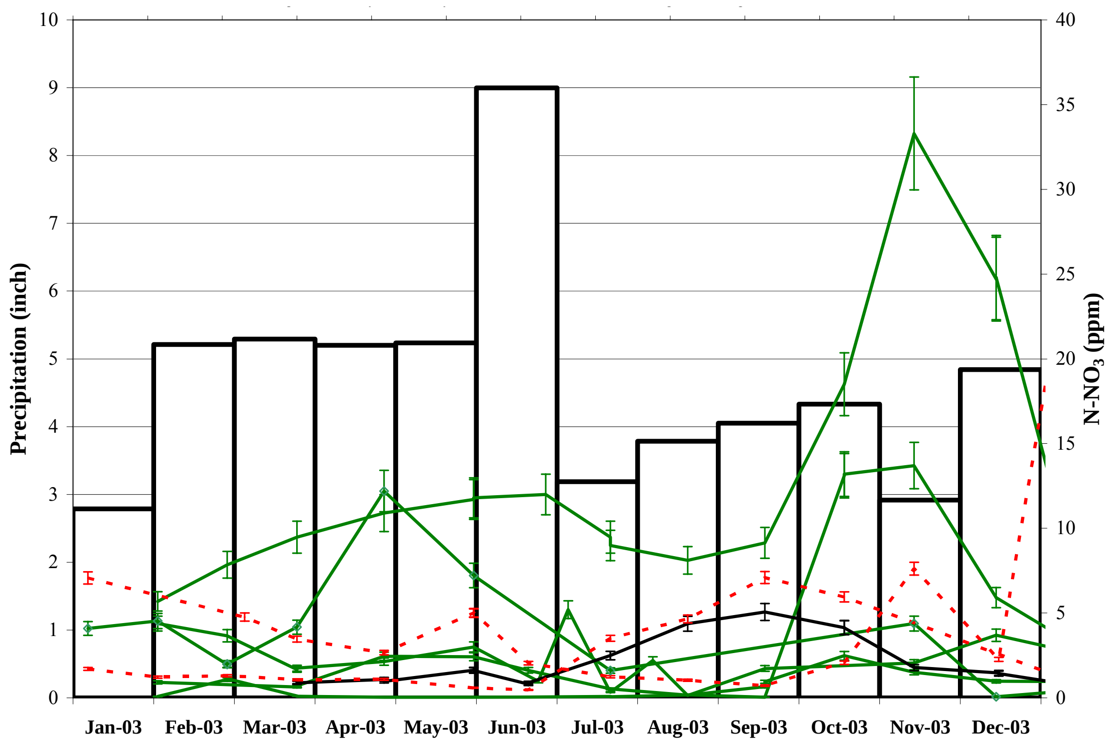

Figure 15 All Turfgrass Sites. *Green lines represent soil water influenced by natural organic fertilizer, red lines represent soil water influenced by chemical fertilizer, the black line represents soil water influenced by no fertilizer. Bars are monthly precipitation totals.*

average in the summer (Maeda et al., 2003). Sites with concentrations below the control site are younger sites that are efficiently using the nitrogen applied as fertilizer by storage in the turf or soil. The green lines represent all five natural organic fertilized sites and the red lines are the two traditional chemical fertilized sites.

Generally nitrate concentrations in soil waters were highest below the natural organic fertilized turfgrass sites, specifically Huntington, East Hampton and Hauppauge. The greatest concentrations of nitrogen-nitrate found in soil waters are during the fall months. This effect can be attributed to a reduction in plant uptake, high levels of mineralization of soil organic nitrogen due to warm, moist soil conditions and reduction in evapotranspiration from summer to autumn seasons (Roy et al., 2000). Other researchers note that soil water collected in summer months should have little to no nitrate since plant uptake and evapotranspiration are high. Concentrations in some samples are significant in the summer months of 2003. This is probably due to the abnormally high precipitation received this year. Refer to Figure 16 to compare monthly precipitation totals in 2003 with an average from 1971-2000 (Northeast Regional Climate Center: CLIMOD (CLImate statistics by a dynamical MODel) http://climod.nrcc.cornell.edu/). February through June have high monthly totals compared to the average. Precipitation totals vary geographically in Suffolk County as shown in Figure 16a. The average of all stations is used to understand precipitation affect on nitrate leaching but in fact monthly precipitation totals can vary as much as 6cm from site to site.

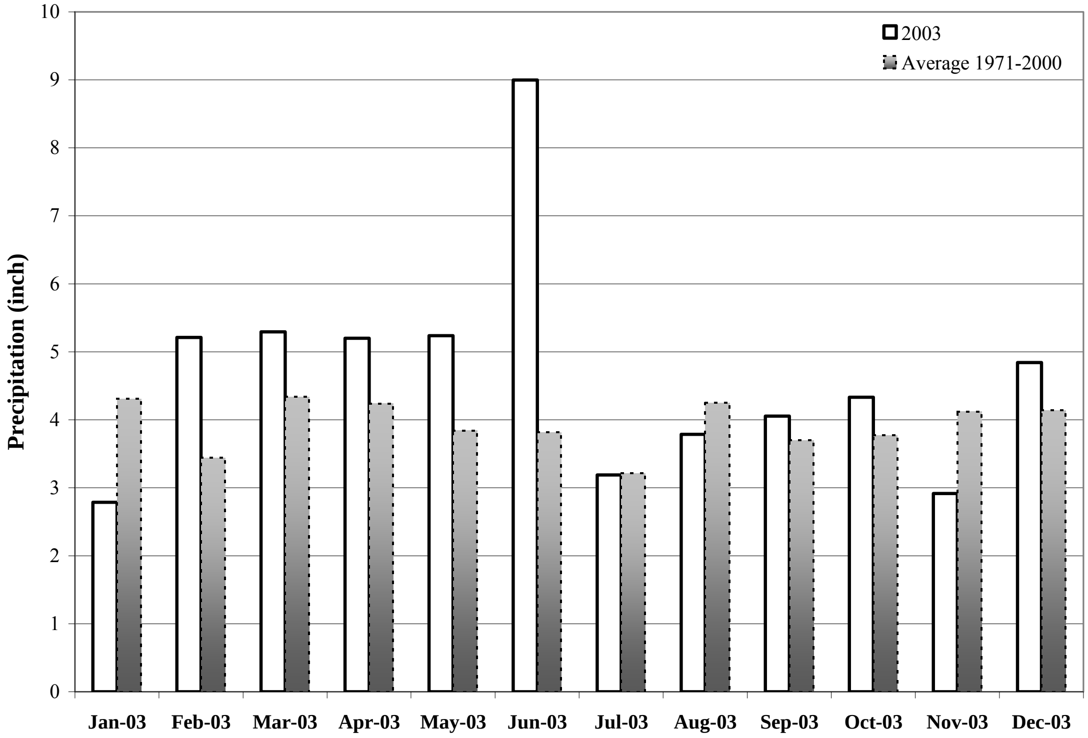

Figure 16 Monthly Precipitation Totals.

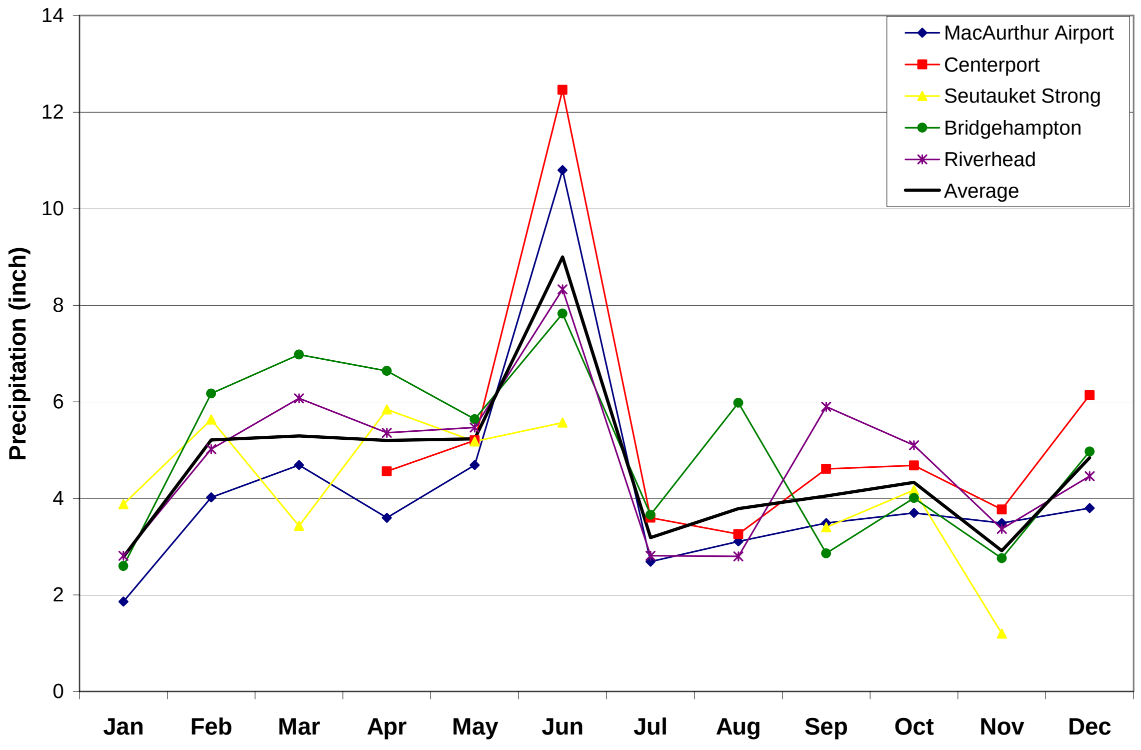

Figure 16a. *Monthly precipitation totals for 2003 (http://climod.nrcc.cornell.edu/)*

Figure 17 compares the two sites at Oakdale, one treated with natural organic fertilizer (green line) and the other with traditional chemical fertilizer (red line). The bars indicate total monthly precipitation in inches. The red arrows indicate timing of traditional chemical fertilizer application, the green arrows indicate time of natural organic fertilizer application and the values are kg of N/acre. The green arrows without kg of N/acre are when compost was applied. Compost is not applied evenly, but the nitrogen content of the compost is less than 1%. The natural organic site was treated with fertilizer only twice during the year, once in spring and once in the fall. The traditional chemical site however was treated 5 times throughout the year at higher application rates than the natural organic site.

The natural organic site was established 6 years ago, has a high infiltration rate, a thin thatch layer, low soil organic matter and a higher leaching index than the traditional chemical site. The traditional chemical plot is the oldest of the eight sites, 47 years, has higher soil organic matter, a slower infiltration rate and a thicker thatch layer. From the site properties it would be predicted that the natural organic site should leach more nitrate. In fact this is seen from January 03' until July 03' at which point the traditional chemical site increases in nitrogen-nitrate leaching and the natural organic site decreases.

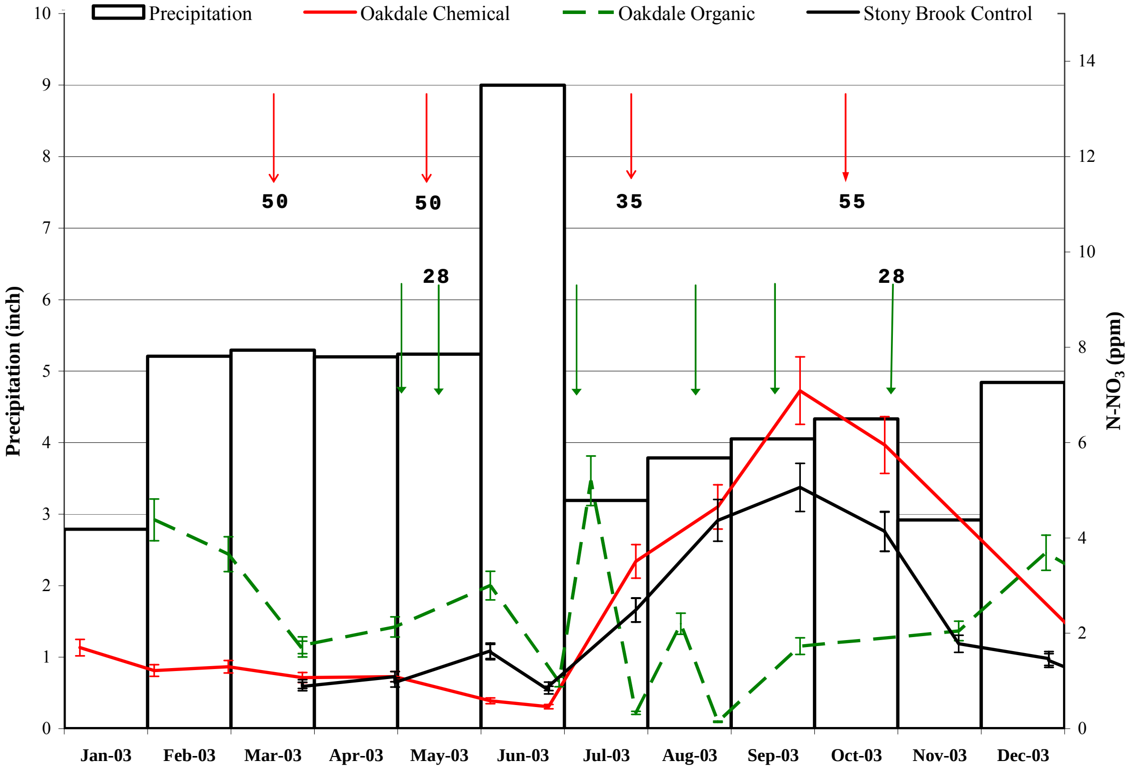

Figure 17 Oakdale turfgrass sites. *The red arrows are time of chemical fertilizer application, the green arrows are time of natural organic fertilizer application and the values are kgN/acre. Green arrows with no values are when compost was applied.*

This increase at the traditional chemical site is most likely due to the higher application of nitrogen, increased autumn mineralization of organic nitrogen and the age of turfgrass system. As described by Petrovic (1990) older lawn sites on Long Island have reached equilibrium in regards to total nitrogen stored in the top 10 cm of soil. This is due to older sites having more soil organic matter and thus need less nitrogen. In the autumn when mineralization increases these older sites have more available nitrogen for mineralization to nitrate which will ultimately leach due to a reduction of plant uptake during the autumn and increased precipitation. Younger sites will store nitrogen. The concentrations in the leachate may not have been as high at the traditional chemical site if the fertilizer application rates or frequency were less. The younger site, treated with natural organic fertilizer, received less fertilizer and that not used by the turf is probably stored in the upper 10cm of the soil organic matter.

The leached nitrate in soil water at the control site at Stony Brook, which is not fertilized, also increases in July through September. The control site, established in the late sixties, is probably leaching decayed organic matter in high concentrations due to the abnormal amount of rain in June (Maeda et al., 2003), age of turfgrass and increased mineralization rates. In winter concentrations below the natural organic site start to increase while the chemical site and control are decreasing. This may be due to the properties of the natural organic site (leaching indices) which lead to increased leaching.

The two traditional chemical maintained sites are compared in Figure 18. Stony Brook (red line) was fertilized with LESCO brand fertilizer which was applied in March, May, July and October. The Oakdale site (blue line) was fertilized using a Scott's Brand 5 bag program. The Oakdale site received a larger total amount of nitrogen applied for the year. The red arrows are time of fertilizer application at the Stony Brook site, the blue arrows are time of fertilizer application at the Oakdale site and the values are kg of N/acre. The bars are monthly total precipitation. From January 03' until July 03' the Stony Brook site has higher concentrations of nitrogen-nitrate in the leachate, which is accurately predicted by the leaching index using infiltration rate and soil organic matter. The higher concentrations in the beginning of the year for Stony Brook could be due to a high infiltration rate and thin thatch layer or a carryover from the previous year's application. Due to the age difference i.e difference in soil organic matter, Oakdale 47 years and Stony Brook 4 years, the Oakdale sites increases in nitrogen-nitrate

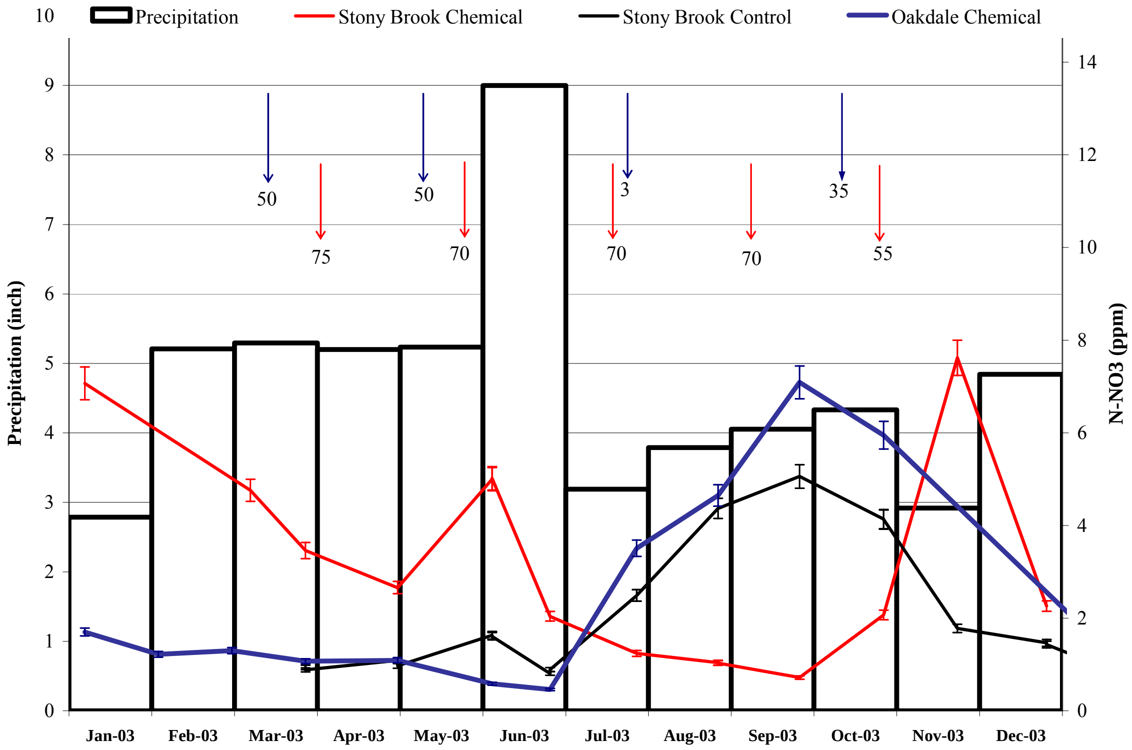

Figure 18 Chemical fertilizer turfgrass sites. *The red arrows are time of fertilizer application at the Stony Brook site, the blue arrows are time of fertilizer application at the Oakdale site and the values are kgN/acre.*

concentrations in July while the Stony Brook site decreases. In November the Stony Brook site again increases in nitrate leaching. This pulse could be from the autumn application, which may not be needed due to the reduction of plant uptake and increased soil mineralization in autumn.

Five sites were maintained by a natural organic landscaper. Figure 19 compares the three younger sites and Figure 20 compares the two oldest sites. Both show timing of fertilizer and compost application and monthly precipitation. In Figure 19 Huntington (orange line) clearly shows higher nitrogen-nitrate concentrations throughout the year compared to the Coram site (purple dashed line) and the Oakdale site (green dotted line). All three sites are less than 10 years old, with Coram being 8 years, Oakdale 6 years and Huntington 10 years. Due to their similar ages and same fertilizer practice we can better compare how infiltration rate and thatch thickness influence nitrate leaching. The leaching index using infiltration rate and soil organic matter accurately predict nitrate leaching. The other index however suggests that Oakdale would have the highest concentrations of nitrate, which is not the case. The infiltration rate is fastest at Huntington and similar for Coram and Oakdale. Oakdale has the thinnest thatch layer followed by Huntington then Coram. Concentrations at Huntington are above the drinking water standard of 10 ppm nitrogen as nitrate throughout most of the year. These are the highest concentrations of all eight sites. This may be explained by the high

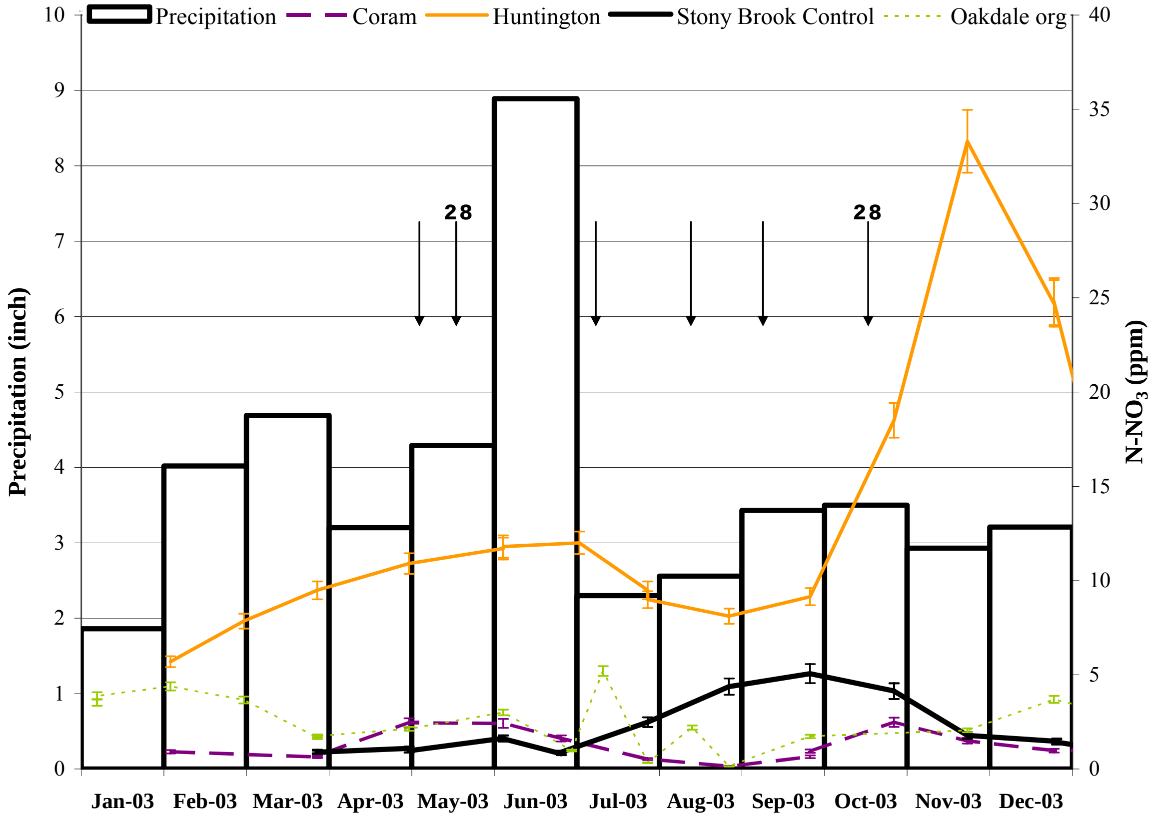

Figure 19 Younger natural organic fertilizer turfgrass sites: Huntington (10years), Coram (8 years), Oakdale (6 years). T*he arrows are time of fertilizer application with values in kgN/acre. Arrows without values are when compost was applied.*

infiltrations rate, which is the highest of all sites, or flow into the lysimeter could be following a preferential path that moved the nitrate at a rate faster than the plants can uptake. Preferential flow is the non-ideal behavior of water flow in soils (Tindall et al., 1999). This implies that part of the soil matrix is bypassed either through a pathway of a crack or fauna tunnel or a portion of the soil with a lower bulk density than the surrounding soil. At Huntington this could be flow through an area with large pores space due to the high gravel content.

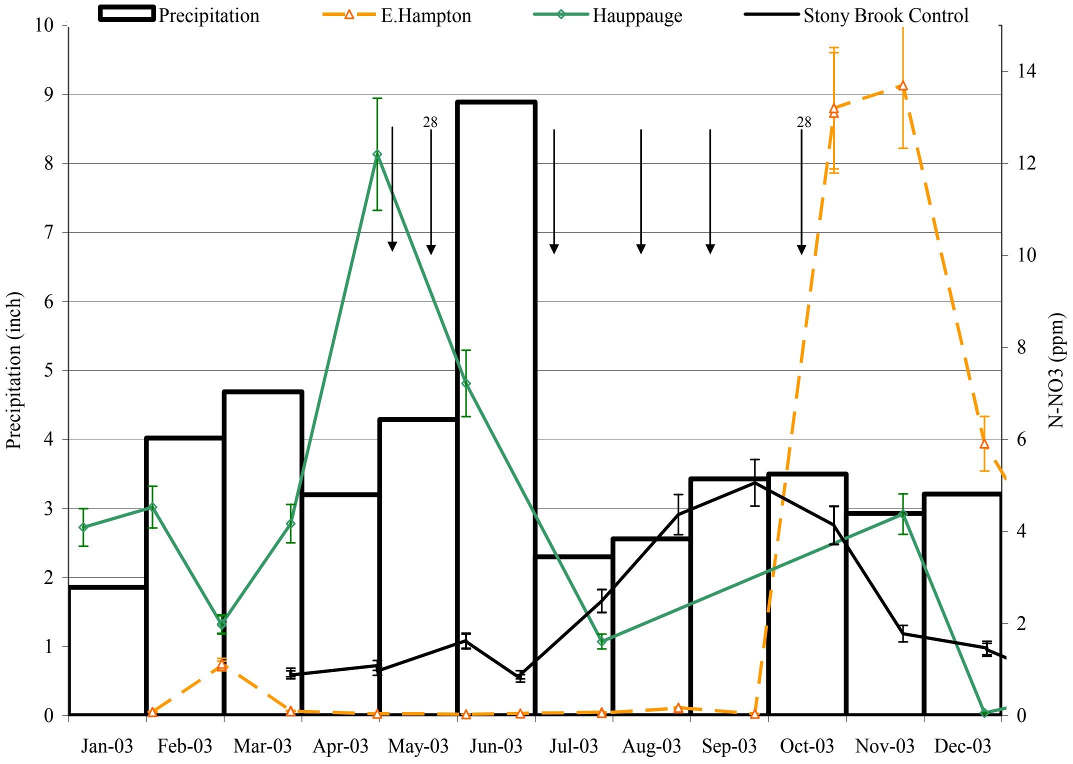

Figure 20 Older natural organic fertilizer turfgrass sites: East Hampton (22 years) and Hauppauge (23 years). *The arrows indicated timing of fertilizer with kgN/ha and the arrows with out values are when the compost was applied.*

There are two sites treated by natural organic fertilizer that are greater than 20 years in age, Hauppauge (23 years) and East Hampton (22 years). The data in Figure 20 show that the soil water collected at Hauppauge has higher nitrate concentrations until September than the soil water collected at East Hampton. East Hampton has values less than 2 ppm from January until September, when the concentrations of nitrogen as nitrate in soil water are above the drinking water standard of 10ppm. Although it is perplexing that East Hampton would have such a jump in concentration the values reported for these months were confirmed with duplicate analysis at the Marine Science Research Center and the Cornell Horticultural Laboratory. This jump in concentration is likely an affect of the dense clay layer starting at 48cm, which the other sites lack. Roy et al. (2000) reported nitrate infiltration down to the clay layer in the summer and autumn months, where it stayed and accumulated until the wetting front initiated flow below the rooting zone. He confirmed this in his model.

Hauppauge has a higher infiltration rate and thinner thatch thickness than East Hampton. The leaching index accurately predicts that Hauppauge would leach more nitrates until October.

iv. Conclusion

There are six general trends of nitrate concentrations of soil water collected below the root zone of maintained turfgrass sites in Suffolk County, Long Island, New York.

(1) Nitrate concentrations remain low and constant from January to June for soil water collected below Oakdale chemical, Stony Brook control, and Coram. From January to March no fertilizer is applied, after application it is assumed that the plant is able to utilize nitrogen and that the volume of water leaching is minimal since precipitation is close to evapotranspiration.

(2) Nitrate concentrations show a decreasing trend from January to June of nitrate collected below the root zone of Stony Brook chemical and Oakdale organic. Nitrate concentrations started high in January due to reduction in plant uptake and reduction of evapotranspiration in the winter months or due to the previous year's fertilizer application. There is a decreasing trend due to the increase of evapotranspiration and plant uptake in the spring months.

(3) Some sites show a peak in nitrate concentration between January and July. The Stony Brook chemical and Oakdale organic site peak in June, roughly a month after the last fertilization application. Hauppauge and East Hampton also have a peak in nitrate between January and June but at these sites the peaks are before fertilizer was applied. It is unclear to why this occurred.

(4) In autumn nitrate concentrations in soil water collected below all sites except Oakdale organic and Coram were above 5 ppm N-NO_3 and East Hampton and

Huntington exceed the drinking water standard of 10 ppm N-NO_3. Other research has found that peaks in autumn are usually from previous fertilizer applications that have been stored in the soil but due to the reduction of plant uptake, increase in soil mineralization, the reduction of evapotranspiration and increase in precipitation in the autumn months nitrate leaching increases (Duff et al., 1997; Roy et al., 2000). The peak concentrations in autumn also occur shortly after fertilizer application. The control site is probably leaching high nitrate concentrations due to the age of the site thus high soil organic matter which was mineralized due to warm, wet soil conditions (Maeda et al., 2003).

(5) The youngest sites Oakdale organic and Stony Brook chemical have concentrations below the control in autumn since the sites are young and are able to store nitrogen in the soil (Petrovic, 1990).

(6) The decrease of nitrate concentrations in December for most sites could be due to a reduction in leaching inhibited by the frozen impermeable ground.

v. Future Work

The first year's results are useful as a baseline study needed for longer term research. In order to better understand which fertilizer treatment, natural organic or traditional chemical, results in soil water with fewer nitrates below the rooting zone tighter constraints must be placed on the site and soil properties. For example all sites should receive the same amount of nitrogen applied at the same time of year. Currently there are five sited treated with natural organic fertilizer and only two sites treated with chemical fertilizer. It would be statistically beneficial if both fertilizer practices had equal amount of sites. Since the control site leached a large amount of nitrogen, at times above the fertilized sites, it is important to have another control site that is younger in turfgrass age with less soil organic matter. It is also necessary to have as a site with native vegetation to asses if non fertilized turfgrass land use leaches more nitrate than undisturbed land use. Soil temperature and soil nitrogen measurements would aid in assessing the extent of soil mineralization and thus understanding the amount of stored nitrogen converted to nitrate.

This study measured nitrate concentrations using lysimeters. Due to the nature of the lysimeters used a mass balance study was not conducted. In order to better asses the leachate one would have to install a different type of lysimeter or model the amount of soil the soil water in the lysimeter is collected from. With know inputs of nitrogen from rain and fertilizer, analysis of soil nitrogen, analysis of nitrogen in grass clippings and measurements of soil water nitrogen a complete nitrogen budget can be constructed for the turfgrass system. Time is also needed to see if the trends seen in the first year continue as the sites reach equilibrium.

vi. References

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IV. Summary

Results of this study assist in placing constraints on nitrate sources of groundwater in the urbanized areas of Suffolk County, Long Island, New York with the use of major elements as nitrate tracers and studying nitrate leaching below maintained turfgrass sites. The importance of this study is eminent since groundwater is the sole source of potable water in Suffolk County and nitrate contamination is increasingly becoming a concern. Notable sources of nitrate contamination are wastewater derived from septic tank/cesspool systems and turfgrass fertilization.

Major element data along with nitrate compositions of groundwater show a distinct relationship between land use and sources of nitrate contamination such that the geochemistry of groundwater associated with (1) vacant or open land use has a signature close to rain water (2) low residential density land use is mostly influenced by rain water with some contributions of soil water and wastewater (3) medium residential density land use plots as a mixture of rain, soil water and wastewater and (4) agricultural land use is not distinguishable from groundwater associated with urban land use.

Evaluating nitrate leaching below turfgrass sites receiving traditional chemical treatment, natural organic treatment or no treatment showed that treatment alone does not determine nitrate leaching below the root zone. The first year results of this study show that thatch thickness, turfgrass age, infiltration rate and timing of application in regards to precipitation and application rate greatly influence nitrate leaching. Future work, placing tighter constraints on soil properties and site characteristic must be conducted to further understand nitrate leaching below maintained turfgrass sites on Long Island.

V. Appendix 1: N-NO$_3$ data for soil water samples

[1] Scott's Brand Fertilizers [2] Lesco Brand Fertilizers.

Date	Treatment	Site	Depth	N-NO$_3$
			cm	ppm
May-03	Chemical^1	Oakdale	60	1.70
Sep-03	Chemical^1	Oakdale	60	20.40
Oct-03	Chemical^1	Oakdale	60	1.64
Nov-03	Chemical^1	Oakdale	60	4.33
Nov-03	Chemical^1	Oakdale	60	4.31
Dec-03	Chemical^1	Oakdale	60	4.53
Dec-03	Chemical^1	Oakdale	60	4.53
Jan-03	Chemical^1	Oakdale	80	1.95
Feb-03	Chemical^1	Oakdale	80	0.06
Mar-03	Chemical^1	Oakdale	80	0.14
Apr-03	Chemical^1	Oakdale	80	0.54
May-03	Chemical^1	Oakdale	80	0.56
Jun-03	Chemical^1	Oakdale	80	0.88
Jul-03	Chemical^1	Oakdale	80	0.87
Aug-03	Chemical^1	Oakdale	80	3.74
Sep-03	Chemical^1	Oakdale	80	1.93
Oct-03	Chemical^1	Oakdale	80	1.57
Nov-03	Chemical^1	Oakdale	80	1.58
Dec-03	Chemical^1	Oakdale	80	1.43
Jan-03	Chemical^1	Oakdale	100	1.70
Feb-03	Chemical^1	Oakdale	100	1.22
Mar-03	Chemical^1	Oakdale	100	1.30
Apr-03	Chemical^1	Oakdale	100	1.07
May-03	Chemical^1	Oakdale	100	1.09
Jun-03	Chemical^1	Oakdale	100	0.58
Jul-03	Chemical^1	Oakdale	100	0.46
Aug-03	Chemical^1	Oakdale	100	3.51
Sep-03	Chemical^1	Oakdale	100	4.65
Oct-03	Chemical^1	Oakdale	100	7.09
Nov-03	Chemical^1	Oakdale	100	5.95
Jan-03	Chemical^1	Oakdale	120	0.02
Feb-03	Chemical^1	Oakdale	120	1.42
Mar-03	Chemical^1	Oakdale	120	1.08
Apr-03	Chemical^1	Oakdale	120	1.26
May-03	Chemical^1	Oakdale	120	1.62
Jun-03	Chemical^1	Oakdale	120	0.96
Jun-03	Chemical^1	Oakdale	120	1.03
Jul-03	Chemical^1	Oakdale	120	0.66
Jul-03	Chemical^1	Oakdale	120	0.69
Aug-03	Chemical^1	Oakdale	120	
Aug-03	Chemical^1	Oakdale	120	63.00
Sep-03	Chemical^1	Oakdale	120	5.58
Sep-03	Chemical^1	Oakdale	120	5.64
Oct-03	Chemical^1	Oakdale	120	6.88
Nov-03	Chemical^1	Oakdale	120	7.84
Dec-03	Chemical^1	Oakdale	120	6.07

Date	Treatment	Site	Depth	N-NO$_3$
			cm	ppm
Jan-03	Chemical^2	Stony Brook	100	7.07
Mar-03	Chemical^2	Stony Brook	100	4.76
Apr-03	Chemical^2	Stony Brook	100	3.46
May-03	Chemical^2	Stony Brook	100	2.66
Jun-03	Chemical^2	Stony Brook	100	5.00
Jun-03	Chemical^2	Stony Brook	100	5.02
Jul-03	Chemical^2	Stony Brook	100	2.04
Jul-03	Chemical^2	Stony Brook	100	*3.60*
Jul-03	Chemical^2	Stony Brook	100	*2.75*
Jul-03	Chemical^2	Stony Brook	100	5.15
Aug-03	Chemical^2	Stony Brook	100	1.24
Aug-03	Chemical^2	Stony Brook	100	1.27
Sep-03	Chemical^2	Stony Brook	100	1.04
Sep-03	Chemical^2	Stony Brook	100	1.03
Oct-03	Chemical^2	Stony Brook	100	0.72
Nov-03	Chemical^2	Stony Brook	100	2.07
Dec-03	Chemical^2	Stony Brook	100	7.62
Jan-03	Chemical^2	Stony Brook	150	0.94
Mar-03	Chemical^2	Stony Brook	150	0.77
May-03	Chemical^2	Stony Brook	150	0.84
Jun-03	Chemical^2	Stony Brook	150	1.27
Jul-03	Chemical^2	Stony Brook	150	1.22
Jul-03	Chemical^2	Stony Brook	150	5.76
Jul-03	Chemical^2	Stony Brook	150	5.40
Aug-03	Chemical^2	Stony Brook	150	1.67
Aug-03	Chemical^2	Stony Brook	150	17.85
Aug-03	Chemical^2	Stony Brook	150	1.20
Sep-03	Chemical^2	Stony Brook	150	2.22
Oct-03	Chemical^2	Stony Brook	150	2.32
Nov-03	Chemical^2	Stony Brook	150	2.19
May-03	Control	Stony Brook	40	2.86
Jun-03	Control	Stony Brook	40	2.58
Jul-03	Control	Stony Brook	40	1.24
Aug-03	Control	Stony Brook	40	4.90
Apr-03	Control	Stony Brook	100	0.94
Apr-03	Control	Stony Brook	100	0.89
May-03	Control	Stony Brook	100	1.09
May-03	Control	Stony Brook	100	0.97
Jun-03	Control	Stony Brook	100	1.63
Jun-03	Control	Stony Brook	100	1.61
Jul-03	Control	Stony Brook	100	0.81
Jul-03	Control	Stony Brook	100	0.89
Jul-03	Control	Stony Brook	100	6.58
Jul-03	Control	Stony Brook	100	8.46
Aug-03	Control	Stony Brook	100	2.49
Aug-03	Control	Stony Brook	100	2.49
Aug-03	Control	Stony Brook	100	1.38
Sep-03	Control	Stony Brook	100	4.37
Oct-03	Control	Stony Brook	100	4.41

Date	Treatment	Site	Depth	N-NO_3
			cm	ppm
Feb-03	Organic	Oakdale	60	4.36
Mar-03	Organic	Oakdale	60	5.35
May-03	Organic	Oakdale	60	6.27
Jul-03	Organic	Oakdale	60	0.10
Aug-03	Organic	Oakdale	60	0.08
Sep-03	Organic	Oakdale	60	0.61
Oct-03	Organic	Oakdale	60	1.53
Dec-03	Organic	Oakdale	60	3.98
Dec-03	Organic	Oakdale	60	4.00
Jan-03	Organic	Oakdale	80	2.65
Feb-03	Organic	Oakdale	80	3.17
Mar-03	Organic	Oakdale	80	2.34
Apr-03	Organic	Oakdale	80	2.70
May-03	Organic	Oakdale	80	3.71
Jun-03	Organic	Oakdale	80	1.27
Jun-03	Organic	Oakdale	80	1.27
Jul-03	Organic	Oakdale	80	0.06
Jul-03	Organic	Oakdale	80	0.02
Aug-03	Organic	Oakdale	80	0.13
Aug-03	Organic	Oakdale	80	0.13
Sep-03	Organic	Oakdale	80	0.97
Sep-03	Organic	Oakdale	80	0.95
Oct-03	Organic	Oakdale	80	1.51
Oct-03	Organic	Oakdale	80	1.31
Nov-03	Organic	Oakdale	80	2.83
Nov-03	Organic	Oakdale	80	2.84
Dec-03	Organic	Oakdale	80	2.00
Dec-03	Organic	Oakdale	80	2.03
Jan-03	Organic	Oakdale	100	3.53
Jan-03	Organic	Oakdale	100	3.88
Feb-03	Organic	Oakdale	100	4.38
Mar-03	Organic	Oakdale	100	3.66
Apr-03	Organic	Oakdale	100	1.67
Apr-03	Organic	Oakdale	100	1.75
May-03	Organic	Oakdale	100	2.13
Jun-03	Organic	Oakdale	100	3.00
Jul-03	Organic	Oakdale	100	0.98
Jul-03	Organic	Oakdale	100	5.20
Aug-03	Organic	Oakdale	100	0.33
Aug-03	Organic	Oakdale	100	2.20
Sep-03	Organic	Oakdale	100	0.14
Oct-03	Organic	Oakdale	100	1.73
Dec-03	Organic	Oakdale	100	2.05
Jan-03	Organic	Oakdale	120	0.81
Feb-03	Organic	Oakdale	120	0.44
Feb-03	Organic	Oakdale	120	0.43
Mar-03	Organic	Oakdale	120	0.88
Mar-03	Organic	Oakdale	120	0.93
Apr-03	Organic	Oakdale	120	0.48

Date	Treatment	Site	Depth	N-NO_3
			cm	ppm
Jan-03	Organic	Hauppauge	60	1.77
Feb-03	Organic	Hauppauge	60	1.13
Mar-03	Organic	Hauppauge	60	1.80
Apr-03	Organic	Hauppauge	60	2.73
May-03	Organic	Hauppauge	60	2.64
Jun-03	Organic	Hauppauge	60	0.19
Jun-03	Organic	Hauppauge	60	0.29
Jul-03	Organic	Hauppauge	60	0.31
Aug-03	Organic	Hauppauge	60	0.98
Sep-03	Organic	Hauppauge	60	5.32
Oct-03	Organic	Hauppauge	60	10.80
Nov-03	Organic	Hauppauge	60	8.40
Dec-03	Organic	Hauppauge	60	6.57
Jan-03	Organic	Hauppauge	80	1.46
Feb-03	Organic	Hauppauge	80	0.63
Mar-03	Organic	Hauppauge	80	2.01
Apr-03	Organic	Hauppauge	80	2.07
Apr-03	Organic	Hauppauge	80	2.07
May-03	Organic	Hauppauge	80	2.17
May-03	Organic	Hauppauge	80	2.27
Jun-03	Organic	Hauppauge	80	1.88
Jul-03	Organic	Hauppauge	80	0.35
Aug-03	Organic	Hauppauge	80	0.84
Sep-03	Organic	Hauppauge	80	1.11
Oct-03	Organic	Hauppauge	80	1.80
Nov-03	Organic	Hauppauge	80	1.12
Dec-03	Organic	Hauppauge	80	0.75
Jan-03	Organic	Hauppauge	100	4.09
Jan-03	Organic	Hauppauge	100	6.25
Feb-03	Organic	Hauppauge	100	4.53
Mar-03	Organic	Hauppauge	100	1.97
Mar-03	Organic	Hauppauge	100	1.99
Apr-03	Organic	Hauppauge	100	4.17
May-03	Organic	Hauppauge	100	12.20
Jun-03	Organic	Hauppauge	100	7.22
Aug-03	Organic	Hauppauge	100	1.61
Dec-03	Organic	Hauppauge	100	4.38
Jan-03	Organic	Hauppauge	120	0.88
Feb-03	Organic	Hauppauge	120	1.28
Mar-03	Organic	Hauppauge	120	1.28
Apr-03	Organic	Hauppauge	120	1.17
May-03	Organic	Hauppauge	120	2.73
Jun-03	Organic	Hauppauge	120	1.93
Jul-03	Organic	Hauppauge	120	0.77
Aug-03	Organic	Hauppauge	120	6.37
Sep-03	Organic	Hauppauge	120	2.88
Oct-03	Organic	Hauppauge	120	9.38
Nov-03	Organic	Hauppauge	120	8.18
Dec-03	Organic	Hauppauge	120	4.34

Date	Treatment	Site	Depth	N-NO_3
			cm	ppm
Feb-03	Organic	Coram	100	0.91
Apr-03	Organic	Coram	100	0.64
Apr-03	Organic	Coram	100	0.70
May-03	Organic	Coram	100	2.45
Jun-03	Organic	Coram	100	2.42
Jul-03	Organic	Coram	100	1.62
Aug-03	Organic	Coram	100	0.53
Sep-03	Organic	Coram	100	0.15
Oct-03	Organic	Coram	100	0.65
Oct-03	Organic	Coram	100	0.95
Nov-03	Organic	Coram	100	2.48
Dec-03	Organic	Coram	100	1.50
Feb-03	Organic	Ehampton	100	0.08
Feb-03	Organic	Ehampton	100	0.08
Mar-03	Organic	Ehampton	100	1.08
Mar-03	Organic	Ehampton	100	1.13
Apr-03	Organic	Ehampton	100	0.11
Apr-03	Organic	Ehampton	100	0.10
May-03	Organic	Ehampton	100	0.04
Jun-03	Organic	Ehampton	100	0.03
Jul-03	Organic	Ehampton	100	0.04
Jul-03	Organic	Ehampton	100	0.05
Aug-03	Organic	Ehampton	100	0.08
Aug-03	Organic	Ehampton	100	0.06
Sep-03	Organic	Ehampton	100	0.16
Sep-03	Organic	Ehampton	100	0.17
Oct-03	Organic	Ehampton	100	0.04
Nov-03	Organic	Ehampton	100	13.10
Nov-03	Organic	Ehampton	100	13.20
Dec-03	Organic	Ehampton	100	13.70
Feb-03	Organic	Huntington	100	5.69
Mar-03	Organic	Huntington	100	7.85
Apr-03	Organic	Huntington	100	9.48
May-03	Organic	Huntington	100	10.90
Jun-03	Organic	Huntington	100	11.70
Jun-03	Organic	Huntington	100	11.80
Jul-03	Organic	Huntington	100	12.00
Aug-03	Organic	Huntington	100	9.48
Aug-03	Organic	Huntington	100	8.99
Sep-03	Organic	Huntington	100	8.11
Oct-03	Organic	Huntington	100	9.14
Oct-03	Organic	Huntington	100	4.80
Nov-03	Organic	Huntington	100	18.50
Dec-03	Organic	Huntington	100	33.30

VI. Appendix 2: Bulk density, water content and porosity for all soil samples

Site	Sample	Depth Interval	Field Bulk Density	Volumetric Water Content	Porosity
		(cm)	(g/cm^3)		%
Huntington	HUo.5	0-5	1.050	0.402	60.379
	HUo.15	5-15	1.432	0.305	45.967
	HUo.25	20-33	1.745	0.292	34.163
	HUo.47	42-57	1.583	0.166	40.261
Coram	COo.5	0-5	1.493	0.423	43.669
	COo.13	5-13	1.796	0.291	32.211
	COo.25	20-32	1.791	0.287	32.409
	COo.45	40-49	1.592	0.267	39.906
	COo.72	67-75	1.750	0.297	33.973
	COo.86	81-92	1.613	0.187	39.139
E.Hampton	EHo.5	0-5	0.771	0.573	70.888
	EHo.10	5-14	1.386	0.424	47.679
	EHo.19	14-24	1.529	0.378	42.312
	EHo.31	26-36	1.746	0.261	34.130
	EHo.48	36-48	1.948	0.347	26.509
	Eho.61	48-61	0.000	0.000	0.000
Hauppauge	HAo.10	0-10	1.633	0.477	38.380
	HAo.21	11-25	1.710	0.334	35.463
	HAo.55	45-55	1.756	0.351	33.750
	HAo.60	55-60	1.733	0.346	34.588
	HAo.68	60-68	1.829	0.335	30.986
	HAo.84	74-84	1.655	0.356	37.546
	HAo.100	90-105	2.013	0.209	24.052
Oakdale org	OAo.10	0-15	1.663	0.254	37.243
	OAo.25	15-36	2.044	0.159	22.856
	OAo.48	38-50	2.031	0.173	23.374
	OAo.59	55-78	nd	nd	nd
	OAo.95	85-105	2.018	0.135	23.856
	OAo.110	105-121	1.976	0.229	25.441
Oakdale chem	OAc.5	0-5	1.181	0.200	55.445
	OAc.13	5-13	1.513	0.101	42.904
	OAc.18	13-25	1.507	0.159	43.133
	OAc.25	13-25	1.799	0.181	32.111
	OAc.30	25-36	1.715	0.161	35.274
	OAc.41	36-47	2.077	0.175	21.615
	OAc.55	50-60	2.004	0.134	24.387
Stony Brook	SBc.5	0-16	1.522	0.394	42.576
	SBc.16	0-16	1.834	0.272	30.802
	SBc.24	16-24	1.651	0.214	37.710
	SBc.36	24-36	nd	nd	nd
	SBc.42	36-42	nd	nd	nd
	SBc.47	42-53	1.949	0.199	26.459
	SBc.58	53-62	1.815	0.202	31.502
	SBc.67	62-81	1.891	0.250	28.639
	SBc.81	62-81	1.937	0.235	26.906
	SBc.89	81-89	1.729	0.265	34.742

VII. Appendix 3: Particle Size Data

		>2mm	>1mm	>0.6mm	>0.2mm	>0.1mm	>0.05mm	>0.002mm		
Site	**Bottom Depth**	**Gravel**	**V.Coarse Sand**	**Coarse Sand**	**Medium Sand**	**Fine Sand**	**V.Fine Sand**	**Silt**	**Clay**	**Texture**
	(cm)	**(%)**	**(%)**	**(%)**	**(%)**	**(%)**	**(%)**	**(%)**	**(%)**	
Oakdale org	15	2.08	8.69	14.86	47.87	11.03	2.12	8.35	3.96	loamy sand
	36	29.96	4.99	10.20	35.96	8.51	1.38	3.63	4.32	sand
	50	25.35	7.11	11.18	35.75	11.57	3.68	2.01	2.87	sand
	78	13.15	11.50	17.67	40.95	8.23	2.20	2.76	3.20	sand
	105	28.76	8.45	15.56	34.49	6.16	1.12	2.58	2.45	sand
	121	13.77	5.85	14.44	45.46	10.30	2.06	5.00	2.70	sand
Hauppauge	13	9.76	4.95	5.86	19.15	5.30	4.67	32.79	16.08	loam
	25	10.33	4.28	4.94	17.24	5.70	6.20	36.91	12.70	loam
	30	47.37	0.97	1.68	7.61	3.19	5.08	23.62	9.29	sandy loam
	35	13.71	4.00	4.41	13.22	4.96	6.64	36.67	14.19	loam
	55	15.37	1.31	2.01	10.40	5.81	9.90	36.65	12.57	loam
	60	2.26	1.48	2.96	17.41	8.98	10.87	36.90	16.60	loam
	68	23.33	1.06	1.97	10.19	5.00	7.30	36.50	13.26	loam
	74	0.26	0.59	1.21	9.41	12.10	12.69	18.85	41.65	clay
	84	4.22	0.69	1.35	7.74	5.34	10.55	27.57	37.93	clay loam
	105	17.06	5.71	9.86	26.27	5.12	6.48	11.57	15.92	sandy loam
Huntington	5	0.88	2.42	10.32	32.15	9.60	4.60	25.24	11.96	sandy loam
	15	5.32	7.93	10.97	28.40	8.63	4.23	21.09	12.37	sandy loam
	25	30.12	5.06	6.35	19.22	5.90	2.91	22.16	7.54	sandy loam
	47	26.01	10.27	11.18	29.71	5.58	2.25	1.37	13.23	loamy sand
Coram	5	1.81	3.31	8.10	38.48	9.52	2.71	23.57	11.37	sandy loam
	13	2.67	3.24	8.27	47.94	10.83	2.29	13.07	7.08	loamy sand
	25	1.38	2.03	5.96	58.84	17.19	3.27	7.48	3.47	sand
	45	1.57	2.20	6.55	47.61	16.50	7.06	12.18	4.97	loamy sand
	72	0.24	0.90	2.86	28.14	15.08	11.86	28.70	11.24	sandy loam
	86	0.37	0.45	1.81	50.11	22.98	6.71	12.53	4.10	loamy sand
E.Hampton	5	0.00	0.38	2.95	31.72	12.26	5.08	13.58	32.94	sandy clay loam
	10	0.15	0.86	4.05	34.05	12.71	4.89	30.77	11.16	sandy clay loam
	19	0.52	0.27	3.04	37.90	14.51	5.48	26.71	10.03	sandy loam
	31	0.10	0.49	3.78	54.59	16.98	3.86	14.66	4.18	loamy sand
	48	0.00	0.26	1.57	21.95	9.89	8.12	18.49	36.33	clay loam
	61	0.00	0.27	1.38	13.86	5.70	8.04	28.95	38.65	clay loam
Stony Brook	5	0.18	1.23	7.38	41.26	13.69	6.13	20.11	9.42	sandy loam
	16	35.89	3.97	6.04	24.30	8.80	3.80	12.27	4.41	loamy sand
	24	3.82	4.03	7.87	36.56	13.88	6.95	20.19	6.47	sandy loam
	36	50.46	4.70	5.56	19.33	6.25	2.87	8.22	2.38	sand
	42	7.38	4.52	8.96	39.14	13.93	6.73	13.78	5.11	loamy sand
	47	7.30	3.27	7.14	36.06	14.37	7.30	17.75	5.74	sandy loam
	58	1.56	3.46	7.40	37.96	14.73	7.49	21.11	7.16	sandy loam
	67	6.14	4.08	7.53	36.22	13.56	6.37	19.13	6.59	sandy loam
	81	12.53	3.33	6.84	35.28	12.77	6.47	16.19	5.68	loamy sand
	89	6.11	3.62	7.74	37.14	13.57	7.26	18.22	5.94	loamy sand