Mill Brook 2010 Water Quality Assessment

DRAFT FINAL REPORT

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January 2011

Acknowledgements:
Charlie Pachico, Seven Gates property manager, provided access to sample at the Crocker Pond spillway. The sampling program was funded by the West Tisbury Selectmen and the Martha's Vineyard Commission.

Executive Summary:
The sampling project was designed to assess phosphorus levels along the length of Mill Brook to try to identify any sources of nutrients and as an input to management of Mill Pond water quality. Four sample rounds were carried out at 8 stations along the length of Mill Brook. The sampling program found that:

- Phosphorus levels are elevated above desirable levels for freshwater ponds along much of the length of Mill Brook including Mill Pond where they were high enough that, during the sampling period, nitrogen was probably limiting the growth of algae in the Pond rather than phosphorus that is typically the limiting nutrient in fresh waters.
- Phosphorus release into the stream is most likely episodic as the result of a short term erosion event adding silt and phosphorus with it or an anoxic period in one of the ponds along the length of the stream that releases phosphorus from storage in the sediment.
- The sampling program found a substantial silt and nutrient load added to the unnamed stream that flows under North Road and into Priester's Pond during late July and again in late August. This location also had a similar nutrient spike during the 2008 sampling program in late July and late September. Possible sources include plowed farm fields, re-suspension of silt from the stream bed by runoff or some other upstream disturbance of the stream bed or banks.
- Sampling did not show a spike in nitrogen associated with wastewater disposal or agriculture probably because the last sampling round was in late August before the groundwater beneath seasonal homes and farm fields reached the stream.

In order to better pin point phosphorus release and movement down the stream, additional, more intensive sampling is required. The sampling program should include more frequent sampling extending further into the fall at least at a subset of the 8 stations sampled in this project. Once identified, source(s) may be addressed lowering phosphorus content in the stream and its ponds. The focus of the sampling program would be on identifying and following phosphorus release down the stream and looking for a fall increase in nitrogen resulting from seasonal wastewater loading and summer agricultural fertility programs.

Project goals:
This sampling program was the result of a recommendation made to identify phosphorus sources along the course of the stream (Wilcox, 2009). In addition to identifying sources of phosphorus along the course of the stream, the project has gathered additional nutrient data that will be utilized by the Massachusetts Estuaries Project in their evaluation of Tisbury Great Pond.

Sampling Locations and Scheduling:
Eight sample stations were identified along the course of Mill Brook and its tributaries and are shown in Figure 1. The descriptive locations of the stations are:

MB1	At the outlet from Mill Pond at the Old Mill building
MB2	At the Scotchman's Lane crossing- downstream side
MB3	At the crossing under State Road near the North Road intersection
MB4	At the unnamed tributary that crosses under North Road and enters Priester's Pond
MB5	Not sampled- used as a blind duplicate sample
MB6	At the unnamed tributary crossing Indian Hill Road just west of Arrowhead Farm
MB7	Unnamed tributary crossing Indian Hill Road just east of Roger's pit
MB8	At the outlet from Crocker Pond
MB9	At the Witch brook crossing of North Road- downstream side

These stations were sampled on April 26, June 1, July 27 and August 30, 2010. The stations are shown on an aerial base in Figure 1 included in Appendix 1.

Sample collection and handling:
One-liter samples were collected at each station and stored on ice for transport to the MVC Offices. At this location, samples were filtered through a 0.22 micron cellulose acetate filter for dissolved nutrient analyses and unfiltered samples prepared for total phosphorus analyses. Samples were filtered through glass fiber filters for analyses for particulate nitrogen and carbon. These samples were sent the same day by Fast Ferry to New Bedford for pick up by personnel from the University of Massachusetts, Dartmouth, Coastal Systems Group lab.

At each station an YSI-85 multi-parameter meter was used to record dissolved oxygen, temperature and specific conductivity.

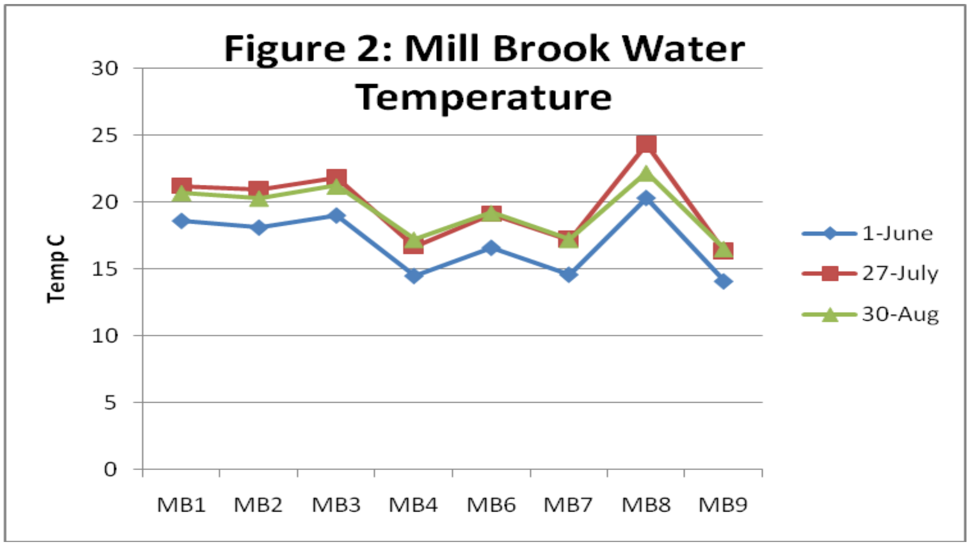
Weather data:
Throughout the course of the sampling program, precipitation was recorded at a backyard rain gauge in West Tisbury at 8:00 of the day indicated in Table 1 in the Appendix. Precipitation is a factor in water quality in the Brook as it washes debris and nutrients from the roads and fields that are in the immediate watershed into the water as well as adding nitrogen contained in the rainfall itself.

The West Tisbury precipitation totals for each month compare to the average for the month from the National Weather Service record in Edgartown as follows:

- April was nearly 2.7 inches below the average 4.22 inches.
- May was about 0.5 inches below the average 3.82 inches.
- June precipitation was about 0.8 inches above the average 3.22 inches
- July precipitation was about 0.3 inches above the average 3.00 inches
- August precipitation was 0.7 inches above the average 4.2 inches.

The April and June sampling runs were within a dry period and each followed a period of 7 to 10 days with minimal precipitation. The July and August runs were within a wet period and each followed significant rain events by 3 to 5 days.

Results:
Stream water temperature follows a pattern that indicates where groundwater influx dominates and cools the water and where exposure to solar heating in the chain of ponds along the Brook raises the water temperature. The stations where cool groundwater lowers the temperature include MB4 on North Road at the unnamed stream flowing into Priester's Pond, MB7 on Indian Hill Road just east of Roger's pit and MB9 from Witch Brook at North Road. Sample points in the stream near to discharge from a pond where solar heating warms the water include MB1 at the Mill Pond outlet, MB3 just downstream from Priester's and MB8 at the Crocker Pond spillway.



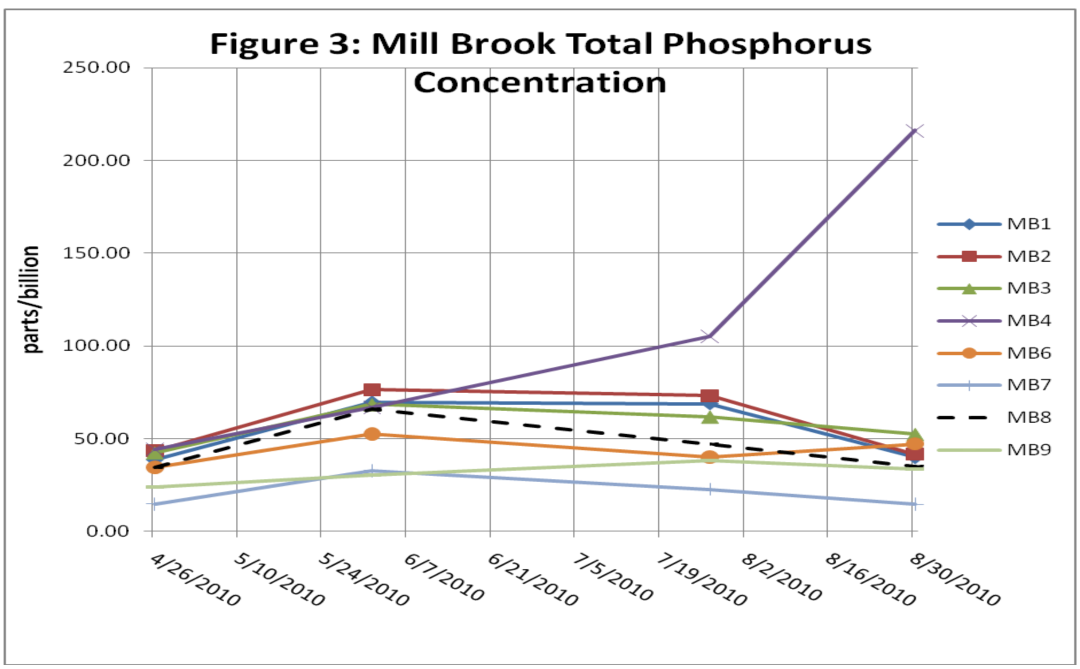
In general, the most striking nutrient-related results are the dramatic increase in all parameters at station MB4 beginning with the July 27 sampling run and increasing with the August 30 sampling round. This occurrence is similar to the results from the 2007 and 2008 stormwater study where total suspended solids, total nitrogen and orthophosphate all spiked during rainfall events preceding the sampling at this station (Wilcox, 2009).

Total Phosphorus:
Background: Total phosphorus is a measure of all forms, including dissolved organic, dissolved inorganic, amorphous and particulate sources of phosphorus (living and dead organisms as well as inorganic precipitates). Phosphorus pollution is a common result of stormwater running off streets and farmland. Phosphorus is strongly attached to soil particles and readily forms insoluble combinations with iron, calcium and aluminum. As a result, the movement of phosphorus through the groundwater is minimal. Eroded stream banks and re-suspended silt caused by stream bed disturbance may also add to this test result because phosphorus bonds to fine soil particles.

Phosphorus pollution is a primary cause of freshwater eutrophication. Phytoplankton and larger aquatic plants utilize phosphorus in the chemical form that is easiest for them to take up- some forms are readily available while others are not. Most of the components of total phosphorus are generally not available to microscopic algae until it is broken down into the soluble orthophosphate form by bacteria or chemical processes. The orthophosphate form is a likely contributor if not the causative factor in the excessive growth of aquatic plants in Mill Pond (and the chain of ponds running up the Brook).

This sampling program was aimed at assessing the concentration of phosphorus along the stream course to see if the data might point to a location where high concentrations indicate a source. The data for total phosphorus are plotted in Figure 3.

<u>Results:</u> While not directly available to stimulate plant growth, total phosphorus is an indicator of the productivity of a fresh water body. In general, total phosphorus is lowest at the most upstream sample locations (stations MB7 and MB9) and highest at the downstream stations (MB1 and MB2). There is a substantial increase in total phosphorus concentration between station MB7 and MB6. The concentration at station MB4 is strongly increased on July 27 and more so on August 30. Despite this increase in concentration, the nearest downstream station, MB3 does not show a spike in phosphorus. It appears that Priester's (upstream from MB3) and Mill (MB1) Ponds are sinks for phosphorus as that nutrient is at lower concentration on the downstream side of the pond than it is upstream. That is not the case with Crocker Pond (MB8).

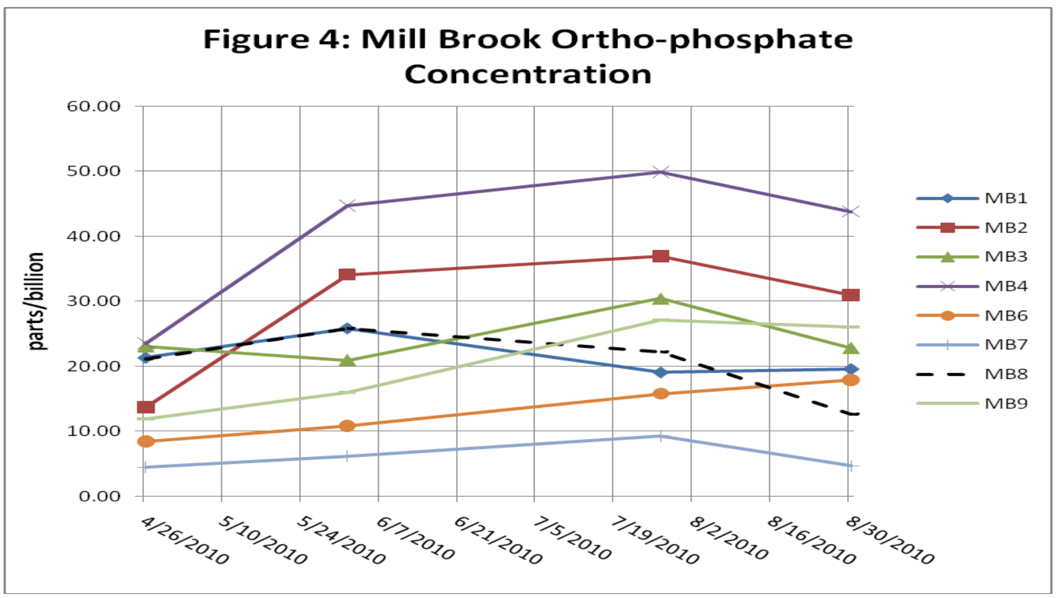


<u>Background on Total Phosphorus Concentrations</u>: The State of Maine recommends a concentration of less than 15 parts per billion (ppb) for great ponds but a goal of 2 to 5 ppb for outstanding pond resources. The EPA average of 25th percentile values (higher quality systems) for streams and rivers in our area during the summer indicates 13.1 ppb. All stations are over the EPA criterion at all times. Wetzel (1983) reported the mean total phosphorus concentration of 71 lakes that were eutrophic was 84.4 parts per billion (ppb). The output from Crocker (MB9), Priester's (MB3) and Mill Pond (MB1) are all well below that concentration.

Inorganic phosphorus:

Background: Ortho-phosphate is the inorganic portion of total phosphorus that is available for uptake by algae, phytoplankton and rooted plants in aquatic systems. It is strongly bonded to silt and clay particles in the soil and doesn't travel far through the soil unless the source is sufficient to saturate the sites in the soil where bonding can occur. Sources include wastewater disposal, fertilizer, road runoff and release from pond bottom sediments during anoxic events. When found in surface waters, it indicates either nearby sources or larger sources that release so much phosphorus that it overcomes the strong bonding in the soil to which it is subjected.

Results: The pattern for ortho-phosphate is very similar to that seen for total phosphorus being higher at stations MB4 and MB2 and lowest at MB7. MB4 is located at North Road and drains into Priester's Pond with farmland in the immediate watershed. MB2 is located at Scotchman's Lane with farmland and low density residential in the immediate watershed. MB7 is located on Indian Hill Road near the headwaters of the unnamed stream with low density residential in the nearby watershed.

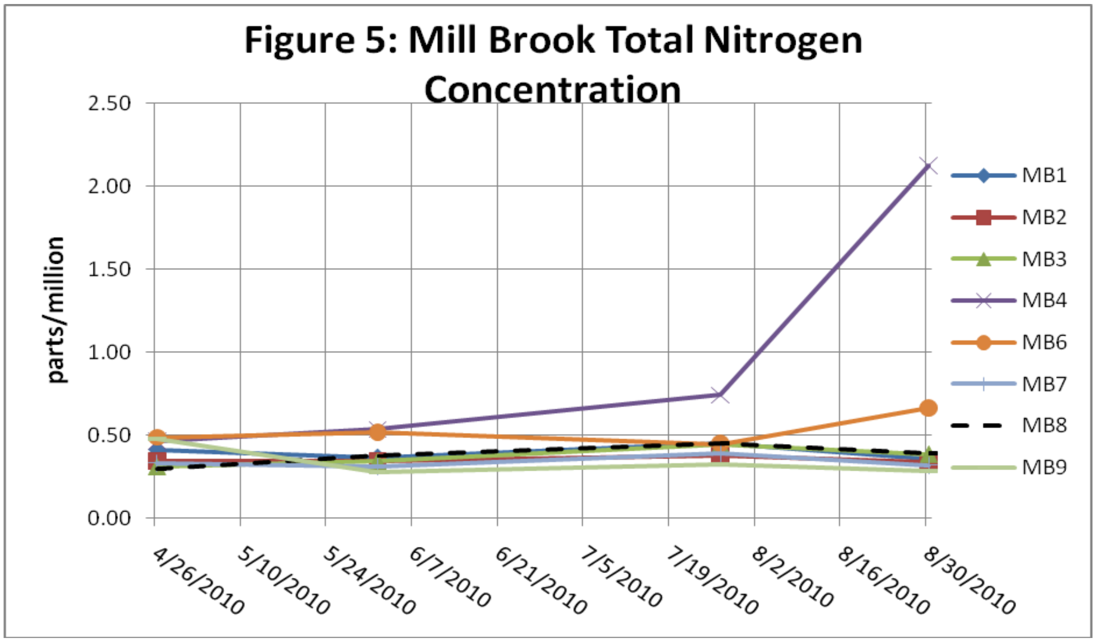


***Background on Ortho-phosphate Concentration:** The EPA average of 25th percentile values (higher quality systems) for streams and rivers in our area during the summer is 5.5 ppb.*

Total Nitrogen:

Background: As with total phosphorus, total nitrogen is a measure of dissolved and particulate sources of nitrogen. Typical sources include wastewater, animal waste, acid rain, fertilizer and stormwater runoff. Sources of dissolved nitrogen stimulate the growth of aquatic plants and microscopic algae that add to the particulate fraction of the total nitrogen.

Results: The pattern is similar to that seen for total phosphorus in that there is a dramatic increase in concentration at station MB4 on July 27 and August 30 and that the concentration at station MB6 is substantially higher than at station MB7 immediately upstream. One difference from the total phosphorus results is that station MB6 replaces station MB2 as second highest concentration. Concentrations at some of the stations show a slight peak during the July 27 sample round and decline for the late August round.



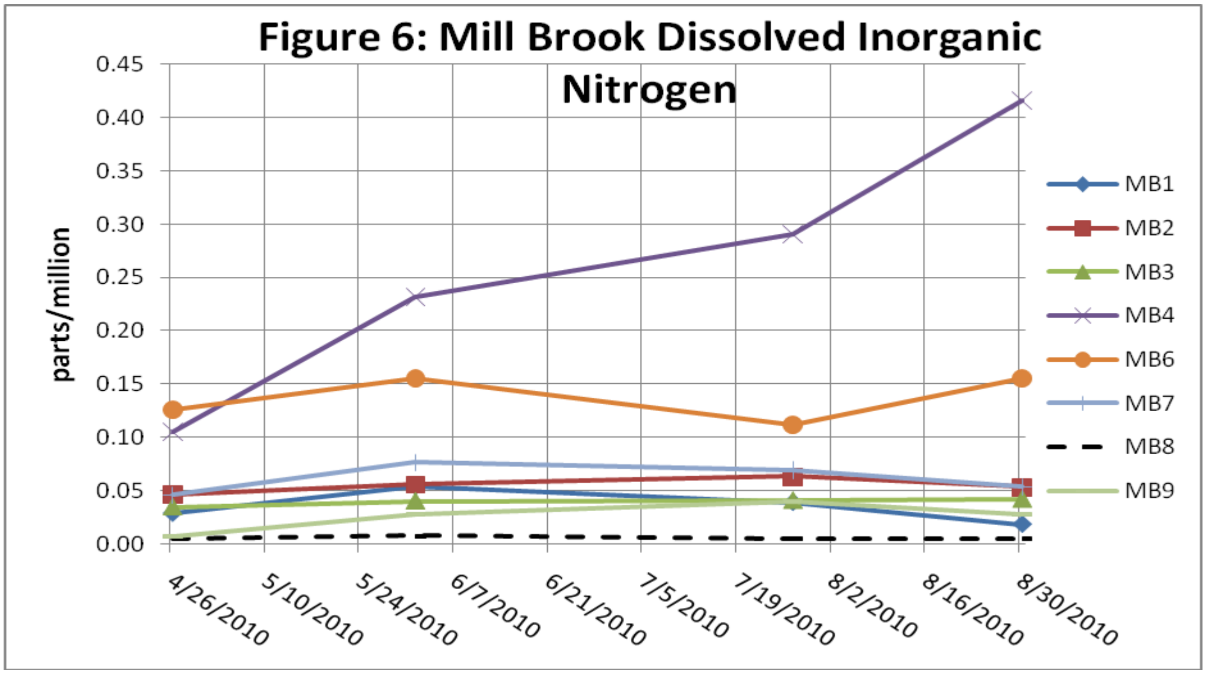
Background on Total Nitrogen Concentration: ***While there is no criterion for total nitrogen at this time, EPA has identified an average concentration in higher quality streams (25th percentile) during the June through September time period of 0.53 ppm (EPA, 2000). Most sample stations are at or near this guidance concentration with the exception of MB4 and MB6.***

Dissolved Inorganic Nitrogen (DIN):

Background: This parameter is the sum of all inorganic nitrogen fractions: nitrate, nitrite and ammonium. It may be added by acid rain, wastewater disposal, fertilizers as well as road runoff. In our area, wastewater is usually the major source of DIN except in localized areas where agriculture is found. In surface water, it may be taken up by growth of algae, phytoplankton and rooted plants and converted into particulate nitrogen. Its uptake and conversion to plant biomass depends on available phosphorus which is usually the nutrient necessary for plant growth that is in short supply in fresh water systems. Finding DIN in the water column indicates that the sources exceed the uptake capacity of the vegetation in the stream at the sample location.

The background concentration of inorganic nitrogen in undeveloped areas is usually less than 0.05 part per million while the concentration in rainfall often exceeds 1 ppm. However, the inorganic nitrogen in rain falling on vegetated soil in the Brook watershed would be extracted and bound into the plant growth cycle as the rainfall infiltrates the soil.

Results: The pattern described for both total phosphorus and total nitrogen is continued for dissolved inorganic nitrogen in Figure 6 in that MB4 is the highest concentration and increases steadily through the sampling period. As with total nitrogen, station MB6 replaces MB2 as the second highest concentration. Generally the concentration of DIN is lower than might be expected possibly due to the low density residential development pattern in the watershed and termination of the sampling program in late August before the seasonal nitrogen addition from wastewater and fertilizer could arrive at the Brook.



<u>Background on DIN Concentration:</u> The EPA average of 25th percentile values (higher quality systems) for streams and rivers in our area during the summer indicates 0.29 ppm. All stations except MB4 are below this level.

<u>Discussion of the Results:</u>

Background on Phosphorus in Fresh Water Systems:

The vast majority of phosphorus in fresh waters is bound up in particles of living and dead phytoplankton. In this form, it is not available to stimulate new algae or larger aquatic plants. The zooplankton that eat algae excrete soluble phosphorus into the water column that is rapidly turned into the next generation of algae. Phosphorus either in dead algae or bound to clay or organic matter is constantly settling onto the bottom where it is removed from the water column and trapped in the sediment (as long as the water column remains oxygenated). So, a constant input of phosphorus is required to sustain large plant populations. The input may be external coming from precipitation, stream or groundwater sources entering the system. Or, the source may be internal if the water column becomes anoxic (without oxygen) when the phosphorus bound in the sediment is chemically released into the water column.

The addition of phosphorus to fresh water systems has been found to stimulate organic matter production in the form of free floating microscopic phytoplankton as well as larger plants (Wetzel, 1983). In theory, one unit of phosphorus can produce 500 units of living algae given available nitrogen and carbon that are generally present in fresh water systems. One pound of added phosphorus can produce 500 pounds of aquatic plant biomass.

As phosphorus input increases, the organic matter production increases eventually pushing the pond into a eutrophic condition where the plant biomass becomes excessive and produces detrimental impacts to system quality. Much of the plant material produced is deposited on the bottom at the end of each season. One of the impacts of excess organic matter is low levels of dissolved oxygen as it decays. As the oxygen level declines in the bottom water, a point is reached where phosphorus stored in the bottom sediment is released into the water column further stimulating growth of plants.

The Carlson trophic state index (1996) is a system devised to classify freshwater ponds into categories of increasing levels of nutrient enrichment. The states are not meant to indicate "good" or "bad" water quality but to describe the condition of the pond in terms of nutrients and organic matter productivity. Typically, eutrophy is understood to describe an excess of nutrients and pond productivity while oligotrophy is a relative lack of productivity. In general, eutrophic conditions are not aesthetically pleasing to pond users.

Table1: Trophic States of Freshwaters

Parameter	Oligotrophic	Mesotrophic	Eutrophic
Total P ug/l	4	15	40
Chlorophyll ug/l	0.7	3.5	12
Secchi extinction- meters	10	3	1.3

Note: ug/l is parts per billion

Mill Pond:

Data sufficient to classify the trophic state of the Pond is lacking at this time. Certainly the growth of larger algae and rooted aquatic plants indicates a summertime excess of productivity that would probably indicate it is eutrophic. What data we do have indicates:

- The concentration of total phosphorus leaving Mill Pond at the spillway exceeds 40 ppb for much of the summer of 2010 suggesting the system was likely eutrophic.
- While chlorophyll data is scarce, a sample from late August 2007 contained 5.2 ppb (Wilcox, 2009) suggesting the system was likely mesotrophic.
- Secchi data is even scarcer partly because the pond is so shallow it is hard to get a reading. However ACT (2006) got a turbidity reading in September 2006 that indicated low levels of suspended particles that implied a mesotrophic condition. During 2005, Secchi depth was over 1.2 meters on 5 dates between early June and early August using a transparency tube (Wilcox, unpublished). This implies a borderline trophic state between mesotrophic and eutrophic.

Mill Pond has a short residence time due to the large stream volume flowing into the limited volume of the pond. Streamflow averages 500,000 cubic feet per day over the course of a year (Healy, 2009). The pond volume is about 185,000 cubic feet (ACT, 2006). Streamflow adds and removes about 3 times the pond volume each day. Some of the daily discharge includes new water that passes straight through because mixing is imperfect so a 95% removal of old water probably occurs every day despite 3 pond volumes passing over the spillway. This is a fairly rapid turnover for a fresh pond and may account for the water transparency being good and the difficulty classifying the pond as eutrophic or mesotrophic.

Orthophosphate is the only type of phosphorus that can be directly incorporated into new algal tissue. In addition to contributing to algae growth, it is very reactive combining with iron (and other cations) to form insoluble precipitates or adsorbing to clay particles and settling out of the water column to the bottom. When it is added to a pond from external sources like stream input, rainfall, runoff or wastewater effluent plumes it is very quickly taken up into algae or settling out of the water column. For shallow lakes and ponds, Wetzel (1983) citing Vollenweider, suggested an external loading as "dangerous" (implying rapid eutrophication) at phosphorus loading equal to or exceeding 0.13 grams of biochemically active phosphorus per square meter of surface area. For the 2.5 acre Mill Pond, this translates to phosphorus load of 1315 grams per year.

The average concentration of orthophosphate at Scotchman's Lane was 0.013 parts per million from April through August, 2010. Focusing on the summer months (June through September) when algal phosphorus uptake is greatest and water quality is lowest, the Mill Brook flow is about 50.4 million cubic feet (Healy, 2009). At 0.013 ppm, the orthophosphate flowing into the wetland at the head of the pond near Scotchman's Lane is about 18,600 grams. A portion of this phosphorus will be bound up in the wetland. The output at the Mill Pond dam at a concentration of 0.010 ppm is 14,300 grams indicating that a considerable amount flows through the Pond and out. Net ortho-phosphorus remaining in the system (including the wetlands) is approximately 4,300 grams. This finding generally supports a conclusion by ACT (2006) that Mill Pond was likely a nutrient sink, trapping nutrients that enter the pond in the system. But it also demonstrates that there is strong likelihood that there is a significant source of supply of phosphorus to Mill Pond that is available to stimulate aquatic plant growth.

At a conversion rate of 500 to 1, the 4,300 grams could produce nearly 2.5 tons of aquatic plant material.

Nitrogen and phosphorus are used to make algal tissue in a ratio of around 16 to 1 (Redfield, 1963). The proportion of these two nutrients in the water column indicates how readily new algal growth can proceed. The ratio of total nitrogen to total phosphorus (TN/TP) provides some insight into which nutrient controls or limits the growth of aquatic plants. When the TN/TP ratio is less than about 10, the system is limited by the availability of nitrogen. Phosphorus appears to become limiting to growth when the ratio is over 10 to 1 (Carlson, 1992).

- In 2010, the average total nitrogen leaving the system was 0.4 ppm while the total phosphorus average was 0.054. The ratio is 7.4 indicating that, on average, the system was limited by the availability of nitrogen.
- On average over three samples from summer 2007, the TN/TP ratio was 11.5 indicating although somewhat less clearly, the system was limited by the availability of phosphorus (Wilcox, 2009).

- In late September 2008 (Wilcox unpublished) the ratio was 24.5 indicating a clearly phosphorus limited system.
- ACT (2006) in a one time sample round found a total N to total P ratio of 25.

From the somewhat small dataset, it appears that Mill Pond varies from being limited by nitrogen to being limited by phosphorus. Mass Estuaries data (Samimy, MEP, 2007) indicates similar average concentration of total nitrogen during their 2005-2006, twice-monthly data collection but the concentration does show episodic spikes in concentration that were not found in the present study.

The ACT sample results include a much higher nitrate concentration (0.47 ppm on average) than was found in the present study (0.02 ppm on average). Low nitrate values were obtained during 2008 (Wilcox, unpublished) when a grab sample was analyzed at 0.005 ppm; in 2007 (Wilcox, 2009) when the average of three samples over the summer was 0.014 ppm and from a single sample in October 2001 that had a concentration of 0.029 ppm (Wilcox unpublished). The wide variation could well be the result of a spike in nitrogen similar to what the MEP data showed.

Overall Sampling Project Results:

Sample Station MB4: The strongest pattern to emerge from the sampling program is the dramatic increase in particulate and nutrient parameters at station MB4 on July 27 and August 30. This includes total phosphorus, total nitrogen, dissolved inorganic nitrogen and ortho-phosphate. The fact that the parameters increase over two sample rounds further supports the validity of the data. Field notes for August 30 indicate that the stream was very silty looking. It is striking that the same pattern was found during 2007-2008 (Wilcox, 2009) when a number of parameters including total suspended solids increased significantly at this station in late July and late September 2008. During 2008, the two sampling rounds showing the sharp increase in concentration were completed well into a large rainfall on July 24 (after 24 hours produced 2.89 inches of rain) and near the beginning of a rainfall that produced 2.43 inches by the morning after the sample round on September 26.

The unnamed stream from which sample MB4 is collected flows parallel to Indian Hill Road through lot15-2.1 (station MB6) then turns south and flows through lot 15-3.1 with Arrowhead Farm fields to the east and west. In some places the stream thread is only 50 to 75 feet from the edges of the field to the east. The stream continues onto lot 14.8 where a hay field on Seven Gates Farm is within 100 to 150 feet of the stream thread (MB4). During the August 30 sampling, plowed fields were observed from North Road in the Seven Gates field. On inspection in the area, it was determined that approximately 15 acres of field was plowed at Seven Gates and another 7 acres at Arrowhead. The furrows were relatively fresh during the field visit and showed little evidence of erosion despite the heavy rain that was recorded on August 23, 24 and 25. I would interpret this to indicate that the field had been turned after this heavy rainfall. Whether the grasses were rotovated or otherwise turned before the moldboard plowing is not known. Ultimately it is not absolutely clear whether or not the fields were disturbed prior to either of the rainfall events before the July or the August sampling rounds.

There are at least 3 possible sources of the observed increase in silt, total phosphorus and nitrogen on July 27 followed by an even larger increase on August 30. Both sample dates followed heavy rainfall by a period of several days. Possible sources of the observed spike in pollutants include:

1. Erosion of particulates from the immediate sub-watershed (the plowed fields) or
2. Erosion of existing stream bed deposits of fine material or
3. Some other event upstream such as a release of water from a dammed pond or some work or other activity in the stream.

The fact that the spike in water quality parameters occurred both in 2008 and 2010 raises questions about whether the source could be a once in 5 or 7 year event like plowing a hayfield. Even if the source of silt and nutrients was the stream bed deposits, those silt deposits would likely have entered the stream from a previous erosion event in the immediate sub-watershed.

Other sample locations: Another pattern that persists through the dataset is a substantial increase in nutrient concentration for all four parameters discussed here between station MB7 upstream from the farm pond on lot 15-2.1and MB6 downstream from this pond. However, the data do not indicate gross pollution and the values found are much lower than those found at station MB4 downstream.

Over the sampling period, there is no significant increase in dissolved inorganic nitrogen in the vicinity of low density residential areas around station MB3 and MB1 that might be expected from wastewater disposal. The concentrations found at stations MB4 and MB6 are the only ones that are substantially above the background level of around 0.02 to 0.05 ppm for inorganic nitrogen. One explanation may be that there is a lag between the time when seasonal houses are occupied and produce a wastewater effluent plume in the groundwater and the point when that plume discharges into the stream due to the travel time for wastewater nutrients to make their way in the groundwater to the stream. In other words, the wastewater nitrogen source doesn't show up in the stream until later in the year than the last sampling round.

There is only a slight increase in DIN between station MB3 near the Priester's Pond outlet and MB2 at Scotchman's Lane despite the presence of a Morning Glory Farm corn field (~ 6 acres) upstream from MB2. This too may be the result of the travel lag between nutrients entering the groundwater beneath the field and the sample point. The time between fertilization beginning in May and the latest sample date in late August may not be long enough to register nitrate from the farm fertility program. The field edge is about 200 feet from the stream and at a travel rate of 1 foot per day in the groundwater, any nitrogen reaching the groundwater from the fields would require 7 months or more to discharge into the stream. On the other hand it is also possible that wetlands along the edge of the stream and just north of Scotchman's Lane may be a sink for nitrogen, removing it from the groundwater before it enters the stream.

The ratio of nitrate to total phosphorus provides some insight into the source(s) of nutrients to the system (Green, 2007). This is because nitrate can be added to the stream from groundwater while phosphorus generally is not. The ratio is dependent on there being sources of groundwater nitrate in the watershed of the stream segment that is sampled. In general, the highest ratios tend to occur during periods of low stream flow when groundwater dominates while the lowest occur during high flow periods when surface runoff becomes more important (Green, 2007). The April and June sample rounds were carried out during dry weather while the July and August rounds followed heavy rain events during a wetter period. The ratios of DIN to total phosphorus for the Mill Brook system are very low and were all multiplied by 1000 to convert them to more easily compared numbers in Table 2. (Greens ratios were whole numbers ranging up into the 100's) The need to multiply the ratios points out that there was little dissolved inorganic nitrogen in the stream during the sampling project. Possible explanations include a lack of DIN sources in the immediate sub-watershed, the lag time previously discussed and a rapid conversion into plant biomass.

Table 2: Ratio of Inorganic Nitrogen to Total Phosphorus

Stream Station	April 26	June1	July 27	August 30
	DIN/TP X 1000	DIN/TP X 1000	DIN/TP X 1000	DIN/TP X 1000
MB1	0.74	0.78	0.57	0.46
MB2	1.07	0.73	0.87	1.28
MB3	0.82	0.59	0.66	0.8
MB4	2.38	3.45	2.77	1.92
MB6	3.65	2.94	2.78	3.28
MB7	3.06	2.34	3.04	3.61
MB8	0.14	0.12	0.1	0.15
MB9	0.29	0.91	1.04	0.81

The three stations where the ratio is highest are stations MB4, MB6 and MB7, highlighted in Table 2. These stations also have colder water temperatures supporting the importance of cold groundwater (see Figure 2). It is interesting to note that the ratio at station MB4 declines somewhat during the significant increase in particulates in the stream during the late July and August sample rounds which may point to surface runoff increasing its dominance over groundwater as a nutrient source at that time.

Sample points at or near ponds have the lowest ratios (MB8 at Crocker, MB3 near Priester's and MB1 at Mill Pond spillways).

Quality Assurance: Blind duplicate samples indicate agreement between the source sample and the blind sample of plus or minus 10% for most dissolved nutrients and total phosphorus and within 25% for nitrate-nitrite and particulate analyses. These are within the lab quality assurance guidelines.

Conclusions and Recommendations:

Phosphorus addition to Mill Brook is probably episodic such as when a source is available during a heavy rain (as at station MB4) or when an anoxic event occurs in a pond releasing phosphorus from the sediment. With the infrequent sampling, event driven (one-time) nutrient loads may be easily missed. This is because even if the flow rate down the stream were only 1000 feet per day, in two weeks a spike in total phosphorus would have travelled the length of the stream and entered Tisbury Great Pond. An anoxic event in one of the ponds along the stream course could release significant phosphorus in a matter of days or weeks that could easily be missed with monthly sampling. In order to better sort out those possibilities, more frequent sampling at all stations over a longer period of time is desirable.

Sampling at station MB1, MB2, MB3 and MB4 frequently during both dry weather and a rain event is needed to both confirm the high levels of pollutants found during 2010 and to better identify a source and the progression of a concentrated spike downstream or to the point where it terminates.

It is likely that some if not all of the ponds along the stream are effective sinks for nutrients. That is, nutrients entering the system are precipitated out or incorporated into aquatic plants and do not leave at the same concentration. This seems to occur not only at Mill Pond but also between MB4 upstream of Priester's and MB3 downstream. During the substantial increase in total phosphorus and total nitrogen in late July and August at MB4, there is no corresponding increase at MB3. A spike does not show up at MB2 further downstream either. This could either result from the nutrient sink phenomenon occurring in Priester's Pond or because the sampling rounds may have missed the spike in concentration as it travelled downstream.

Sampling further into the fall would be useful to evaluate the groundwater travel time delays for seasonally used wastewater systems and fertilized agricultural fields.

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APPENDIX 1

Rainfall Record

Water Chemistry Analyses

Key to Chemistry Table:

Analyses by Univ. of Mass Dartmouth Coastal Systems Group Lab

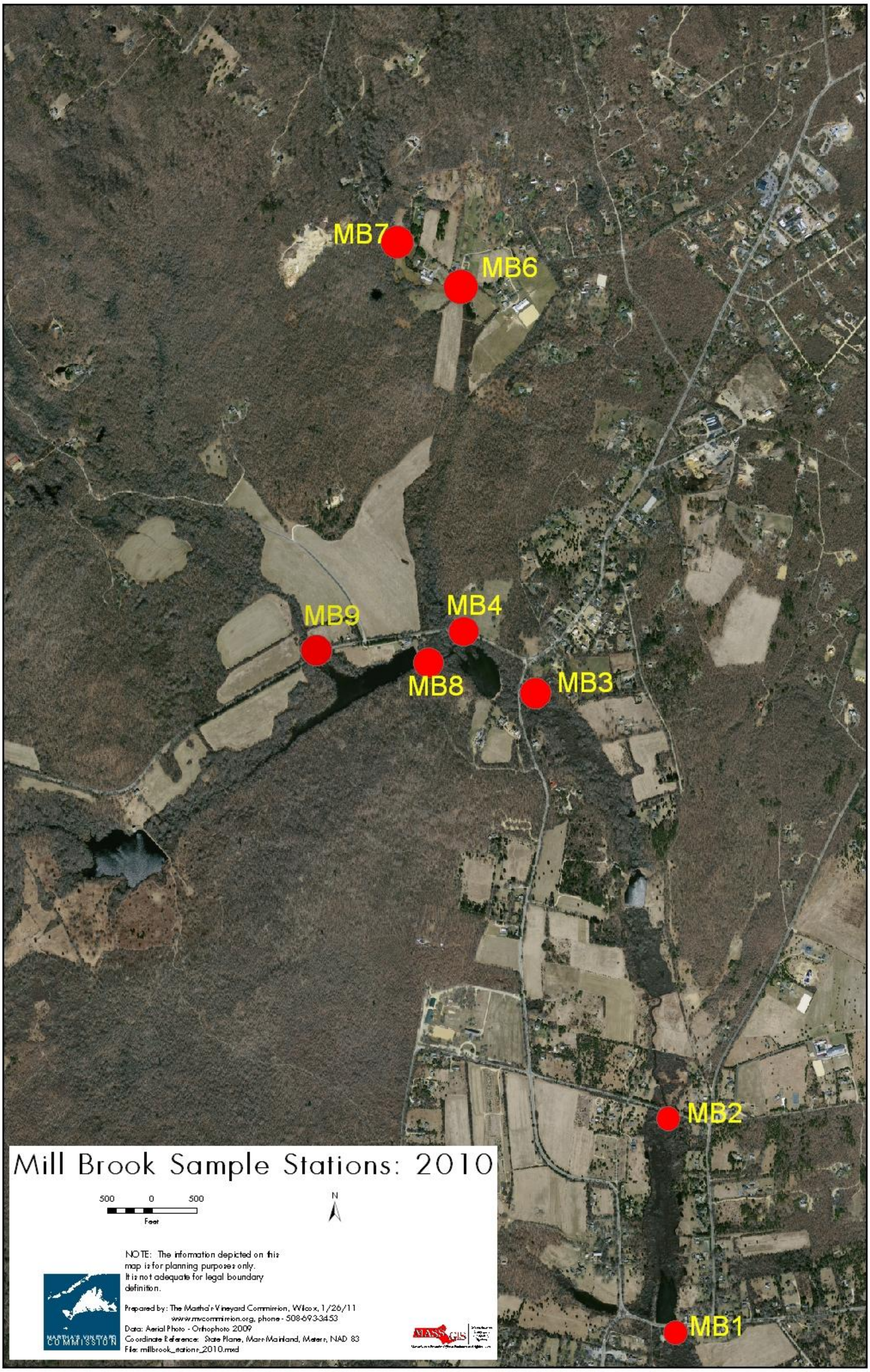
uM	micromoles Generally based on molecular weight and a fraction of a part per million
PO4	orthophosphate
TP	total phosphorus
NH4	ammonium
NOX	nitrate and nitrite
DIN	dissolved inorganic nitrogen that is the sum of NOX and NH4
DON	dissolved organic nitrogen such as urea or amino acids
POC	particulate organic carbon
PON	particulate organic nitrogen
C/N	carbon to nitrogen ratio
TON	total organic nitrogen that is the sum of PON and DON
TN	total nitrogen that is the sum of NOX, DON and PON

Table 1: Precipitation record

Month	Date	Rainfall in inches
April	10	0.1 +
	11	0.12
	17	0.76
	18	0.03
	26	0.39
	27	0.13
	28	0.03
April TOTAL		1.56
May	4	0.1
	14	0.03
	15	0.09
	19	3.00
	27	0.04
	30	0.08
May Total		3.34
June	2	0.07
	5	1.49
	10	0.41
	11	0.09
	13	1.58
	17	0.05
	23	0.29
	27	0.05
June Total		4.03
July	14	0.23
	15	0.2
	20	0.9+
	21	0.14
	24	1.61
	25	0.2
July Total		3.28
August	6	0.97
	17	0.35
	19	0.07
	23	0.83
	24	1.2
	25	1.45
	26	0.03
August Total		4.90

MILL BROOK

Sample ID	Depth	Date	PO4 (uM)	TP (uM)	NH4 (uM)	NOX (uM)	DIN (uM)	DON (uM)	TSS mg/L	POC (uM)	PON (uM)	C/N Ratio	TON (uM)	TN (uM)
MB1		4/26/2010	0.7	1.25	0.6	1.41	2.05	24.68	NA	36.65	2.64	13.91	27.32	29.36
MB1		6/1/2010	0.8	2.25	1.8	2.08	3.87	17.00	NA	70.82	5.26	13.46	22.26	26.13
MB1		7/27/2010	0.6	2.22	0.8	1.98	2.78	25.69	NA	48.50	3.75	12.94	29.44	32.23
MB1		8/30/2010	0.6	1.29	0.6	0.66	1.30	20.90	NA	44.98	3.41	13.19	24.31	25.62
	Mill Pond out		0.69	1.75		1.53	2.50	22.07		50.24	3.76			
MB2		4/26/2010	0.4	1.40	0.8	2.51	3.33	17.95	NA	47.06	3.35	14.04	21.30	24.63
MB2		6/1/2010	1.1	2.46	1.3	2.69	3.99	17.72	NA	40.18	2.95	13.60	20.67	24.67
MB2		7/27/2010	1.2	2.36	1.4	3.17	4.53	18.51	NA	53.43	3.91	13.67	22.42	26.95
MB2		8/30/2010	1.0	1.34	1.3	2.48	3.82	17.72	NA	36.79	2.55	14.45	20.27	24.08
	Scotchman's		0.93	1.89			3.92	17.97		44.37	3.19			
MB3		4/26/2010	0.7	1.37	0.7	1.76	2.49	15.32	NA	49.86	4.20	11.88	19.52	22.00
MB3		6/1/2010	0.7	2.21	1.4	1.45	2.88	15.50	NA	66.86	5.90	11.34	21.40	24.29
MB3		7/27/2010	1.0	1.99	1.6	1.30	2.93	23.10	NA	54.92	5.50	9.99	28.60	31.53
MB3		8/30/2010	0.7	1.69	1.8	1.19	3.00	19.49	NA	62.99	4.91	12.84	24.40	27.41
	Priester out		0.78	1.81			2.83	18.35		58.66	5.13			
MB4		4/26/2010	0.8	1.43	0.9	6.59	7.50	16.66	NA	96.00	8.92	10.76	25.58	33.08
MB4		6/1/2010	1.4	2.16	4.5	12.01	16.53	19.24	NA	32.52	2.45	13.27	21.69	38.22
MB4		7/27/2010	1.6	3.39	4.2	16.60	20.77	21.12	NA	193.14	11.07	17.45	32.19	52.96
MB4		8/30/2010	1.4	6.97	9.7	20.02	29.72	41.28	NA	1230.33	80.64	15.26	121.93	151.65
	Priester ephemeral		1.31	3.49			18.63	24.58		388.00	25.77			
MB5		4/26/2010	0.5	1.11	0.3	0.14	0.31	16.13	NA	106.98	7.25	14.75	23.38	23.69
			-24.31%	-24.62%	0.00%	86.52%	-9.25%	2.01%		-11.82%	-7.51%			
MB5		6/1/2010	1.5	2.17	4.4	12.11	16.54	18.36	NA	46.79	3.43	13.64	21.79	38.32
			1.82%	0.30%	-1.97%	0.81%	0.06%	-4.71%		15.19%	14.96%			
MB5		7/27/2010	0.3	0.88	1.5	3.02	4.56	16.95	NA	104.65	7.41	14.12	24.36	28.92
			0.00%	17.74%	-16.52%	-3.81%	-8.29%	-15.76%		64.79%	61.88%			
MB5		8/30/2010	0.6	1.62	0.6	0.67	1.23	25.03	NA	69.70	7.66	9.10	32.69	33.92
			0.00%	22.82%	-14.53%	1.61%	-6.01%	17.98%		22.76%	32.21%			
			-5.62%	4.06%	-8.25%	21.28%	-5.87%	-0.12%		22.73%	25.38%			
MB6		4/26/2010	0.3	1.11	3.2	5.76	8.99	17.74	NA	120.42	7.82	15.40	25.55	34.54
MB6		6/1/2010	0.4	1.70	7.3	3.82	11.07	17.70	NA	119.28	7.97	14.97	25.66	36.74
MB6		7/27/2010	0.5	1.30	3.2	4.81	7.97	19.34	NA	73.44	4.47	16.45	23.81	31.78
MB6		8/30/2010	0.6	1.52	5.4	5.70	11.08	27.02	NA	145.21	9.24	15.72	36.25	47.33
	Below Rogers		0.43	1.41			9.78	20.45		114.59	7.37			
MB7		4/26/2010	0.1	0.48	1.3	2.00	3.27	15.03	NA	93.57	5.26	17.78	20.30	23.56
MB7		6/1/2010	0.2	1.05	2.5	2.97	5.46	13.66	NA	51.94	2.86	18.16	16.52	21.98
MB7		7/27/2010	0.3	0.74	1.8	3.13	4.95	19.85	NA	55.90	3.03	18.43	22.89	27.84
MB7		8/30/2010	0.2	0.48	1.3	2.47	3.81	15.89	NA	50.55	2.86	17.68	18.75	22.56
	Above Rogers		0.20	0.69			4.37	16.11		62.99	3.50			
MB8		4/26/2010	0.7	1.11	0.3	0.05	0.34	15.81	NA	51.68	4.94	10.45	20.75	21.09
MB8		6/1/2010	0.8	2.12	0.5	0.14	0.54	19.25	NA	77.58	6.88	11.28	26.12	26.66
MB8		7/27/2010	0.7	1.51	0.4	0.29	0.34	21.67	NA	92.34	10.20	9.05	31.88	32.22
MB8		8/30/2010	0.4	1.12	0.3	0.07	0.36	21.87	NA	55.46	5.54	10.02	27.41	27.77
	Crocker out		0.66	1.47			0.40	19.65		69.27	6.89			
MB9		4/26/2010	0.4	0.77	0.4	0.13	0.50	30.02	NA	59.53	3.51	16.96	33.53	34.03
MB9		6/1/2010	0.5	0.98	1.0	0.98	1.98	14.34	NA	73.49	3.27	22.46	17.61	19.59
MB9		7/27/2010	0.9	1.24	0.8	2.06	2.86	18.27	NA	39.47	1.86	21.19	20.13	22.99
MB9		8/30/2010	0.8	1.09	0.6	1.41	1.96	16.44	NA	30.59	1.60	19.18	18.04	20.00
	Witch Brook		0.66	1.02			1.82	19.77		50.77	2.56			


MB7
MB6
MB9
MB4
MB8
MB3
MB2
MB1
Mill Brook Sample Stations: 2010
500 0 500
Feet
N
NOTE: The information depicted on this map is for planning purposes only. It is not adequate for legal boundary definition.
Prepared by: The Martha's Vineyard Commission, Wilcox, 1/26/11
www.mvcommission.org, phone - 508-693-3453
Data: Aerial Photo - Orthophoto 2009
Coordinate Reference: State Plane, Mass Mainland, Meters, NAD 83
File: millbrook_stations_2010.mxd
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