APPENDIX A – Water Monitoring Reports

Water Monitoring Results

for 2006

Molly Ann Brook 319h

Contract RPF# RP06-079

Watershed Restoration Project

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Introduction

This report summarizes the results of the first season of stream monitoring conducted by William Paterson University on the waters of Molly Ann Brook, Passaic County, New Jersey (HUC Code 02030103120040). The overall goal of the monitoring program is to support planning for the restoration and protection of Molly Ann Brook. The project is conducted under a non-point source pollution 319(h) grant NJDEP # RP-06-079.

Field and analytical procedures used by William Paterson University and by other certified laboratories on this project along with sample site descriptions are detailed in the Quality Assurance Protection Plan (QAPP - Preakness Brook 319(h) Project – NJDEP# RP-05-086) as amended for Molly Ann Brook. For the purpose of this report, the map showing sample locations is included in Figure 1. There were six main-stem sampling stations as indicated on the map and several tributary sampling locations all of which are also listed in Table 1 below (and Tables 6a and b at the end of the report). It is important to note that sampling sites were deliberately chosen to avoid any influence of CSOs located along Molly Ann Brook in Paterson. Station 6, furthest downstream, was located a few hundred meters upstream from the first CSO encountered by the Brook in Paterson.

Table 1: Sampling locations along Molly Ann Brook and its tributaries.

Site id #	Site Name	Latitude (N)	Longitude (W)
1	High Mountain inlet to Haledon Reservoir	40°58.839’	74°12.208’
1a	Franklin Lakes Wetland	40°59.134’	74°12.110’
2	Buehler Cultural Center & Pool	40°58.104’	74°11.421’
2a	East High Mountain	40°58.048’	74°11.402
3	North Haledon Municipal Complex	40°57.213’	74°11.133’
3a	Squaw Brook	40°57.507’	74°11.163’
4	Manchester High School/High Mountain Road	40°56.463’	74°10.993’
4a	Quarry	40°57.007’	74°10.843’
4b	WPUNJ	40°57.015’	74°11.226’
4c	Terrace	40°57.184’	74°11.033’
4d	Haledon Avenue	40°56.455’	74°11.015’
4e	Eastern Christian	40°56.709’	74°10.870’
5	Belmont Avenue Bridge	40°55.899’	74°11.059’
6	Preakness Avenue Bridge/AMNET AN0276	40°55.275’	74°11.646’

Molly Ann Brook is a tributary of the Passaic River with a watershed area of approximately 20.0 km^2 (7.80 mi^2). The stream’s headwaters are on High Mountain along the border of Wayne, North Haledon and Franklin Lakes. A full description of its course can be found in the QAPP document reference above. Presentation and discussion of all existing, publicly-available water quality data for Molly Ann Brook can be found in the Addendum to that same QAPP.

Monitoring Results

Precipitation

When evaluating non-point-source pollution, runoff has to be considered as one of the primary variables controlling the transport of potential pollutants from the land surface into flowing and standing water bodies. That runoff will be directly related to precipitation events in the watershed. Later on in this report we will discuss direct measurements of discharge. However, the importance of precipitation is such that all of the following discussions should be viewed within the context of rainfall events during the monitoring period. Therefore, summary graphs of local 24-hour precipitation graphs are included here as Figure 2 (a thru d) for August through November 2006.

Several potential sources of precipitation data should be adequate for the purposes of this study:

1. The weather stations maintained by William Paterson University on the main campus at the Science Building and at Oldham Pond directly on Molly Ann Brook in North Haledon. Both of these stations collect and record precipitation events at 1 hour intervals continuously.

2. The weather stations in Little Falls on the grounds of the Passaic Valley Water Commission and in Wayne at the Mountain View Water Treatment Plant. These stations record rainfall at 15 minute intervals continuously, and the results are reported on the internet. However, the data from these sites are not always consistently reported on the web.

3. The weather station in Caldwell. Daily rainfall values are consistently reported from this site on the internet. However, the Caldwell site is some distance from the Molly Ann Brook watershed and the results may vary significantly from primary sources.

Overall, qualitatively, the 2006 monitoring season was a wet one; especially the 30-day period in which the 5-in-30 TMDL sampling was conducted. Some of the sampling was conducted during significant rain events. Due to the extremely short runoff collection times for this urban watershed, sampling results need to be evaluated on time spans as short as 15 minutes. These events are addressed in the discussion below.

The relationship between water quality and runoff is complex but, in general, we may expect the following generalizations to hold:

1. Rainfall will dilute most of the inorganic, dissolved species such as sodium, potassium, calcium, chloride, and possibly sulfate (see discussion below). This is because base flow to Molly Ann Brook comes from groundwater that has a relatively long residence time in low-yielding

aquifers (Houghton, 1990) within the valley. Groundwater flow through these aquifers is primarily through fractures. These factures contain abundant salts including calcite and sulfates which dissolve into the groundwater.

2. Runoff from the urban environment dominated by single family homes on lots with lawns will result in the solution and washout of fertilizers. Thus, increases in nutrients may be expected to correspond with rainfall events.

3. Runoff will wash fecal material from wildlife and pets into the stream channel. The resilience of live coliform bacteria in standing fecal matter has been well established (Walesh, 1989; Pitt & Burton, 2002). Thus, rainfall events can be expected to result in elevated fecal levels in the stream – a "first-flush effect".

Biological Monitoring

Fecal Coliforms

Seven sets of fecal samples were collected on dates and at sites as listed in Tables 1 and 6a & 6b. The fecal coliform sampling was carried out in two stages. The first stage was a "5-in-30" series designed to fulfill the requirements for establishing a fecal TMDL for the stream. It is our intention to repeat this series in 2007. Sampling started on August 18 (the first day of the grant) and ended on September 15, 2006. Due to the continuing high temperatures well into the Fall of 2006 and based on the results of the "5-in-30" sampling, a preliminary "trackdown" sampling was conducted on November 9, 2006. Further attempts at "trackdown" were subsequently suspended until the Spring of 2007.

Samples were analyzed (see project QAPP for analytical details) for total fecal coliforms and *E. coli*. *E. coli* are a component species among all coliform bacteria and are considered to be a better indicator of human fecal contamination; hence, a more reliable indicator of biological hazard than overall fecal contaminant values. *E. coli* concentrations should be and were always lower than total coliform concentrations. On three dates some or all samples were analyzed at the William Paterson Laboratory as check samples.

The six graphs within Figure 3 (a thru f) summarize the results of the "5-in-30" sampling – the last figure is the geometric mean of the 5 days of sampling. The results for each analysis are plotted against distance upstream on the main Molly Ann channel from its confluence with the Passaic River in West Side Park in Paterson. Figure 3f shows the overall geometric mean for all measurements of *E. coli* relative to total fecal coliforms. This ratio varies with a very narrow range between 0.4 and 0.6 which is very close to the same results obtained on Preakness Brook in Wayne. This suggests that *E.*

coli may have limited value above and beyond fecal coliform as an indicator of human fecal contamination.

Figure 4 is a map that summarizes the results of an initial attempt at "tracking-down" possible sources of fecal contamination in Molly Ann Brook. The map has sample sites labeled with total fecal coliform and *E. coli* results for the November 9th sampling series.

Macroinvertebrates

Macroinvertebrates present in the stream water and on stream bed surfaces were collected using fine nets placed across the stream to collect organisms released into the stream water by disturbance of the bed. Samples were collected for analysis on the September 22, 2006 at the following locations (these results are preliminary):

Table 2: Macroinvertebrate Sampling – 2006 season

Site ID	Site (refer to Figure 1)	Total # Taxa	%EPT
MAB1	Above Haledon Reservoir	4	56
MAB2	Buehler Pool	12	73
MAB3	Municipal Complex	9	69
MAB4x	Bayer – 100 m upstream of Manchester HS	13	36

This project started late in the field collection season for macroinvertebrate sampling. Previous work on Molly Ann Brook reported in the addendum to the QAPP found a consistent decline in water quality indicated by macroinvertebrate population downstream from the outlet of Oldham Pond. Those findings appear to still hold true for Molly Ann Brook. Sample counting and classification is still in progress as is the final calculation of all indices and statistics.

Sampling for macroinvertebrates within the channelized portion of Molly Ann (sites MAB4, 5 and 6) will be considerably more difficult than sampling at sites upstream because the Brook is fenced in and there are few points where the channel has appropriate characteristics for safe and meaningful sampling. During the 2007 season we intend to re-visit all stations and resample.

Water Quality

Some water quality variables can only be measured accurately in situ in the field. Others require the collection of field samples, their preservation and transport to a laboratory where they can be analyzed at some time after collection. Field measurements can be made at discrete intervals using one or more instruments or recorded continuously by remotely-deployed automatic instruments capable of continuously monitoring the stream water for a set of variables at a particular site and from which those data are either collected at a later date or continuously transmitted to a collection station.

In-situ Measurements

Discrete

During three of the sample monitoring series, standard water quality variable were measured at each of the six main-channel sites. – temperature, conductivity (specific conductance), dissolved oxygen, pH and some turbidity measurements. These data can be supplemented for purposes of interpretation with a substantial amount of field measurements of the same variable made by us in prior studies. There is also a small number of field measurements reported by the USGS along with laboratory analytical results in a few of their yearly water quality reports. Figure 5 (a thru d) summarizes these measurements by plotting the values as a function of distance upstream fro the confluence of Molly Ann Brook with the Passaic River.

There were no major sources of surface water with altered temperature to affect the water temperature of Molly Ann Brook; hence, water temperature was simply a function of the air temperature – in general increasing somewhat from its source on High Mountain to its confluence with the Passaic River.

Conductivity (or specific conductance which is the value of conductivity corrected to 25^{o}C) is a measure of the total dissolved species in the water and varies primarily with precipitation – since rain generally has low dissolved ions, its conductivity is low – approaching 0. Historically base flow stream water in Molly Ann Brook has a conductivity of about 200 uS (the unit of conductivity and specific conductance is the Seimen, generally recorded as micro-Seimens or uS). Runoff containing road salt and evaporation and evapo-transpiration of stream and pond water result in increased concentration of dissolved salts which leads to elevated conductivity typically in the range of 400 to 600 uS. During droughts or during very warm intervals, stream conductivity may increase to more than 1000 uS.

Continuous

On four occasions in 2006 a YSI 6920 water quality sonde was deployed successfully at two locations along Molly Ann Brook – twice at Oldham Pond for the periods 8/27 to 9/8 and 10/27 to 11/7; and twice at the Bayer site (about 100 meters upstream from the MAB4 site at Manchester HS) for the period 9/14 to 22 and 10/10 to 20.

Deploying the sonde successfully is challenging. It is a complex and temperamental instrument that has to perform delicate measurements with precision and accuracy in a hostile environment. That hostile environment is both natural (extreme range of stream discharge and heavy burden of organic activity) and manmade (vandalism). The sonde, therefore, has to be carefully placed both to measure water quality accurately and survive stream conditions and harm by humans.

For the most part, the sonde (as indicated in Figure 6 thru 9) appears to have operated successfully and accurately with the exception of the dissolved oxygen measurement for the period September 14 to 22, 2006. The membrane of the DO probe became clogged with organic matter which likely caused the low DO readings. These low readings are inconsistent with almost all other DO measurements on the stream during this and previous analytical seasons.

Laboratory Analysis

Two sets of laboratory analysis of water quality variables were made on samples collected under this phase of the project:

1. The contract certified analytical laboratory (Integrated Analytical Laboratories) conducted nutrient analyses (dissolved N & P) on samples collected at the same time and location as bacteriological samples.

2. Analyses of major dissolved ions and nutrient were also conducted at the certified analytical laboratory of William Paterson University at Oldham Pond.

Figure 10 summarizes the results of nitrogen analyses obtained by the certified contracted analytical laboratory on the “5-in-30” sample set collected in August and September.

Phosphorous was so rarely detected by the method employed by the certified laboratory that it can be summarized as only a few discrete measurements in the table below:

Table 3: Detectable phosphorus levels in Molly Ann Brook

Date	Site	P (ug/L)
8/25/06	MAB4 – Manchester HS	111
8/25/06	MAB5 – Belmont Avenue	75
8/25/06	MAB6 – Preakness Avenue	74

Analyses of major ions were conducted at the certified laboratory of William Paterson University. All major anions and cations were analyzed. The results are summarized in a single tri-linear diagram presented in Figure 11.

Discharge

As noted above under Precipitation, water runoff across land surfaces into the waters of the Brook can be expected to have a significant if not controlling influence on water quality. Ideally one would like to know the discharge of the stream at every point (or at least at every sampling site) along the main stem channel continuously over time.

This would be prohibitively expensive to accomplish. While measurements of discharge are an integral part of this project, some combination of data sources has to be made in order to arrive at the desired values.

The potential sources of discharge measurements are as follows:

1. Overall mean values of discharge based on comparison with other local streams.
2. Direct, discrete measurements of instantaneous discharge made at specific locations via standard USGS stream flow gauging methods (cross-section & velocity profile method).
3. Stream stage from the USGS gage at North Haledon (#013896809). Although this gage monitors stage continuously at 15 minute intervals, it is a flood stage gage only and does not record base flow.
4. Continuous stream velocity and water depth monitoring using a Doppler flow meter. This approach has the potential to provide quality data automatically, but requires that a rating curve be established via simultaneous discrete discharge measurements. There were also technical problems with this approach as discussed below.
5. Synthesis of discharge at any point within the watershed based on computer modeling.

The overall, mean annual discharge of the Molly Ann Brook watershed at its mouth should be approximately 11.76 cfs (0.333 m^3/s) based on comparison with other regional watersheds.

Because of the emphasis placed on collecting the bacteriological and macroinvertebrate samples during the end of the collection season in the Fall of 2006, only five discharge measurements were made on the upper reaches of the Brook. The results of these measurements were made so far and are summarized in Table 4 below:

Table 4: Discharge measurements for 2006 sampling season.

Site	Date	Time	cfs	m^3/s
Haledon Reservoir inlet MAB1	10/6/06	09:25	0.220	0.0062
Buehler Pool & Cultural Center MAB2	10/6/06	09:45	2.717	0.0769
N. Haledon Municipal Complex MAB3	10/6/06	10:15	3.998	0.1132
Oldham Pond Outlet MAB4x	10/6/06	10:30	7.529	0.2132
Haledon Avenue MAB4y	10/6/06	11:00	0.406	0.0115

The sum of the last two sites in this table (7.935 cfs, or 0.2247 m^3/s) should be the discharge at the Manchester MAB4 location. (We were not able to reach the MAB4 site directly because the lock on the gated fence was rusted closed.)

Although the USGS does maintain a flood-stage warning station at the Municipal Complex site (MAB3) along Molly Ann Brook, very few other discharge measurements have been made by the Survey and there is no rating curve for the flood gage. This is unfortunate because the gage does provide good stage data during storms when it is impossible to obtain discharge by cross-sectional methods due to the extreme ”flashiness” of the stream. Attempts will be made in the Spring of 2007 to “catch the tail” of some storm peaks via cross-sectional methods and develop a rating curve for this USGS gage which can be correlated with precipitation at Oldham Pond which is only a few hundred meters downstream.

Several attempts were made during the late summer and fall of 2006 to establish a Doppler stream velocity/depth gage at the outfall of Oldham Pond. Unfortunately, both equipment units malfunctioned, and one was completely destroyed. A new unit is on order and will be installed as soon as it arrives. This unit should be capable of recording all flow stages of the Brook at any interval of time desired along with velocity and temperature.

Ideally, whatever discrete or continuous discharge measurement that can be made at individual sites in conjunction with measured precipitation will be used to calibrate a watershed-wide stream flow model such as SWMM or equivalent. Once that model is developed then discharge at any point in the watershed over any time period can be derived. Those data can then be used to evaluate the loads for such variables as fecal bacteria and nutrient from any portion of the watershed under known conditions. The task of preparing such a model is assigned to the engineering consultant for this project.

Discussion & Summary

Bacteriological

There were few times when fecal coliform levels at any of the monitored sites along Molly Ann Brook were at or below the 200 cfu/100 ml standard for the stream's designated uses. Concentrations above 20,000 cfu/mL were measured at the Belmont Avenue site on August 25, 2006. Except for one site (Buehler MAB2) the geometric mean of total fecal coliform was above 1000 cfu with a marked increase in total fecal coliform and *E. coli* at the two downstream sites (Belmont Avenue MAB5 and Preakness Avenue MAB6).

The relationship between fecal coliform levels and precipitation strongly supports the hypothesis presented above; namely, that high coliform concentrations are associated with storm events. Table 5 below summarizes total fecal coliform concentrations on different days along with a qualitative summary of weather conditions preceding and during sample collection. The fecal coliform numbers reported here were "normalized" by dividing each day's measured value at each sampling site by the geometric mean values reported in Figure 3 and then taking the average of each of the six sites for that date.

Table 5: Summary results of fecal coliform levels and precipitation events within the Molly Ann Brook watershed for the 2006 sampling season

Date	"Normalized" fecal coliform (measured/mean)	Weather conditions
August 18, 2006	0.499	Moderate rain 2 days prior
August 25, 2006	2.821	Light rain during sampling preceded by 8 dry days
September 12, 2006	0.308	Preceded by 5 dry days
September 14, 2006	2.784	Heavy rain during sampling
September 15, 2006	2.498	Heavy rain during sampling

Fecal concentrations were high during the three days on which it was raining during the sampling period, and low on two days when there had been a dry spell of two to five days. It had not rained for 8 days prior to the August 25th series during which collection precipitation was about 0.5 inch. This event had the highest "normalized" fecal coliform concentrations. Similarly, the September 14th sampling was conducted during a precipitation event of nearly 1 inch of rain and had been preceded by 7 dry days.

The results from the series of "trackdown" samplings conducted on November 9, 2006 suggest that the major source of elevated fecal coliform was downstream from the Manchester HS site MAB4; i.e., it is likely within the channelized portion of Molly Ann Brook within the town of Haledon and City of Paterson. Fecal coliform levels in all of the "trackdown" samples from minor tributaries of Molly Ann were, however, above the

200 cfu/100 mL standard with a general increase in levels downstream. A portion, if not all of that bacterial population in these samples is almost certainly due to the large waterfowl population in the middle section of the watershed.

Macroinvertebrates

The results so far of the macroinvertebrate sampling seem to confirm the observation that stream habitat quality declines markedly below Oldham Pond.

Water Quality

Field Measurements

Field measurements of water quality variables made along the length of Molly Ann Brook on three dates revealed the following trends:

- A slight increase in temperature going downstream.
- After an initial jump in pH going downstream, the Brook's waters attained a uniform pH and remain slightly alkaline.
- There was a general increase in conductivity downstream except during rainfall events when conductivity declines markedly.
- Dissolved oxygen levels were, for the most part, at saturation or even super-saturation levels during these daytime sampling events.

The sonde results for two sites showed that there was a very narrow but discernible range in pH, DO and temperature due to diurnal fluctuations. pH especially varied over a very narrow range. Night time levels of dissolved oxygen as recorded by the sonde did not fall far below 60 to 70% saturation. Conductivity, on the other hand, was seen to vary significantly (as much as a factor of 5 or 6) due to precipitation events.

Laboratory Measurements

Nutrient N levels measured on samples from each site along the Brook on five different days and summarized in Figure 10 appear to show a consistent dip in nitrate level at site MAB4, Manchester HS and another dip at site MAB6 at Preakness Avenue superimposed on a general overall increase in nitrate-N downstream.

The one set of major ion analyses conducted on samples collected on August 18, 2006 and presented in the tri-linear diagram in Figure11 revealed two distinct trajectories – one trajectory for upstream samples that is characteristic of urban streams and reflects a dual increase in chloride, sodium and sulfate over distance, and a second trajectory for the downstream samples which was dominated by an increase in % sodium and potassium with little change in the relative proportion of other ions.

Discharge

The few discharge measurements that were made seem to indicate a near-linear trend in discharge versus distance along the channel (see Figure 11). If this relationship holds up with further data it should facilitate the calculation and estimation of discharge overall for the stream. The linear trend line projected to the mouth of the stream yielded a value fairly close to the mean annual discharge for Molly Ann Brook (0.333 m^3/sec) noted above.

References

Houghton, H., 1990, "Groundwater in the Newark Basin," in Aspects of Groundwater in New Jersey: Seventh Annual Meeting of the Geological Association of New Jersey, October 26-27, 1990, Brown, J.O., and Kroll, R.L., eds.

Pitt, R.E., and Burton, G.A., 2002, Stormwater Effects Handbook: A Toolbox for Watershed Managers, Scientists & Engineers, Lewis Publishers, CRC Press, 896 pp.

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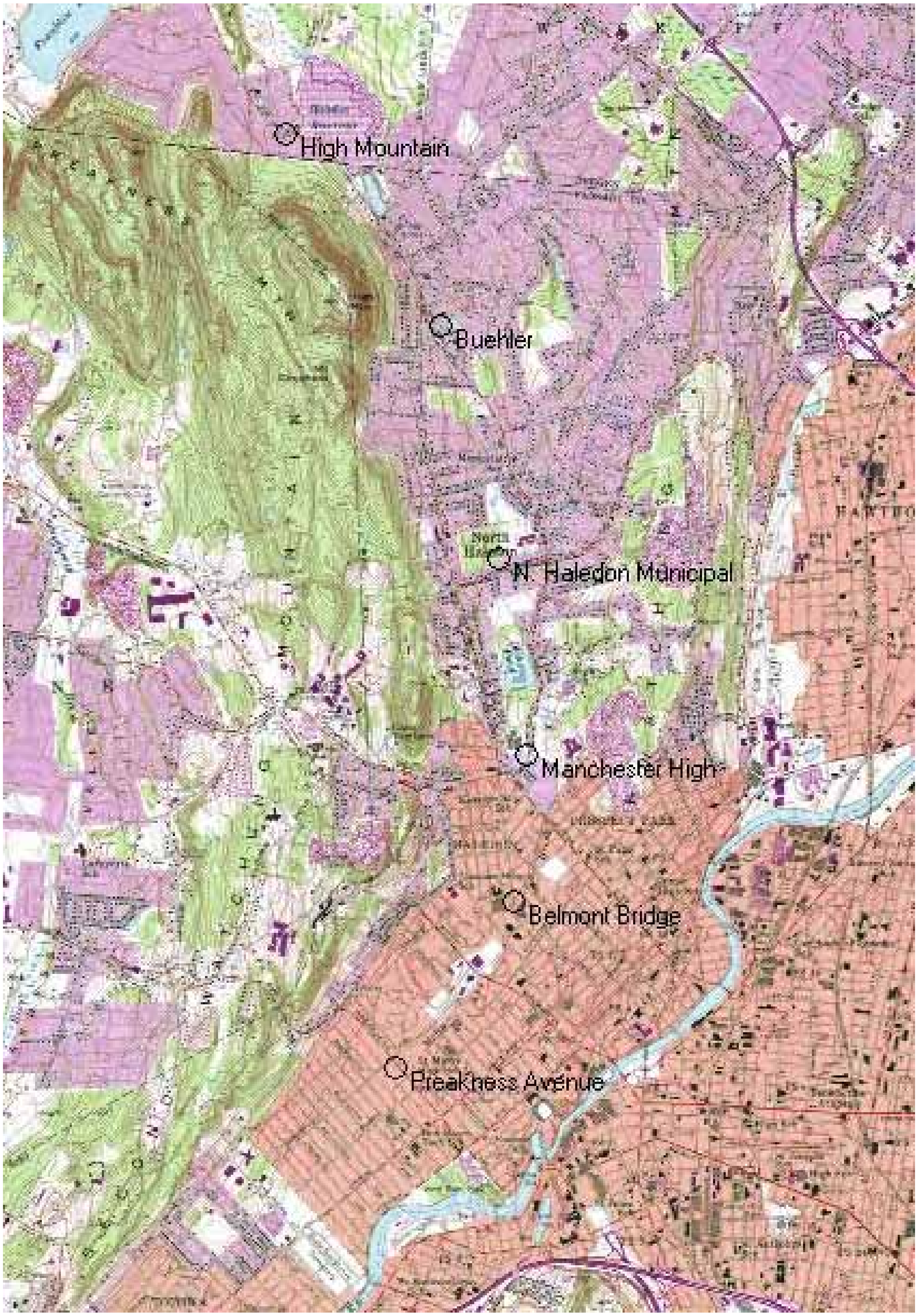


Figure 1 – Molly Ann Brook Watershed Sampling Sites

Table 6a. Molly Ann Brook Watershed Sampling Sites and Collection Form – Main Stem Sites:

Lower Passaic River Alliance – WMA4
Molly Ann Brook 319h
Restoration and Protection Fecal Coliform & BST Sampling 2006/2007
Dr. Richard R. Pardi or Dr. Michael Sebetich & students, William Paterson University
Samples delivered to ______________________________

Flow Conditions: ______________________________
Date: ______________
Time: ______________

Sample id	Site Name	Sampling Time	Latitude	Longitude	Parameters Monitored
MAB1	High Mountain inlet to Haledon Reservoir		40°58.839'	74°12.208'	
MAB2	Buehler Cultural Center & Pool		40°58.104'	74°11.421'	
MAB3	North Haledon Municipal Complex		40°57.213'	74°11.133'	
MAB4	Manchester High School/High Mountain Road		40°56.463'	74°10.993'	
MAB5	Belmont Avenue Bridge		40°55.899'	74°11.059'	
MAB6	Preakness Avenue Bridge/AMNET AN0276		40°55.275'	74°11.646'	

Table 6b. Molly Ann Brook Watershed Sampling Sites and Collection Form – Tributary Sites:

Lower Passaic River Alliance – WMA4
Molly Ann Brook 319h **Flow Conditions:** ______________________________
Restoration and Protection Fecal Coliform & BST Sampling
2006/2007 **Date:** ____________
Dr. Richard R. Pardi or Dr. Michael Sebetich & students, William Paterson University
Samples delivered to __________________________________ **Time:** ____________

Sample id	Site Name	Sampling Time	Latitude	Longitude	Parameters Monitored
MAB1a	Franklin Lakes Wetland		40^{o}59.134’	74^{o}12.110’	
MAB2a	East High Mountain		40^{o}58.048’	74^{o}11.402	
MAB3a	Squaw Brook		40^{o}57.507’	74^{o}11.163’	
MAB4a	Quarry		40^{o}57.007’	74^{o}10.843’	
MAB4b	WPUNJ		40^{o}57.015’	74^{o}11.226’	
MAB4c	Terrace		40^{o}57.184’	74^{o}11.033’	
MAB4d	Haledon Avenue		40^{o}56.455’	74^{o}11.015’	
MAB4e	Eastern Christian		40^{o}56.709’	74^{o}10.870’	

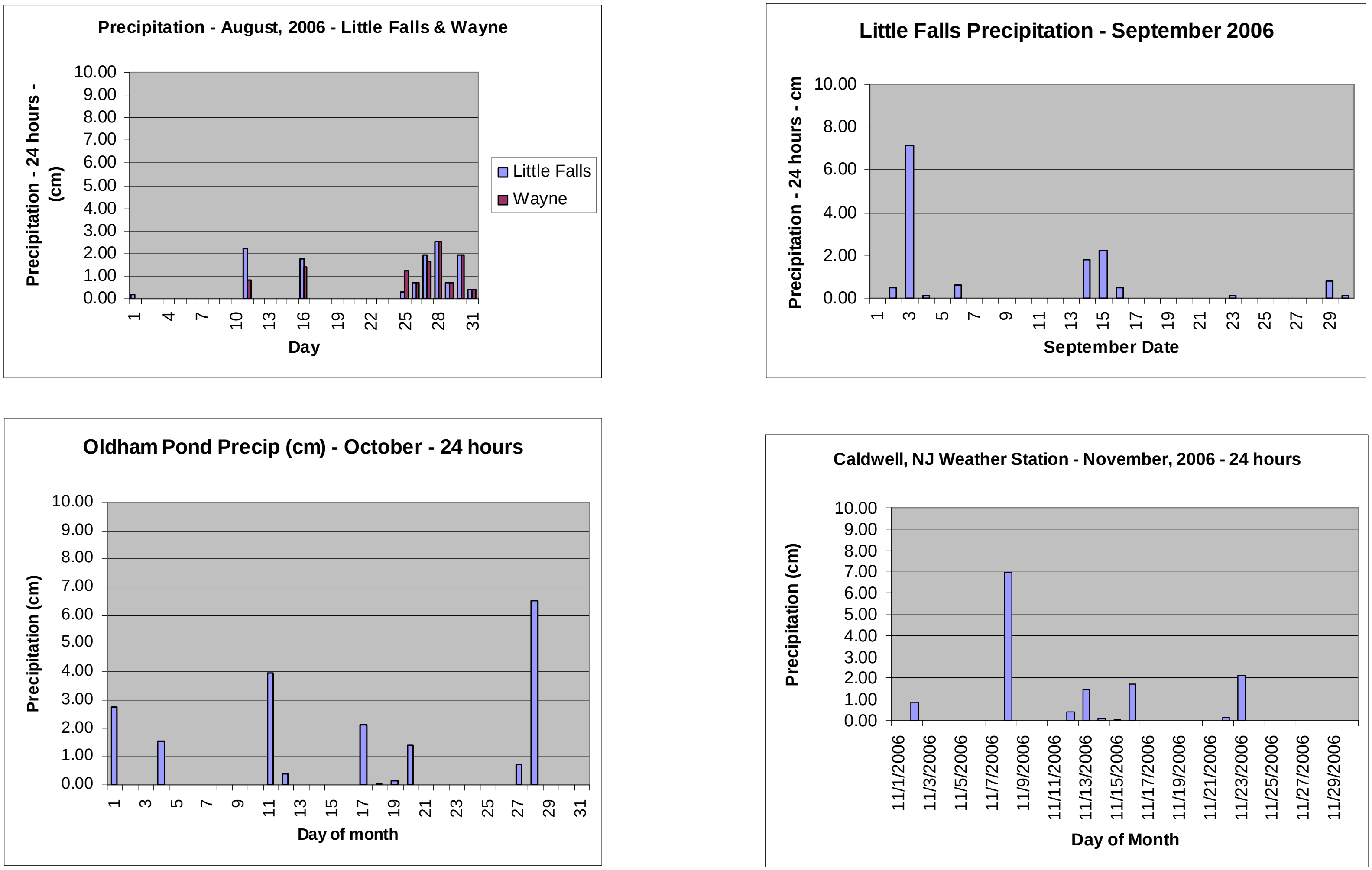


Figure 2a thru d: Precipitation measured at several different local weather stations. Data from Oldham Pond is available to replace all of this surrogate data for future analyses.

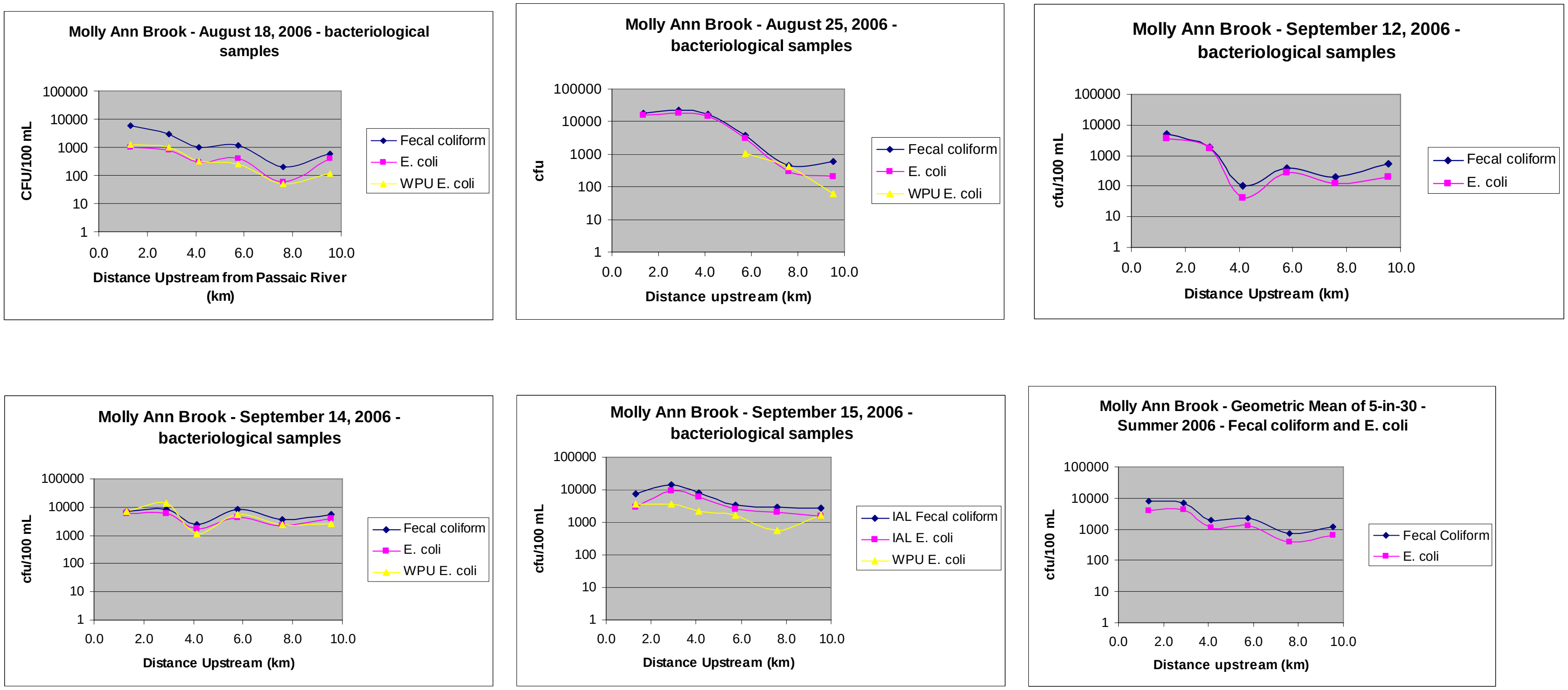


Figure 3a thru f: Total fecal coliform and *E. coli* results for “5-in-30” sampling of Molly Ann Brook conducted between August 18 and September 15, 2006.

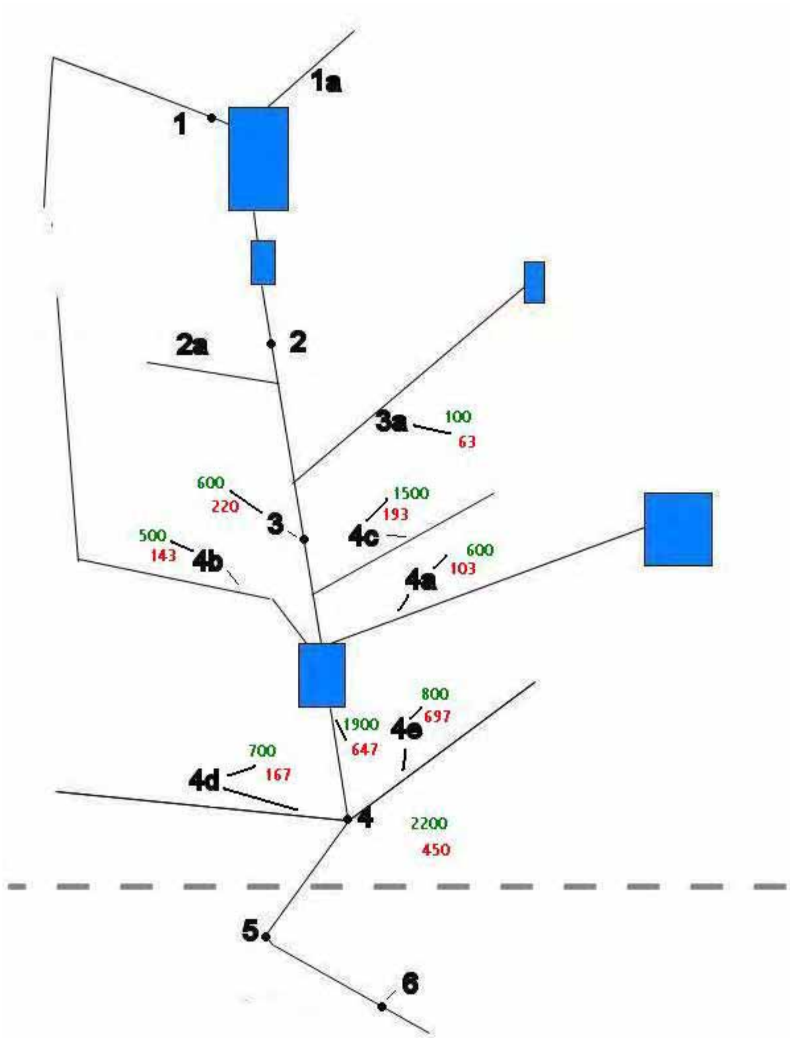


Figure 4: Summary of "trackdown" sampling conducted November 9, 2006. Green values are total fecal coliform and red are *E. coli* in cfu/100 mL.

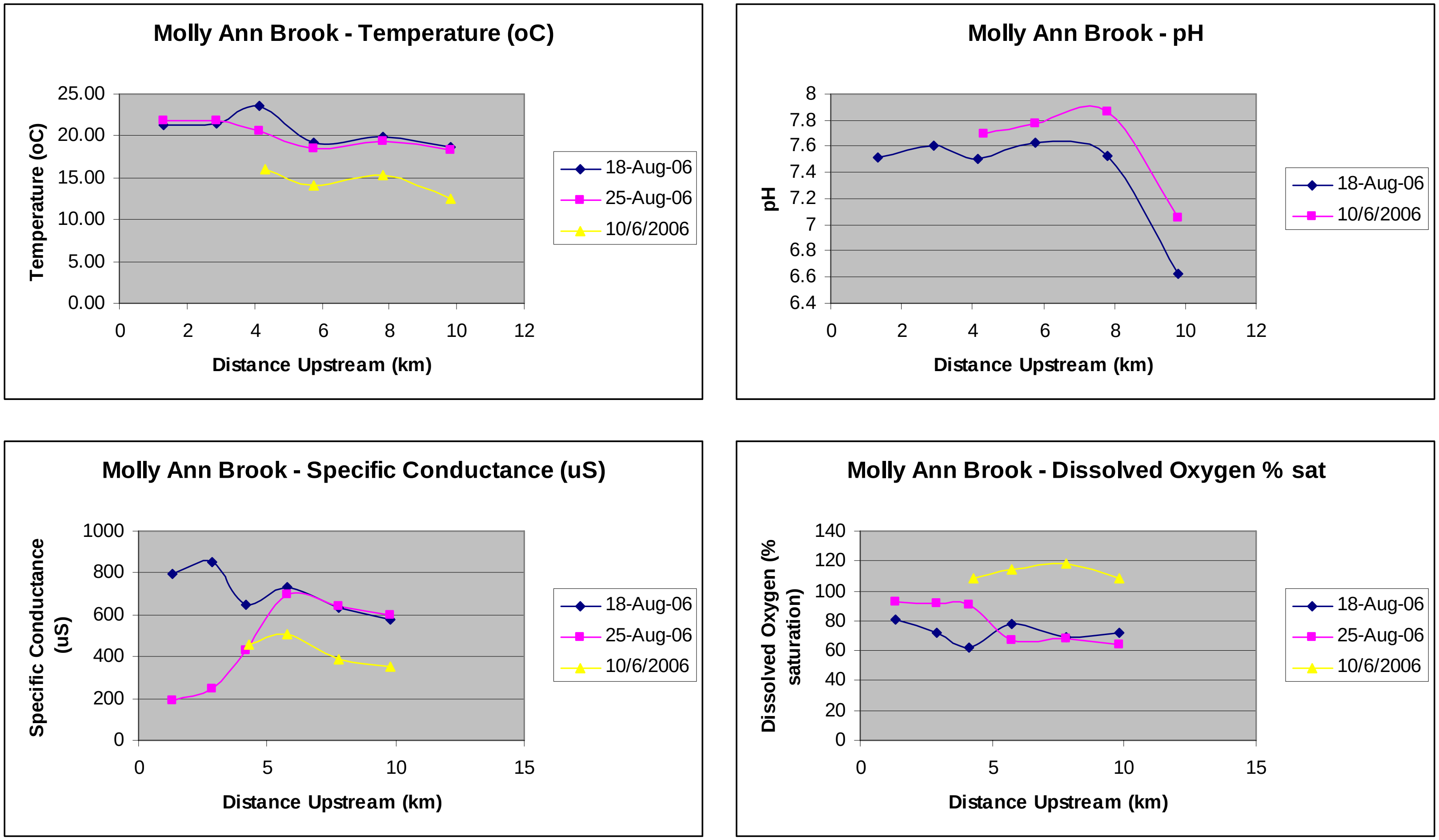
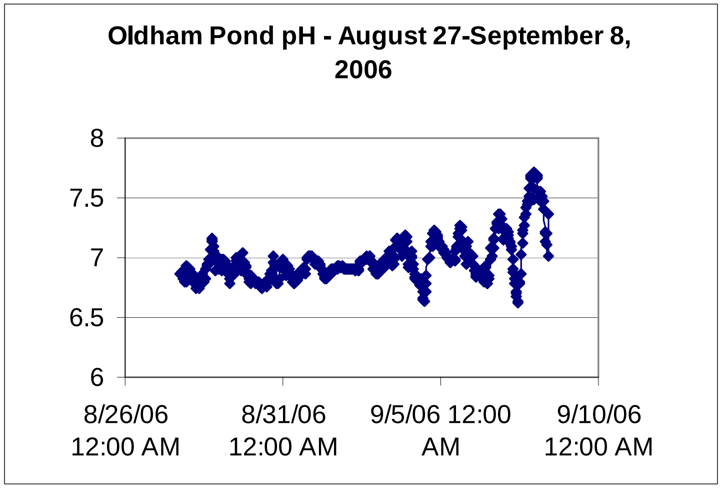
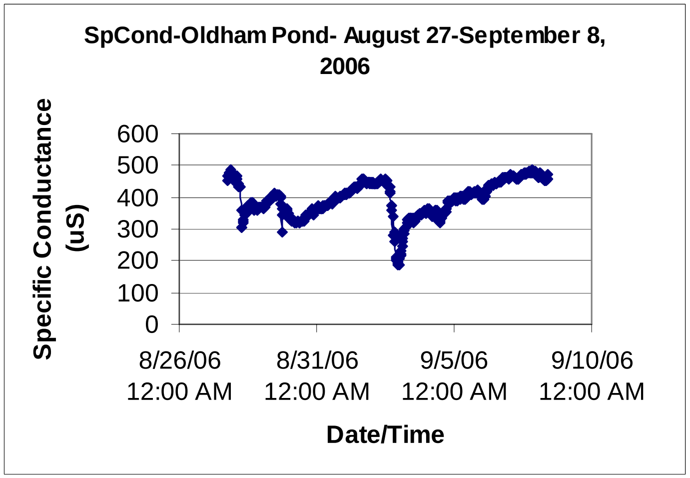
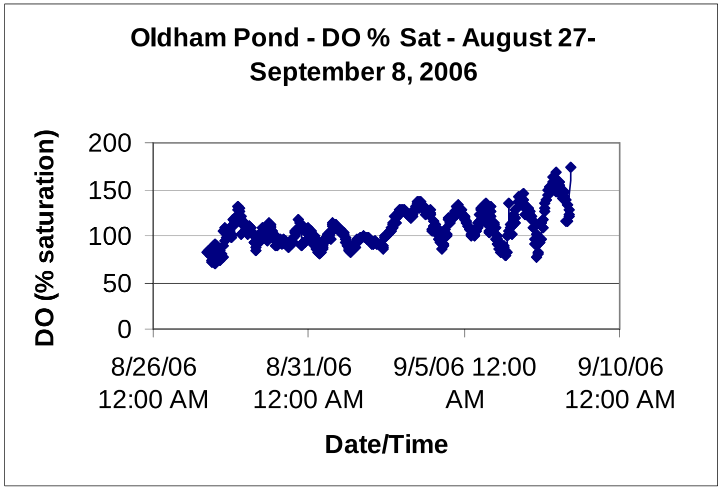


Figure 5: Field measurements of water quality variables made on three different days during 2006 monitoring season along Molly Ann Brook.







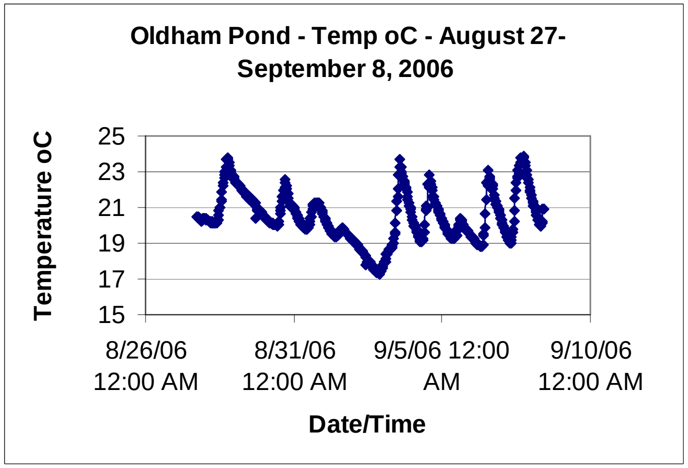
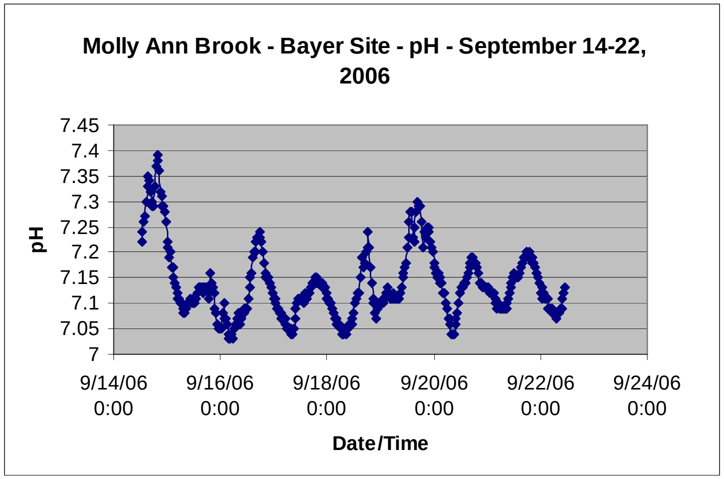
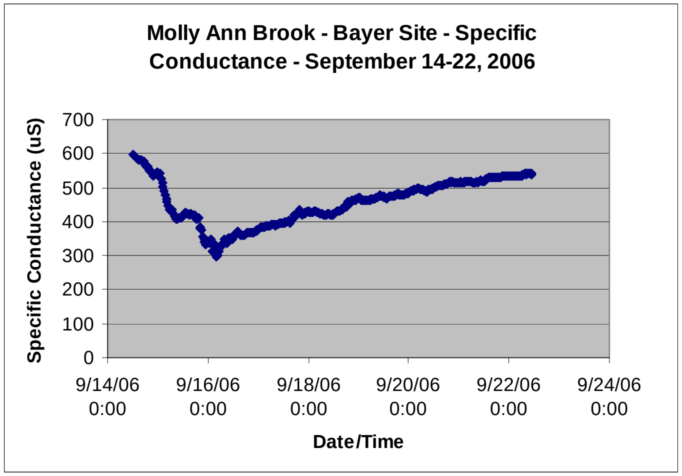
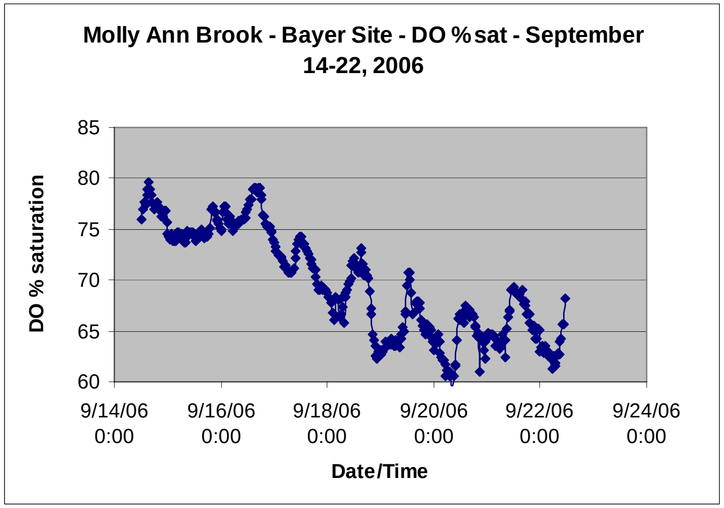


Figure 6: Results of deployment of the YSI 6920 sonde in Oldham Pond from August 27 to September 8.







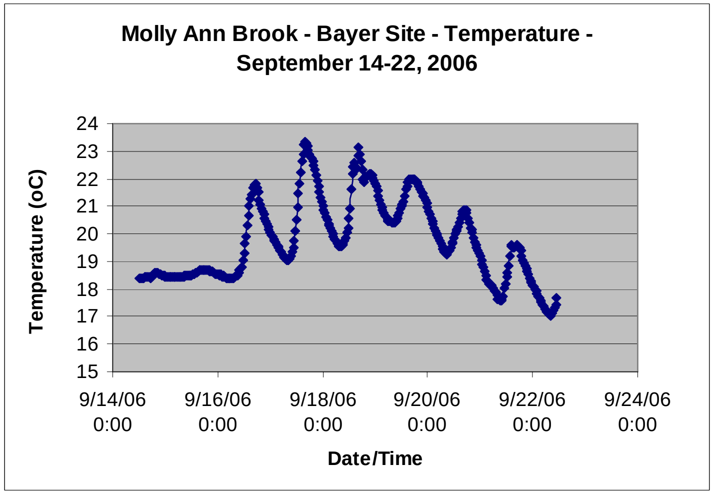
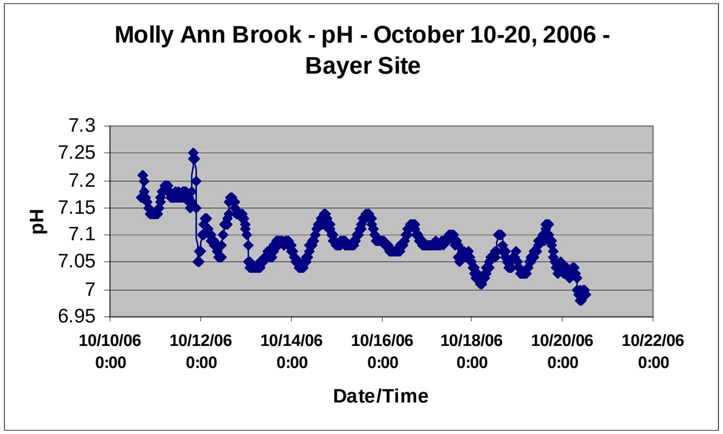
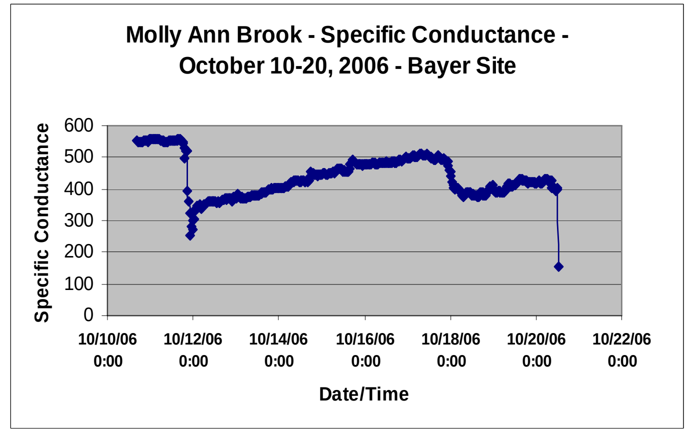
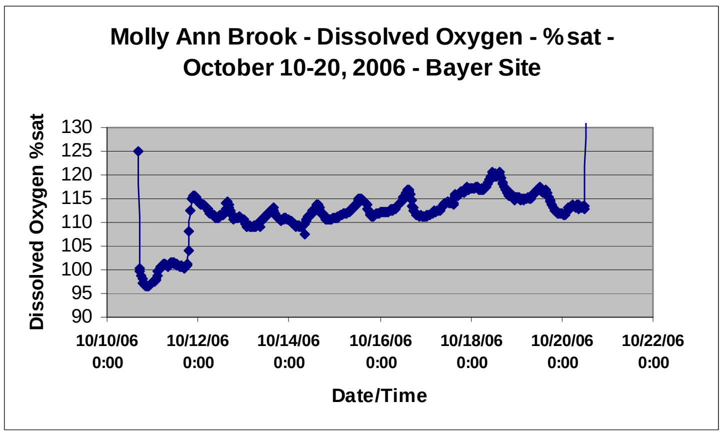


Figure 7: Results of the deployment of the YSI 6920 sonde for the period September 14 to 22 at the Bayer site – about 100 m upstream from site MAB4 at Manchester HS.







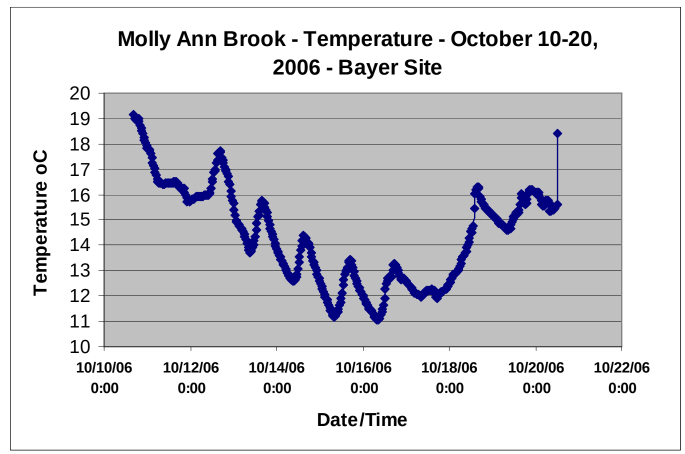
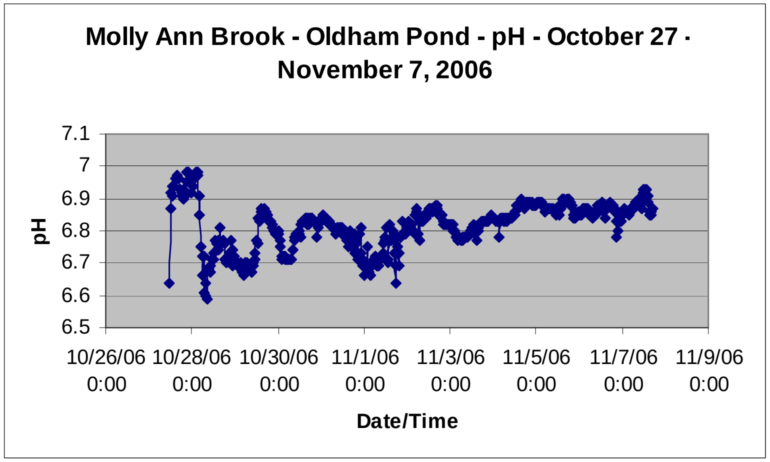
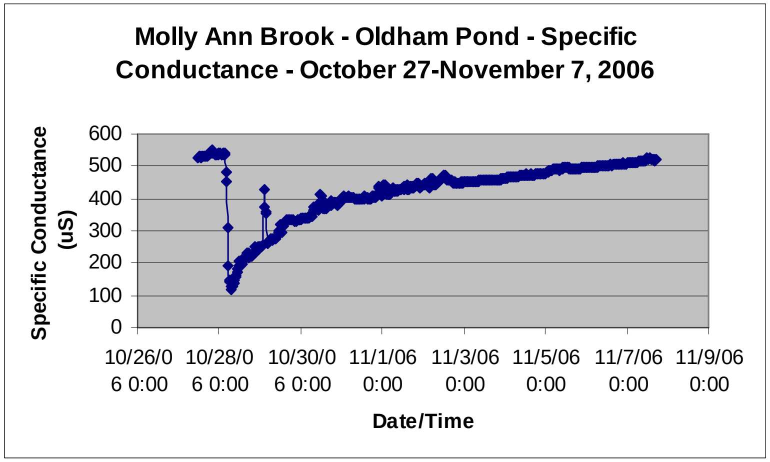
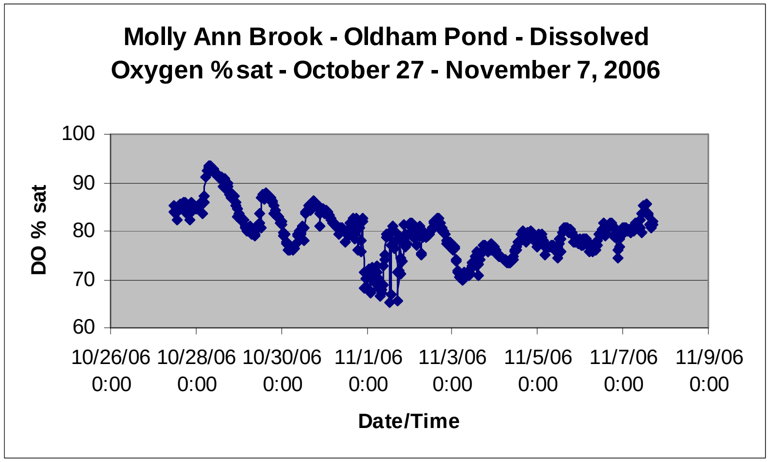


Figure 8: Results of the deployment of the YSI 6920 sonde at the Bayer site for the period October 10 to 20, 2006. This site is approximately 100 m upstream from site MAB4 at Manchester HS. Spikes at the start and end of these series are due to disturbance during placement and removal of the sonde.







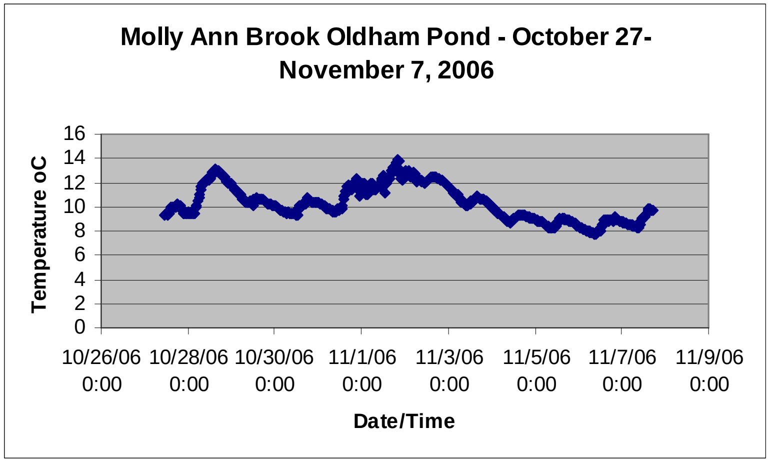


Figure 9: Results of the deployment of the YSI 6920 sonde at Oldham Pond for the period October 27 to November 7, 2006.

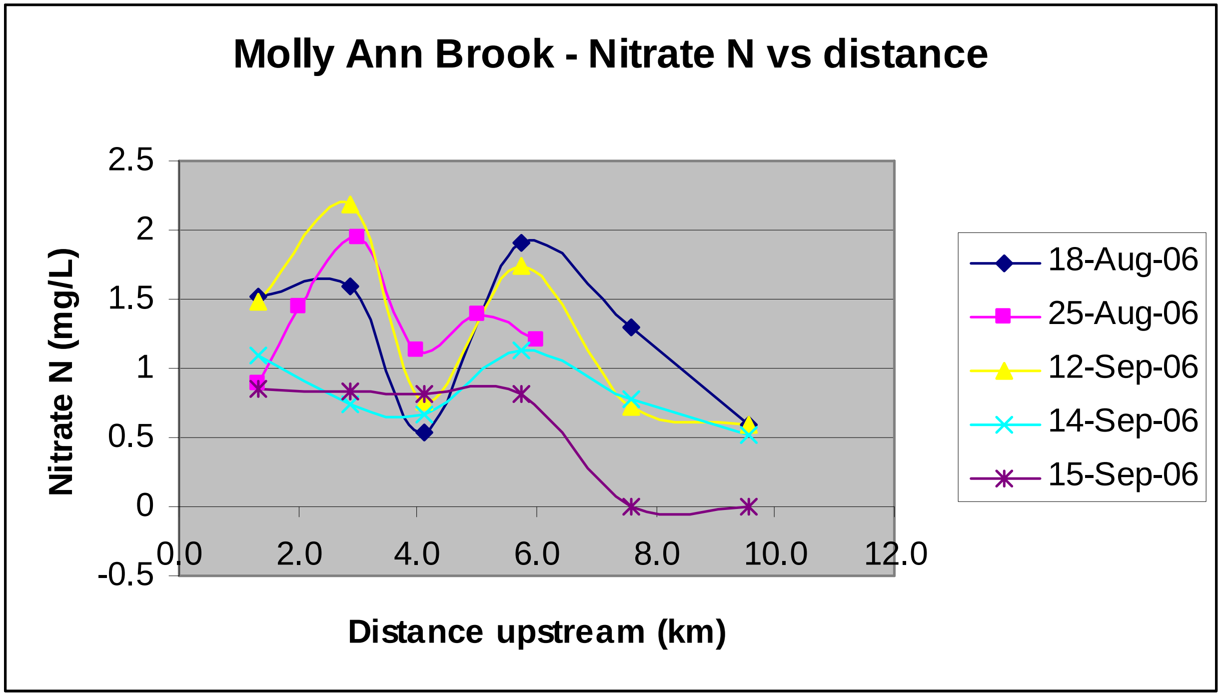


Figure10: Dissolved inorganic nitrate N in Molly Ann Brook at each of the six sampling sites along Molly Ann Brook for the five sampling dates of the "5-in-30" sampling period between August 18 and September 15, 2006.

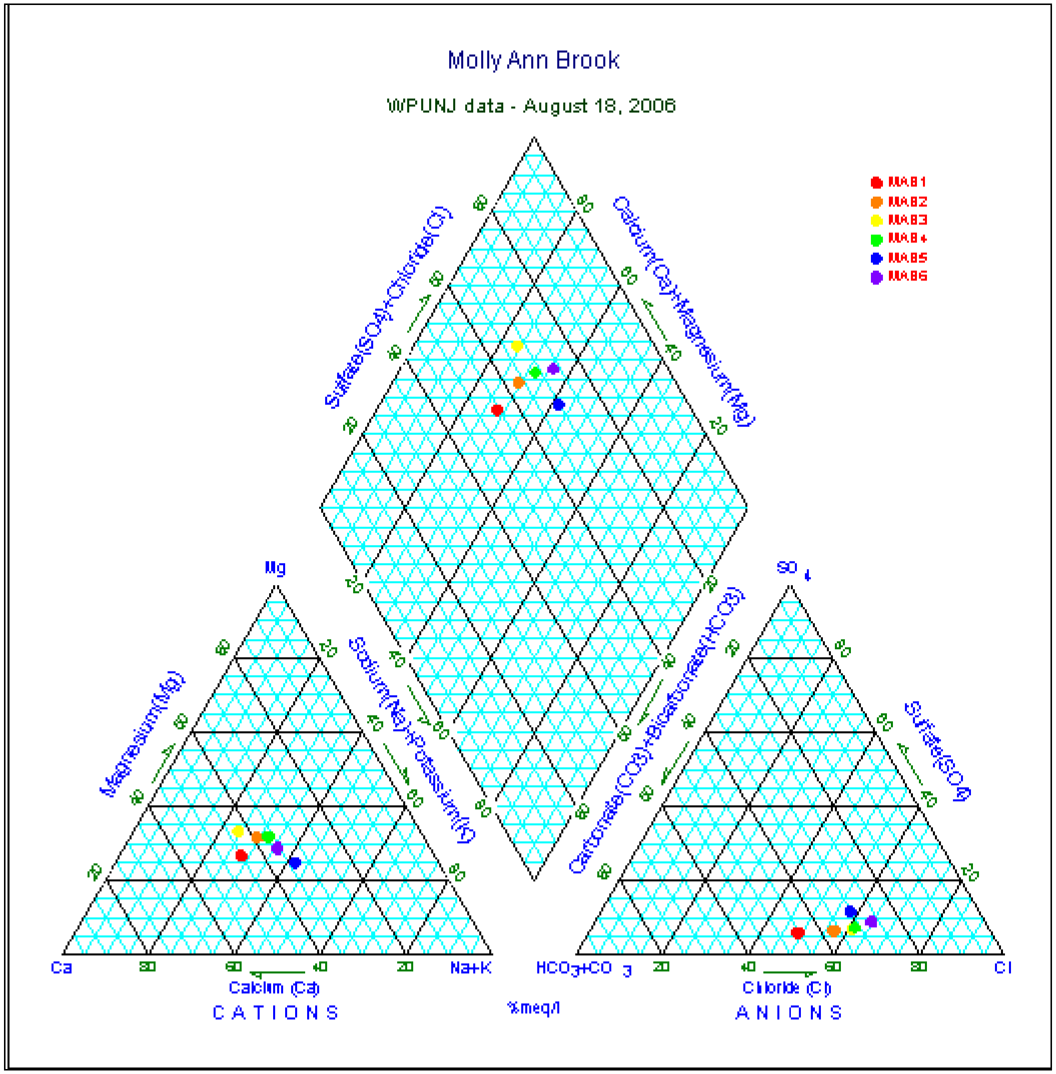


Figure 11: Tri-linear diagram generated from analytical data derived from samples collected August 18, 2006.

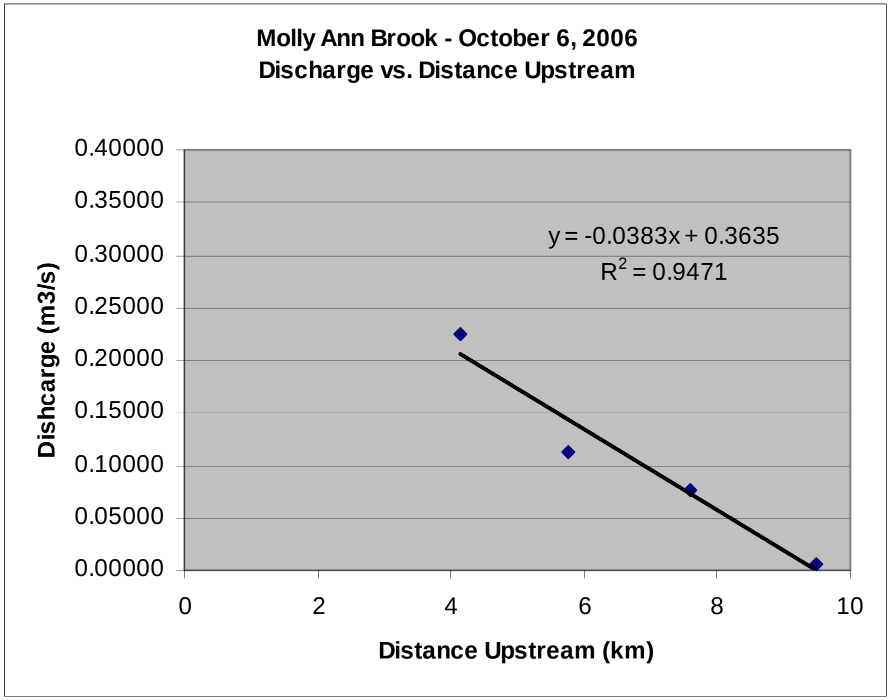


Figure 12: Discharge measurements at 4 upstream sites along Molly Ann Brook measured on October 6, 2006.

Water Monitoring Results

for 2007

Molly Ann Brook 319h

Contract RPF# RP06-079

Watershed Restoration Project

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Tables

Introduction

This report summarizes the results of the second season of stream monitoring conducted by William Paterson University on the waters of Molly Ann Brook, Passaic County, New Jersey (HUC Code 02030103120040). The overall goal of the monitoring program is to support planning for the restoration and protection of Molly Ann Brook. The project is conducted under a non-point source pollution 319(h) grant NJDEP # RP-06-079. This report for the 2007 sampling season compliments the previous report submitted for the 2006 sampling season. An overall summary of the results for both seasons is contained in the preceding Executive Summary.

Field and analytical procedures used by William Paterson University and by other certified laboratories on this project along with sample site descriptions are detailed in the Quality Assurance Protection Plan (QAPP - Preakness Brook 319(h) Project – NJDEP# RP-05-086) as amended for Molly Ann Brook. For the purpose of this report, the map showing sample locations is included in Figure 1. There were six main-stem sampling stations as indicated on the map and several tributary sampling locations all of which are also listed in Table 1 below (and Tables 4a, b and c at the end of the report). It is important to note that sampling sites were deliberately chosen to avoid any influence of CSOs located along Molly Ann Brook in Paterson. Station 6, furthest downstream, was located a few hundred meters upstream from the first CSO encountered by the Brook in Paterson.

Site id #	Site Name	Latitude (N)	Longitude (W)
1	High Mountain inlet to Haledon Reservoir	40°58.839’	74°12.208’
1a	Franklin Lakes Wetland	40°59.134’	74°12.110’
2	Buehler Cultural Center & Pool	40°58.104’	74°11.421’
2a	East High Mountain	40°58.048’	74°11.402
3	North Haledon Municipal Complex	40°57.213’	74°11.133’
3a	Squaw Brook	40°57.507’	74°11.163’
4	Manchester High School/High Mountain Road	40°56.463’	74°10.993’
1x	Haledon Avenue Bridge	40°56.218’	74°10.898’
2x	Ida Street Bridge	40°56.164’	74°10.928’
3x	Post Street Footbridge	40°56.104’	74°10.936’
4x	Roe Street Bridge	40°56.044’	74°10.974
5x	Clinton Street Bridge	40°55.963’	74°11.004
4a	Quarry	40°57.007’	74°10.843’
4b	WPUNJ	40°57.015’	74°11.226’
4c	Terrace	40°57.184’	74°11.033’
4d	Haledon Avenue	40°56.455’	74°11.015’
4e	Eastern Christian	40°56.709’	74°10.870’
5	Belmont Avenue Bridge	40°55.899’	74°11.059’
6	Preakness Avenue Bridge/AMNET AN0276	40°55.275’	74°11.646’

Table 1: Sampling locations along Molly Ann Brook and its tributaries.

Molly Ann Brook is a tributary of the Passaic River with a watershed area of approximately 20.0 km^2 (7.80 mi^2). The stream’s headwaters are on High Mountain along the border of Wayne, North Haledon and Franklin Lakes. A full description of its course can be found in the QAPP document reference above. Presentation and discussion of all existing, publicly-available water quality data for Molly Ann Brook can be found in Section II of this report.

Monitoring Results

Precipitation

When evaluating non-point-source pollution, runoff has to be considered as one of the primary variables controlling the transport of potential pollutants from the land surface into flowing and standing water bodies. That runoff will be directly related to precipitation events in the watershed. Later on in this report we will discuss direct measurements of discharge. However, the importance of precipitation is such that all of the following discussions should be viewed within the context of rainfall events during the monitoring period. Therefore, summary graphs of local 24-hour precipitation graphs are included here as Figure 2 (a thru f) for April through September 2007.

The weather station maintained by William Paterson University at Oldham Pond directly on Molly Ann Brook in North Haledon has provided all the data needed to evaluate weather conditions at all times during the sampling season. This station collects and records precipitation events and other meteorological variables at 1 hour intervals continuously.

Overall, qualitatively, the 2007 monitoring season was even wetter than the 2006 one; rainfall for the 6-month period from April to September 2007 was above normal. In graphs of monitoring results that follow, rainfall for the 48 hour period preceding sampling and relative discharge at the time of sampling are indicated.

The relationship between water quality and runoff is complex but, in general, we may expect the following generalizations to hold:

1. Rainfall will dilute most of the inorganic, dissolved species such as sodium, potassium, calcium, chloride, and possibly sulfate (see discussion below). This is because base flow to Molly Ann Brook comes from groundwater that has a relatively long residence time in low-yielding aquifers (Houghton, 1990) within the valley. Groundwater flow through these aquifers is primarily through fractures. These factures contain abundant salts including calcite and sulfates which dissolve into the groundwater.

2. Runoff from the urban environment dominated by single family homes on lots with lawns will result in the solution and washout of fertilizers. Thus, increases in nutrients may be expected to correspond with rainfall events.

3. Runoff will wash fecal material from wildlife and pets into the stream channel. The resilience of live coliform bacteria in standing fecal matter has been well established (Walesh, 1989; Pitt & Burton, 2002). Thus, rainfall events can be expected to result in elevated fecal levels in the stream – a "first-flush effect".

Biological Monitoring

Fecal Coliforms

Seven sets of fecal samples were collected on dates and at sites as listed in Tables 1 and 4a, b and c. Sites listed in Table 4b and c within the channelized section of Molly Ann Brook and along Squaw Brook were added during this sampling season. A sampling was also conducted on September 26, 2007 along Squaw Brook in an attempt to identify potential sources of fecal contamination along that tributary. The additional sites along Squaw Brook are identified in Figure 4.

The fecal coliform sampling was carried out in three stages. The first stage was conducted on two dates – May 16 and June 19, 2007. The goal of these preliminary studies was to establish whether or not the high levels of fecal bacteria observed during the 2006 season were continuing into 2007. The results of these studies confirmed that observation. Therefore, a detailed "5-in-30" sampling program was designed and conducted. The second stage was a "5-in-30" series designed to fulfill the requirements for establishing a fecal TMDL for the stream. Sampling started in June, 2007 and ended inn July , 2007. As with last year's monitoring, continued warm temperatures into the Fall 2007 allow some bacteriological "track-down" sampling which along with some targeted studies conducted during this summer constitute a third phase of the sampling.

Samples were analyzed (see project QAPP for analytical details) for total or fecal coliforms and *E. coli*. *E. coli* are a component species among all coliform bacteria and are considered to be a better indicator of human fecal contamination; hence, a more reliable indicator of biological hazard than overall fecal contaminant values. *E. coli* concentrations should be and were always lower than total coliform concentrations. Samples were analyzed for fecal coliform and E. coli by Integrated Analytical Laboratories (IAL) in Randolf, New Jersey. On several dates some or all samples were analyzed at the William Paterson Laboratory as check samples. Note that William Paterson results are for <u>total</u> coliforms and *E. coli.*

The six graphs within Figure 3 (a thru f) summarize the results in units of concentration of the "5-in-30" sampling – the last figure is the geometric mean of the 5 days of sampling. The results for each analysis are plotted against distance upstream on the main Molly Ann channel from its confluence with the Passaic River in West Side Park in Paterson. Figure 3f shows the overall geometric mean for all (IAL) measurements of *E. coli* and fecal coliforms. Not shown in this report (see 2006 report) is the ratio of E. coli to fecal coliform which continues to vary within a very narrow range between 0.4 and 0.6.

The results continue to demonstrate that Molly Ann Brook exceeds the MCL for both fecal and *E. coli* bacteria for all stations along the Brook for every sampling date. The pattern of geometric or exponential increase in fecal bacteria concentration down stream continues to be observed as it was for the 2006 sampling season.

The same results of the “5-in-30” sampling are reported in Figures 3g through l as loads instead of concentration. These loads have been calculated using measured or calculated discharge for each sampling site for each date of sampling. There is a dramatic increase in load between the first two stations (above Haledon Reservoir and Buehler Pond), and a more gradual increase in load downstream. Some settling of bacteria in Oldham Pond appears to be indicated by the consistent “dip” in concentration and load that appears between station 3 and 4 (North Haledon Municipal Complex and Manchester HS).

A third stage of sampling was conducted on four dates so far – June 26, June 28, July 18 and September 26, 2007 The results of the first three dates are contained in figures 3n through p. The results of the September 26 sampling can be seen in Figure 4 which is a schematic map that summarizes the results of an attempt at “tracking-down” possible sources of fecal contamination entering from Squaw Brook into Molly Ann Brook. The map has sample sites labeled with *E. coli* results for this sampling series. The concentration of fecal bacteria within the channelized section of Molly Ann Brook on June 26 & 28 (Figure 3c) does not provide any strong indication of a potential source of fecal bacteria along that stretch of the stream. The sampling on July 18 was conducted during a storm event along the same, channelized section of the stream and shows the notable increase in bacterial concentration during a storm. Although Squaw Brook does appear to contribute a modest level of bacterial load to the main stream, the most remarkable feature of this sampling series was the absence of any bacteria at the Passaic County Bridge 139 site where Saw Mill Road crosses Squaw Brook. This lack of bacteria parallels an observed fish kill in which several dace were observed either dead or dying in the stream. A likely cause of both observations may be the disposal of swimming pool or hot tub water directly to the stream without pre-treatment.

Macroinvertebrates

Macroinvertebrates present in the stream water and on stream bed surfaces were collected using fine nets placed across the stream to collect organisms released into the stream water by disturbance of the bed. This is known as the kicknet method (Hilsenhoff, 1988; Klemm, et al., 1990; Plafkin, et al., 1989). Samples were collected for analysis on the dates and at the locations listed in Tables 2a through e on the following pages. In addition to the samples collected for this project, some available data from samples collected along Molly Ann Brook in 2003 are also presented since they provide important information about the effects on habitat of stream channelization carried out between 2003 and 2006.

Three different indices of habitat condition are used in the discussion below and presented in the graphs and tables that accompany that discussion – the biotic index, the % EPT (macroinvertebrate fraction composed of orders *Ephemeroptera, Plecoptera and Tricoptera*), and a count of the total number of macroinvertebrate orders present (order richness).

The biotic index has been calculated as follows:

$$\frac{\sum o_i * bs_i}{n}$$

where, o_i is the number of organism of an order, bs_i is the Biotic score of that family (Hilsenhoff, 1988) and n is the total number of organisms of all orders.

Biotic order index

A total of six stream sites were sampled in 2006-2007 (Tables 2a through e). This method revealed no major differences in the biotic order index among the sites on Molly Ann Brook (Fig. 1 at end of this discussion). The mean index ranged from 1.8 at the Buehler site to 5.1 (Municipal and Manchester sites). The lower the index value the higher the water quality.

The total number of organisms (16 and 22) per sampling effort was always lowest at MAB1 (High Mountain), the uppermost site on the section of the stream that entered North Haledon Reservoir. At MAB1 the stream was most narrow and had the least discharge of the six major sampling sites. Thus, low biotic diversity and abundance were expected at MAB1, and we should not place much weight on the quantitative results from this site. This is why we discount the highest biotic order index (5.42) calculated for that site.

At MAB2 (Buehler), two samplings resulted in a biotic order indices of 1.85 and 4.84. Although, the data for all sites indicate no major differences, MAB2 yielded the lowest mean index (3.34) of all sampling sites. This site may be heavily influenced by runoff from the adjacent parking lot.

MAB3 (Municipal Building, N. Haledon) was sampled three times. One side of the stream is heavily shaded with trees in summer and the opposite side abuts municipal athletic fields. The east shore of MAB3 has undergone significant erosion and scouring by Molly Ann Brook during recent storm events. The biotic order index ranged from 3.52 to 5.11 with a mean of 4.33 (n = 3).

MAB4 (Manchester H.S.) was located at the upper end of the stream channelization designed by the Army Corps of Engineers for flood control in the downstream municipalities. The sampling site was completely open (no cover) and the sides were of rip-rap and concrete walls. As expected, MAB4 yielded the highest biotic order index mean (5.01; n = 2) of all sampling sites. Another location, called the Bayer (Lanxess) Site, was sampled once, and had a biotic index of 3.95. The Bayer Site was located between Oldham Pond dam and MAB4 and the data have been combined with that for MAB4 about 200 meters downstream. At the Bayer site, Molly Ann Brook flows along the eastern edge of a former industrial lot that is now undergoing mitigation. A small amount of water is discharged to Molly Ann Brook from the pump and treat operation on the site. That discharge is minor compared to normal flow in the stream.

MAB5 (Belmont Avenue Bridge) was sampled once and had a biotic order index of 4.18. This site was adjacent to the parking lot of the Aquino Colonial Funeral Home on Belmont Avenue and just downstream of the Belmont Avenue Bridge in Haledon. It is highly influenced by runoff from the urban surroundings.

MAB6 (Preakness Avenue) was located in Paterson, and the macroinvertebrate sampling site was upstream of the Preakness Avenue Bridge. The mean biotic order index was 4.07 (n = 2).

General observations on the macroinvertebrates sampled

Except for MAB1, mayfly larvae (Ephemeroptera) were sampled at all locations. Mayflies are generally considered indicators of clean water, and many mayfly species would be absent in an urban stream such as Molly Ann Brook. However, we did not identify to species or family, but only to taxonomic order. A more detailed analysis, to family or species, would reveal a stronger interpretation of stream water quality and the presence or absence of mayflies in Molly Ann Brook.

Caddisfly larvae (Tricoptera) were sampled at all sites. They are generally considered clean water indicators, because many of the case-building species are found only in clean waters. However, the non-case builders that were sampled in Molly Ann Brook are found in a variety of freshwaters including lower-water-quality urban streams.

EPT %

Using the kicknet method, the resulting EPT % for the six major sites averaged about 45% (see Fig.1). Generally, the higher the percentage of Ephemeroptera, Plecoptera and Tricoptera, as a group, the higher the water quality. As expected, the lowest EPT % (19%) was found at MAB4 (Manchester), but two of the highest were at the most urban downstream sites, Belmont (64%) and Preakness (54%). The highest EPT % was at MAB 2 Buehler (73%) and the next highest at MAB3 Municipal Bldg (68%) both on Sep 22, 2006. Again, probably the presence of not so sensitive mayfly and caddisfly larvae in the most downstream samples resulted in an artificially high EPT % indicator of higher water quality.

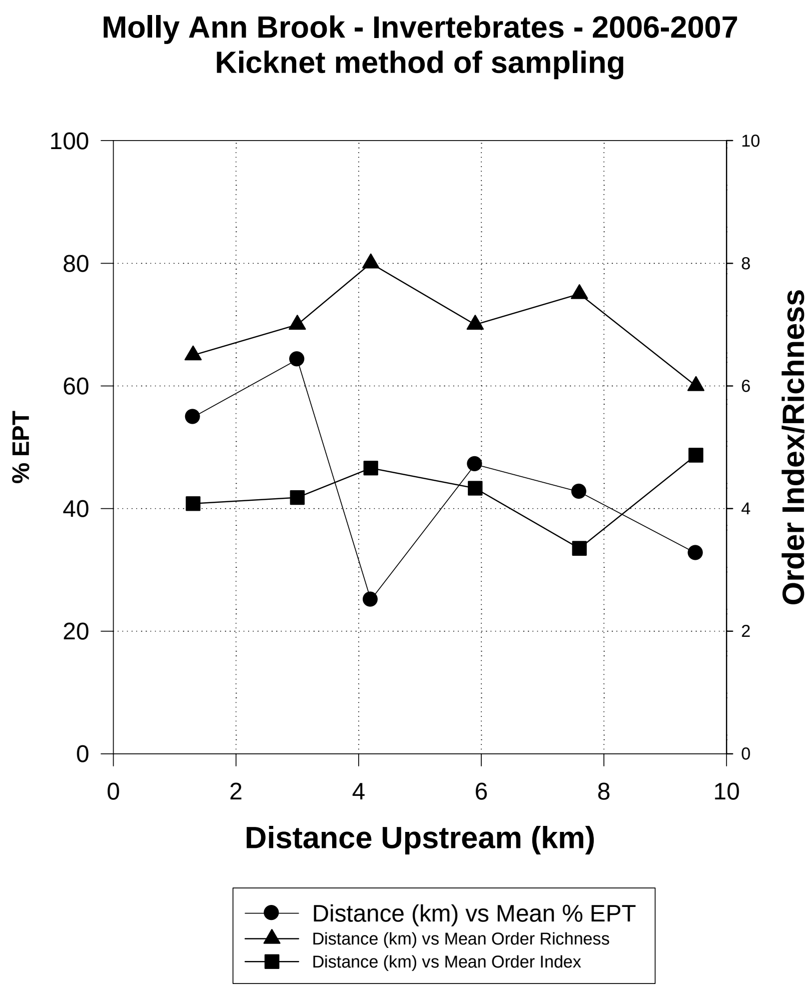

Figure 1: Summary results of macroinvertebrate sampling during 2006-2007 seasons.

Surber Sample Method and Five-Minute Method in 2003

During May – August 2003, six sites on Molly Ann Brook were sampled for macroinvertebrates. Three sites were upstream of Overlook Road in North Haledon, and three were downstream of High Mountain Road, in Haledon and Paterson, NJ (Table 2e). The three upstream sites were located in more suburban areas, similar to those described above in **Kicknet Method 2006 – 2007**. One of the upstream sites, Municipal Building, was the same. Two downstream sites (Manchester & Belmont) were the same as those sampled and described in the **Kicknet Method 2006 – 2007**. A third downstream site (Chamberlain) is very close to site MAB6 (Preakness) noted in the previous discussion. However the results were dramatically different.

A Surber sampler is a commonly used device for sampling macroinvertebrates in shallow streams such as Molly Ann Brook. The Surber sampler has a one square foot metal frame attached to a mesh sampling net. The frame is pressed against the bottom substrate of the stream riffle, the sediment and rocks are stirred and the discharged organisms are swept into the mesh net. The net contents are emptied into a bucket with clean water and then passed through a sieve. Forceps are used to pick the organisms from the sieve and place in a container of alcohol. Two or more Surber samples are usually taken at a site.

In the five-minute method, rocks are lifted from the shallow riffle and rinsed in a bucket of clean water to remove the organisms. This procedure is done for five minutes. The water and organisms are poured over a sieve, and the organisms are removed using forceps, and placed in alcohol.

Surber sampler method EPT %

The difference in EPT % between the upstream sites and downstream sites was dramatic (Table 2e and Figure 2). In the three upstream sites the grand mean EPT % was 68.1%, and in the three downstream sites it was 6.6%. Significantly, stonefly (Plecoptera) larvae were sampled in all three upstream sites, but not stonefly larvae were found in the three downstream sites. Additionally, water penny, the larval form of an indicator beetle species (Coleoptera) was also sampled at the three upstream sites, but not at the downstream sites.

Five-minute method EPT %

Again, the difference in EPT % was striking (Table 2e and Figure 2). The grand mean EPT % in the upstream sites was 60.1%, and in the downstream sites it was 11.8%. A few Stoneflies were sampled at upper site 2 and at lower site 6. Water pennies were sampled only at upper site 2.

Why the difference in EPT % between 2003 and 2006 – 2007?

The difference in sampling results between the two studies was remarkable. The results from 2003 were expected, because we have observed the ecological dichotomy between the upper and lower sections of Molly Ann Brook. Based on ecological considerations, the upper section should have higher water quality and the macroinvertebrate community should reflect it by having a substantially higher EPT % than the lower channelized section that exists from High Mountain Road in Haledon to the Passaic River in Paterson. The results of the 2003 study confirmed our hypothesis of higher EPT % in the upper section.

Why did the results of the 2006 – 2007 study not support the same hypothesis? The two major differences between the two investigations were the sampling method and the myriad ecological changes that time can cause. Both the Surber sampler method and the kicknet method are well established procedures for studying the distribution and abundance of macroinvertebrates in streams, and should yield comparable results. The five-minute rock sampling method is sufficient for sampling macroinvertebrates that inhabit rocky substrates in streams, but does not permit sampling organisms in the hyporheic zone. However, it is good enough to accurately sample enough macroinvertebrates to show differences in EPT % between higher and lower quality water in streams. Therefore, we think that hydrological changes in Molly Ann Brook between 2003 and 2006 – 2007 may have been enough to decrease the differences in distribution and abundance of macroinvertebrates between the upper and lower sections.

Water discharge is the major hydrological variable that might have changed between 2003 and 2006-2007, and thereby affected biological indices such as EPT %. We will continue to study the macroinvertebrate community and physico-chemical variables of Molly Ann Brook to assess water quality.

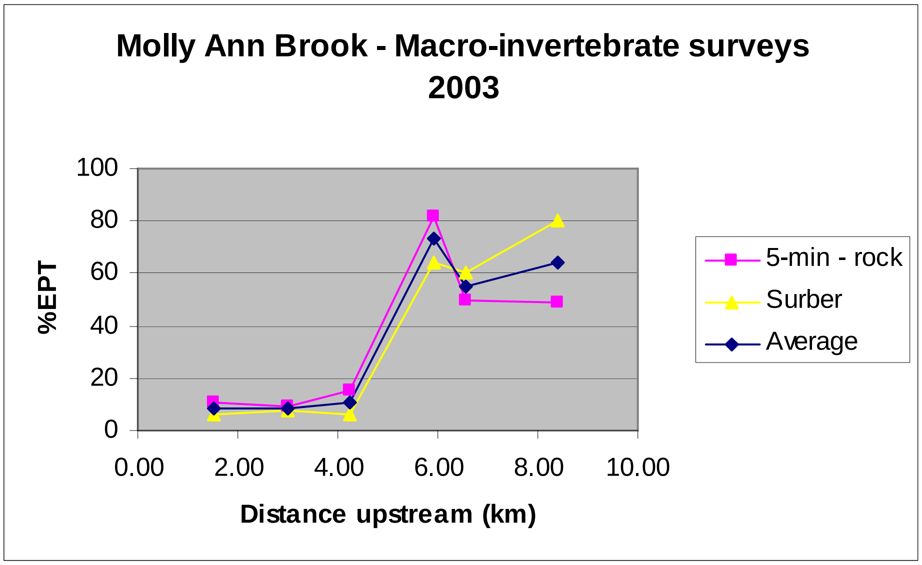

Table 2a: Macroinvertebrate Sampling – September 22, 2006

Site ID	Site (refer to Figure 1)	Biotic Index	Total # Taxa	%EPT
MAB1	Above Haledon Reservoir	4.32	8	56.2
MAB2	Buehler Pool	1.85	7	72.6
MAB3	Municipal Complex	3.52	5	68.5
MAB4x	Bayer (Lanxess) Site	3.95	9	36.4

Table 2b: Macroinvertebrate Sampling – May 5, 2007

Site ID	Site (refer to Figure 1)	Biotic Index	Total # Taxa	%EPT
MAB2	Buehler Pool	4.84	8	12.7
MAB3	Municipal Complex	5.11	7	22.2
MAB5	Belmont Avenue	4.18	7	64.3
MAB6	Preakness Avenue	4.62	6	41.2

Table 2c: Macroinvertebrate Sampling – May 24 & 29, 2007

Site ID	Site (refer to Figure 1)	Biotic Index	Total # Taxa	%EPT
MAB1	Above Haledon Reservoir	5.42	4	9.1
MAB2	Buehler Pool		7	12.7
MAB3	Municipal Complex	5.11	7	22.2
MAB4	Manchester HS	5.09	7	19.5
MAB5	Belmont Avenue	4.18	7	64.3
MAB6	Preakness Avenue		6	35.7

Table 2d: Macroinvertebrate Sampling – August 14, 2007

Site ID	Site (refer to Figure 1)	Biotic Index	Total # Taxa	%EPT
MAB3	Municipal Complex	4.37	9	50.9
MAB4	Manchester HS	4.93	8	19.3
MAB5	Belmont Avenue			
MAB6	Preakness Avenue	3.53	7	68.5

Table 2e: Macroinvertebrate Sampling – Summer, 2003 – Means of Surber and 5-minute sampling

Site ID	Site (refer to Figure 1)	Total # Taxa	%EPT
1	High Mountain Road & Sicomac Ave	8	48.8
2	Squaw Brook Road	12	49.6
3	Municipal Complex	7	81.9
4	Manchester HS	10	15.1
5	Belmont Avenue	8	9.8
6	Chamberlain Avenue	11	10.5

Water Quality

Some water quality variables can only be measured accurately in situ in the field. Others require the collection of field samples, their preservation and transport to a laboratory where they can be analyzed at some time after collection. Field measurements can be made at discrete intervals using one or more instruments or recorded continuously by remotely-deployed automatic instruments capable of continuously monitoring the stream water for a set of variables at a particular site and from which those data are either collected at a later date or continuously transmitted to a collection station.

In-situ Measurements

Discrete

During five of the sample monitoring series, standard water quality variable were measured at each of the six main-channel sites. – temperature, conductivity (specific conductance), dissolved oxygen, pH and some turbidity measurements. These data can be supplemented for purposes of interpretation with a substantial amount of field measurements of the same variable made by us in prior studies (see Section II Existing Data Report). Figure 5 (a thru d) summarizes this year's measurements by plotting the values as a function of distance upstream from the confluence of Molly Ann Brook with the Passaic River.

Temperature

There were no major sources of surface water with altered temperature to affect the water temperature of Molly Ann Brook; hence, water temperature was simply a function of the air temperature – in general increasing somewhat from its source on High Mountain to its confluence with the Passaic River.

pH

The value of pH in water is a function of the pH of precipitation, the interaction of precipitation with soil and rock and biological activity in the water. Rain in the northern New Jersey area has a pH in the 4 to 5 range. The pH of water which comes in contact with soil for any period of time in this area is between 7 and 8 due to the high base content of the rocks (basalt). Hence in Molly Ann Brook pH outside of the 7 to 8 range will reflect primarily biological activity. High pH (above 8) will be seen in warm, sunlit water as plant growth absorbs any CO_2 present. Similarly, low pH (below 7) will occur at night and in colder water due to respiration and the production of CO_2. Sewage water from both storm sewers and waste water lines can usually be expected to have high pH values in the 8 to 9 range. Observed pH in Molly Ann Brook during 2007 was fairly constant at about 7.2 to 7.6 with some marked variability within the channelized section of the stream.

Conductivity

Conductivity (or specific conductance which is the value of conductivity corrected to 25^{o}C) is a measure of the total dissolved species in the water and varies primarily with precipitation – since rain generally has low dissolved ions, its conductivity is low – approaching 0. Historically base flow stream water in Molly Ann Brook has a conductivity of about 200 uS (the unit of conductivity and specific conductance is the Seimen, generally recorded as micro-Seimens or uS). Runoff containing road salt and evaporation and evapo-transpiration of stream and pond water result in increased concentration of dissolved salts which leads to elevated conductivity typically in the range of 400 to 600 uS. During droughts or during very warm intervals, stream conductivity may increase to more than 1000 uS. In contrast to the 2006 results, conductivity for 2007 showed an almost mono-tonic increase downstream.

Dissolved Oxygen

Dissolved oxygen is controlled by plant activity and temperature. Sunlight falling on algae promotes photosynthesis which leads to elevated O_2 values. Respiration at night and at depth consumes O_2. All discrete field measurements were made during daylight hours and have values near or even above saturation levels. See the next section, though, for continuous measurements of dissolved oxygen which include night-time values.

Continuous

On three occasions in July, August and September, 2007 a YSI 6920 water quality sonde was deployed successfully at the Oldham Pond Dam outlet and at the Bayer/Lanxess site along Molly Ann Brook.

Deploying the sonde successfully is challenging. It is a complex and temperamental instrument that has to perform delicate measurements with precision and accuracy in a hostile environment. That hostile environment is both natural (extreme range of stream discharge and heavy burden of organic activity) and manmade (vandalism). The sonde, therefore, has to be carefully placed both to measure water quality accurately and survive stream conditions and harm by humans.

For the most part, the sonde (as indicated in Figure 6 thru 8) appears to have operated successfully and accurately with the exception of the dissolved oxygen measurement for some period as noted. As indicated on the Figures, the pH probe of the 6920 sonde malfunctioned during the August 9 to 27 period and again around September 11-12 (Figure 8) while the membrane of the DO probe was damaged during heavy flow following a storm during the August 31 to September 13 sampling period.

It is worth noting that the range of observed diel swings in stream field variables is comparable to that observed for the Passaic River itself (TRW/OMNI, 2005 through 2007).

Laboratory Analysis

Several sets of laboratory analysis of water quality variables were made on samples collected under this phase of the project at the NJ certified Rosengren Field station laboratory at William Paterson University:

1. Dissolved orthophosphate and alkalinity analyses on samples collected at the same time and location as bacteriological samples.

2. Analyses of major dissolved anions and cations.

Figures 9 summarize the results of nitrogen & phosphorus analyses obtained on the sample sets collected on various dates from May and July, 2007. Figure 10 summarizes the results of sulfate and fluoride analyses conducted on the same sets of samples. In each case the concentration of dissolved species is plotted as a function of distance upstream from the confluence of Molly Ann Brook and the Passaic River.

Alkalinity vs. distance upstream is summarized in Figure 11 along with the results of other major anions and cations presented in a single tri-linear diagram.

Discharge

As noted above under **Precipitation**, water runoff across land surfaces into the waters of the Brook can be expected to have a significant if not controlling influence on water quality. Ideally one would like to know the discharge of the stream at every point (or at least at every sampling site) along the main stem channel continuously over time. This would be prohibitively expensive to accomplish. While measurements of discharge are an integral part of this project, some combination of data sources has to be made in order to arrive at the desired values.

The overall, mean annual discharge of the Molly Ann Brook watershed at its mouth should be approximately 11.76 cfs (0.333 m^3/s) based on comparison with other regional watersheds.

During the 2007 monitoring season, substantial effort was made to establish discharge along Molly Ann Brook by the following means:

- Discrete measurements of discharge by the USGS profile methodology at various stations along the length of the Brook.
- Continuous monitoring of flow velocity and depth using Doppler instruments installed in the stream bed.
- Calibration of storm flows at the USGS flood gage at station MBA #3 and correlation with other measured flows.

A Doppler stream velocity/depth gage was set up in May at the outfall of Oldham Pond and a second in August at the Bayer/Lanxess site about 100m downstream. This second Doppler instrument records the whole flow of Molly Ann Brook during storm events when flow over the Oldham Pond dam occurs at all three spillways. The instrument on the main outflow of Oldham Pond does not record storm flow when such flow occurs over the two western-most spillways.

Results of discharge measurements and estimates of discharge for all sampling dates are contained in Section V of this report.

Discussion & Summary - 2007

Bacteriological

There were no times when fecal coliform levels at any of the monitored sites along Molly Ann Brook were at or below the 200 cfu/100 ml standard for the stream's designated uses. Neither did the E. coli levels ever fall within the MCL of 126 cfu/100 mL. Concentrations above 10,000 cfu/mL were measured at the Preakness Avenue site in May 2007, but levels for 2007 did not reach as high overall as they did during the 2006 sampling season. However, this year, the geometric mean of total fecal coliform was above 1000 cfu at every station.

The relationship between fecal coliform levels and precipitation strongly supports the hypothesis presented above; namely, that high coliform concentrations are associated with storm events. Table 3 below summarizes total fecal coliform concentrations on different days along with a qualitative summary of weather conditions preceding and during sample collection. The fecal coliform numbers reported here were "normalized" by dividing each day's measured value at each sampling site by the geometric mean values reported in Figure 3 and then taking the average of each of the six sites for that date.

Table 3: Summary results of fecal coliform levels and precipitation events within the Molly Ann Brook watershed for the 2007 sampling season

Date	"Normalized" fecal coliform (measured/mean)	Weather conditions
May 16	0.46	Relatively dry, discharge slightly below normal
June 29	1.09	Relatively wet, discharge slightly below normal
July 5	1.64	Several wet periods precede sampling, discharge slightly above normal
July 11	0.93	Relatively dry, discharge substantially below normal
July 17	0.60	Relatively dry, discharge substantially below normal
July 20	1.19	Several very wet periods precede sampling, discharge high

Fecal concentrations were generally higher following periods of heavy precipitation, but not necessarily very long periods of precipitation. Conversely, sustained dry periods and low discharge correlate with lower fecal concentrations.

The results from the series of "trackdown" samplings conducted on the channelized section in June of the stream and Squaw Brook in September do not indicate any significant "hot spots" of bacterial contamination beyond the overall increasing-downstream trend along the entire length of the stream.

Macroinvertebrates

The results of the macroinvertebrate sampling reveal a somewhat more complex relationship between habitat quality and distance along the main channel of the stream. Unlike older studies and even last years monitoring results, habitat decline does not necessarily decrease monotonically with distance downstream.

Water Quality

Field Measurements

Field measurements of water quality variables made along the length of Molly Ann Brook on various dates revealed the following trends:

- A slight increase in temperature going downstream with a consistent decline at the North Haledon Municipal Complex site (MAB#3) and consistent maxima at the Manchester HS site (MAB #4). Note that the stretch of the stream above MAB #3 is largely wooded and shaded, while site MAB #4 is at the start of a heavily urbanized area that receives significant runoff from heavily impacted tributaries.

- The Brook's waters have a fairly uniform, slightly alkaline pH with a weak increasing trend downstream. There is some indication of anomalous behavior in pH in the channelized section between MAB # 4 and MAB #5.

- There was a general increase in conductivity downstream except during rainfall events when conductivity declines markedly. The lowest levels of conductivity approach values typical of groundwater in this region (200 uS)

- Dissolved oxygen levels were, for the most part, at saturation or even super-saturation levels during these daytime sampling events.

The sonde results for two sites showed that there was a very narrow but discernible range in pH, DO and temperature due to diurnal fluctuations. Night time levels of dissolved oxygen as recorded by the sonde fell to levels as low as 20% saturation during dry periods, but quickly recovered following storm events. DO levels as low as 20% saturation may be expected to have serious negative effects on the fish and macroinvertebrate populations. Such low levels of dissolved oxygen are likely the consequence of the decomposition of organic matter in stagnant pools along the length of the stream which would, in wetter periods, have been flushed with better-oxygenated water. Conductivity, on the other hand, was seen to vary significantly (by a factor of about 2) due to precipitation events.

Laboratory Measurements

Dissolved inorganic phosphorus levels were low at all times and all stations and showed no particular pattern along the length of the stream. Dissolved N levels measured on samples from each site along the Brook on seven different days and summarized in Figure 9, on the other hand, show a consistent peak at site MAB #3 and a consistent dip at sites MAB #4 and #5, but with a maxima tending to occur at the most downstream site (MAB #6). Sulfate (Figure 10a) also show a consistent pattern of increase downstream with little variation in concentration between different dates except for the last station (MAB #6). Fluoride (Figure 10b), like phosphorus does not appear to follow any consistent pattern except that, on average, it may be the only ion to decrease with distance downstream.

The major ion analyses presented in the tri-linear diagram in Figure11 confirm that salt (NaCl) addition is the major chemical change occurring among the major ions, while the consistency in the proportions of the various anions and cations, shows that evapo-transpiration dominates as a mechanism of water volume change along the length of the stream. This implies that relatively little groundwater enters the stream along its length and that subsurface geochemical processes occurring throughout the watershed are uniform.

Discharge

The focus on establishing discharge for the stream during this year's monitoring season resulted in the ability to quantify load for fecal coliform. This analysis could also be used to calculate load for any other variable such as nutrients.

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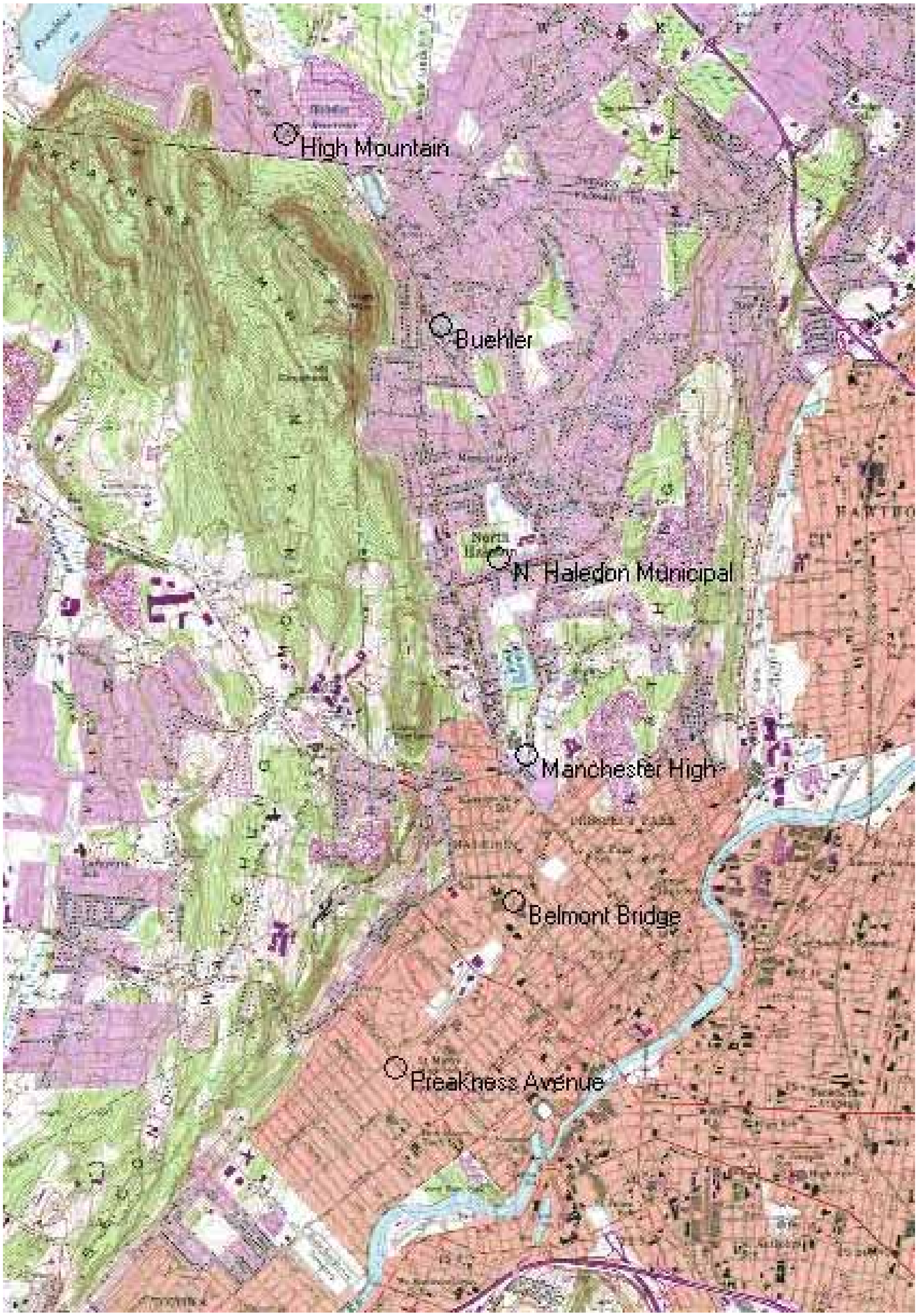


Figure 1 – Molly Ann Brook Watershed Sampling Sites

Table 4a. Molly Ann Brook Watershed Sampling Sites and Collection Form – Main Stem Sites:

Lower Passaic River Alliance – WMA4
Molly Ann Brook 319h
Restoration and Protection Fecal Coliform & BST Sampling 2006/2007
Dr. Richard R. Pardi or Dr. Michael Sebetich & students, William Paterson University
Samples delivered to ______________________________

Flow Conditions: ______________________________
Date: ______________
Time: ______________

Sample id	Site Name	Sampling Time	Latitude	Longitude	Parameters Monitored
MAB1	**High Mountain inlet to Haledon Reservoir**		**40°58.839’**	**74°12.208’**	
MAB2	**Buehler Cultural Center & Pool**		**40°58.104’**	**74°11.421’**	
MAB3	**North Haledon Municipal Complex**		**40°57.213’**	**74°11.133’**	
MAB4	**Manchester High School/High Mountain Road**		**40°56.463’**	**74°10.993’**	
MAB5	**Belmont Avenue Bridge**		**40°55.899’**	**74°11.059’**	
MAB6	**Preakness Avenue Bridge/AMNET AN0276**		**40°55.275’**	**74°11.646’**	

Table 4b. Molly Ann Brook Watershed Sampling Sites and Collection Form – Tributary Sites:

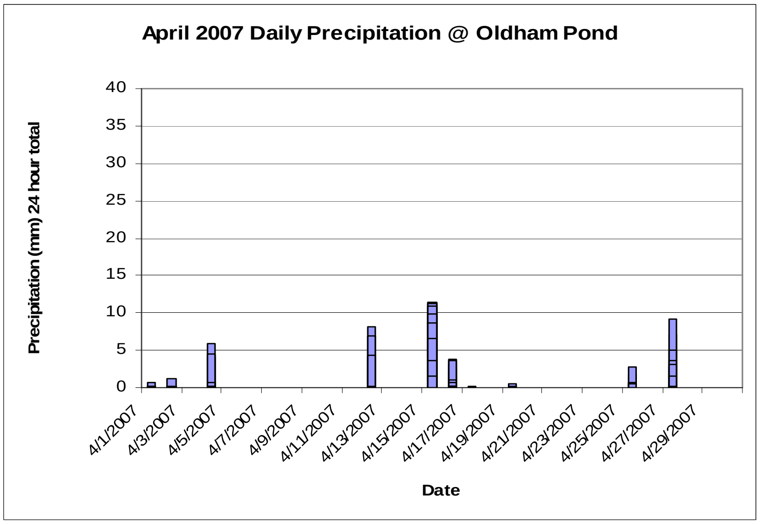
Lower Passaic River Alliance – WMA4
Molly Ann Brook 319h **Flow Conditions:** ________________________________
Restoration and Protection Fecal Coliform & BST Sampling
2006/2007 **Date:** ______________
Dr. Richard R. Pardi or Dr. Michael Sebetich & students, William Paterson University
Samples delivered to ____________________________________ **Time:** ______________

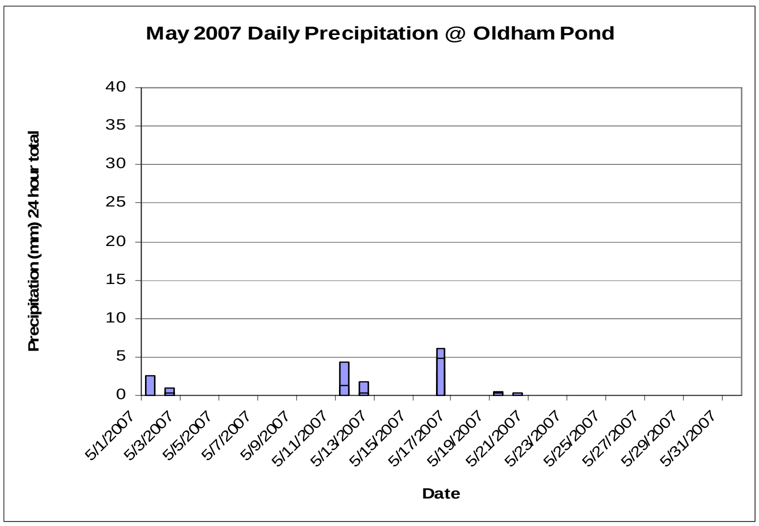
Sample id	Site Name	Sampling Time	Latitude	Longitude	Parameters Monitored
MAB1a	Franklin Lakes Wetland		40°59.134’	74°12.110’	
MAB2a	East High Mountain		40°58.048’	74°11.402	
MAB3a	Squaw Brook		40°57.507’	74°11.163’	
MAB4a	Quarry		40°57.007’	74°10.843’	
MAB4b	WPUNJ		40°57.015’	74°11.226’	
MAB4c	Terrace		40°57.184’	74°11.033’	
MAB4d	Haledon Avenue		40°56.455’	74°11.015’	
MAB4e	Eastern Christian		40°56.709’	74°10.870’	

Table 4c. Molly Ann Brook Watershed Sampling Sites and Collection Form – Channelized Sites:

Lower Passaic River Alliance – WMA4
Molly Ann Brook 319h **Flow Conditions:** ____________________________________
Restoration and Protection Fecal Coliform & BST Sampling
2006/2007 **Date:** ______________
Dr. Richard R. Pardi or Dr. Michael Sebetich & students, William Paterson University
Samples delivered to ____ **Time:** ______________

Sample id	Site Name	Sampling Time	Latitude	Longitude	Parameters Monitored
MAB1x	**Haledon Avenue Bridge**		40°56'13.05"N	74°10'53.89"W	
MAB2x	**Ira Street Bridge**		40°56'09.82"N	74°10'55.67"W	
MAB3x	**Post Street Footbridge**		40°56'06.23"N	74°10'56.17"W	
MAB4x	**Roe Street Bridge**		40°56'02.63"N	74°10'58.45"W	
MAB5x	**Clinton Street Bridge**		40°55'57.80"N	74°11'00.25"W	





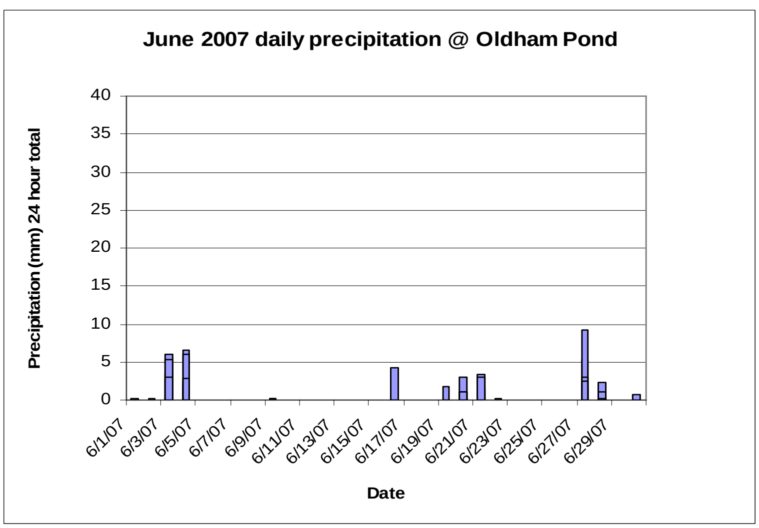
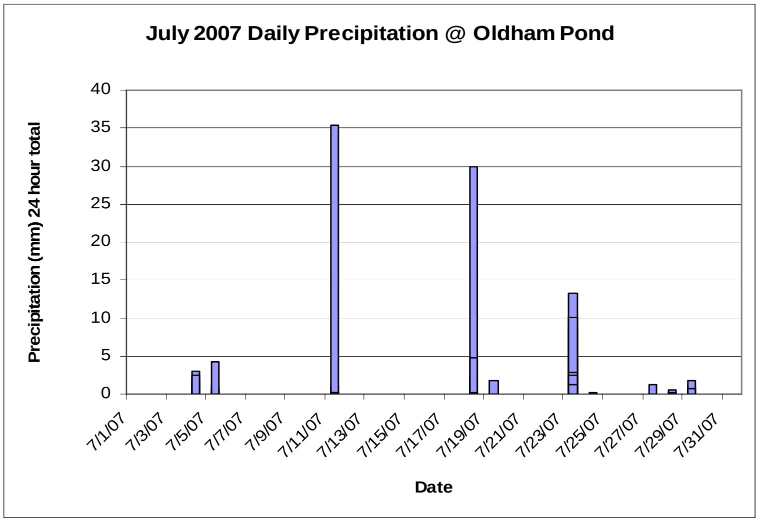
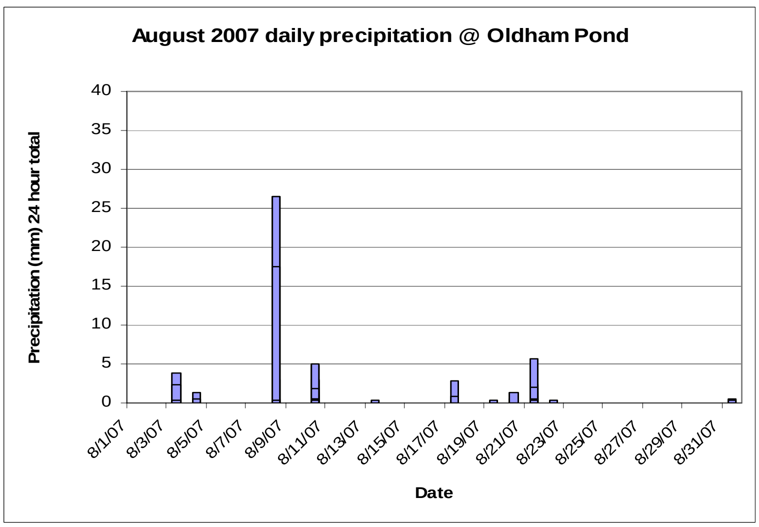


Figure 2a thru c: Daily precipitation for the months April to June, 2007 based on hourly measurements from the weather station at Oldham Pond.





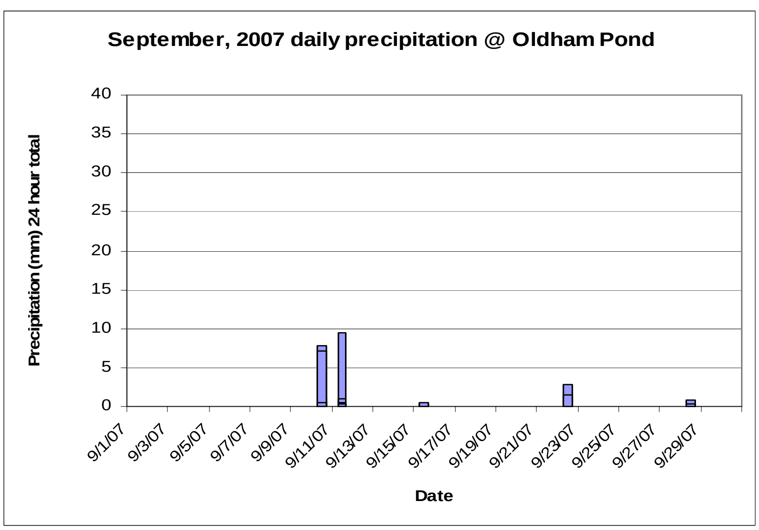


Figure 2d thru f: Daily precipitation for the months July to September, 2007 based on hourly measurements from the weather station at Oldham Pond.

Table 5: Mean annual discharge in m^3/s and cfs at each of the main channel stations along Molly Ann Brook. Based on trends in measured values on various dates and total stream discharge based on watershed area.

Station	Mean annual discharge m^3/sec	Mean annual discharge cfs
MAB1	0.006	0.208
MAB2	0.076	2.698
MAB3	0.091	3.201
MAB4	0.163	5.755
MAB5	0.227	7.996
MAB6	0.253	8.937

Table 6: Discharge on specific bacteriological sample collection dates during 2007 relative to mean annual discharge and 48-hour precipitation prior to bacteriological sampling in mm and inches.

Date	Relative Discharge	Precipitation 48-hour mm	Precipitation 48-hour in
May 16	0.84	0	0
June 19		0	0
June 26		0	0
June 28	0.40	22.6	0.89
June 29	0.77	26.2	1.03
July 5	1.17	15.5	0.61
July 11	0.22	0	0
July 17	0.20	0	0
July 18		37.3	1.47
July 20	1.39	2.3	0.09
September 26			

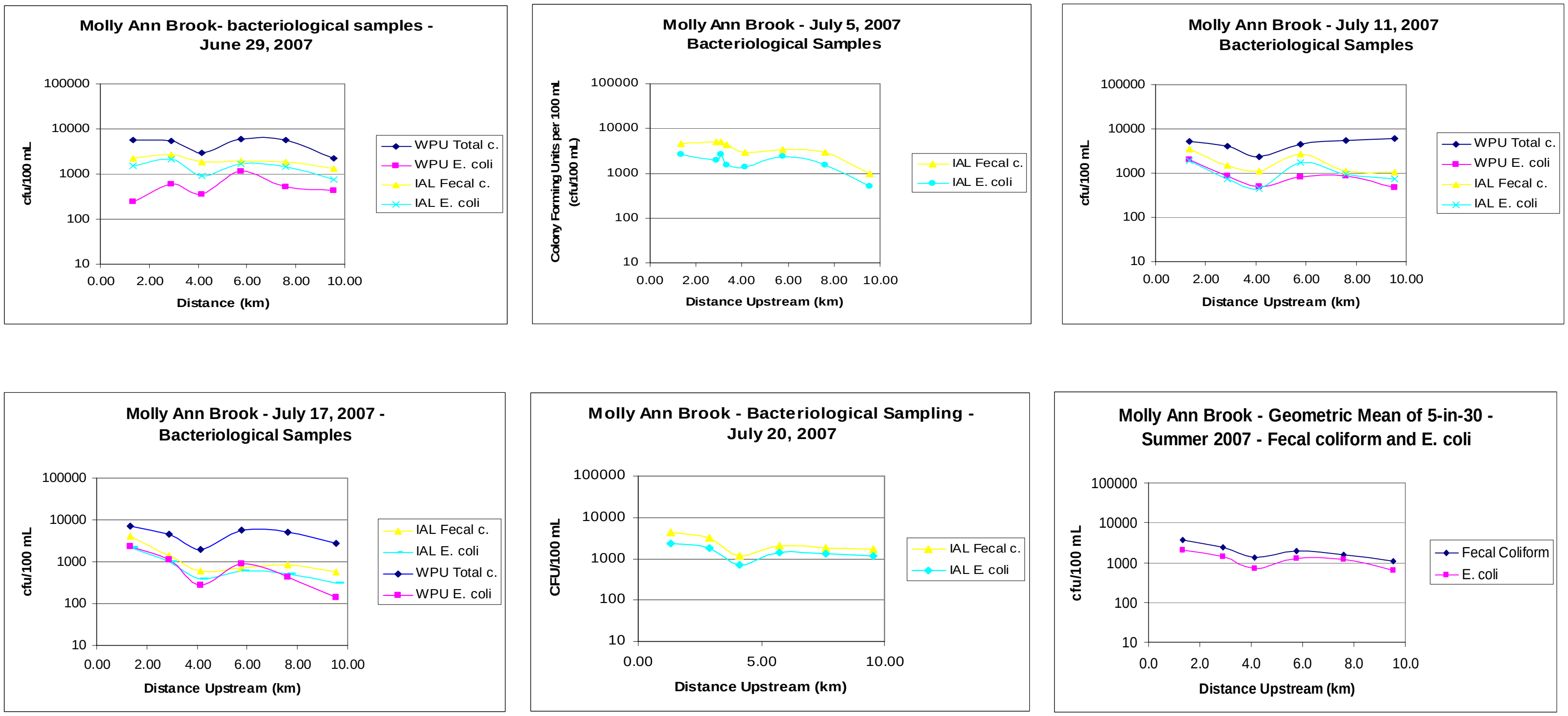
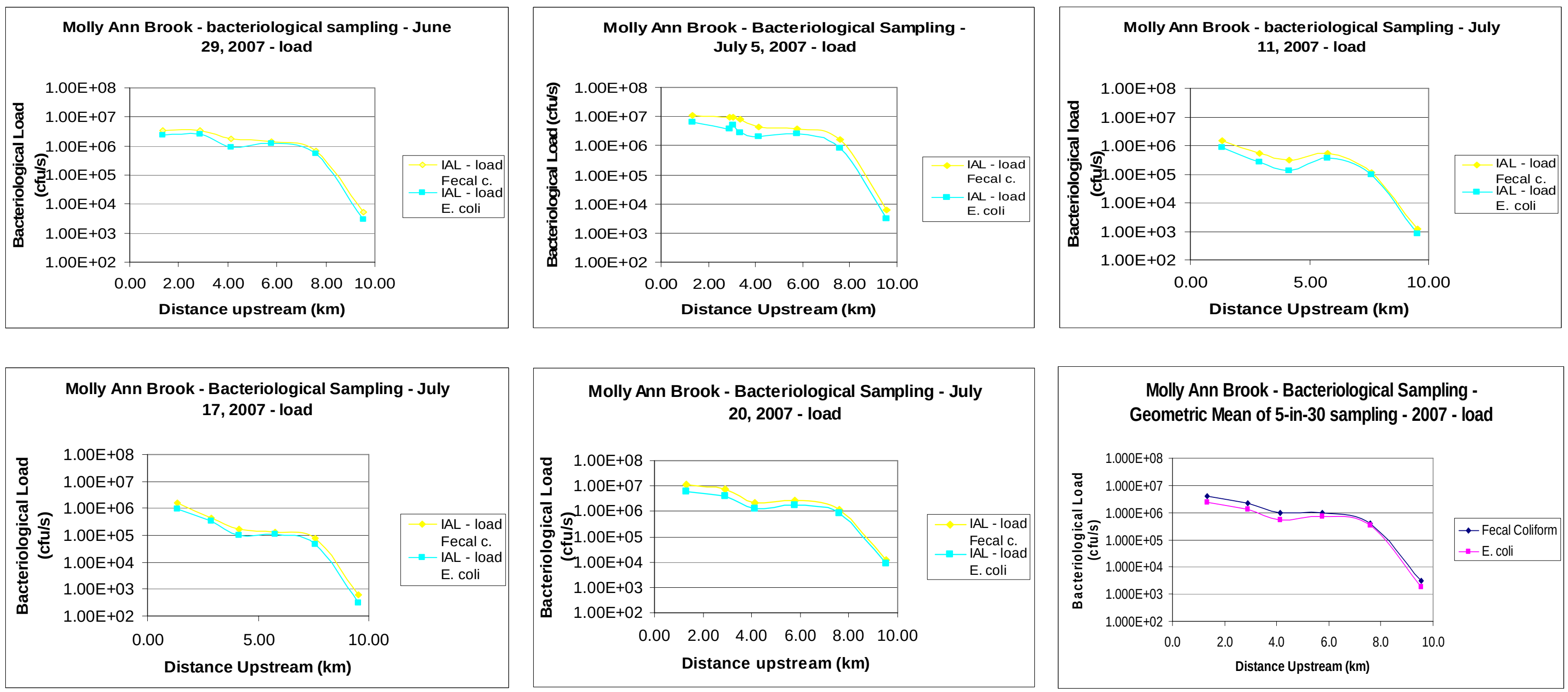
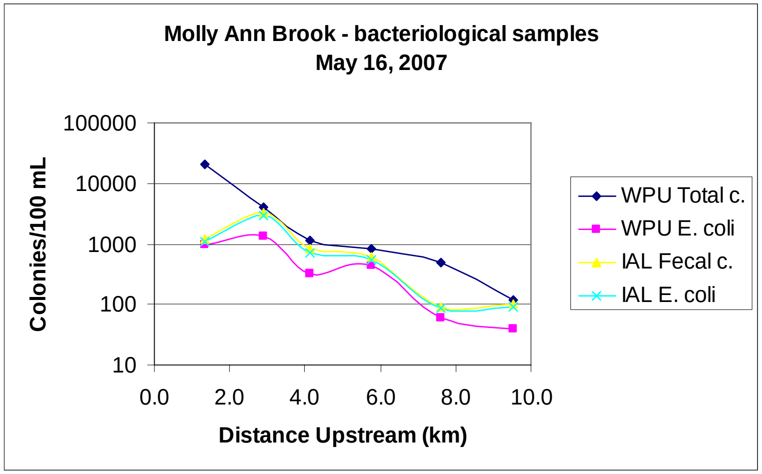
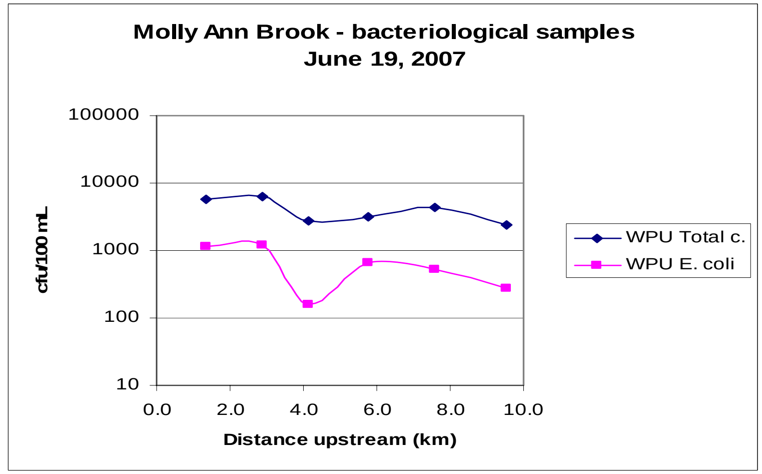


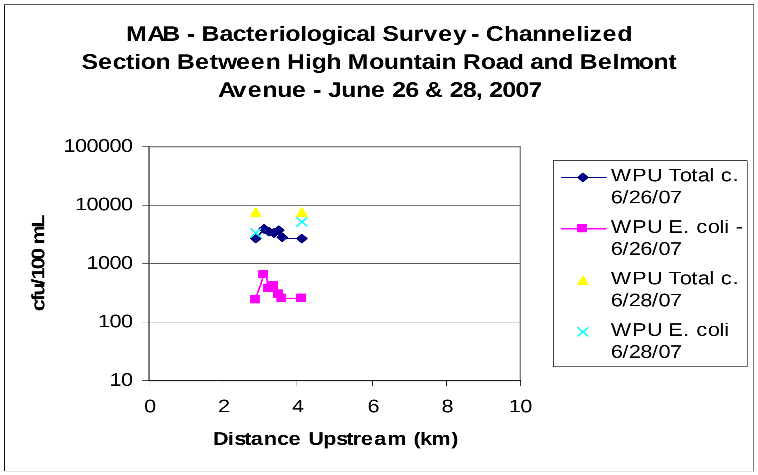
Figure 3a thru f: Total fecal coliform, fecal coliform and *E. coli* results for "5-in-30" sampling of Molly Ann Brook conducted between June 29 and July 20, 2007. IAL refers to results from Integrated Analytical Laboratories, WPU from William Paterson University. Results are in concentration units of colony forming units per 100 mL.

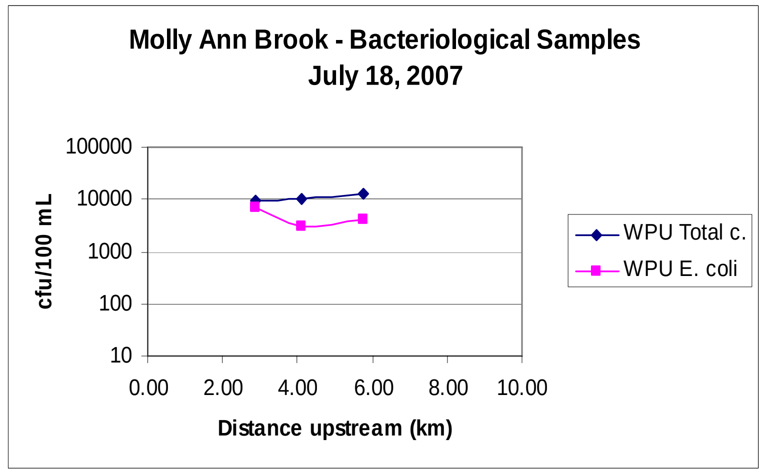


Figures 3g thru l. Total fecal coliform, fecal coliform and *E. coli* results for "5-in-30" sampling of Molly Ann Brook conducted between June 29 and July 20, 2007. IAL refers to results from Integrated Analytical Laboratories, WPU from William Paterson University. Results are in load per unit time units of colony forming units per second based on discharge as reported in Section IV.









Figures 3m thru p. Total fecal coliform, fecal and *E. coli* results for other sampling of Molly Ann Brook conducted during the 2007 monitoring season. IAL refers to results from Integrated Analytical Laboratories, WPU from William Paterson University. Results are in concentration units of colony forming units per 100 mL.

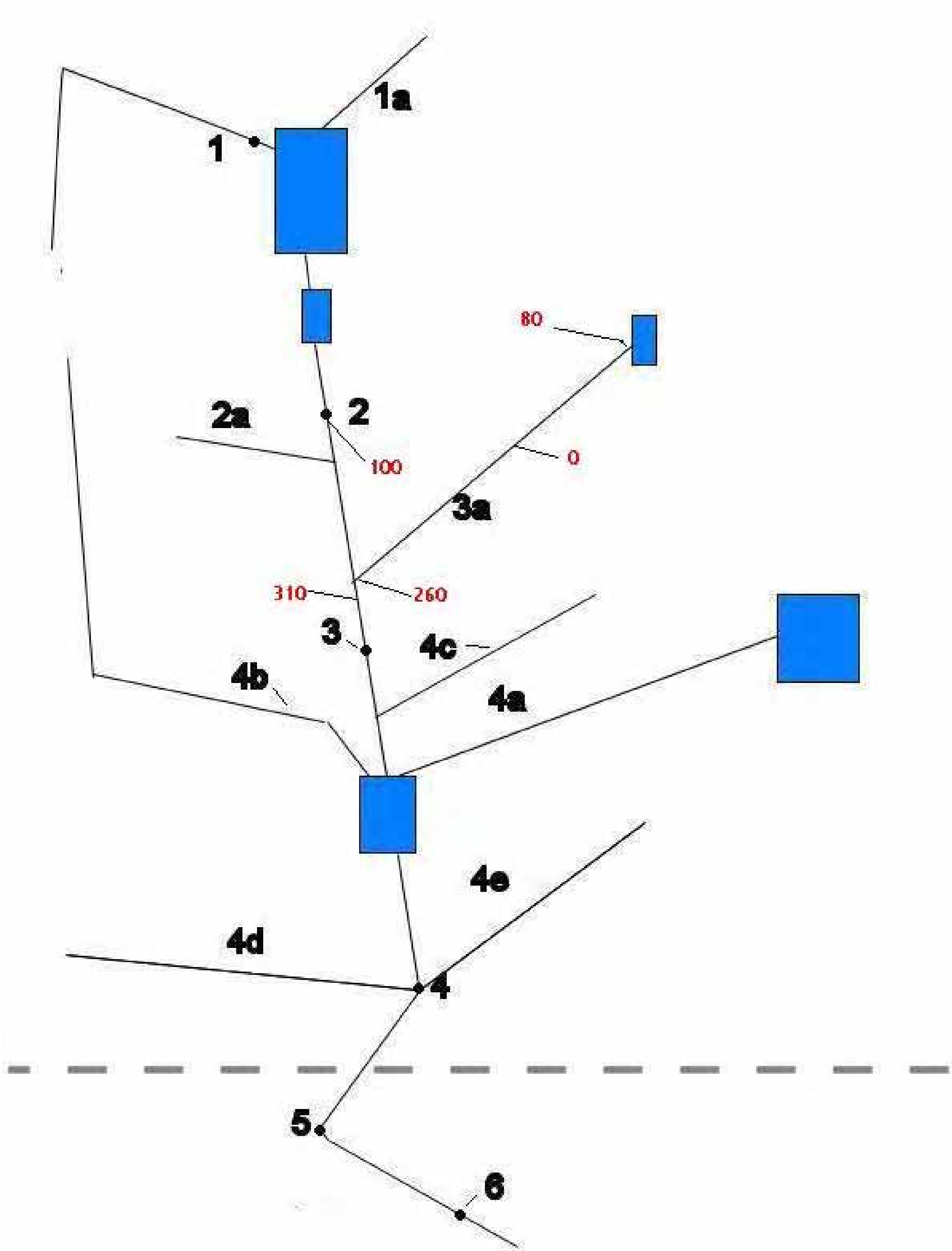


Figure 4: Summary of "trackdown" sampling conducted September 26, 2007. Values in red are *E. coli* in cfu/100 mL.

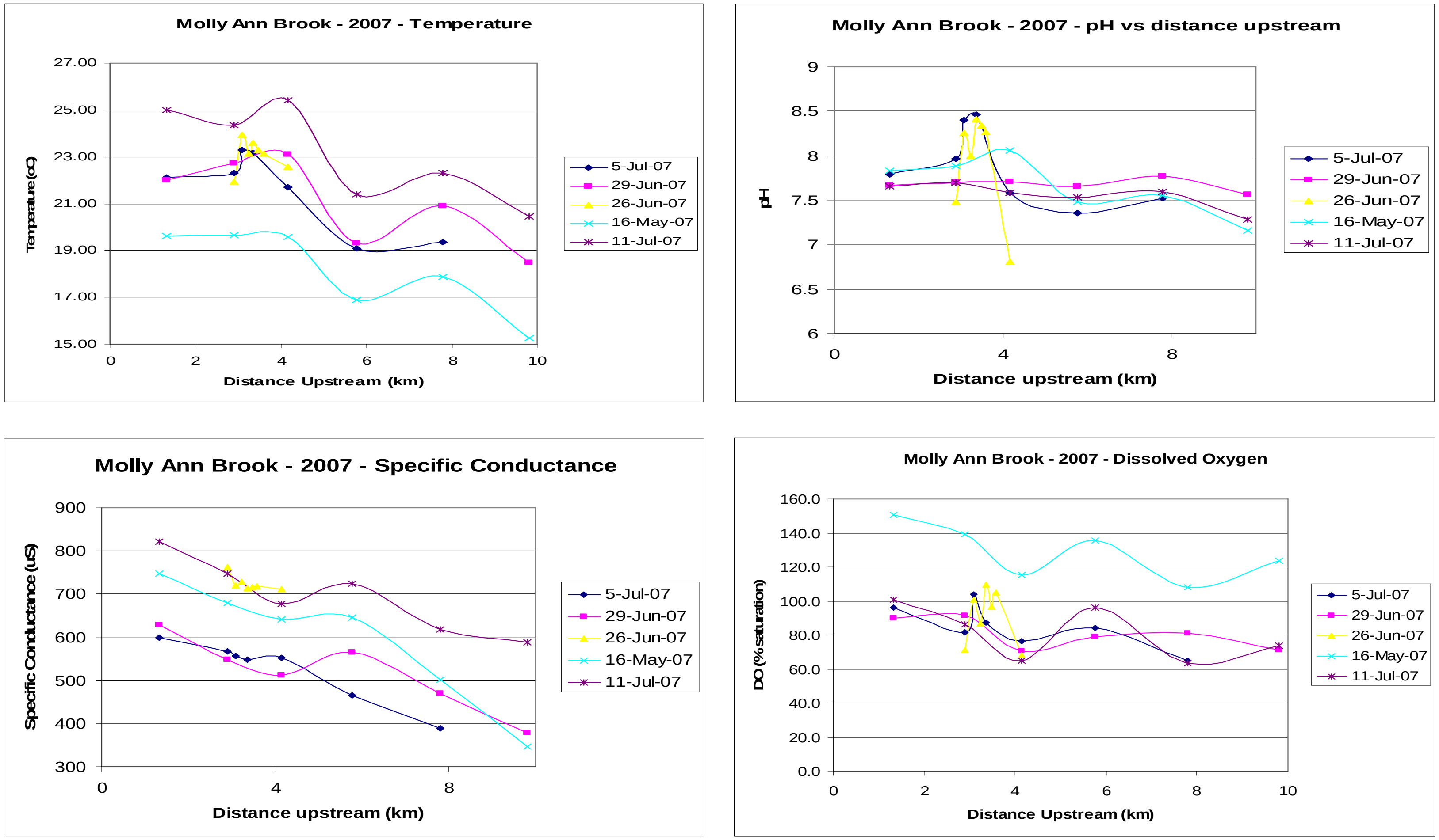


Figure 5: Field measurements of water quality variables made on five different days during 2007 monitoring season along Molly Ann Brook.

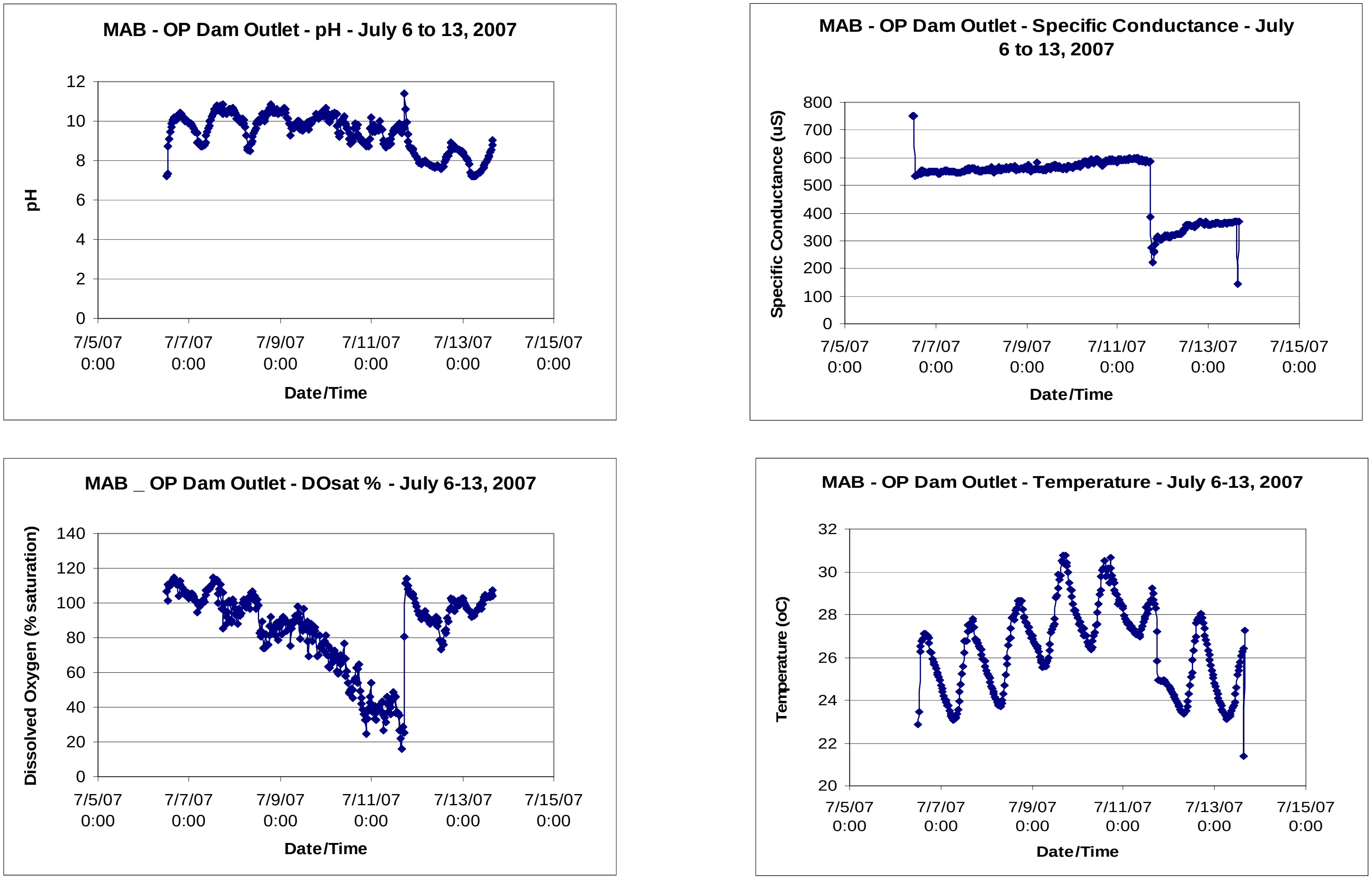
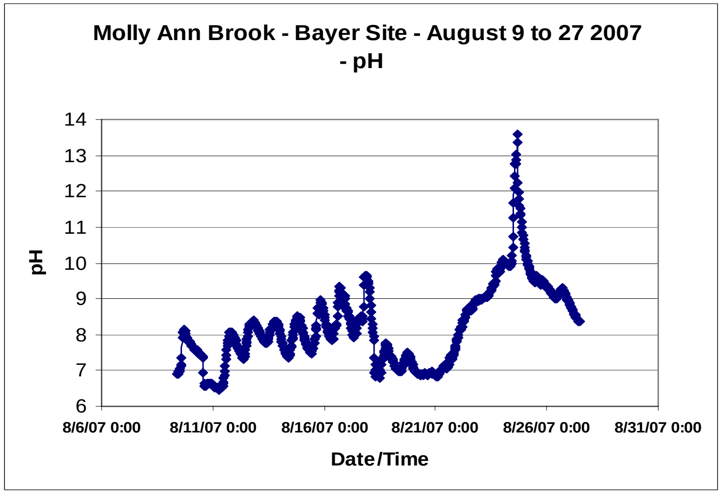
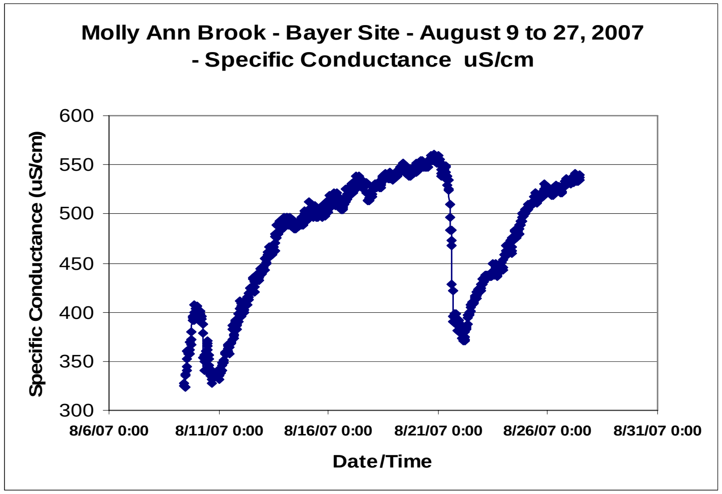
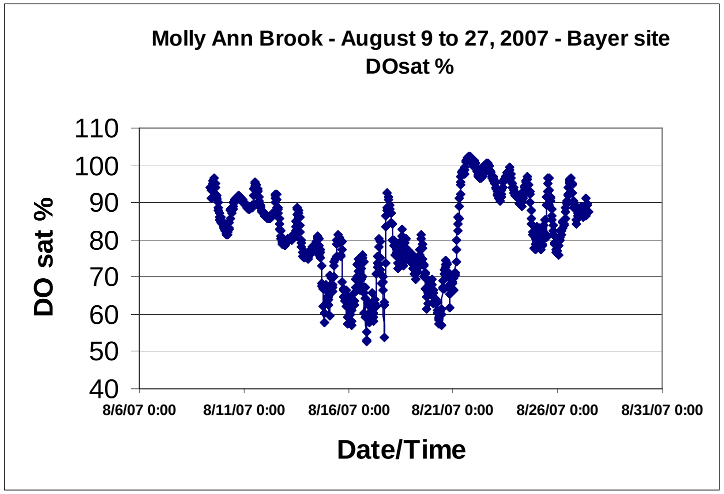


Figure 6: Results of the deployment of the YSI 6920 sonde for the period July 6 to 13 at the Oldham Pond Dam outlet site which is about 500 meters upstream from site MAB4 at Manchester HS. Spikes at the start and end of these series are due to disturbance during placement and removal of the sonde.







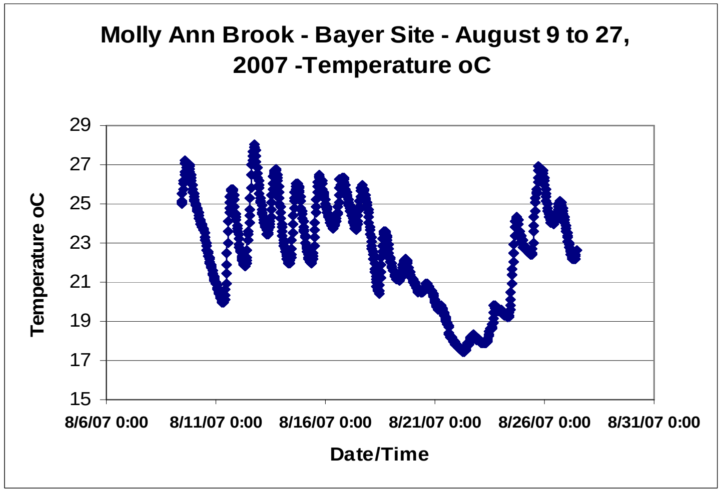


Figure 7: Results of the deployment of the YSI 6920 sonde for the period July 6 to 13 at the Bayer (Lanxess) site which is about 100 meters upstream from site MAB4 at Manchester HS. The pH probe clearly malfunctioned after about July 17th or 18th.

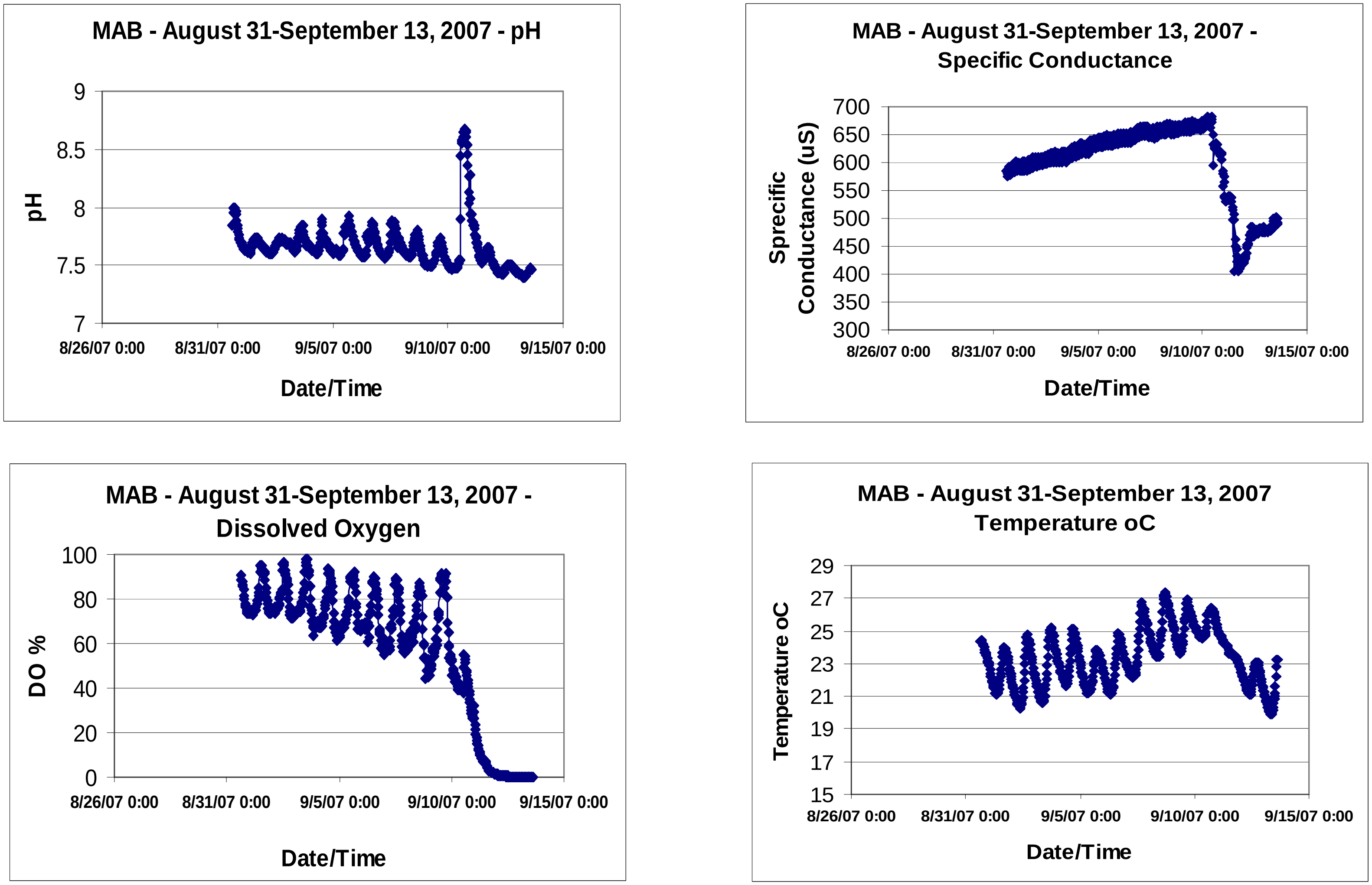
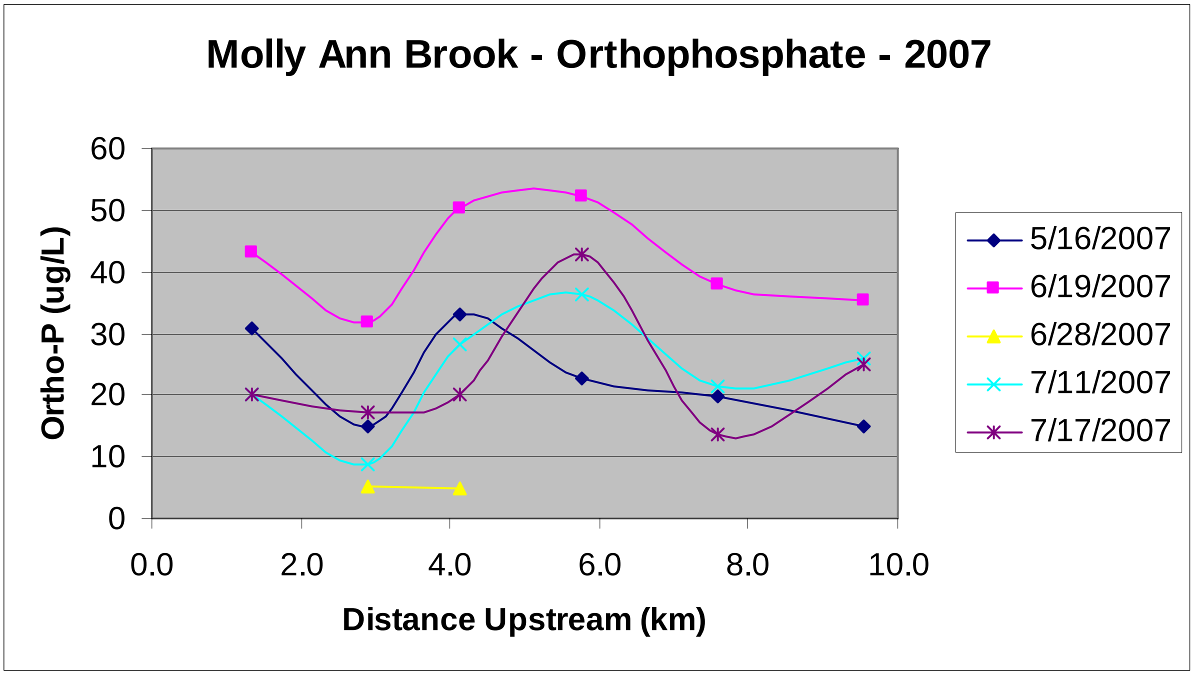


Figure 8: Results of the deployment of the YSI 6920 sonde at the Bayer site for the period August 31 to September 13, 2007. This site is approximately 100 m upstream from site MAB4 at Manchester HS. The DO probe membrane ruptured during the storm flow on September 11.



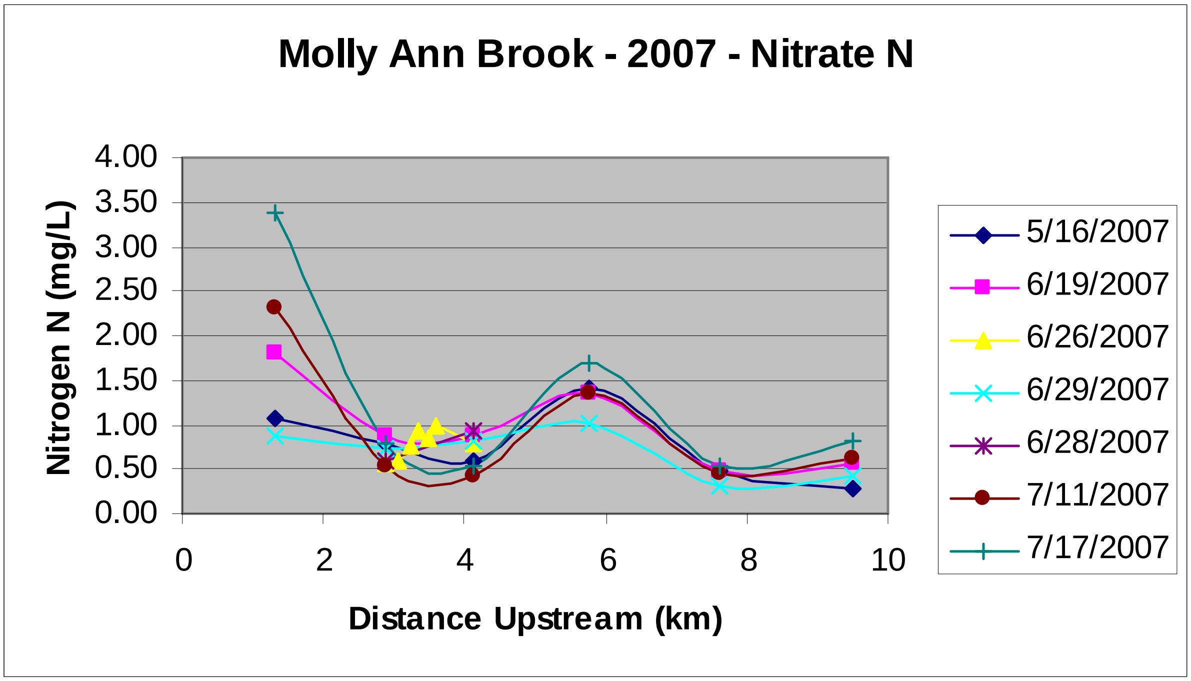
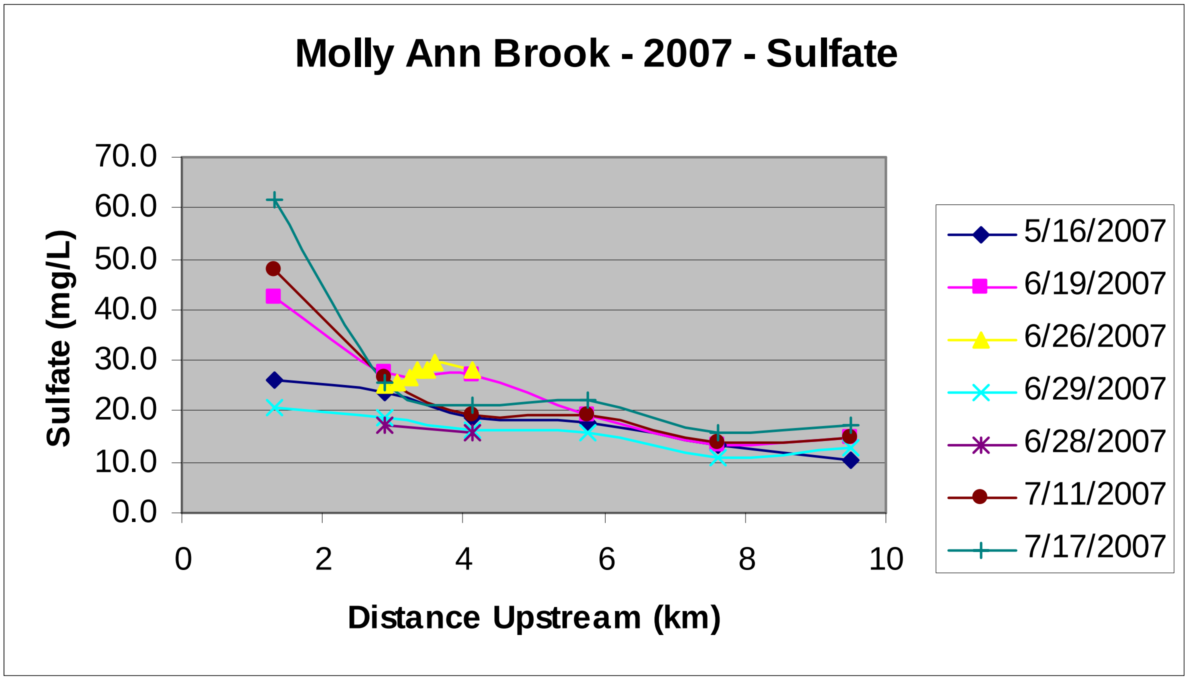


Figure 9: Dissolved inorganic phosphate P (as P) and nitrate (as N) in Molly Ann Brook at sampling sites along Molly Ann Brook for various dates during the 2007 monitoring season..



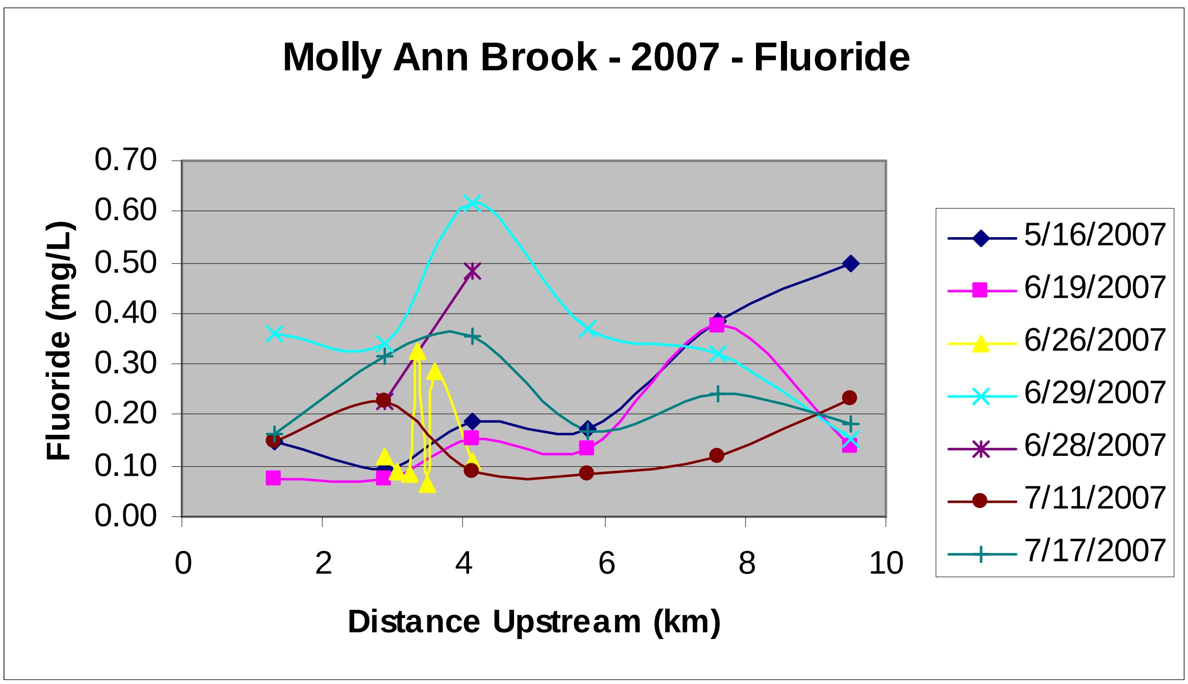


Figure10: Dissolved inorganic sulfate and fluoride in Molly Ann Brook at sampling sites along Molly Ann Brook for various dates during the 2007 monitoring season..

Na	K	Ca	Mg	Cl	HCO3	CO3	SO4	NO3
28.5	0.7	24.1	13.8	39.6	84.4	0.1	10.5	1.3
48	1.6	30.4	20.7	78.5	80.2	0.1	13.4	2.1
57.1	1.9	42.5	30.2	105.6	101	0.2	17.6	6.2
67.3	2	39.3	26	113.7	101.1	0.6	18.8	2.6
70.2	2.1	45	26	120.3	107.1	0.4	23.4	3.6
80.1	2.6	43	28.3	135.8	110.2	0.4	26.3	4.8
32.6	1.2	29.2	6.9	68.8	123.3	0.1	14.8	2.5
46.2	1.7	32.6	9.9	93.3	105.5	0.2	13.2	2.2
50.1	2	47.1	14.9	121	112.9	0.2	19.4	6
68.2	3	43.8	11.8	123	99.6	0.2	27.2	3.8
78.2	3	50	12.3	135.5	109.8	0.2	27.6	3.8
98.3	2.6	59.9	14.4	141.8	147.5	0.4	42.6	8
79.1	2.7	63.6	12.4	128.5	99.3	0.2	28.2	3.5
79.9	2.9	65.2	12.6	123.4	104.8	0.2	29.7	4.3
79.5	2.5	41.8	13.8	116.2	105	0.2	28	3.7
84.7	4.4	37.8	13.4	116.5	117.4	0.2	28	4.1
84.3	2.6	42.2	15.2	124.7	98	0.2	26.8	2.6
83.2	3.5	44.8	15.6	123.4	131.2	0.5	25.7	2.7
88.9	2.7	45.9	16.1	126.4	131.2	0.5	25	2.5
49.5	5.3	36.5	9.9	80	77.1	0.2	15.8	4.1
55.7	8.2	40.1	10.6	87.1	104.8	0.2	17.1	2.6
45.7	1.4	37.6	9	53.2	110.5	0.2	12.6	1.9
47.9	2.1	33.7	9.7	72.8	95.3	0.3	11.1	1.4
54.1	4.7	45.8	12.9	91	101	0.2	15.6	4.5
52	3.7	36.8	10	82.6	80.3	0.2	16.1	3.6
53	5.8	37.6	10.3	90.1	88.2	0.2	18.7	3.2
58.3	6.1	39.9	10.4	98.1	95.8	0.2	20.9	3.8
59.2	4.4	55.2	12.8	81.5	148.8	0.1	14.7	2.8
64.4	4.1	48.4	13.8	105.2	107.5	0.2	14	1.9
58.8	3.1	63	18.1	122	119.7	0.2	19	6
72.2	4.1	47.1	13.8	114.7	99.9	0.2	19	1.9
83.3	4.8	53.3	14	135.9	107.4	0.3	26.6	2.4
91.2	4.3	64.8	13.9	131.3	119.2	0.3	48	10.2
50.5	5.8	48.7	11.3	89.9	144.6	0.2	17.2	3.6
54	3.5	41	11.8	107.2	104.8	0.2	15.6	2.3
53.1	4.2	55.9	15.9	132.2	105	0.2	22.1	7.5
54	3.3	39.7	10.4	101.2	117.4	0.2	21.4	2.4
69.5	3.7	46.3	11.6	123.2	98	0.2	25.8	3.5
91.4	3.3	59.3	11.8	127.7	131.2	0.5	61.6	15
66.7	9.8	50.4	15.6	112.7	164.6	0.1	22.1	2.8
83.2	12.1	54.6	13.2	140.9	110.9	0.1	26.2	6.2
58.8	3.8	47.6	13.6	96.6	110.7	0.2	15.5	2.4
59.8	5.6	67.6	17.8	120.6	135.4	0.4	22.7	7.2
56.6	6.6	60.5	16.9	115	126.3	0.4	20.2	6.6

Table 7: Chemical analytical data based on analyses of samples collected from Molly Ann Brook during the 2007 sampling season and used in tri-linear diagram on the following page.

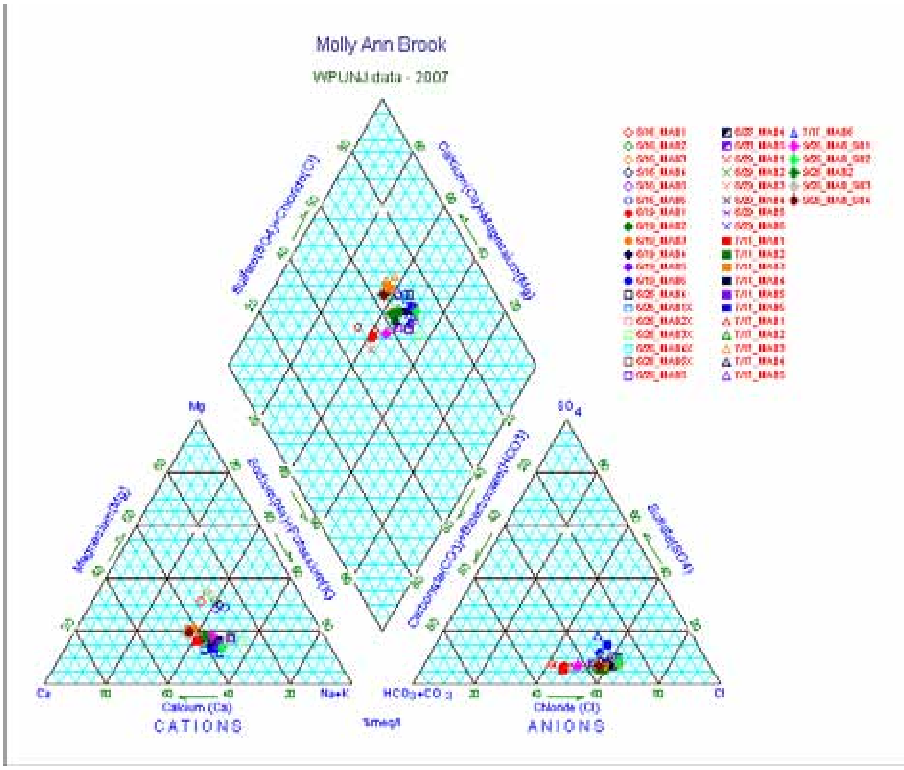


Figure 11: Tri-linear diagram generated from analytical data derived from samples collected during 2007.

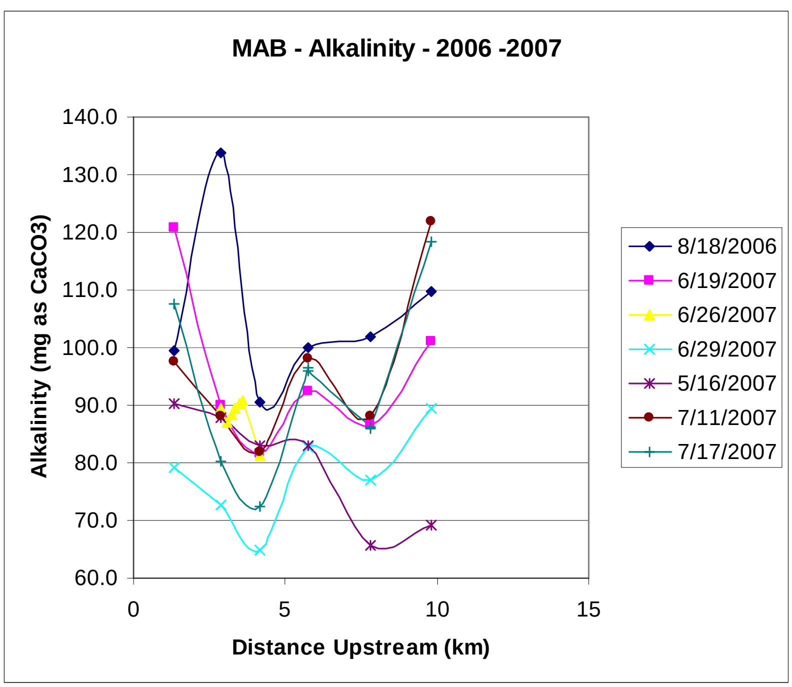


Figure 12: Alkalinity plotted against distance upstream for samples collected during 2007.