Kings Agricultural Wetland and Biodiversity Conservation Initiative

Results of Water Quality Monitoring
2007-2010

Prepared By

Michael Brylinsky
Acadia Centre for Estuarine Research
Acadia University
Wolfville, Nova Scotia

For

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SUMMARY

As part of the Kings Agricultural Wetland and Biodiversity Conservation Initiative being carried out by the Nova Scotia Department of Natural Resources, a water quality monitoring program was initiated at two agriculture demonstration sites located within the upper reaches of the Cornwallis River watershed.. One of the major objectives of this project is to evaluate the efficacy of Beneficial Management Practices (BMPs) implemented at the demonstration sites to improve water quality within the Cornwallis River. This report describes the approach taken to monitor and evaluate water quality and the results that have been attained over the period between 2007 and 2009.

The water quality parameters monitored include nutrient concentrations, fecal coliform bacteria numbers, turbidity, water temperature, conductivity, pH and dissolved oxygen levels. The results obtained to date indicate that water quality at the demonstration sites is severely impacted as exemplified by high levels of nutrients and fecal coliform numbers and, at times, high turbidity and low dissolved oxygen levels. This is also true of water quality within the River prior to its entering the demonstration sites.

There is some evidence to indicate that some of the BMPs implemented to date, which mainly include riparian zone fencing and construction of artificial wetlands, have had an impact on improvement of water quality, and that this is likely to increase as the biological components of the riparian buffer zones and constructed wetlands further develop.

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1. Introduction

During 2006, the Nova Scotia Department of Natural Resources began implementation of the Kings Agricultural Wetland and Biodiversity Conservation Initiative (KAWBCI) as part of the Greencover Canada Plan. The primary objective of the KAWBCI is to determine the effectiveness of a variety of Beneficial Management Practices (BMPs) aimed at reducing the impact of agricultural activities on wetlands and water quality. As part of this initiative, in the late fall of 2006 a water quality monitoring program was established at two demonstration sites, one at a large beef operation and another at a large dairy operation. The primary objective of the water quality program is to obtain baseline data prior to and after implementation of BMPs designed to improve water quality in order to evaluate their efficacy in improving water quality.

Beginning in 2007, a number of BMPs were initiated at the demonstration sites. These included (1) fencing livestock out of a buffer strip established along the River's edge to encourage the development of a natural riparian zone; (2) construction of bridges for livestock crossings over, rather than through, the River; (3) provision of alternative livestock watering systems to alleviate the need for livestock watering directly from the River; and (4) construction of artificial wetlands to treat a milkhouse waste stream and surface runoff from a livestock feedlot.

2. Approach

The two demonstration sites chosen for this project are located within the upper reaches of the Cornwallis River watershed on agricultural lands owned by Andrew VanOostrum and Timothy Lamb. Initially, the intent was to establish two primary water quality monitoring sites, one located where the River entered the uppermost demonstration site and another where the River exited the lowermost demonstration site, the intent being to determine changes in water quality as river water flows through the two demonstration sites. However, it became apparent that there were a number of land use activities within areas of the watershed separating the two demonstration sites that could make it difficult to evaluate water quality changes resulting solely from land use activities occurring at the two demonstration sites. As a result, two primary water quality monitoring stations were established at each demonstration site, one where the River first enters each site and one were the River last exits each site, for a total of four primary monitoring sites. In addition to the primary monitoring sites, an additional 12 secondary monitoring sites were also monitored for coliform bacteria and nutrient concentrations. Appendix I contains aerial photos illustrating the location of each primary and secondary monitoring site in relation to the boundaries of the two demonstration sites, and Table 2.1 lists the years each of the sites was monitored and the parameters monitored at each site.

Table 2.1. Summary of monitoring site names, monitoring periods and parameters monitored.

Name	Water Body*	Years Monitored	Parameters Monitored
Primary Sites			
VCU	Cornwallis River	2007/2008/2009	Water Depth, Temperature, Conductivity, pH, Dissolved Oxygen, Turbidity, Nutrients, Coliforms
VCL	Cornwallis River	2007/2008/2009	
LCU	Cornwallis River	2007/2008/2009	
LCL	Cornwallis River	2007/2008/2009	
Secondary Sites			
LF	Fisher Brook	2007/2008/2009	Water Depth, Temperature, Conductivity, Turbidity, Nutrients, Coliforms
VCP	Watering Pond	2009	Water Depth, Nutrients, Coliforms
VWP	Barnyard Pond	2009	
VBP	Feedlot Pond	2009	
LPC	Wetland	2009	
LFL	Fisher Brook	2008/2009	Nutrients, Coliforms
LFLIS	Cornwallis River	2009	
LSTO	Septic Tank Outflow	2009	
LPIN	Wetland Inflow	2008/2009	
LPOUP	Wetland Outflow	2009	
LPOU	Fisher Brook	2008/2009	
LT	Tributary	2007/2008/2009	

* See site maps (Appendix I) for specific locations of each monitoring site.

Over the entire three year period of the study, a total of 16 sites were monitored for nutrient and coliform bacteria concentrations. At the VanOostrum farm, coliform and nutrient concentrations were monitored at five sites. Two were located within the Cornwallis River, one where it entered the farm (VCU) and one where it exited the farm (VCL). The remaining three sites were located within ponds located on the farm (VCP, VWP and VBP). A total of eleven sites were monitored for nutrients and coliform concentrations at the Lamb farm. Three sites were within the Cornwallis River, one just above where it entered the farm (LCU), one where Fisher Brook, which runs through the farm, entered the River (LFL) and one just below where it exited the farm (LCL). Three sites were located within Fisher Brook, one where it entered the farm (LF), one where the outflow of the constructed wetland entered the Brook (LPOU), and one just above where the Brook entered the Cornwallis River (LFLIS). Four sites were associated with the outflow from the milk house which flowed into the constructed wetland. These were located within the septic tank (LSTO), at the outflow of the septic tank prior to where it entered the wetland (LPIN), within the wetland pond (LPC), and at the outflow of the wetland pond (LPOUP). The last site monitored (LT) was located at a tributary flowing into the Cornwallis River near where the River exited the farm.

3. Methodology

3.1 Continuously Monitored Water Quality Parameters

A number of water quality parameters were monitored continuously using Yellow Spring Instruments (YSI) 6000 series Sondes. These included: water temperature, water depth, conductivity, pH, dissolved oxygen and turbidity. Each sonde was encased within PVC tubing having open ends that allowed water to flow freely over the probes (Figure 3.1). The probe end was deployed in the downstream direction and was elevated approximately 15 cm above the river bottom by two metal bars on the downstream end of the PVC tubing[1].

Figure 3.1 YSI Sonde and PVC tubing used for placement on River bottom.

All data loggers were programmed to log each parameter at 15 minute intervals and were retrieved, downloaded, recalibrated and re-deployed at approximately one month

[1] Initially, the probes were oriented upstream, but this often resulted in heavy accumulations of sediments on the surface of the probes during events of high sediment load which influenced the ability of the probes to respond properly, especially in the case of dissolved oxygen measurements.

intervals. At these times one litre water samples were also collected for analysis of suspended particulate matter (SPM) concentration and this information was used to determine the relationship between turbidity (measured as Nephelometric Turbidly Units (NTUs) by the data loggers) and SPM.

SPM measurements for calibration of the turbidity sensors were made by filtering one litre water samples through pre-weighed Watman GF/C glass fiber filters and oven drying the filters at 60-70 ºC to a constant dry weight. SPM was determined as the difference between the pre-weight and final weight. The relationship between NTUs and SPM concentrations is illustrated in Appendix II.

3.2 Water Depth, Current Velocity and River Discharge

Although the YSI sondes recorded water depth, they lack the sensitivity required to measure the small changes in depth necessary to obtain accurate data for determining discharge rates at each site. As a result, HOBOware PRO depth loggers were deployed at each primary monitoring site and at the Upper Fisher Brook secondary site. These were also encased in PVC tubing and placed directly on the River bottom within the centre of the River channel. Logged depth measurements were corrected for variations in barometric pressure by atmospheric pressure measurements collected by a base reference logger located at ground level under a small building nearby the Upper VanOostrum monitoring site during 2007 and nearby the Upper Fisher Brook site during 2008 and 2009.

Measurements of current velocity and water depth collected during 2008 and 2009 using a GLOBAL Model FP101 flow probe were used to construct current velocity-depth rating curves for each monitoring site (Appendix III). The rating curves were used to calculate a stage-discharge relationship (Appendix IV) for each monitoring site using the relationship between surface area and depth at each site, and this relationship was used to calculate water discharge, and sediment and nutrient loading.

3.3 Nutrients

Nutrients (total nitrogen, nitrite+nitrate, ammonia, total phosphorous and phosphate) were monitored at biweekly intervals between May and November, and at monthly intervals between December and April. Water samples for nutrient analyses were collected from just below the surface in pre-acid washed polyethylene bottles and stored frozen until analysis. All nutrient analyses were carried out at the water quality laboratory of the K.C. Irving Environmental Centre at Acadia University using a Technitron automated nutrient analyzer.

3.4 Fecal Coliform Bacteria

Samples for fecal coliform bacteria were collected at the same locations and time intervals as nutrient samples. The water samples were collected in pre-sterilized containers and kept refrigerated until processing which was carried out within 24 hours of collection. All samples were processed at the Microbiological Laboratory of the Biology Department at Acadia University using the membrane filtration technique and 24 hour incubations at 44.5 °C on mSC media.

4. Results

The initial stages of the monitoring program proved to be problematic. Cold weather during early 2007 resulted in ice formation on the surface of the River and it was not possible to retrieve the loggers until mid March 2007. In some cases, especially at the shallower sites, the River froze completely to the bottom and the loggers became entirely encased in ice. Although the loggers continued to collect data during this period, it is unlikely that any of this data is useful as it does not represent conditions during winter thaw episodes when some periods of free flowing water over the ice layer occur. As a result of the problems associated with ice formation and the potential for damage to the loggers, the YSI loggers were removed in mid-November or early December in subsequent years and not redeployed until early April after the winter ice had melted.

In addition, for a number of reasons related to problems encountered during the 2007 deployments when the dataloggers often became completely covered with sediments, after 2007 the Upper Van and Upper Fisher Brook monitoring sites were relocated a short distance downstream from the 2007 sites to locations where new culverts had been installed during 2007. This alleviated the sediment problem resulting in an improved data set.

4.1 Water Temperature

Water temperature (Fig.4.1) showed little variation between sites. There was a distinct seasonal trend with maximum temperatures of about 23°C occurring during late July and early August. The critical water temperature for cold water fish species such as salmonids (ca. 20 °C) was typically exceeded during most of July and August at the VanOostrum and Lamb primary monitoring sites during all years.

The Upper Fisher Brook site was slightly cooler than all other sites. Maximum water temperatures were about 20°C, which suggests that a significant portion of its inflow originates from groundwater sources.

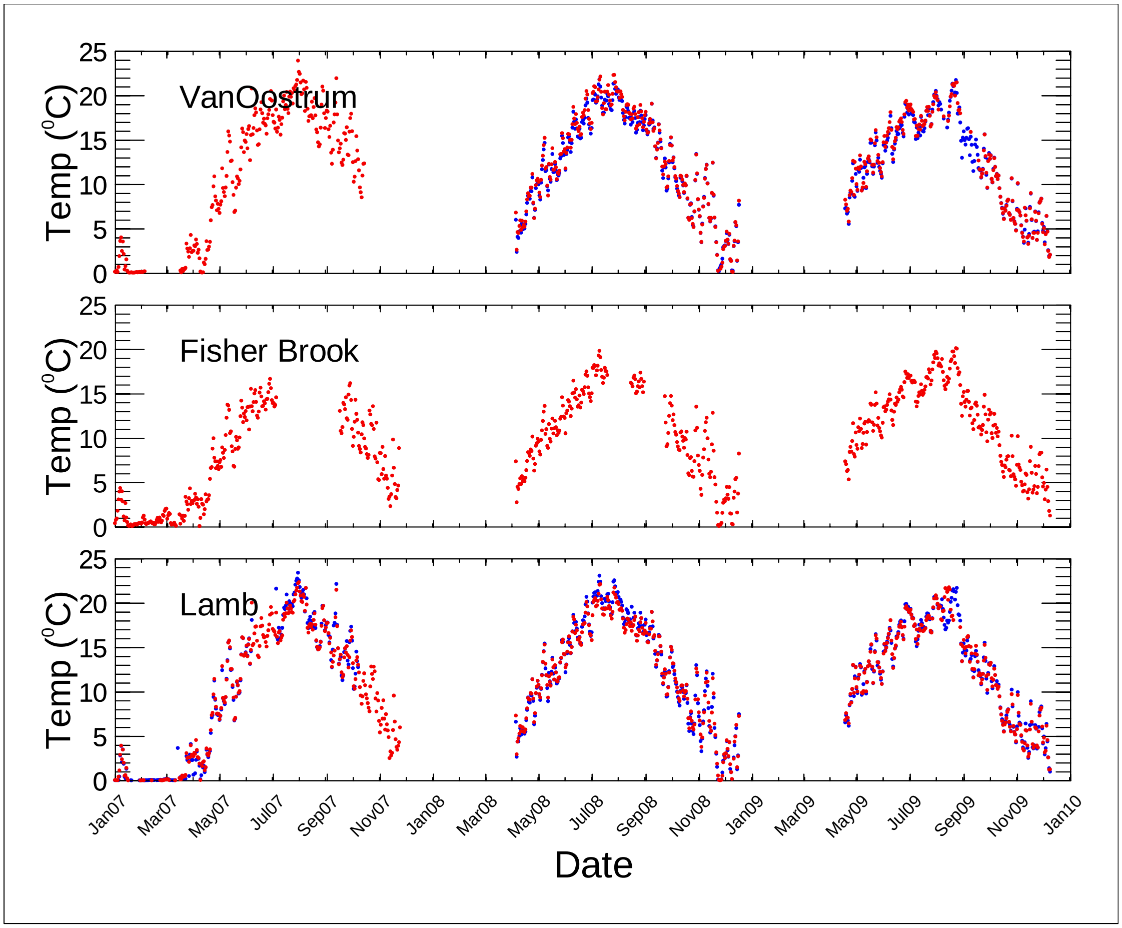


Fig. 4.1 Seasonal variation in water temperature at each site (blue dots represent the Upper monitoring site and red dots represent the Lower monitoring site).

4.2 Conductivity and pH

Conductivity (an indirect measure of dissolved salt content) was generally quite high and showed considerable seasonal variation with relatively low values during the cooler months and very high values during the summer months (Fig. 4.2). At the VanOostrum monitoring sites the conductivity of inflowing water was slightly higher than that of the outflowing water. Conductivity values at the Fisher Brook site were slightly higher than all the other sites which, like water temperature, is likely a result of higher proportions of groundwater inputs which typically contain a much higher salt content than surface waters. The Lamb monitoring sites exhibited significantly higher conductivity levels at the outflow than at the inflow which may be due, in part, to the influence of Fisher Brook.

At all sites conductivity values exhibit an inverse relationship to water depth (Fig. 4.3), a result of a greater proportion of groundwater inputs to surface water inputs during periods of low water.

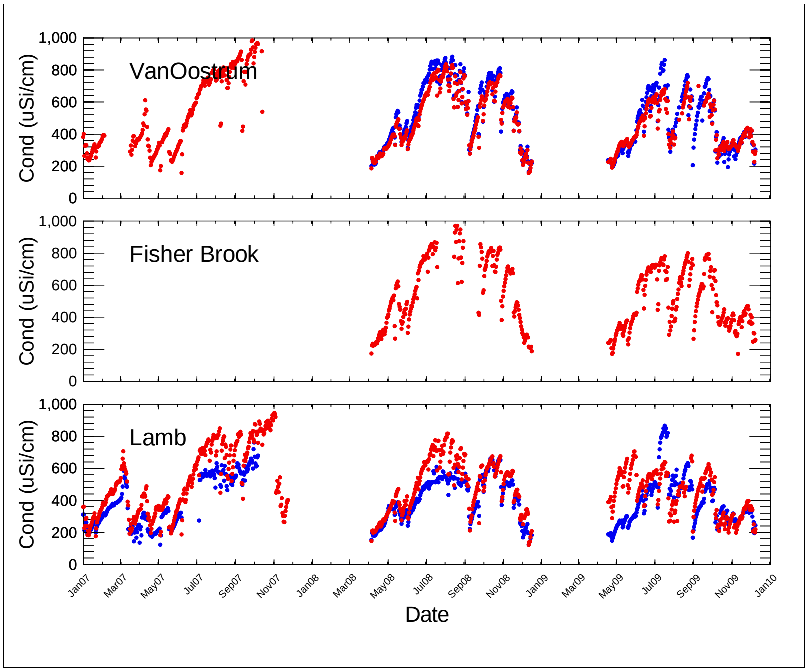


Fig. 4.2 Seasonal variation in water conductivity at each site (blue dots represent the Upper monitoring sites and red dots represent the Lower monitoring sites).

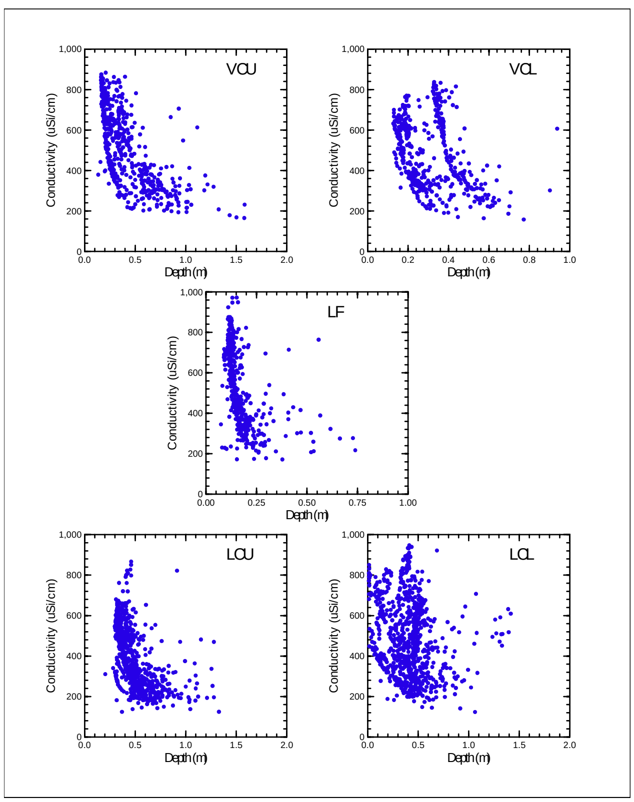


Fig. 4.3 Relationship between water depth and conductivity.

The values of pH at all sites were also quite high ranging between about 7 and 8 (Fig. 4.4). The high and relatively stable pH values indicate that the high conductivity levels of the River are likely due to salts of carbonates, the main buffering component of natural fresh waters.

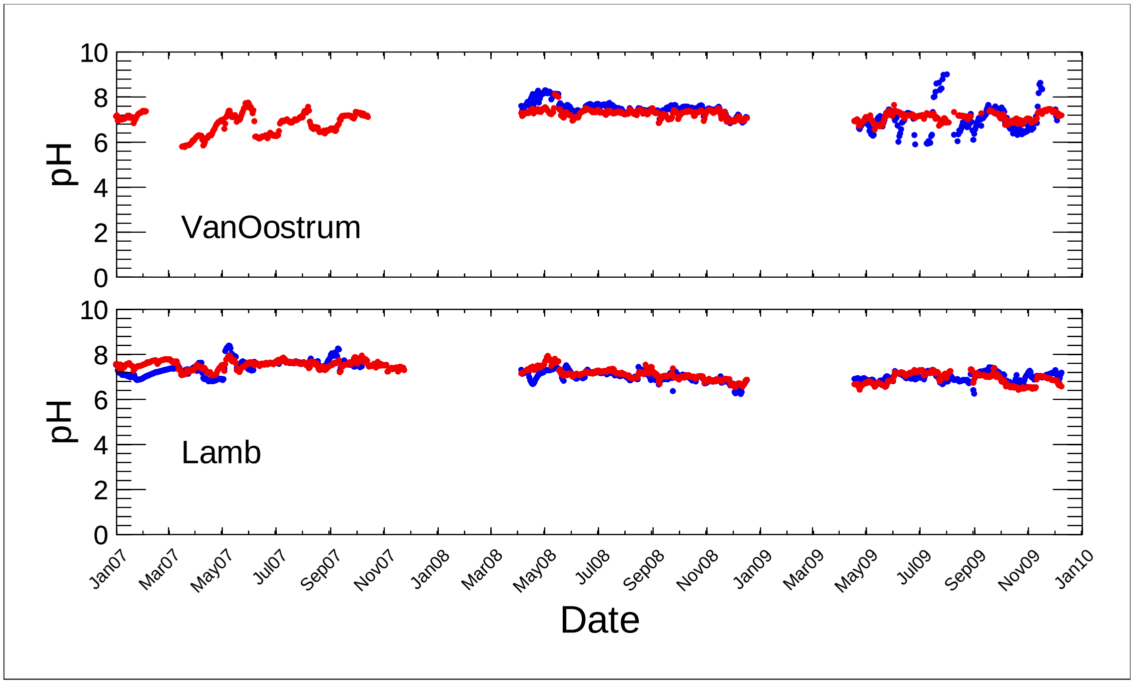


Fig. 4.4 Seasonal variation in pH at each site (blue lines represent the Upper monitoring sites and red lines represent the Lower monitoring sites).

4.3 Dissolved Oxygen Concentration and Percent Saturation

Continuous monitoring of dissolved oxygen concentration was not entirely successful. In many instances, particularly during periods when suspended sediment concentrations were high, the dissolved oxygen probe failed to operate properly. Fig. 4.5 illustrates the variation in dissolved oxygen at each site at which YSI Sondes were deployed (only those values of dissolved oxygen recorded when the probe was determined to be operating properly are shown[2].).

Dissolved oxygen levels ranged from highs reaching to nearly 20 mg/L to lows of 0 mg/L. There was considerable seasonal variation, the highest values occurring during early spring and late fall and the lowest values occurred during the late summer. There were also times when there were significant differences between water entering and leaving the sites in which water leaving typically had much lower dissolved oxygen values than water entering. This was most pronounced at the Lamb site and occurred

[2] The YSI Sonde records a parameter (dissolved oxygen charge) that provides an indication of whether or not the dissolved oxygen probe is working properly.

during the late summer when water depths were low and water temperatures high. At the VanOostrum site it occurred in the late summer and fall.

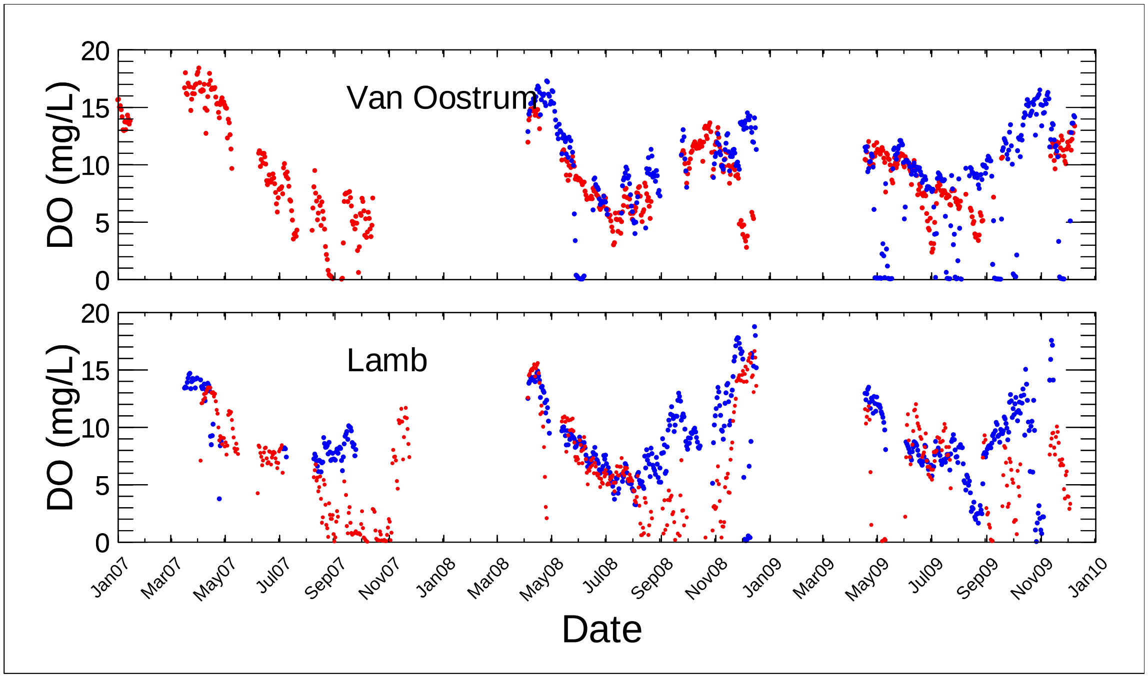


Fig. 4.5 Seasonal variation in dissolved oxygen concentration at each site (blue dots represent the Upper monitoring sites and red dots represent the Lower monitoring sites).

Percent dissolved oxygen levels also varied greatly. In some instances percent saturation values exceeded 100 percent (Fig 4.6), particularly in the early spring during high water flows associated with snow melts, and during low water levels in the summer when a greater proportion of the River originates from cold groundwater flows that gradually become heated resulting in a decrease in the dissolved oxygen level required for saturation to occur.

At times, percent saturation fell below 50%, the value considered to be stressful for aquatic organisms, especially cold water fish species such as brook trout. This typically occurred during August and lasted until early November at both the Lower VanOostrum and Lower Lamb site, but was more extensive at the latter.

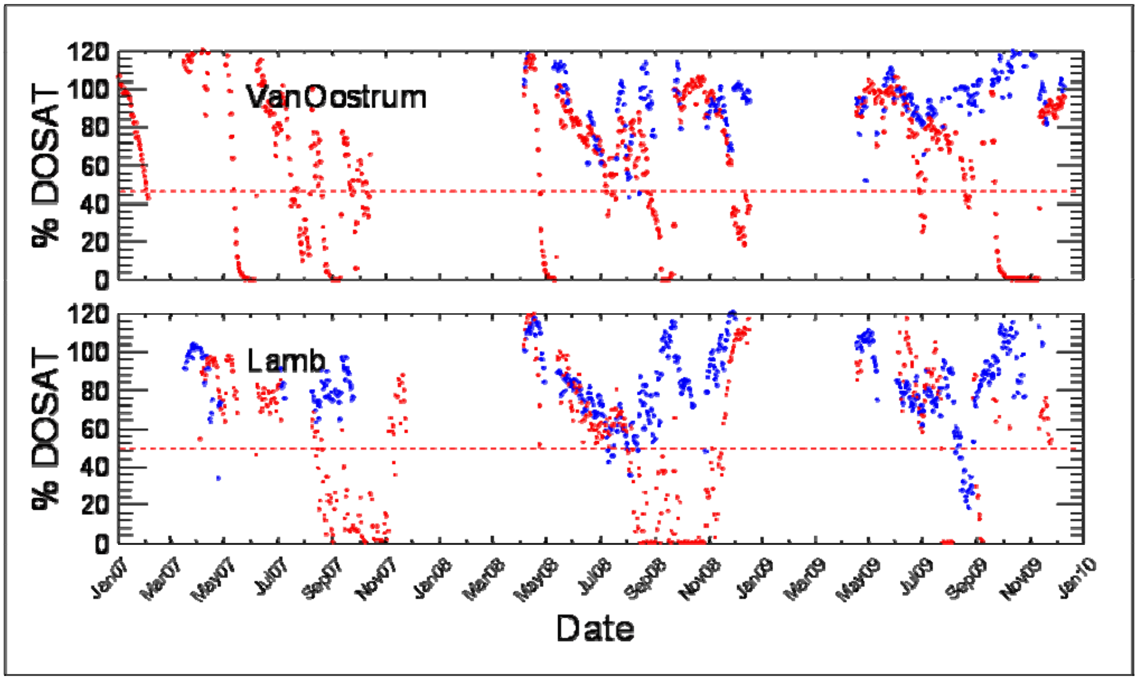


Fig. 4.6 Seasonal variation in percent dissolved oxygen saturation at each site (blue dots represent the Upper monitoring sites and red dots represent the Lower monitoring sites; dotted red lines indicate the critical 50% saturation level).

4.4 Turbidity

Turbidity, an indirect measure of suspended particulate matter concentration, exhibited considerable variation and often attained values greater than 1000 NTUs (Fig.4.7).

Many of the higher values were associated with periods of high precipitation, but some high turbidity events occurred during times of low precipitation suggesting that activities associated with individual land use practices within the watershed are important with respect to increasing sediment inputs to the River.

In most instances, turbidity levels were greater at the Lower than at the Upper monitoring sites. An exception to this was at the VanOostrum site during 2009 when the upper site exhibited higher turbidity levels than the lower site. This was likely a result of the failure of a livestock watering system resulting in the necessity to remove the riparian zone fencing in this area to allow livestock access to the River for watering.

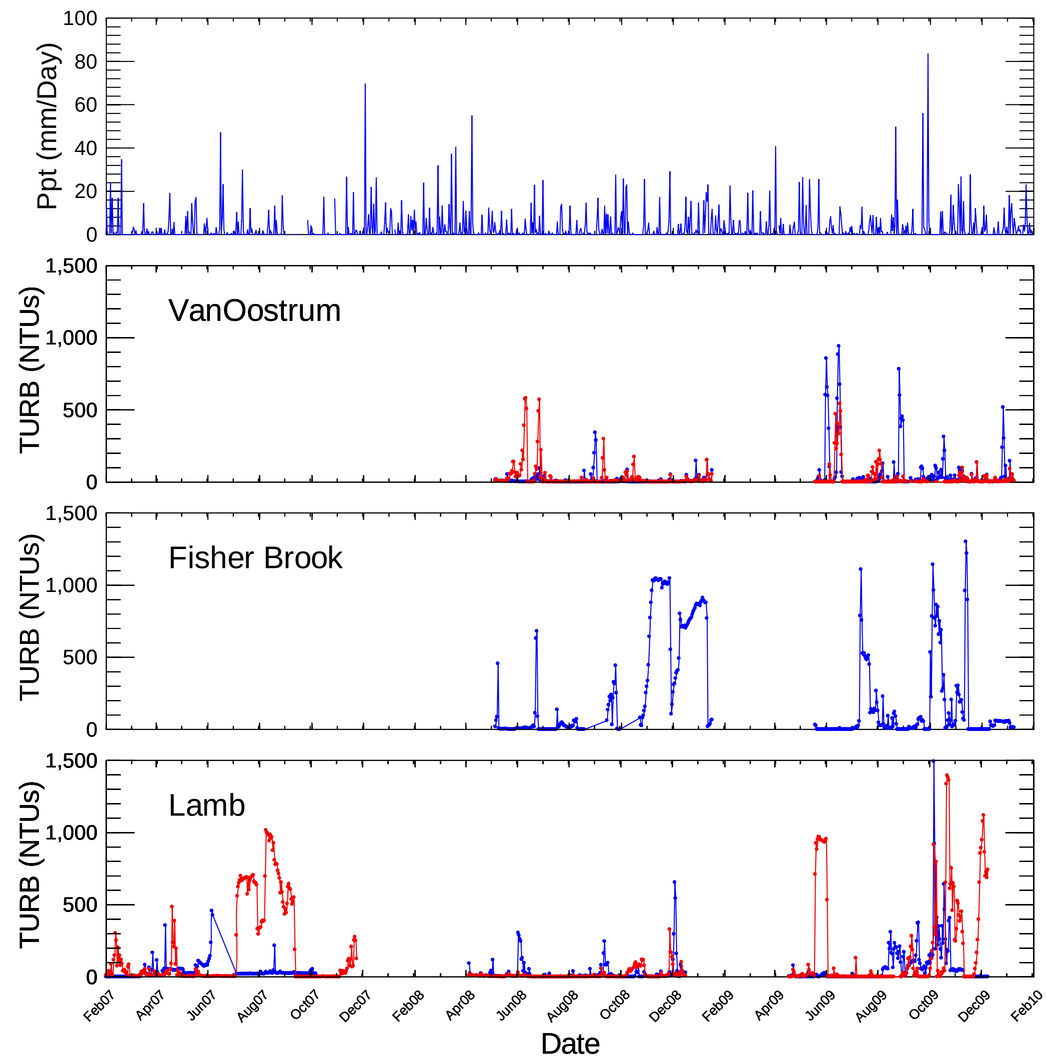


Fig. 4.7 Seasonal variation in total daily precipitation as recorded at the Kentville Research Agricultural Research Station (upper panel) and mean daily turbidity at each monitoring site (blue lines represent the Upper monitoring sites and red lines represent the Lower monitoring sites).

4.5 Nutrients

4.5.1 Primary Monitoring Sites

Total nitrogen levels varied considerably among the primary monitoring sites (Fig. 4.8). At the VanOostrum farm, concentrations were generally similar at the Upper and Lower monitoring site. In contrast, at the Lamb farm total nitrogen levels were much higher at the Lower than at the Upper monitoring site. This may indicate land use activities located within the watershed between the Upper and Lower monitoring sites that result in significant nitrogen loading to the River. This site also exhibited a distinct seasonal variation with highest total nitrogen levels occurring during the summer.

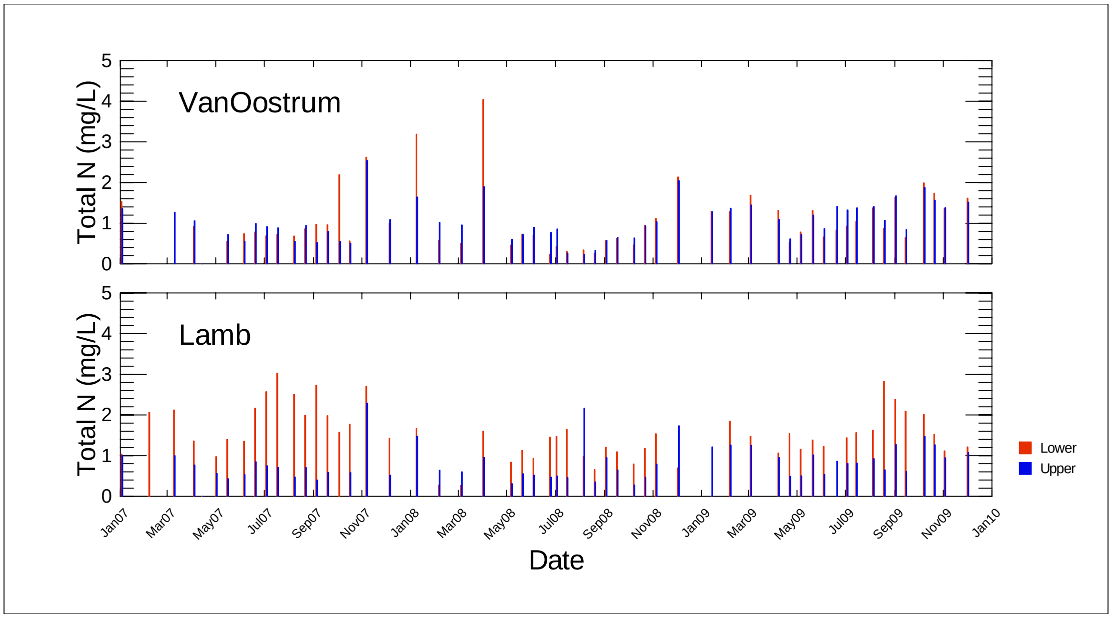


Fig. 4.8 Total nitrogen concentrations at the primary monitoring sites.

At both sites, most of the total nitrogen is in the inorganic NO_x-N form which showed the same spatial and seasonal trends as total nitrogen (Fig. 4.9). At the Lamb sites during the summer of 2007 they were often near the CCME maximum guideline of 2.9 mg/L nitrate-N for the protection of aquatic life (CCME 2002).

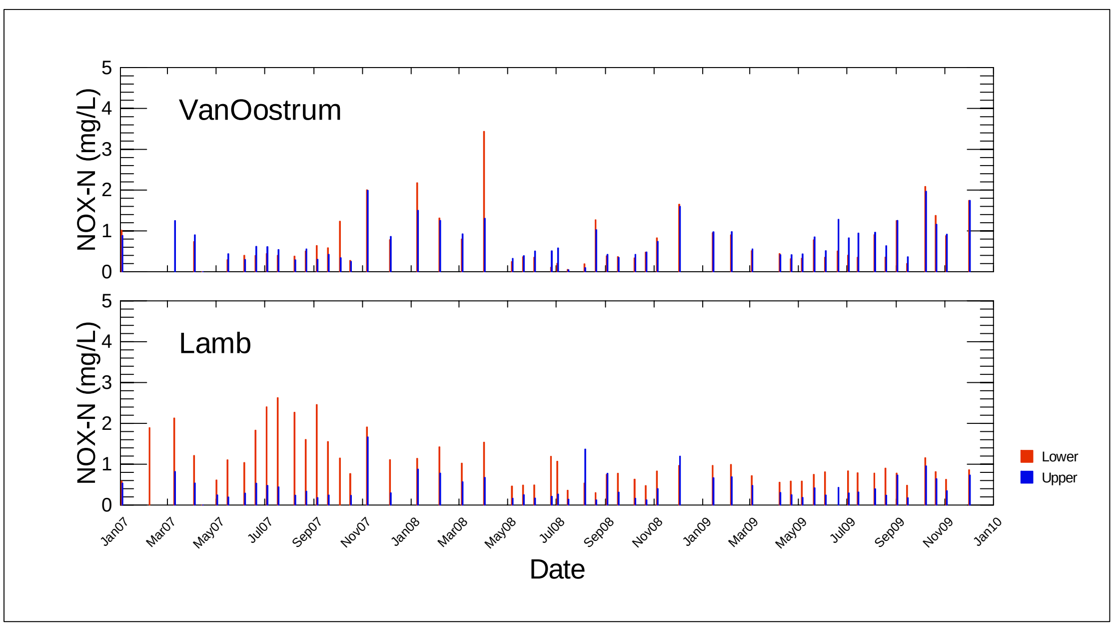


Fig. 4.9 Nitrate nitrogen concentrations at the primary monitoring sites.

Except for a short period during the late summer of 2009, ammonia levels were very low at most times (Fig.4.10).

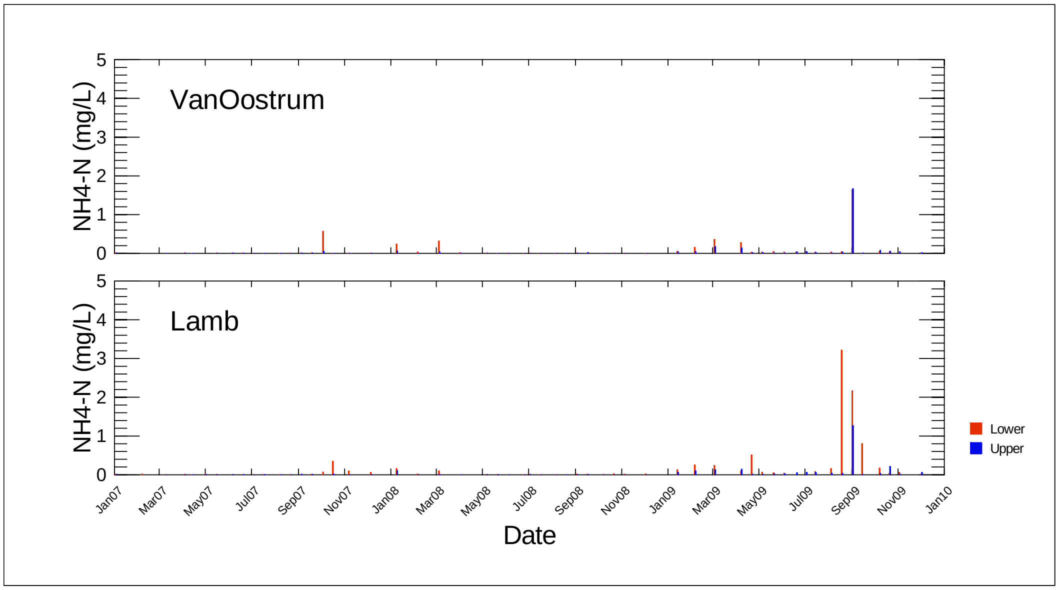


Fig. 4.10 Ammonia nitrogen concentrations at the primary monitoring sites.

In contrast to nitrogen, total phosphorus levels at the primary monitoring sites were exceptionally high, often exceeding levels greater than 0.1 mg/L (Fig 4.11 and 4.12)[3]. Much of the total phosphorous was present in the labile phosphate form which is typically present in concentrations below the analytical limits of detection in un-impacted aquatic systems.

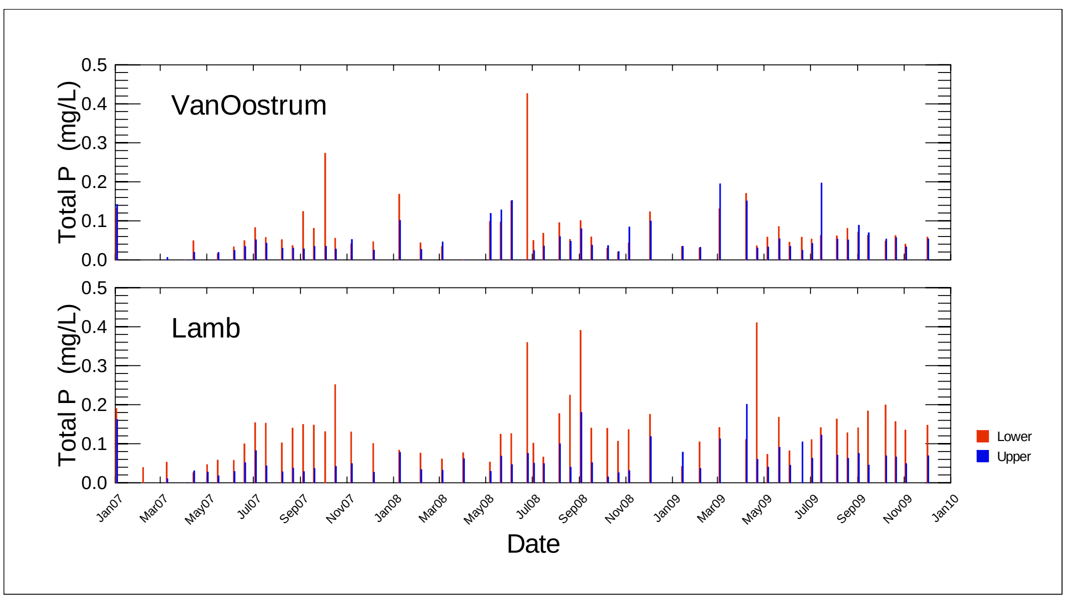


Fig. 4.11 Total phosphorus concentrations at the primary monitoring sites.

[3] The CCME guideline for protection of aquatic life is 0.030 mg/L total phosphorus (CCME 2002).

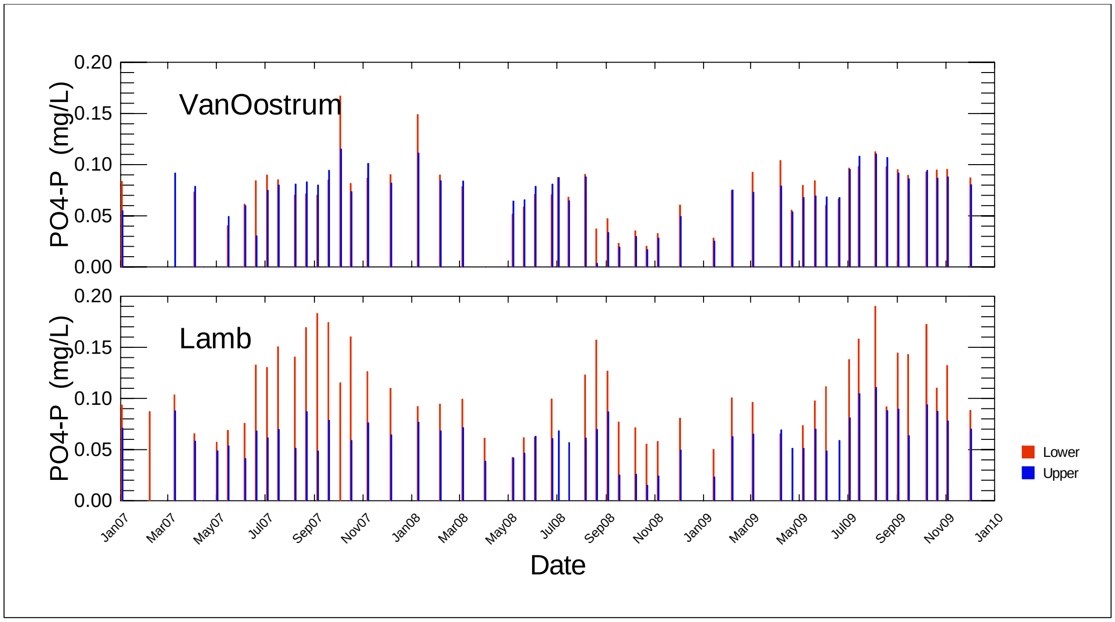


Fig. 4.12 Phosphate concentrations at the primary monitoring sites.

As was the case with nitrogen, phosphorus concentrations at the VanOostrum farm were generally similar at the Upper and Lower monitoring site, but at the Lamb farm phosphorus levels were much higher at the Lower than at the Upper monitoring site.

4.5.2 Secondary Monitoring Sites

Many of the highest nutrient concentrations were observed at the secondary monitoring sites associated with Fisher Brook (monitoring sites LF, LPOU and LFLIS), and the Lamb farm milkhouse waste stream sites (monitoring sites LSTO, LPIN, LPC and LPOUP).

The Fisher Brook sites were monitored for different periods of time: Site LF, located where Fisher Brook first enters the Lamb farm, has been monitored over the entire three year period of the study. Site LPOU, located where the outlet of a constructed wetland enters Fisher Brook, was monitored in 2008 and 2009, and site LFLIS; located just above where Fisher Brook enters the Cornwallis River, was only monitored in 2009. Nitrogen concentrations at these sites are illustrated in Fig.4.13

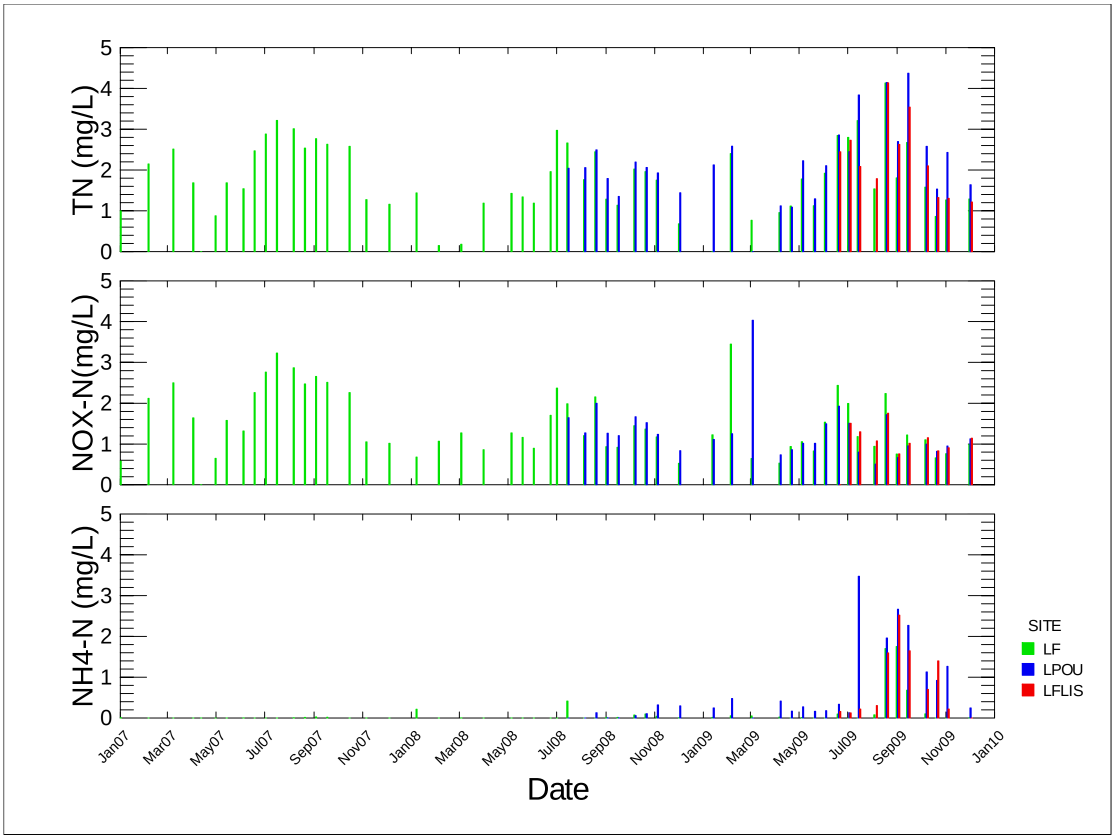


Fig. 4.13 Nitrogen levels at the monitoring sites associated with Fisher Brook.

There was a strong seasonal variation in the total nitrogen levels at site FL with the highest concentrations occurring during summer. There also appears to have been significant annual variation with decreasing levels over the course of the study. As was the case with the primary monitoring sites, most of the nitrogen is in the NO_X-N inorganic form. During the years in which they were monitored, sites LPOU and LFLIS exhibited similar total nitrogen and NO_x-N concentrations to site LF, but during 2009 NH_4-N levels were considerably higher which may be a result of the effluent of the constructed wetland entering Fisher Brook.

Total phosphorus concentrations at site LF were much lower than those at the primary monitoring sites and showed little seasonal or annual variation (Fig.4.14). In contrast, they were very high at sites LPOU and LFLIS which is almost certainly due to the effluent form the constructed wetland, which receives effluent form the milkhouse waste stream, entering Fisher Brook.

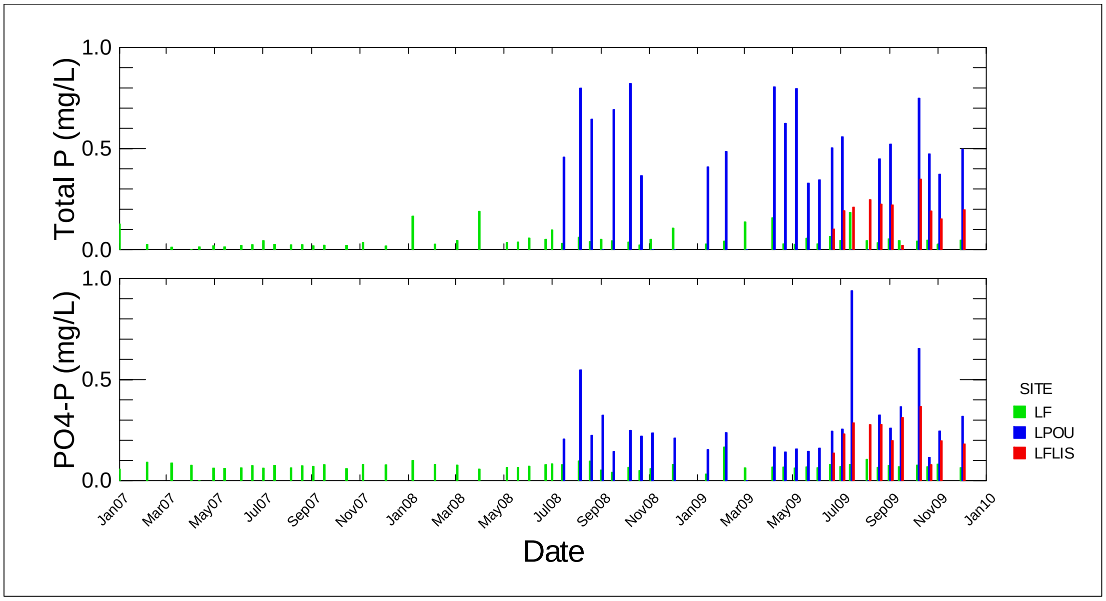


Fig. 4.14 Phosphorus levels at the monitoring sites associated with Fisher Brook.

Four of the secondary monitoring sites were associated with the Lamb farm milkhouse waste stream. These included site LSTO located at the septic tank, site LPIN located where the milkhouse waste stream enters the constructed wetland, site LPC located within the constructed wetland, and site LPOUP, located at the effluent of the constructed wetland just prior to where it enters Fisher Brook.

Fig. 4.15 illustrates the nitrogen concentrations at each of these sites during 2009. As would be expected, the levels of all forms of nitrogen at site LSTO, which is located at the septic tank, are extremely high. Although these levels are greatly reduced at site LPIN, the input to the wetland, there is little further reduction within the wetland or at the effluent of the wetland. Of particular concern is that much of the inorganic nitrogen is in the NH_4-N form. Values at the septic tank are, as would be expected, very high at times approaching more than 200 mg/L. At the other sites associated with the milkhouse waste stream, values as high as 40 mg /L were observed, indicating that the entire waste stream is unlikely to contain much dissolved oxygen and is quite toxic to most forms of aquatic life[4].

Phosphorus levels in the milkhouse waste stream are also very high (Fig. 4.16). Although there is some reduction in phosphorus as the waste stream flows through the wetland, the final concentrations of total phosphorus and inorganic phosphorus prior to where the effluent enters Fisher Brook often exceed 20 and 10 mg/L, respectively.

[4] The CCME guideline for protection of aquatic life for ammonia is 2.2 mg/L ammonia-N.

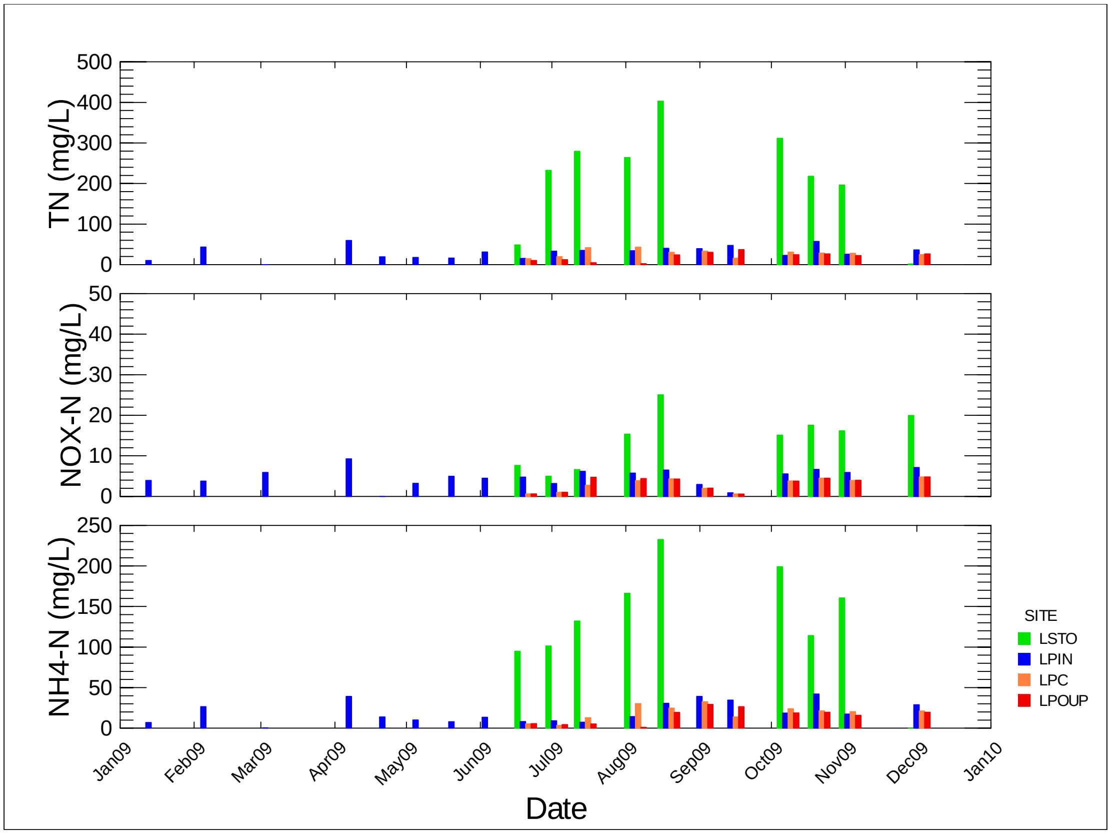


Fig. 4.15 Nitrogen levels at the monitoring sites associated with the Lamb farm milkhouse waste stream during 2009 (note the differences in scales).

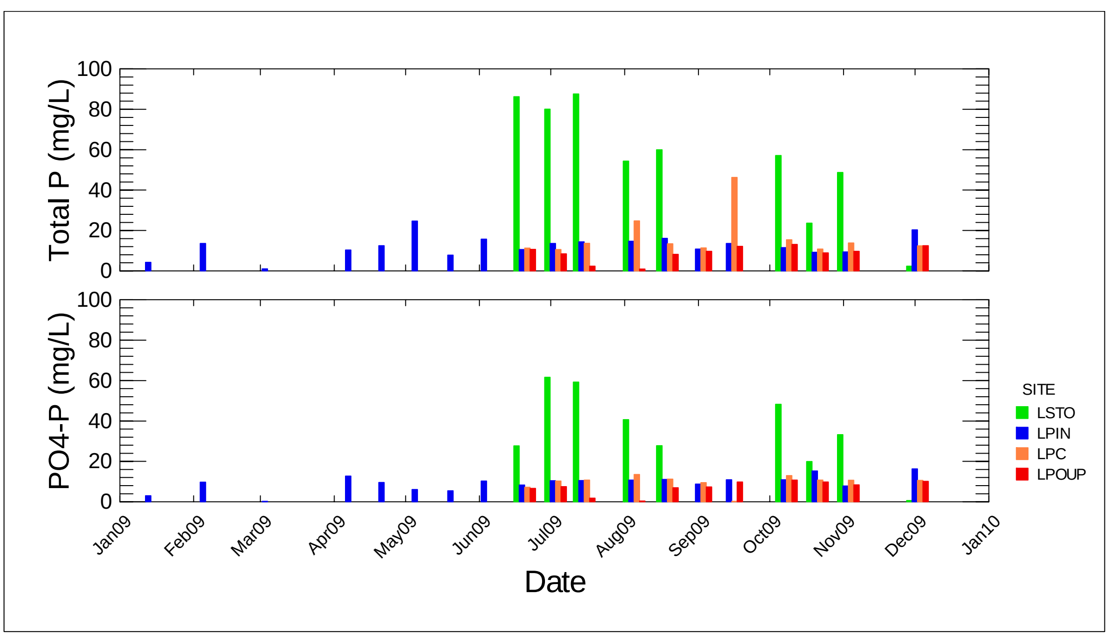


Fig. 4.16 Phosphorus levels at the monitoring sites associated with the Lamb farm milkhouse waste stream during 2009.

Beginning in mid-June of 2009, nutrient levels were also monitored at three ponds located on the VanOostrum farm. These included: site VCP, a constructed wetland pond; site VBP a constructed wetland pond designed to collect runoff from a nearby feedlot, and; site VWP, a small existing pond located on the western border of the farm. Figs. 4.17 and 4.18 illustrate the levels of nitrogen and phosphorus concentrations observed at each of these sites.

Only one of the three ponds, site VBP, exhibited high nutrient levels where NO_X-N and NH_4-N are quite high and above the CCME guidelines for protection of aquatic life. The high ammonia levels also indicate that this site is low in dissolved oxygen levels. The high nutrient concentrations observed is not unexpected as this site was designed to receive nutrient runoff from a feedlot. In addition, this pond was only recently constructed and has not had the time necessary for development of vegetation, either around the perimeter of the pond or within the wetland itself, to effectively assimilate nutrients contained within the runoff from the feedlot.

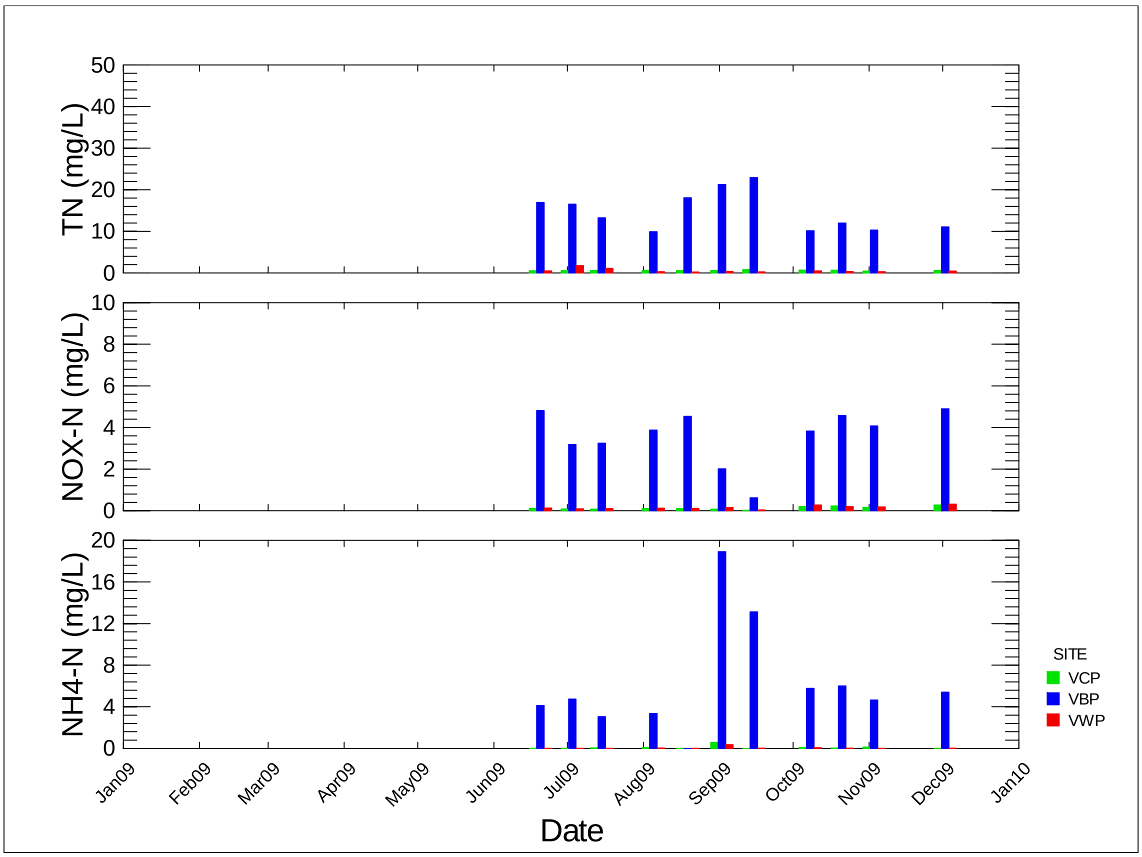


Fig. 4.17 Nitrogen concentrations at the ponds located on the VanOostrum farm (note differences in scale).

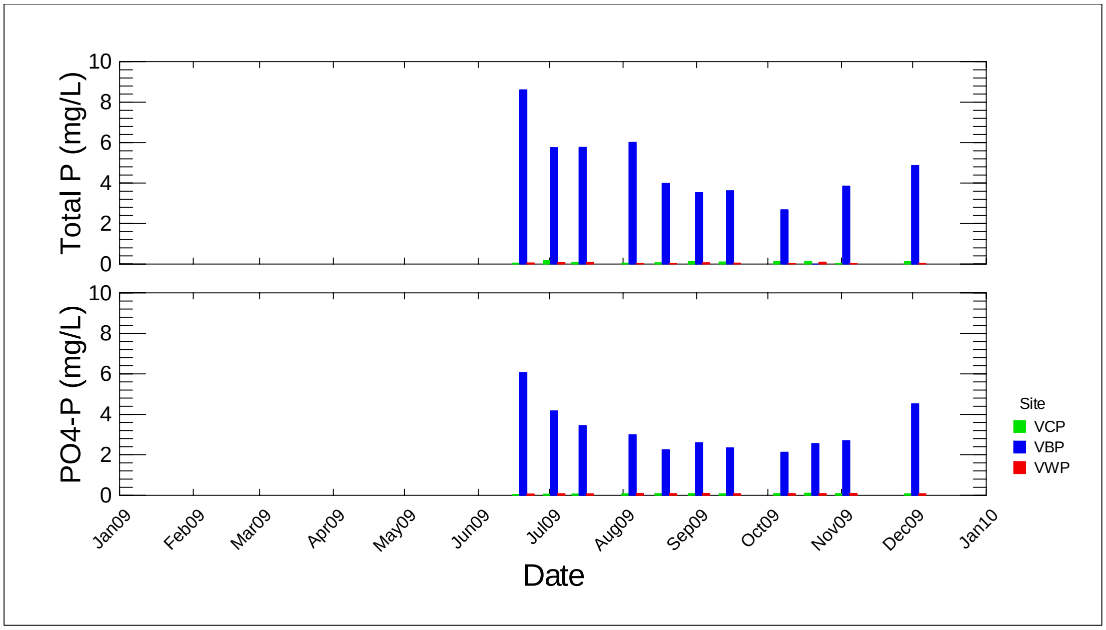


Fig. 4.18 Phosphorus concentrations at the ponds located on the VanOostrum farm,

4.6 Fecal Coliform Bacteria

With few exceptions, fecal coliform numbers at the primary monitoring sites were very high at all times (Fig. 4.19). Numbers were seldom less than 100/ml and often exceeded 1000/ml.

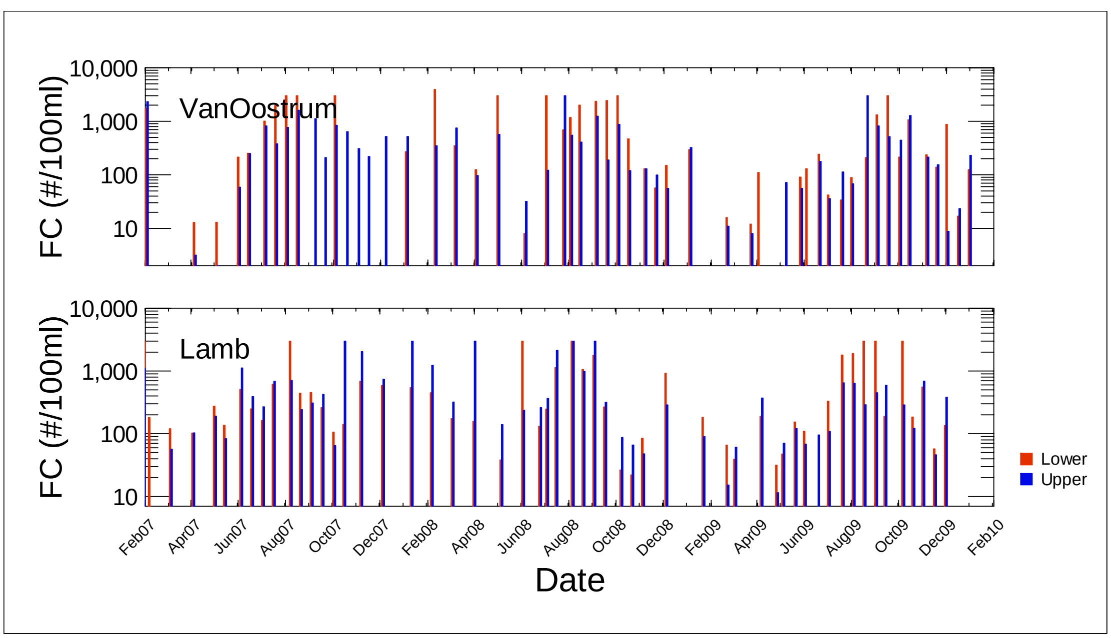


Fig. 4.19 Seasonal variation in fecal coliform numbers at the primary monitoring sites.

The highest values occurred during the summer months. At both the VanOostrum and Lamb sites, fecal coliform numbers were at most times slightly higher at the Lower than at the Upper monitoring site. In only a few instances, mainly during the winter periods, were coliform numbers below 100 ml/L, the level often recommended not to be exceeded for waters used for livestock watering.

Fecal coliform numbers were also very high at all of the secondary sites associated with Fisher Brook (Fig 4.20). These sites exhibited the same seasonal trends as did the primary monitoring sites, i.e., highest values in summer and lowest values in winter.

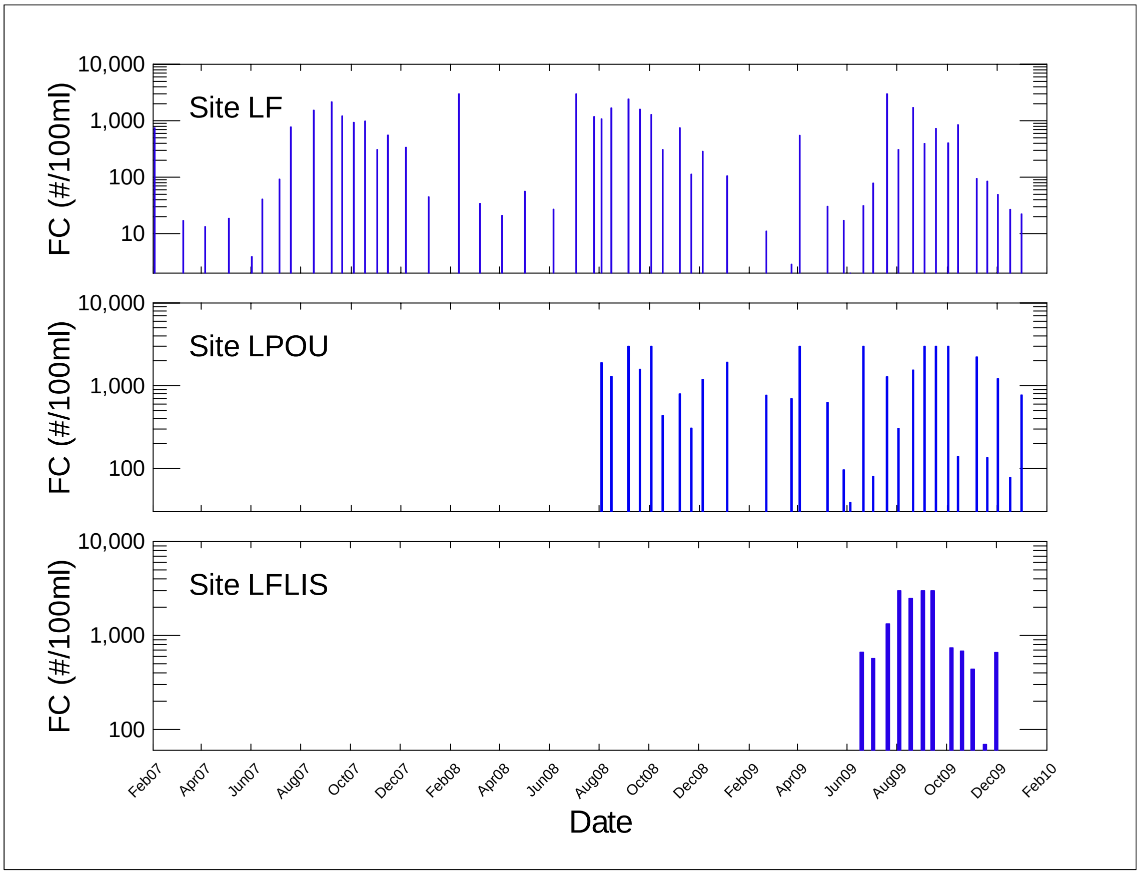


Fig. 4.20 Seasonal variation in fecal coliform numbers at the Fisher Brook monitoring sites.

Fecal coliform levels at all of the sites associated with the Lamb farm milkhouse waste stream (Fig. 4.21) were almost always above the maximum level of detection (3000/ml).

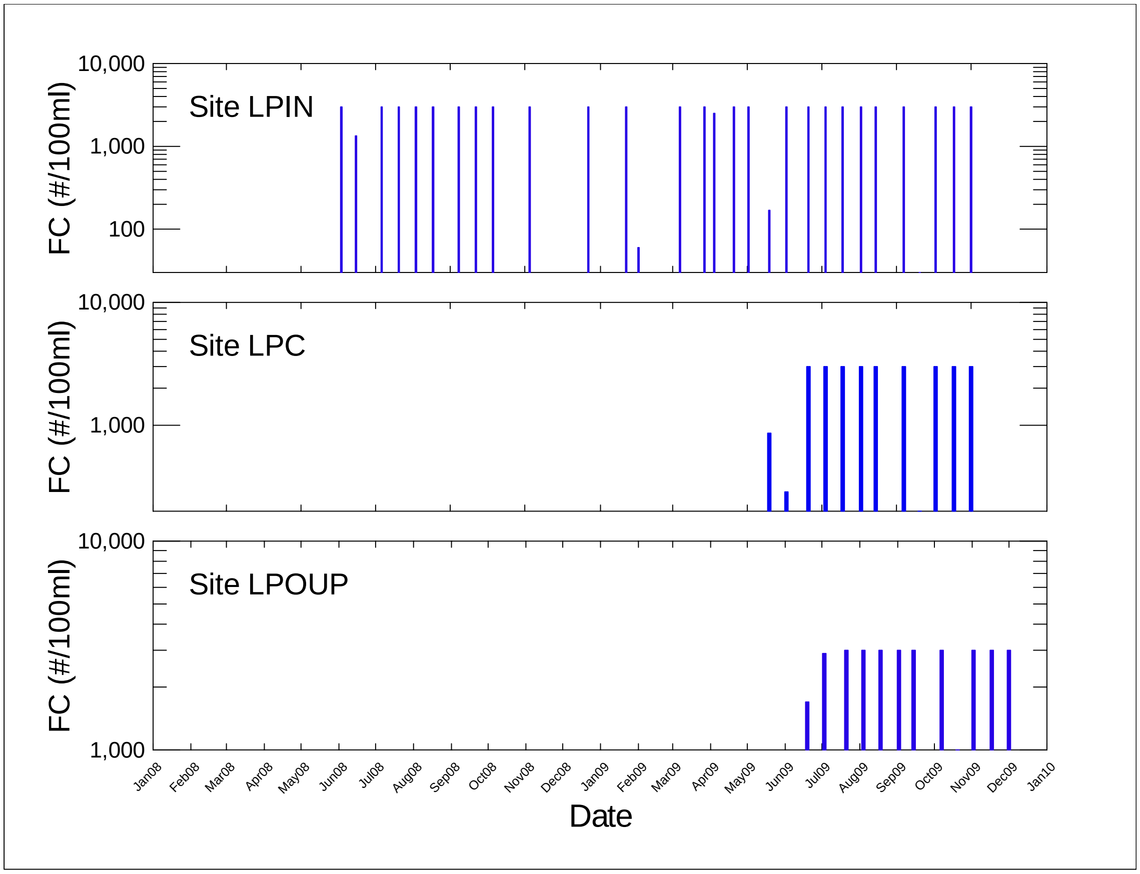


Fig. 4.21 Fecal coliform numbers at the sites associated with the Lamb farm milkhouse waste stream.

Coliform numbers at the pond sites located at the VanOostrum farm were, with the exception of site VBP, the lowest of all sites monitored (Fig. 4.22). At sites VWP and VCP coliform numbers were often below 100/ml. At site VBP they were mostly above the maximum limit of detection which is to be expected as this site is a newly constructed pond designed to receive run off from a livestock feedlot.

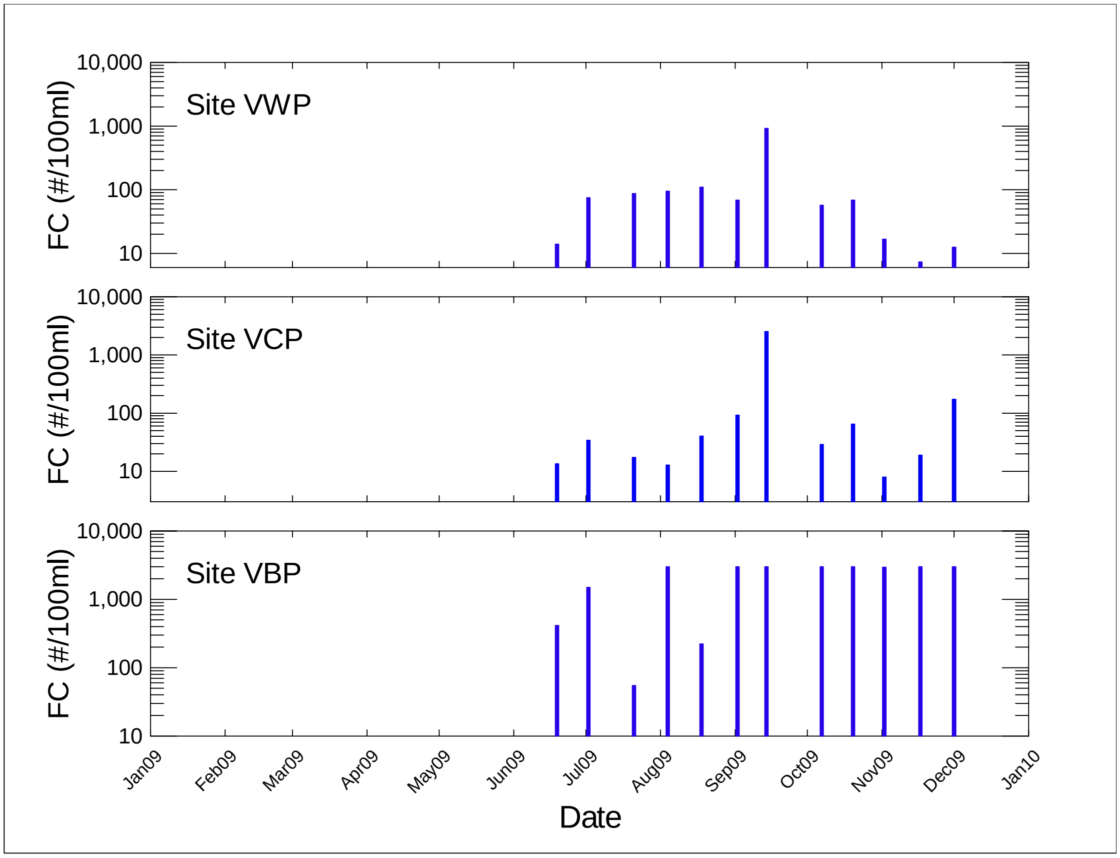


Fig. 4.22 Fecal coliform numbers at the VanOostrum farm pond sites.

4.7 Water Discharge and Loadings

4.7.1 Water Discharge

Total daily precipitation and daily water discharge at each monitoring site during the times for which data necessary for calculating discharge were available are illustrated in Fig. 4.23. There is a good relationship between daily precipitation events and daily water discharge.

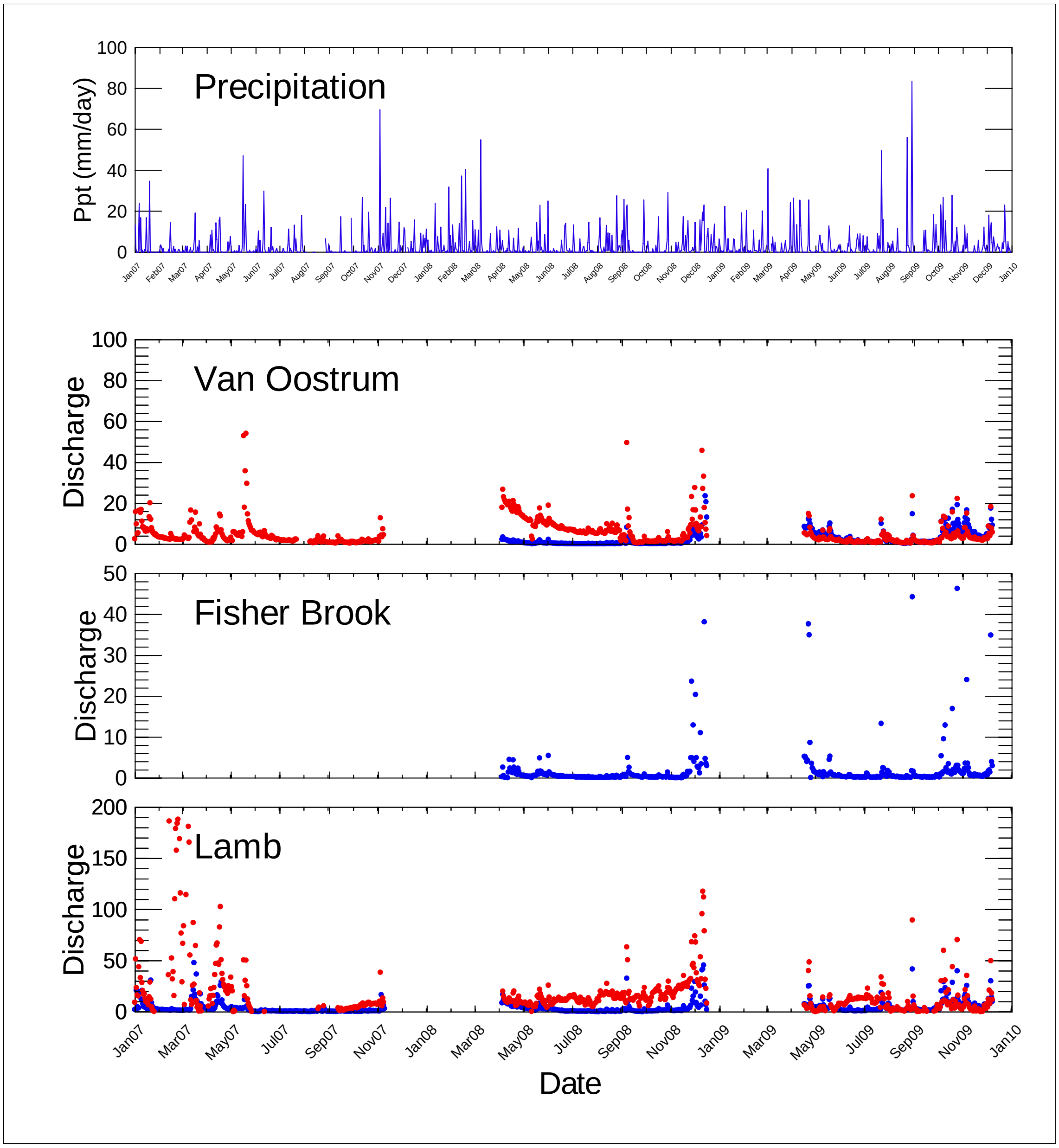


Fig. 4.23 Seasonal variation in daily total precipitation and water discharge (m3/day). Blue dots represent Upper sites; red dots represent Lower sites. Note differences in scales.

4.7.2 Loadings

SPM, nutrient and coliform loadings were calculated for those monitoring sites equipped with YSI sondes and water depth loggers. These sites included VCU, VCL, LF, LCU and LCL. Loadings were calculated only for 2008 and 2009 as a result of problems experienced in obtaining valid rating curves for calculation of water discharge during the 2007 monitoring program. Loadings were calculated on a monthly basis using average monthly values of water discharge.

Total monthly SPM loadings (Fig. 4.24) varied a great deal between sites and annually. During 2008 at the VanOostrum site, SPM loadings were highest at the Lower site. This trend was reversed during 2009 when loadings were greatest at the Upper site. This difference is most likely to have resulted from the problems associated with a solar powered watering system during 2009 that necessitated removal of the riparian fencing adjacent to the Upper site resulting in livestock access to the River at a location immediately above the Upper water quality monitoring site. In addition, the lower values observed during this same period at the Lower monitoring site may also have been due to the recently constructer wetland designed to collect surface water runoff from the livestock feedlot.

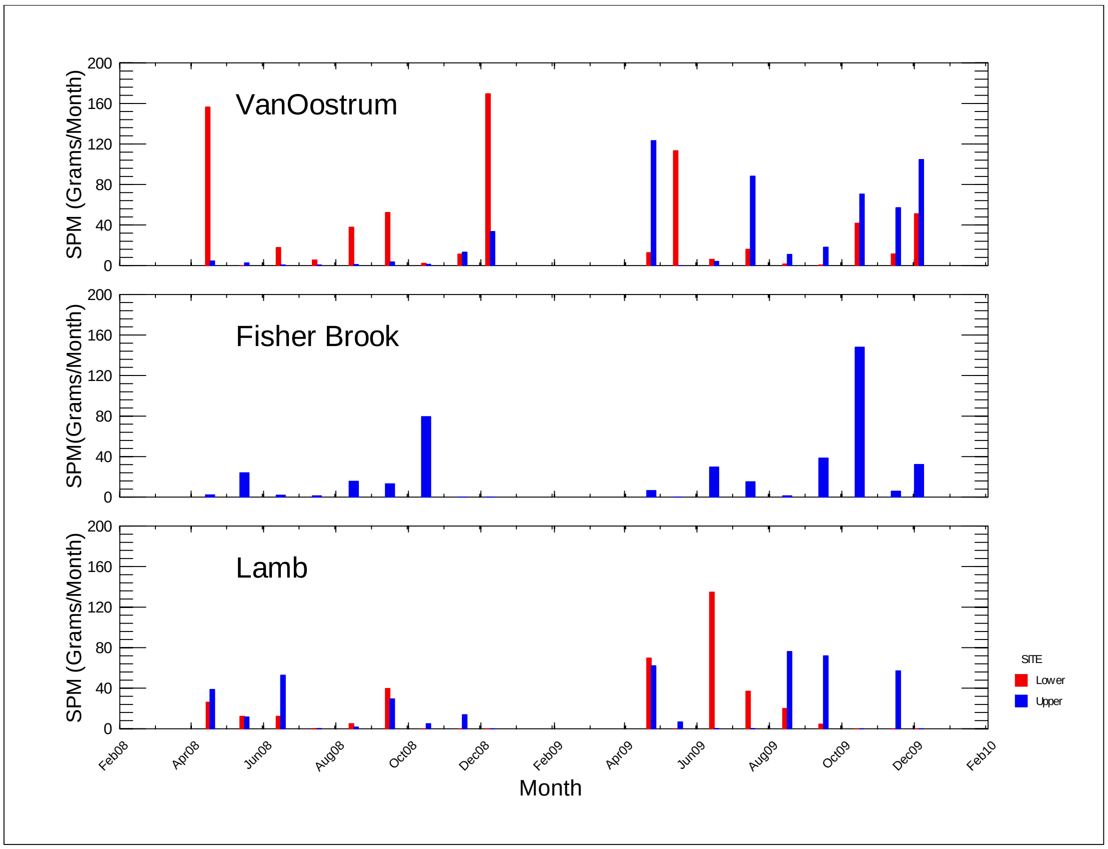


Fig. 4.24 Monthly variation in Suspended Particulate Matter loading.

The Fisher Brook site, with a few exceptions, had the lowest SPM loadings, a reflection of its relatively well developed riparian zone and its high groundwater input.

At the Lamb site, other than SPM loadings being generally lower during 2008 than during 2009, there was little evidence of any consistent trends in the relative loadings between the Upper and Lower monitoring site.

Total nitrogen loadings (Fig.4.25) varied a great deal between sites as well as between years. They were highest at the Lamb sites and lowest at the Fisher Brook site which is again most likely a reflection of the greater proportion of groundwater relative to surface water runoff entering the Fisher Brook site, as well as its relatively well developed natural riparian zone. At all sites they were substantially lower during 2009 than during 2008.

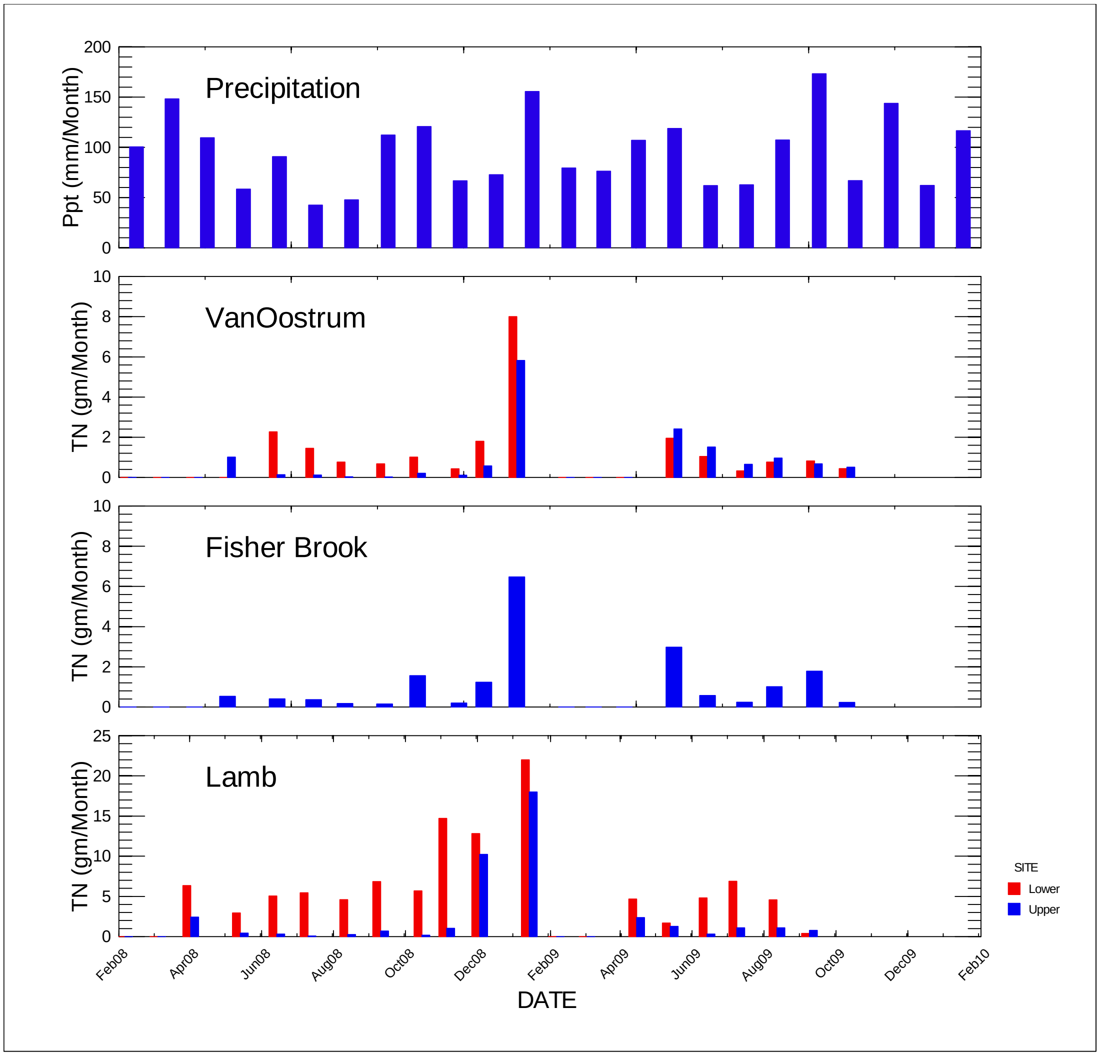


Fig. 4.25 Monthly variation in total precipitation and total nitrogen loadings (note differences in scale).

Total phosphorus loadings (Fig. 4.26) also varied a great deal between sites but generally showed the same trend of being lowest at the VanOostrum sites, intermediate at the Fisher Brook site and highest at the Lamb sites. There was also the same trend in the annual variation between years with much lower loadings in 2009 compared to 2008. In addition, the difference in loadings between Upper and Lower sites was much reduced in 2009 compared to 2008.

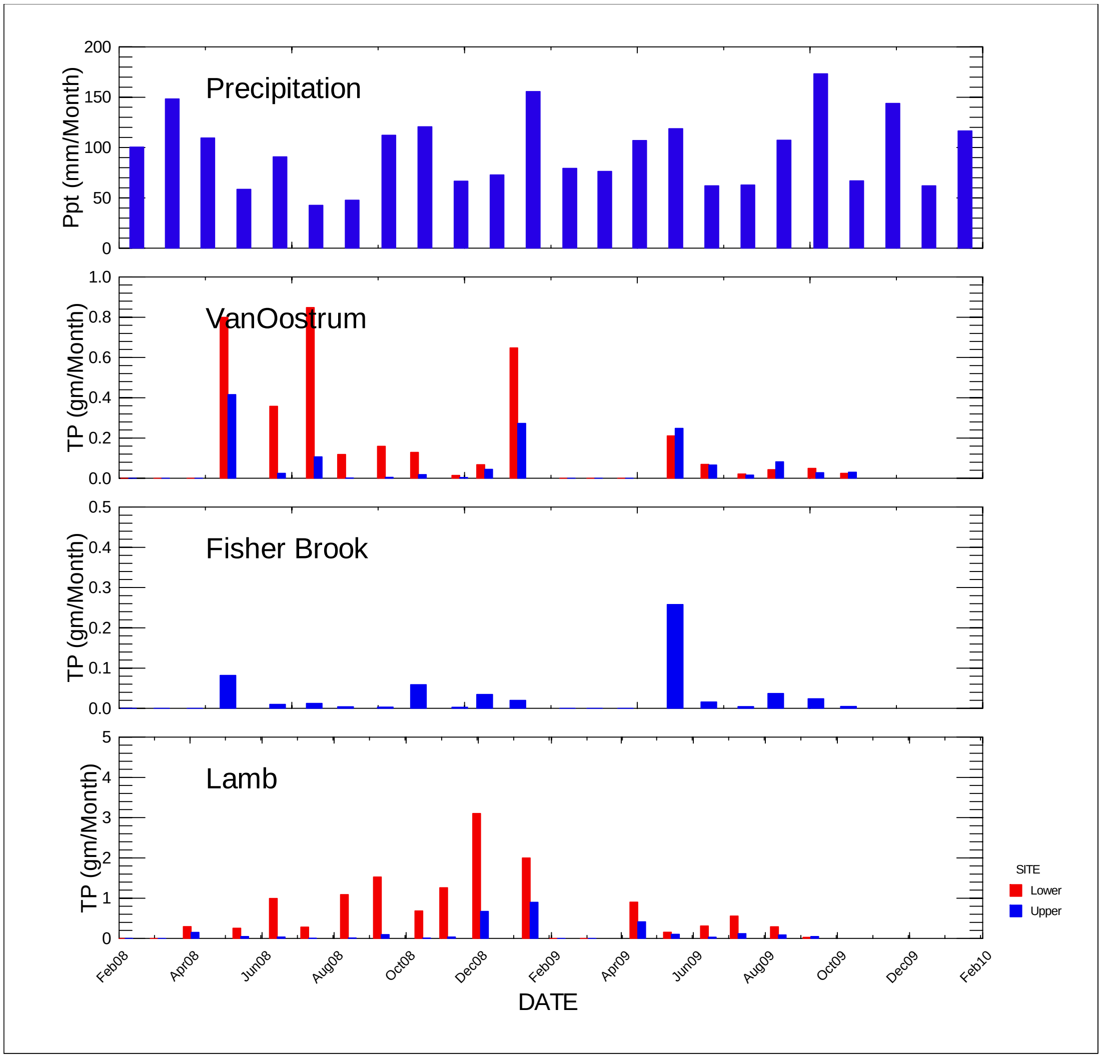


Fig. 4.26 Monthly variation in total precipitation and total phosphorus loading (blue bars represent Upper sites and red bars represent Lower sites). Note differences in scales.

In an attempt to determine if there exist any obvious trends in the mean values of each loading parameter, the differences in the mean values of each for 2008 and 2009 were compared, along with the mean annual value of daily precipitation (Fig. 4.27).

Mean daily precipitation was about 20 percent higher in 2009 than 2008. The differences in mean values of the loading parameters between years varied greatly among the different sites. At the Upper VanOostrum site, SPM was greater during 2009 than 2008 which may be related to the livestock watering problem previously discussed. At the Lower site there was little difference between years. Total nitrogen and total phosphorus values showed opposite trends. At both the Upper and Lower sites, total nitrogen was lower and total phosphorus greater during 2008. At the Upper site, fecal coliform mean values were about equal, but during 2009 much lower at the Lower site. The latter may be related to construction of the artificial wetland designed to receive surface runoff from the livestock feedlot.

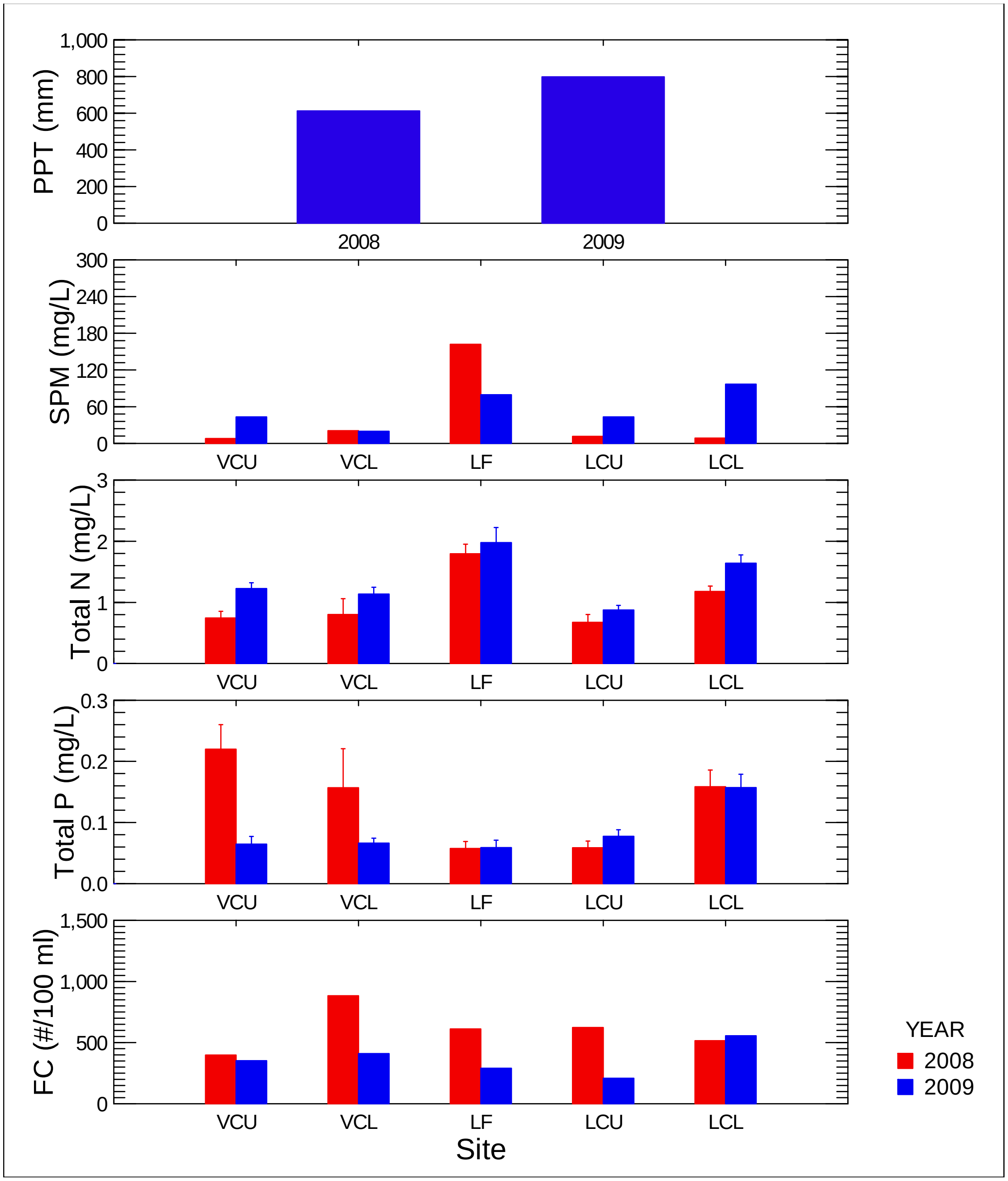


Fig. 4.27 Mean annual values of daily precipitation and loadings for 2008 and 2009 (error bars, where shown, represent one standard deviation of the mean).

At the Fisher Brook site both SPM levels and fecal coliform numbers were much lower during 2009 than 2008, and total nitrogen and total phosphorus varied little between years.

At the Lamb sites, SPM levels were much greater during 2009 at both the Upper and Lower sites. Total nitrogen and total phosphorus were also higher in most instances, but the differences were not great. Mean fecal coliform numbers at the Lower site changed little between years but were much lower at the Upper site during 2009.

5. Discussion

Based on the results attained after three years of water quality monitoring, it is obvious that water quality within the area of the Cornwallis River that passes through both of the demonstration sites remains seriously impaired. It is characterized by high fecal coliform numbers, high nutrient concentrations, periodic episodes of high sediment concentrations and, at times, high water temperatures and low levels of dissolved oxygen.

It is important to note that, in most cases, based on the monitoring results at the Upper and Lower primary monitoring sites, it is apparent that water quality entering the farm sites is already of poor quality, and that the BMPs implemented, which include mainly riparian zone fencing and construction of artificial wetlands, will do little to improve the quality of water already entering the farm sites from areas located higher within the watershed of the River.

Despite the generally poor water quality that still exists, comparisons of water quality between 2008 and 2009 at the primary monitoring sites does show some evidence of an improvement in water quality. At the VanOostrum primary monitoring sites, both total phosphorus and coliform loadings were substantially lower in 2009 than 2008 SPM and total nitrogen loadings, however, varied little between years. At the Lamb primary monitoring sites, although SPM levels were much higher during 2009, the remaining loading parameters showed little change.

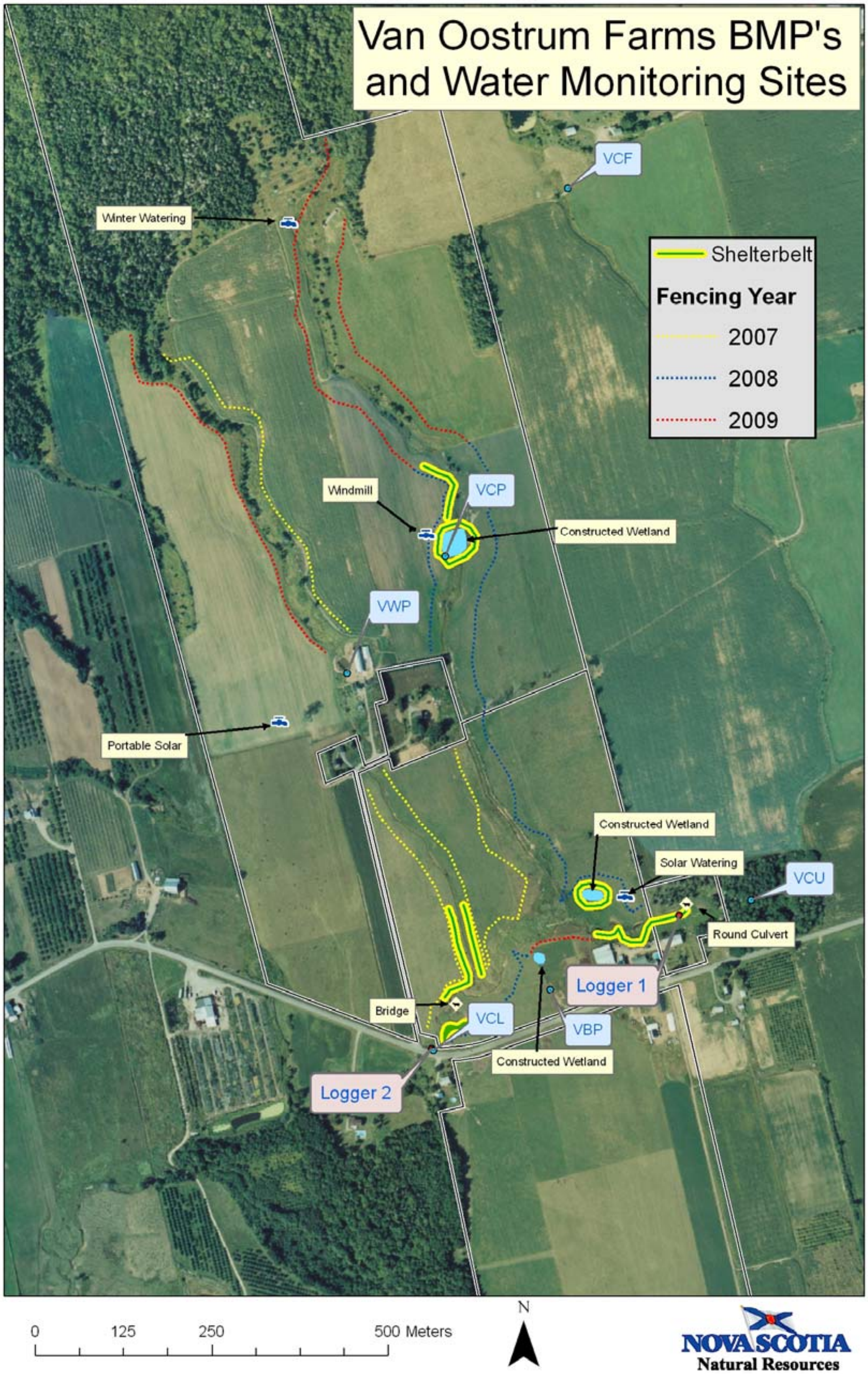
Perhaps most disappointing thus far, is the fact that the constructed wetland at the Lamb farm does not appear to be having an appreciable impact in terms of assimilating the nutrients contained within the milkhouse waste stream and reducing the nutrient input to Fisher Brook and, subsequently, to the Cornwallis River. This is likely a result of the extraordinarily high amounts of nutrients emanating from the milkhouse, at which about 300 cows are milked daily.

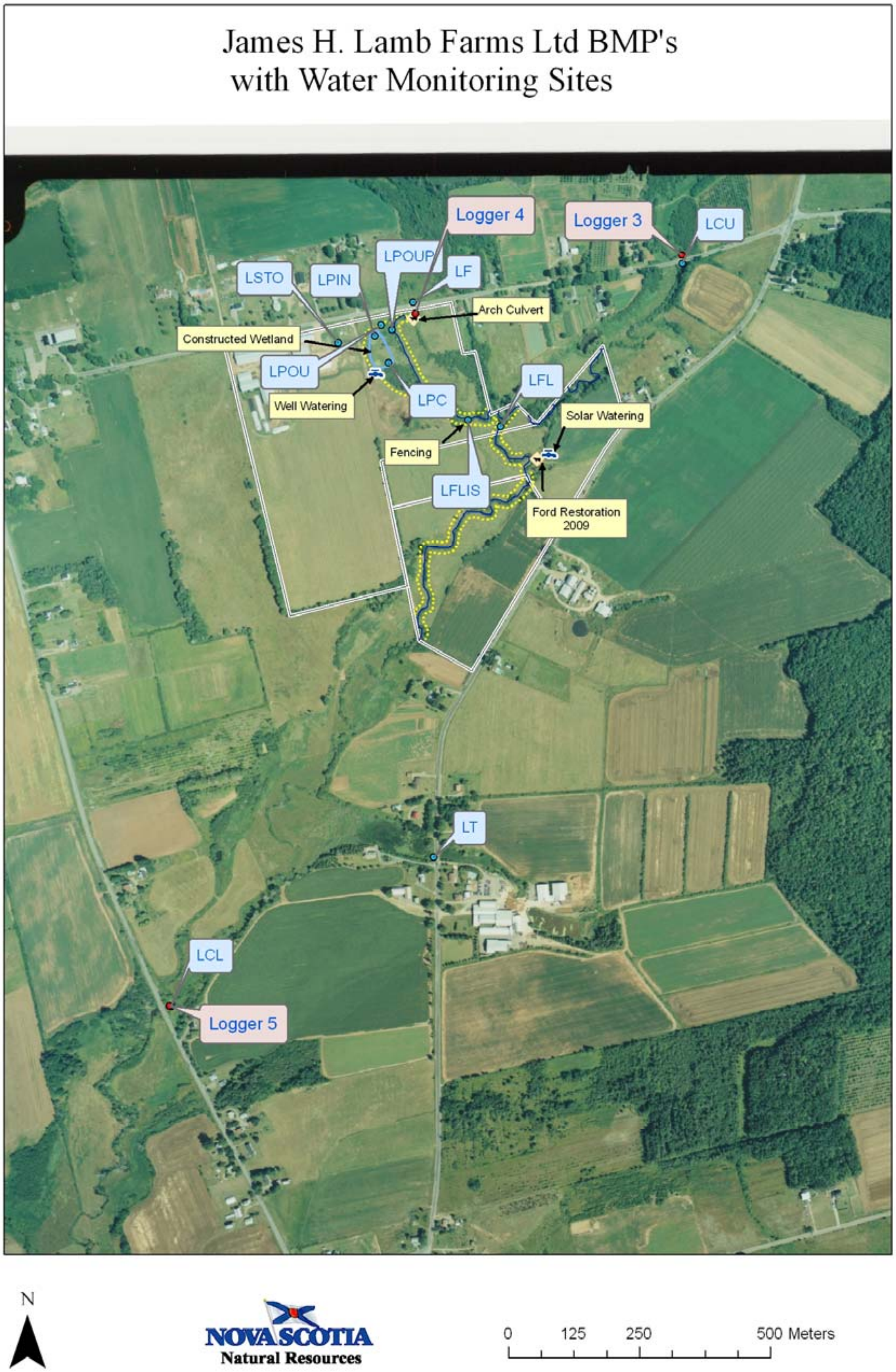
6. References

CCME. 2002. Canadian Council Ministers of the Environment Canadian Environmental Quality Guidelines, Ottawa, Ontario.

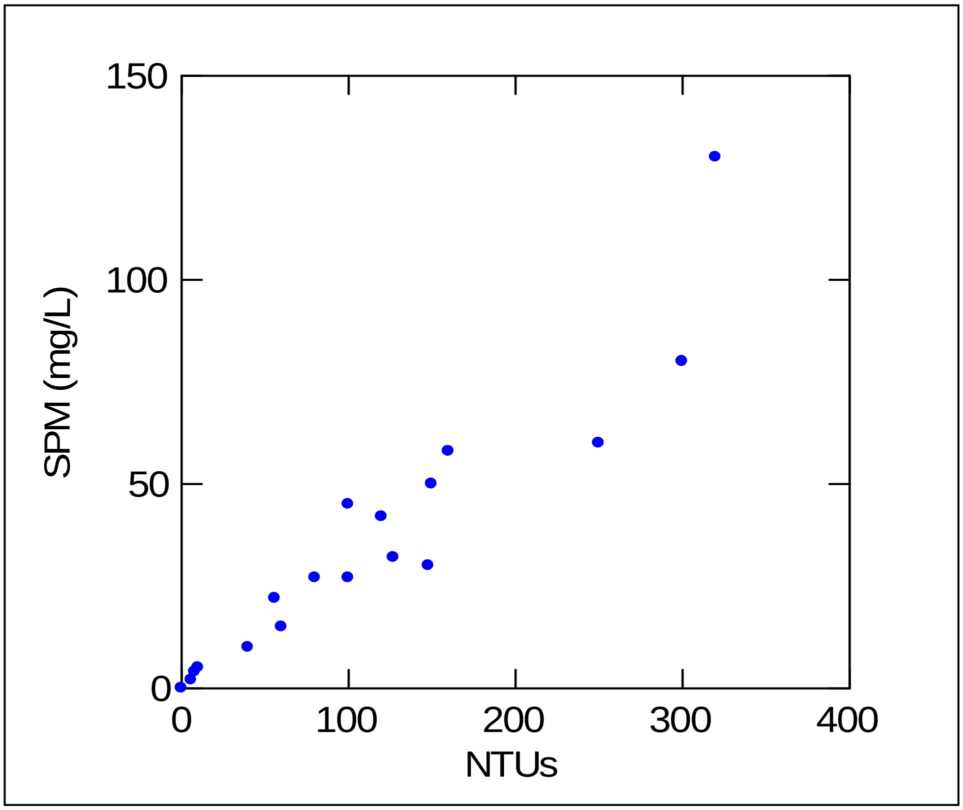
APPENDIX I

Aerial Photos Showing Locations of Primary Water Quality Monitoring Sites


Van Oostrum Farms BMP's and Water Monitoring Sites
Shelterbelt
Fencing Year
2007
2008
2009
VCF
Winter Watering
Windmill
VCP
Constructed Wetland
VWP
Portable Solar
Constructed Wetland
Solar Watering
VCU
Round Culvert
Logger 1
Bridge
VCL
VBP
Constructed Wetland
Logger 2
0
125
250
500 Meters
N
NOVA SCOTIA
Natural Resources

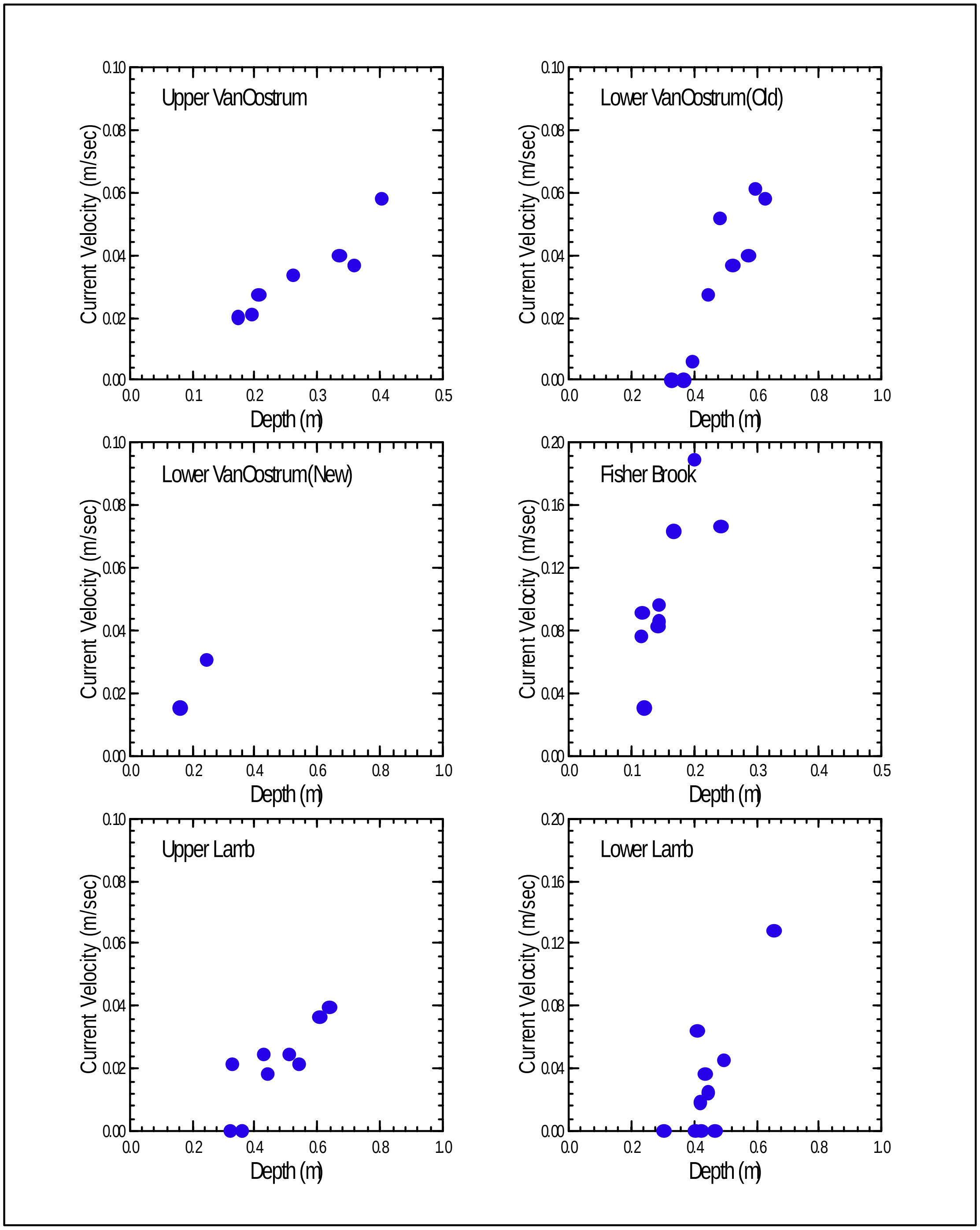

James H. Lamb Farms Ltd BMP's
with Water Monitoring Sites
Logger 4
Logger 3
LCU
LPOUP
LSTO
LPIN
LF
Arch Culvert
Constructed Wetland
LPOU
Well Watering
LPC
LFL
Solar Watering
Fencing
LFLIS
Ford Restoration
2009
LT
LCL
Logger 5
N
NOVA SCOTIA
Natural Resources
0
125
250
500 Meters

APPENDIX II



Relationship Between NTUs and SPM
(SPM=0.316 x NTU – 0.234; r^2 = 0.885).

Appendix III
Current Velocity-Depth Rating Curves



Appendix IV
Stage-Discharge Relationships