Vermont Water Resources and Lake Studies Center
Annual Technical Report
FY 2009

Introduction

The Annual Report for the Vermont Water Resources and Lake Studies Center for FY2009 is attached. The grant awarded under the State Water Resources Research Institute Program is 06HQGR0123

Research Program Introduction

In the 2009-2010 project year the Vermont Water Resources and Lake Studies Center continued its collaboration with the Department of Environmental Conservation in the Vermont Agency of Natural Resources (VTANR). In recognition of state matching support provided by VTANR, the Vermont Water Center RFP for 2009 was designed to specifically address several broad aspects of river management that are of direct interest to the Department of Environmental Conservation. Additional support for the Vermont Water Center was provided by the Lintilhac Foundation, which helped to support additional research on dairy farm waste management practices. Proposals on any topic relevant to the mission of the Water Center are considered. However, in with input from the VTANR and the Advisory Board for the Vermont Water Center the 2009-2010 RFP contained the following guidance about proposals that would be of particular interest. We sought proposals that would:

1. advance scientific understanding that helps quantify the contribution of sediment and nutrients derived from fluvial processes in Vermont’s rivers;

2. establish the socio-economic justifications, costs, and benefits associated with or represented by river corridor protection in Vermont; and

3. contribute to Vermont's river corridor management, restoration, and protection infrastructure. Within these broad areas several questions of particular interest were identified. We sought proposals that woulld strengthen and help validate Vermont’s fluvial geomorphic-based model for describing sediment regime departures from reference or equilibrium conditions, which strongly influence the magnitude of sediment and nutrient production, transport, and attenuation or storage on a watershed scale. Suggested research areas of particular interest included proposals to:

A. build on the existing ANR stream geomorphic assessment protocol, develop techniques for systematically identifying critical in-stream source areas, meaning those segments of the river system that contribute a disproportionate amount of the total P/sediment load

B. quantify how sediment and nutrient reductions may be achieved by managing river systems toward equilibrium conditions, and alleviating constraints to sediment load attenuation at a watershed scale,

C. examine and quantify the P and sediments available to be mobilized by fluvial processes and represented in various legacy sediment accretions in the Northern Lake Champlain watershed,

D. quantify sediment and P production in selected meso/macro scale examples and relate to the extant of fluvial geomorphic evolution or adjustment processes and the driving forces and stressors for such adjustments,

E. collect new and/or use existing data to test fluvial-geomorphic-based models currently being applied by the River Management Program and generate innovative new map products, or

F. place fluvial adjustment processes and sediment/P production rates on a geologic time scale/continuum such that a comparison of rates of sediment/P delivery to receiving waters can be made. Proposals were also solicited to address socio-economic analyses which would build upon the Vermont River Management Alternatives White Paper and other VT DEC River Management Program fact sheets and papers published by the VTANR River Management Program and available at http://www.anr.state.vt.us/dec/waterq/rivers.htm. Suggested research areas included projects to:

A. identify/test/validate innovative voluntary landowner and municipal incentives that could be created in Vermont to enhance participation in river corridor protection initiatives,

B. quantify the socio-economic costs and benefits of river corridor protection, or

C. identify economic factors that have driven river and river corridor management historically (nineteenth and twentieth centuries) as compared with current day economic drivers and develop ways to use this information in way to that might influence public perception/values.

During the 2009-2010 project year a total of 4 proposals were funded; two on-going projects and two new projects. These projects are described below. The report by Lovell and McIntosh is a final report. The report by Hill is an interim report. Due to technical difficulties early in this project the PI had to delay some analyses. The Director of the Vermont Water Center granted a no-cost extension to Hill to complete this work. A detailed final report will be included in the 2010-2011 Annual Report. The reports by Morrissey and Rizzo and by Ross are interim reports after the first year of projects that were intended to run for two years. Detailed final technical reports will be included in the 2010-2011 Annual report.

Treatment Solutions to Reduce Nutrient and Bacterial Inputs to Lake Champlain at Shelburne Farms

Basic Information

Title:	Treatment Solutions to Reduce Nutrient and Bacterial Inputs to Lake Champlain at Shelburne Farms
Project Number:	2008VT32B
Start Date:	3/1/2009
End Date:	2/28/2010
Funding Source:	104B
Congressional District:	First
Research Category:	Water Quality
Focus Category:	Water Quality, Non Point Pollution, Agriculture
Descriptors:	None
Principal Investigators:	Sarah Lovell, Alan Mcintosh

Publications

There are no publications.

FINAL REPORT

Treatment Solutions to Reduce Nutrient and Bacterial Inputs to Lake Champlain at Shelburne Farms

PROJECT DATES:
March 1, 2008 - February 28, 2009

PRINCIPAL INVESTIGATORS:
Sarah Taylor Lovell (PI) and Alan McIntosh (co-PI)
Deane Wang & Hisa Kominami

Submitted to:

Vermont Water Resources and Lake Studies Center

for work in cooperation with:

The Agency of Natural Resources, State of Vermont,
The Lintilhac Foundation,
and Shelburne Farms

18 May 2010

EXECUTIVE SUMMARY

Ecological and social functions of Lake Champlain are increasingly threatened by high concentrations of contaminants such as phosphorus which promotes the growth of algae and aquatic plants. Of the 80% of phosphorus entering the lake from non-point sources, approximately 55% is contributed by agricultural activities (Lake Champlain Steering Committee, 2003). Animal waste from agricultural livestock also contributes to harmful strains of bacteria that threaten the health of individuals swimming at public beaches or drinking the water.

Improving the quality of runoff from dairy farms in the Lake Champlain Basin has been challenging and is still a top priority for regional lake management efforts. Long-term studies indicate that lake water quality goals have not been achieved and that doing so will require additional pollution reduction from agricultural sources within the basin. Three studies of water quality were conducted to investigate the relationship between farming practices and runoff entering the lake from Shelburne Farms, a 590-ha pasture-based dairy farm on the shores of Lake Champlain in Vermont.

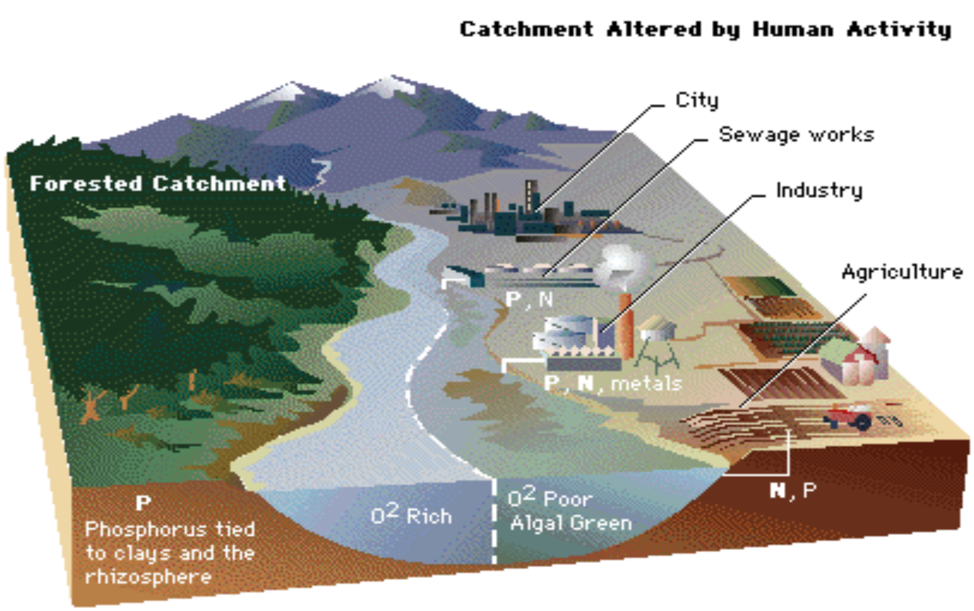
In the first study, agricultural runoff and near-shore lake water quality were monitored through grab sampling during four summers between 2004 and 2008. Monitoring revealed that total phosphorus (TP), dissolved reactive phosphorus (DRP), total suspended solids (TSS), and Escherichia coli concentrations were loosely comparable to concentrations reported for agricultural watersheds in which best management practices (BMPs) had been implemented. However, two lake swimming areas frequently violated Vermont state water quality standards for E. coli after storm events. Results also demonstrated that the two strongest contributors to surface water pollution were the dairy barnyard area and catchment draining to Orchard Cove.

For the second study, the site suitability of three existing composting areas on the farm were evaluated based on a Natural Resource Conservation Service (NRCS) conservation practice standard. The analysis was performed using a geographic information system (GIS) and criteria defined by the NRCS. Results revealed that one composting area is unlikely to pose a threat to water quality. However, the two other composting areas were only partly within suitable areas and may require remedial measures to ensure adequate water quality protection. Additionally, the analysis revealed that one previously used composting area was not properly sited and could potentially have been a source of pollutants to a nearby drainage ditch that discharges into Lake Champlain.

The third study evaluated the start-up performance of the recently built stormwater treatment system at reducing pollutants in agricultural stormwater from the 5-ha dairy barnyard catchment. Between July and December 2009, treatment performance was evaluated by 1) comparing storm flow and non-event flow concentrations of particulate phosphorus (PP), total dissolved phosphorus (TDP), TP, DRP, TSS, and E. coli at the treatment system's inlet and outlet, and 2) quantifying TP and TSS removal efficiencies of a treatment system component (gravel wetland)

during two storms. Results demonstrated that mean storm flow concentrations were significantly lower ($p < 0.05$) at the treatment system's outlet for all measured parameters except E. coli. For one storm in mid-November and another in early December, the gravel wetland retained 39 and 13% of P and 42 and 38% of TSS, respectively.

The results from this study suggest that balancing water quality protection and dairy farming may continue to pose challenges at Shelburne Farms despite long-standing BMPs (e.g., rotational grazing, livestock exclusion, comprehensive nutrient management planning) and recent remedial measures (e.g., stormwater treatment system). However, the results also indicate that adopting additional site-specific BMPs and BMP systems could further reduce agricultural nonpoint source pollution. Indeed, achieving society's water quality goals for Lake Champlain may require more precise P management and more effective measures to control P loss on dairy farms.



INTRODUCTION

The Environmental Protection Agency (EPA) estimates that eutrophication is the most common impairment of surface waters in the US, threatening the supply of clean water used for drinking, recreation, aquatic habitat, and many other functions (US EPA 1996). Eutrophication can be defined as "the process of fertilization that causes high productivity and biomass in an aquatic ecosystem. Eutrophication can be a natural process or it can be a cultural process accelerated by an increase of nutrient loading to a lake by human activity" (EPA/Great Lakes National Program Office). Nutrient enrichment in streams and lakes can result in oxygen depletion, algal blooms, and reduced biodiversity – all of which threaten the overall health and functions of these systems (Carpenter et al. 1998).

Based on an extensive review of the literature, Carpenter et al. (1998) concluded that eutrophication is a widespread problem caused by overenrichment with P and N, in part due to nonpoint pollution from agricultural activities including excess fertilization and manure production. They suggest that a reduction in surplus nutrient flows from agricultural systems and a decrease in agricultural runoff could result in lower levels of nutrients in surface waters, but recovery from the eutrophic state is often a slow process.

As with most large lake systems, water quality in Lake Champlain is largely determined by the quality of surface water runoff from its watershed. Inputs of phosphorus from a variety of nonpoint sources including stormwater (fertilizers, detergents, etc.), agriculture (manure, feed, and fertilizers), and sediment erosion have played a large role in the eutrophication and blooms of toxic algae found in Lake Champlain. In fact, nonpoint sources are estimated to account for 80% of the phosphorus entering the lake, and agriculture contributes up to 55% of this portion (Lake Champlain Basin Steering Committee, 2003). As a result of the decline in water quality, millions of dollars have been spent on the development and implementation of Lake Champlain total maximum daily loads (TMDL's) to reduce P inputs from the watershed. Pathogens including bacteria, viruses, and parasites are another cause for concern regarding the quality of the water in Lake Champlain. If ingested while swimming or drinking contaminated water, these organisms can result in gastrointestinal illnesses that threaten the health of the public. Livestock manure is known to be a source of these pathogens, so agricultural management including grazing, manure storage facilities, and manure applications as fertilizer play a critical role in water quality (Fajardo et al 2001).

Shelburne Farms, a 1400-acre working farm with 250-270 cows including young stock, milking cows, and beef cows, strives to demonstrate sustainable farming practices. The farm represents interests of many farms in the Lake Champlain watershed with a focus on sustainable local food production, agri-tourism, and environmental stewardship. The issue of water quality, however, is particularly critical as Shelburne Farms is located directly on Lake Champlain. The implementation of best management practices including a grass-based system, large land base for manure spreading, and comprehensive Nutrient Management Plan, would suggest that Shelburne Farms has low potential for nutrient runoff and bacterial contamination from agricultural activities.

The purpose of these studies was to 1) characterize the scope of the nonpoint source pollution problem at Shelburne Farms through a summer sampling program employing grab samples, 2) provide an analysis of site suitability for composting operations, and 3) evaluate the initial efficacy of a stormwater treatment system for the 5-ha dairy barnyard catchment area.

METHODS

Each of the studies required different methods, described below.

<u>Agricultural runoff and near-shore lake water quality</u>

To assess the quality of agricultural runoff into Lake Champlain from Shelburne Farms, grab samples were collected at various locations on the farm during four summers between 2004 and 2008. Over these four summers, twenty-one storm flow and four baseflow samples were collected at various sites on the farm.

Collected samples were transported on ice to the Agricultural and Environmental Testing Laboratory at the University of Vermont and stored at 4°C until further processed. Within 24 h, TDP and DRP samples were filtered using pre-washed 45-μm membrane filters and were either stored at -20°C until analyzed or analyzed immediately. DRP concentrations were determined colorimetrically using the stannous chloride method (Eaton et al., 1998). TP samples were either stored at -20°C until analyzed or were stored for less than a month at 4°C until analyzed. TP and TDP concentrations were determinedcolorimetrically using the stannous chloride method following digestion with persulfate (Eaton et al., 1998). PP was determined by subtracting TDP values from TP values. TSS was measured by weighing the dried residue on a glass-fiber filter disk following filtration and drying at 103° to 105°C (Eaton et al., 1998). All *E.coli* samples were analyzed within 24 h of collection using the Quanti-Tray ® method (Eaton et al., 1998).

<u>Site suitability of three existing composting areas</u>

Site suitability was modeled using GIS algorithms from several developed data layers. High resolution Chittenden County LIDAR data was converted and interpolated (krigging algorithm in Geo-Analyst) into a Digital Terrain Model (DTM) for all of Shelburne Farms. The DTM was used to generate hill shade and slope layers. The shoreline and residences were digitized from orthophotos from the Chittenden County Metropolitan Planning Organization (CCMPO) to define areas unsuitable for siting compost piles. Based on the NRCS selection criteria, a 500' buffer was created for the residence layer and a 300' buffer was created for the shoreline layer. Using the streams layer from a GIS geodatabase obtained for Shelburne Farms, a 100' buffer was created for existing streams. The soils layer used in this analysis was obtained from the USDA-NRCS soil survey data available through the Vermont Center for Geographic Information (VCGI). Layers for seasonal high water table and slopes less than eight percent were also created. The land use/land cover layer from the Shelburne Farms geodatabase was used to find either hayfields or open land. The site suitability analysis map was developed from these data layers and the Vermont NRCS criteria for siting composting areas (NRCS, 2009).

Start-up performance of the stormwater treatment system

Rainfall was measured using a RG3-M HOBO Data Logging Rain Gauge (Onset Computer Corporation, Pocasset, MA). Temperature was measured at 30-minute intervals using the same data logger used for measuring rainfall, which was housed in a RS1 Solar Radiation Shield (Onset Computer Corporation, Pocasset, MA).

Grab samples were collected during storm flows and non-event flows at the entry and exit points of the stormwater treatment system. Storm flows were sampled at least once per storm event, but multiple samples were often collected so that data were representative of different stages of flow through the treatment system. When multiple samples were collected, results were averaged to provide a storm average for each measured parameter. During non-event flows, there was usually very low flow into the inlet pond and gravel wetland, but never flow through the entire system. Non-event samples were usually collected weekly, though gravel wetland maintenance and storm flows sometimes prevented sample collection.

Gravel wetland inflows were measured in the inlet water level control structure using a sharp-crested 30° V-notch weir and a 6712 automatic sampler with an Isco 750 Area Velocity Flow Module (Teledyne Isco, Inc., Lincoln, NE). The flow module was placed in a stilling well and recorded the height of water passing through the V-notch weir at 2- minute intervals. During stormflows, a water level rise of 2.5 cm above the lowest point in the V-notch weir triggered the automatic sampler to collect up to 24 discrete 1000 ml samples.

Gravel wetland outflows were measured in the outlet water level control structure using a 6712 automatic sampler with an Isco 720 Submerged Probe Flow Module (Teledyne Isco, Inc., Lincoln, NE). The flow module was placed in a stilling well and recorded water level at 2-minute intervals. Water levels were then converted to flow rates using Manning's equation for a smooth PVC pipe with a 99-mm interior diameter and a slope of 0.03. A higher Manning's roughness coefficient (0.037) than what is typically used for smooth PVC (0.011 to 0.017) was used because it resulted in predicted flow rates that best approximated empirical flow rates measured on two separate occasions.

Flow rates were determined empirically during the falling limb of two storm flows by recording the time it took to fill a specified volume in the cylindrical outlet water level control structure and dividing the volume by the corresponding time. Flow rate was measured four times during each storm flow, averaged, and then compared to predicted flow rates using a range of different roughness coefficients. During storm flows, a water level rise of 1.5 cm above the bottom lip of the outflow pipe triggered sampling to begin.

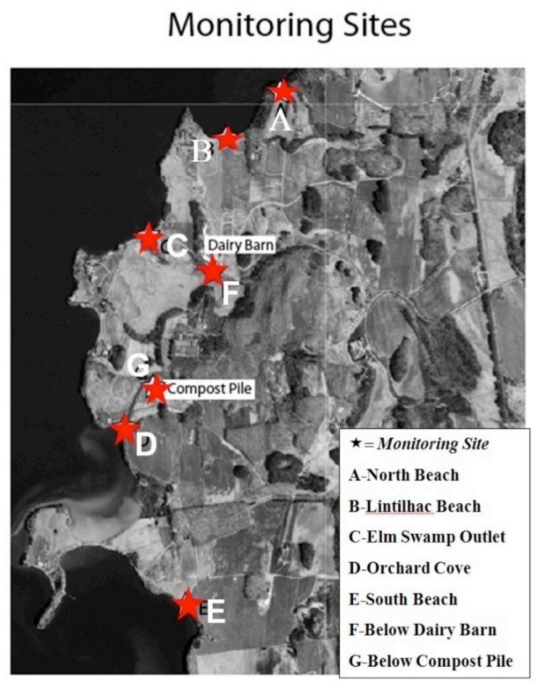
Water quality analyses followed the procedures used for grab sample analyses. All statistical tests for phosphorus, TSS, and *E. coli* were performed using JMP software version 8.0.1 (SAS

Institute, 2009) at an α of 0.05. Paired *t* tests were performed for parameters meeting the assumption of normality, while Wilcoxon signed-rank tests were performed when the distribution of differences were non-normal. Boxplots were created in STATA version 11 (StataCorp, 2009). Boxplot outliers were defined according to Tukey.

RESULTS

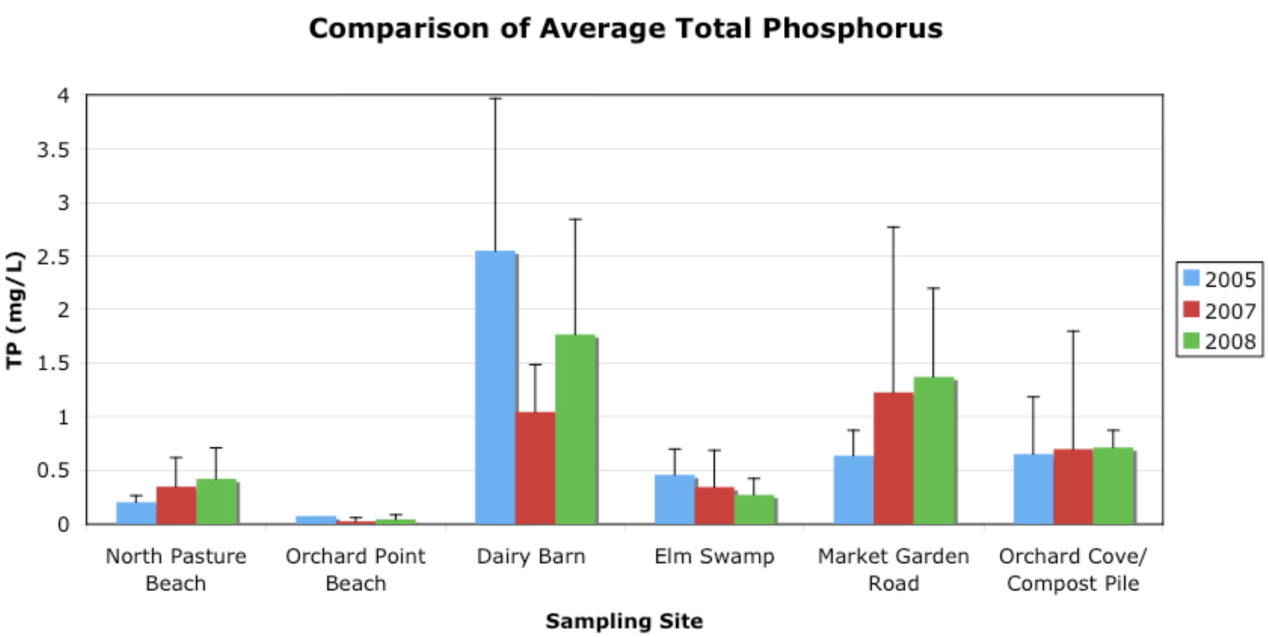
<u>Agricultural runoff and near-shore lake water quality</u>

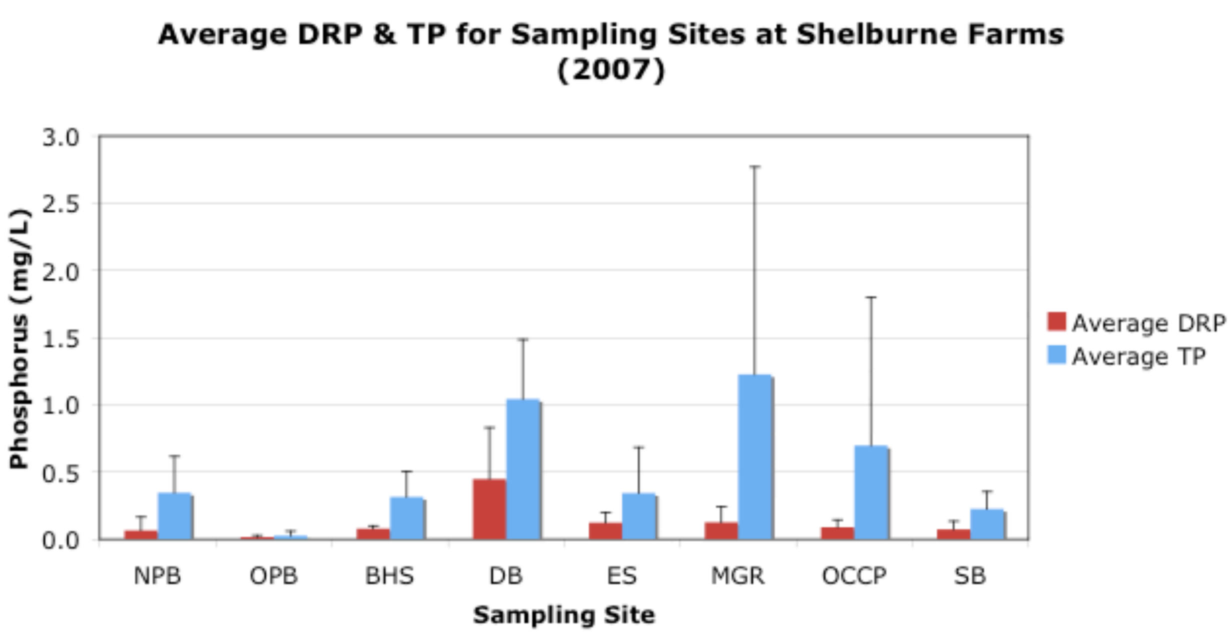
Over four summers, twenty-one storm flow and four baseflow samples were collected at various sites on the farm. Storm event rainfall amounts ranged from as little as 0.5 cm to as high as 5.2 cm. For all summers, precipitation during the month of July was higher than thirty-year precipitation averages for the area.



Stormflow median TP concentrations at outfall sites were from 0.3 to 0.6 mg L^{-1}. These results were comparable to values reported for similar studies in the Northeast. Bishop et al. (2003), for instance, reported annual flow-weighted mean TP concentrations from 0.276 to 0.363 mg L^{-1} for storm event monitoring in a small dairy farm watershed in the Catskills region of New York. The 160-ha dairy farm in the study implemented numerous BMPs and showed modest water quality improvements over four years of extensive monitoring (Bishop et al., 2003). A similar study conducted in a 38-ha dairy farm watershed reported outlet TP concentrations as high as 0.648 mg L^{-1} during storm events despite whole farm planning and the implementation of numerous BMPs (Noll and Magee, 2009). McDowell et al. (2001) also reported a mean TP concentration of 0.4 mg L^{-1} and a concentration range from 0.024 to 1.318 mg L^{-1} for stormflows for a 39.5-ha agricultural watershed in the Chesapeake Bay Basin.

TP concentrations were frequently below 1.0 mg L^{-1}, but high concentrations were observed at individual sites - OCCP on June 4, 2007, at SBN on July 22, 2005 and August 1, 2005. TP was also high at ES on July 22, 2005, but only compared to other sampling dates at that site. It is difficult to know why TP concentrations were high at OCCP, SBN, and ES on those particular dates, since TP concentrations in surface runoff can vary significantly at a sampling location both during and between storm events. High TSS concentrations were also observed at OCCP, SBN, and ES on those dates, which suggest that higher amounts of particulate phosphorus were likely present in surface runoff.


Comparison of Average Total Phosphorus
TP (mg/L)
0
0.5
1
1.5
2
2.5
3
3.5
4
2005
2007
2008
North Pasture Beach
Orchard Point Beach
Dairy Barn
Elm Swamp
Market Garden Road
Orchard Cove/ Compost Pile
Sampling Site


Average DRP & TP for Sampling Sites at Shelburne Farms (2007)
Phosphorus (mg/L)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Average DRP
Average TP
NPB
OPB
BHS
DB
ES
MGR
OCCP
SB
Sampling Site

Baseflows were sampled only twice for TP, but the concentration range for outfall sites (0 to 0.4 mg L^{-1}) was also comparable to ranges reported in the scientific literature. Medalie (2007) and McDowell et al. (2001), for instance, reported ranges from 0.018 to 0.233 mg L^{-1} and 0.003 to 0.252 mg L^{-1}, respectively. Additionally, Budd and Meals(1998) reported an inter-quartile range from 0.1 to 0.3 mg L^{-1} for agricultural streams based on an extensive review of the literature. Bishop et al. (2003) reported 0.06 mg L^{-1} as the average annual flow-weighted mean TP concentration for baseflows from four years of post BMP monitoring.

Storm flow median DRP concentrations at outfall sites were from 0.05 to 0.12 mg L^{-1}, while the total range was from 0.01 to 0.29 mg L^{-1} . Like TP, DRP concentrations were also comparable to similar studies conducted in agricultural watersheds. McDowell et al. (2001) reported a mean DRP concentration of 0.128 mg L^{-1} and a total range from 0.005 to 1.090 mg L^{-1}.
Figure @ shows the percent TP as DRP at outfall sites during stormflows. The results suggest that particulate phosphorus losses are generally higher at NPB and OCCP than at the other outfall sampling sites.

Taken together, the results demonstrate that phosphorus concentrations at outfalls were consistent with values reported for similar agricultural watersheds where BMPs have been effective at reducing phosphorus loading to downstream water bodies.

TP concentrations at stream/drainage ditch sites tended to vary more and were frequently higher than at other sampling locations on the farm. Stream/drainage ditch concentrations ranged from low (0.07 mg L^{-1}) to high (4.4 mg L^{-1}). Lower TP concentrations were occasionally observed at BHS, DB, and MGR, but never at DBM, indicating that the dairy barnyard acts as a significant pollutant source during summer storms. Not surprisingly, the highest median values were from the DB (1.5 mg L^{-1}) and DBM (2.0 mg L^{-1}), sampling sites located directly downstream from the dairy barnyard area. Though barnyards are generally small in spatial extent, they can contribute to significant summertime P loading, especially if linked to hydrologically active areas (Hively et al., 2005). High TP concentrations were also observed at MGR, which suggests that there may be an upstream pollutant source. The greater variability and high concentrations observed at DB and MGR might be caused by sediment-laden surface runoff from nearby dirt roads. On several occasions during field sampling, sediment- laden runoff was observed flowing into drainage ditches upstream from the two sampled locations.

TP concentrations were lowest at BHS (0.1 to 1.6 mg L^{-1}), a sampling site below intensively grazed upland pastures, but these concentrations were somewhat higher compared to values reported by others (Bishop et al., 2003; Noll and Magee, 2009). Field observations suggest that remedial measures in upstream areas could improve water quality observed at BHS. Since much of the TP at BHS is likely particulate phosphorus, reducing sediment inputs into the stream from roadside drainage ditches and stream crossings could help to reduce phosphorus loading. In addition, reducing cow traffic near the headwater of the stream reach is also likely to improve downstream water quality. Indeed, numerous studies indicate thatthe most effective non-point source BMPs dissociate pollutant source areas from areas prone to generating runoff (Easton et al., 2008). Currently, cows congregate very close to the stream headwater because of a gate that connects two pastures in that location. As a result, cows deposit manure close to the stream and expose soils from heavy traffic, which can both lead to increased phosphorus losses. Stream channel and bank erosion may also contribute to high particulate phosphorus losses at BHS, and may be representative of natural processes within the stream reach.

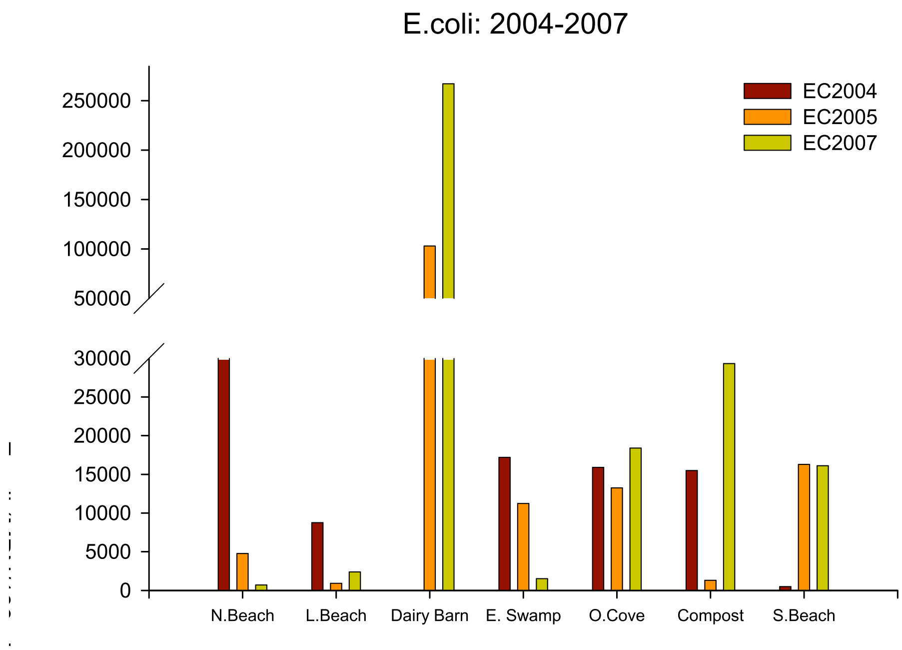
The frequently high TP concentrations observed at DB, DBM, and MGR suggest the presence of upstream pollutant sources, however, concentrations observed at stream/drainage ditch sites were also much lower than values reported in other studies. Very high TP concentrations (13 to 18 mg L^{-1}) have been reported in surface runoff from cow paths, barnyards, and barnyard filter strips (Hively et al., 2005; Schellinger and Clausen, 1992). Nevertheless, extremely high TP concentrations were never observed at Shelburne Farms despite sampling downstream from likely pollutant sources.

Lake sampling revealed that TP and DRP concentrations at wading depth were frequently lower compared to outfall concentrations. At ES_L, TP concentrations were between two-fold and fourteen-fold lower than at ES for eight of the ten sampled events and ranged from 0.01 to 0.3 mg L^{-1}. DRP concentrations were nearly two-fold to five- fold lower at ES_L for all sampling events and ranged from 0.01 to 0.09 mg L^{-1}. Concentrations at OPB_L were similar to ES_L and ranged from 0 to 0.3 mg L^{-1} for TP and from 0 to 0.05 mg L^{-1} for DRP. Both TP and DRP concentrations were generally lower at OPB_L. For nearly all dates, in-lake TP concentrations were higher than the main lake phosphorus criterion (0.010 mg L^{-1}) and frequently were as high or higher than TP concentrations reported for eutrophic parts of the lake. The results suggest that storm flow discharges frequently affected near-shore lake phosphorus concentrations at Shelburne Farms.

During summer storms, *E. coli* concentrations at lake sites ranged from 5 to 12,993 MPN/100 ml OPB_L and from 31 to 15,900 MPN/100 ml at ES_L. Median concentrations at OPB_L and ES_L were 116 and 649 MPN/100 ml, respectively. The results indicated that *E. coli* concentrations exceeded Vermont's 77 MPN/100 ml beach bathing standard 75% of the time at OPB_L and 82% of the time at ES_L. This suggests that swimming near outfalls during or shortly after storm events probably poses risks to human health.

Average *E. coli* concentrations (MPN/100 ml) at swimming areas in 2008.

	Monitored Swimming Areas	
Sampling Date	**Orchard Point Beach**	**Elm Swamp Lake**
7/3/08	133	649
7/9/08	44	285
7/13/08	5	62
7/18/08	80	435
7/20/08	>2419	2419
7/24/08	10462	9208
8/2/08	93	1986



Average *E. coli* concentrations (MPN/100 ml) at sampling sites in 2007. Highlighted rows indicate days where background flows were sampled.

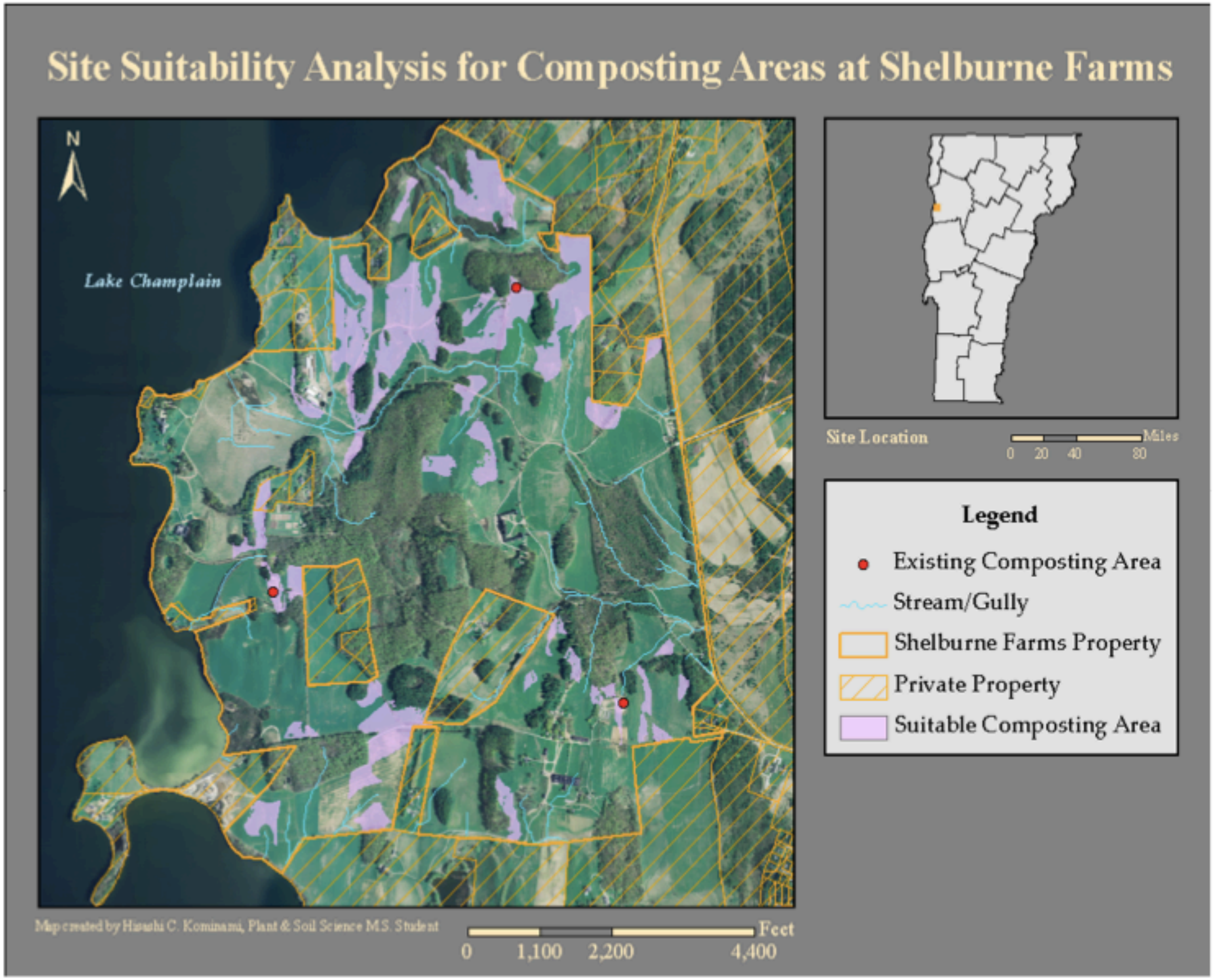
	Monitored Outflows & Drainages						
Sampling Date	**NPB**	**BHS**	**DB**	**ES**	**MGR**	**OCCP**	**SB***
5/29/07	80	NA	421	NA	17	793	1
6/4/07	225	NA	117,430	113	84,595	2,076	2
6/19/07	1,476	2,500	629,250	2,419	84,595	141	44
7/6/07	NA	NA	4,100	NA	NA	NA	NA
7/9/07-(1)	124	3,915	980,400	2,419	7,875	2,076	1,176
7/9/07-(2)	NA	NA	NA	NA	NA	2,419	2,419
7/13/07	2,419	29,500	93,000	1,410	2,000	410	4,310
7/19/07	413	26,450	311,800	1,220	26,050	139,230	121,008
8/9/07	170	1,110	1,000	NA	100	6	2

With some exceptions, the results of this study suggest that current BMPs at Shelburne Farms are as effective at reducing pollutant concentrations in agricultural runoff as in similar agricultural watersheds in the Northeast. Outfall concentrations of TP, DRP, TSS, and *E. coli* were comparable to concentrations reported for extensively monitored agricultural watersheds with BMPs. However, TP, TSS, and *E. coli* concentrations werefrequently high at sampling sites in the OCCP watershed, which suggests that agricultural activities within the watershed are degrading downstream water quality. Field observations provided support for our hypothesis that the composting area within the OCCP watershed may be a significant source of agricultural pollution. Other upstream areas within the watershed including the cultivated field, farm roads, and drainage ditch channel may also contribute to high pollutant concentrations observed in surface runoff. Unusually high TP concentrations observed at some outfall sites were coincident with high TSS concentrations suggesting that soil erosion is an important pathway for P losses from the landscape.

Lake sampling demonstrated that swimming near stormwater outfalls during or shortly after storm events is very likely a risk to human health. However, additional data provided by Shelburne Farms suggests that the risk to human health from waterborne pathogens may be short-lived. Specifically, *E. coli* samples collected one day after rainfall events never exceeded the Vermont bacteriological water quality standard at swimming areas. Nevertheless, further research is needed to determine the extent of fecal contamination in near-shore areas of the lake as a result of stormwater discharges. Though current BMPs appear to be generally effective for phosphorus and suspended sediments, achieving Vermont water quality standards for the lake may require additional and more site-specific BMPs.

<u>Site suitability of three existing composting areas</u>

Below is the map output of suitable areas identified through our analysis and the locations of existing composting areas at Shelburne Farms. The site suitability analysis indicates that only the northernmost composting site at Shelburne Farms is located completely within a suitable area and is not likely to pose risks to air and water quality. Since the composting site is nearly surrounded by woodlands and bordered by suitable pastures to the south, it suggests that odor, runoff, and leaching from the site are not likely a problem. The soils at the site are classified as a Stockbridge stony loam and therefore should provide good drainage. Runoff and leachate from the site are likely to infiltrate at the site and in pastures to the south.


Site Suitability Analysis for Composting Areas at Shelburne Farms
N
Lake Champlain
Site Location
0 20 40 80 Miles
Legend
Existing Composting Area
Stream/Gully
Shelburne Farms Property
Private Property
Suitable Composting Area
Map created by Hisashi C. Kominami, Plant & Soil Science M.S. Student
0 1,100 2,200 4,400 Feet

The easternmost composting site is located in areas identified in the analysis as being both suitable and unsuitable. Closer inspection of the unsuitable areas revealed that the eastern part of the site and areas west were excluded because of steep slopes and that the northern part of the site was excluded because of a gully less than 100 ft away. Though these results suggest that runoff and leaching from the site could pose water quality problems, observations during site visits seemed to suggest that the site could be used for composting, perhaps with some modifications, without adversely impacting water quality. There appeared to be sufficient flat areas for the composting operation and the areas east and west of the composting site could provide adequate infiltration for runoff and leachate. It is also possible that the gully may not act as significant transport pathway for pollutants from the site.

According to the NRCS, sites that do not meet allthe criteria can still be used for composting areas if modifying the site adequately protects against surface and ground water pollution. Runoff diversion ditches, earthen berms, and windrow covers are a few examples of site modifications that could be used to keep runoff and leachate within the composting area. Soils at the site and in the vicinity are all Palatine silt loams, which are likely to provide good drainage and allow for proper compost management. Our analysis results at this particular site point to some of the limitations of using coarse resolution GIS data and indicate that on the ground fact checking can be very useful. Fact checking at this site revealed the site could potentially be used for siting a composting area, even though our analysis results indicated the opposite. Nevertheless, for this particular composting site, consulting with a qualified soil scientist or agricultural engineer would help to determine more conclusively whether the site could be used without compromising water quality.

Our analysis also revealed that there are numerous other parcels of varying size on the farm that could serve as temporary storage areas for dairy manure. However, because our analysis represents a starting point for locating composting areas, other criteria may also need to be considered to determine whether sites are actually suitable. In Shelburne Farms' case, protecting the visual quality of the landscape and minimizing odor problems may limit the number of available sites that could be used. Prevailing winds on the property could also restrict the use of certain areas if winds at a site carry odors to neighboring properties or to areas frequented by visitors. Access to composting sites and a nearby water source are also important since farm equipment and water are both necessary for properly managing composts. It is also preferable to site composting areas close to where finished composts will be used. The suitable areas identified in this analysis that abut private property lines may also not be suitable if landowners are not willing to allow those sites to be used.

Start-up performance of the stormwater treatment system

Results from inlet and outlet grab sampling of the stormwater treatment system and intensive sampling of the gravel wetland indicate that, for most storms, the system effectively reduced pollutants in agricultural runoff from the barnyard area between early July 2009 and early December 2009.

1. Inlet and Outlet Grab Sampling

Between 10 July and 10 December 2009, twelve storm flows were sampled, representing approximately half of all runoff-producing storm events during the study period. Storm event characteristics such as rainfall amount, precipitation intensity, and duration varied considerably for the sampled storm flows.

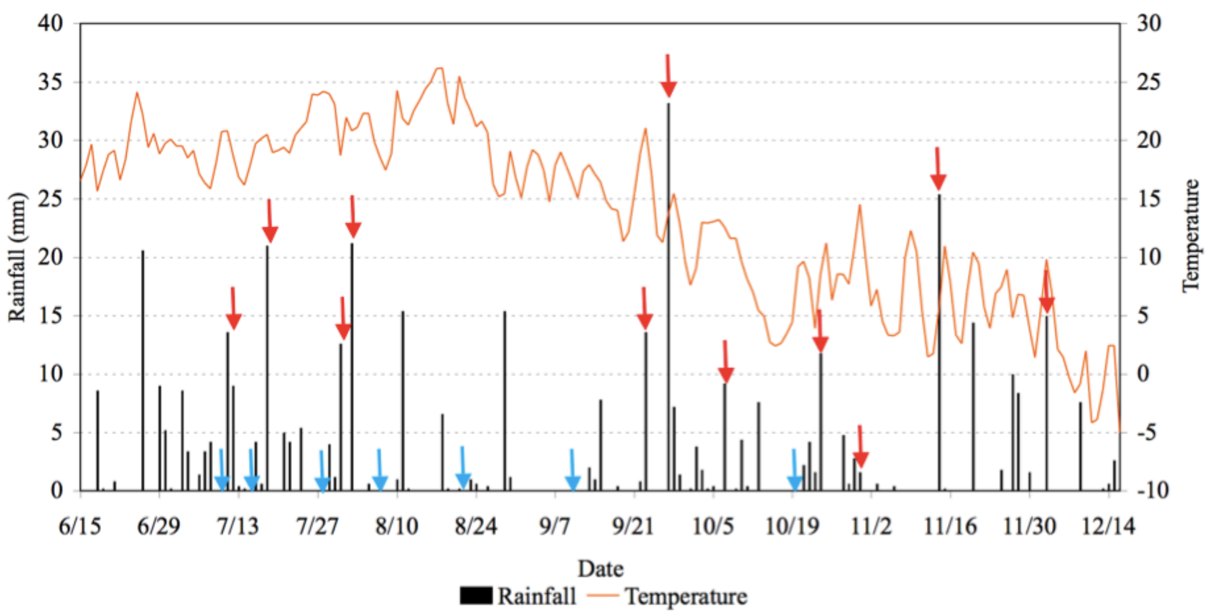


Figure 4.3. Sampling dates, daily rainfall, and average temperature at the stormwater treatment system during the study period, July 10, 2009 to December 10, 2009. Red arrows indicate storm flow sampling and blue arrows indicate non-event flow sampling

Of the twelve storm flows sampled, half were grab sampled either two or three times, and two were intensively sampled with automatic samplers. Because multiple grab samples were often collected during each storm flow, samples from the study were representative of various stages of flow through the treatment system including the rising limb, peak, and falling limb of storm flows. Overflow from the inlet pond to the outlet pond was observed for three different storm flows and could also have occurred on three other dates. The storm event from 27 September through 28 September 2009 had the highest rainfall amount of any of the storms during the study period, is likely to have resulted in overflow, and produced a bimodal runoff response.

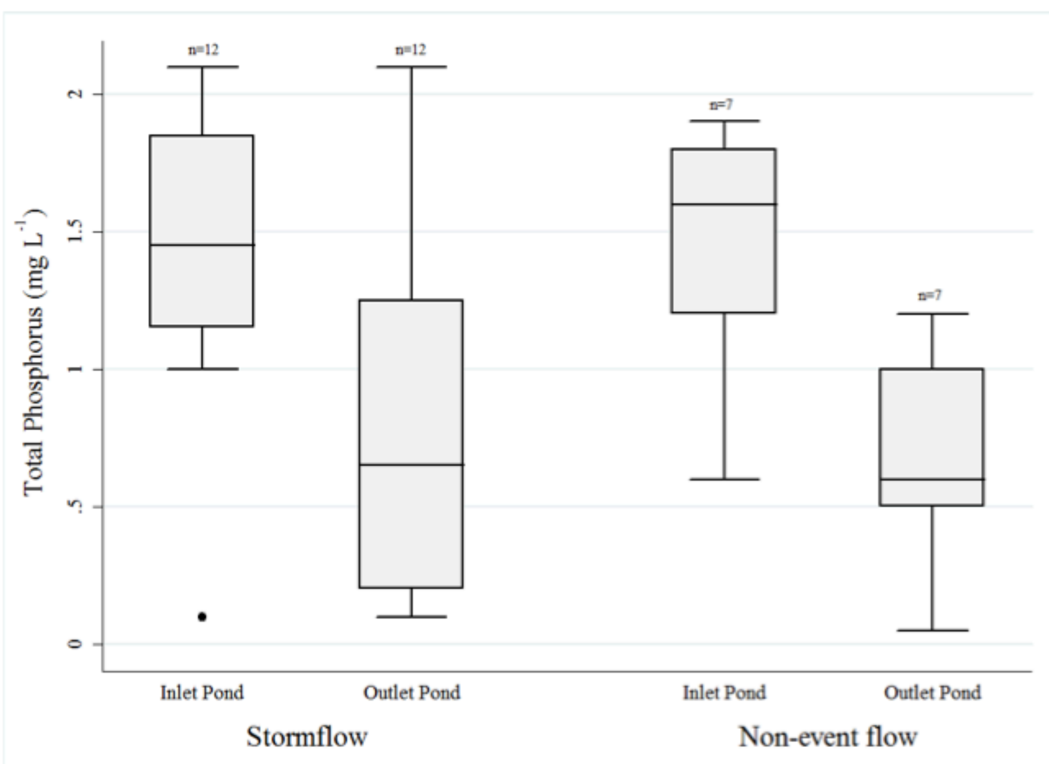
Sampling		[TP]		[PP]		[TDP]		[DRP]		[TSS]		[*E. coli*]		
Date	**Time**	**Inlet**	**Outlet**	**Inlet**	**Outlet**	**Inlet**	**Outlet**	**Inlet**	**Outlet**	**Inlet**	**Outlet**	**Inlet**	**Outlet**	**Description of Flow**
7/11	7:40 PM	1.8	0.7	1.1	0.4	0.8	0.3	0.7	0.3	36	30	4,400	100	Flow into gravel wetland
7/12	9:13 AM	2.1	1.7	1.1	1.0	1.0	0.8	1.1	0.8	113	81	236,000	242,000	Near peak flow through system, overflow may have occurred
7/12	5:40 PM	2.0	1.9	0.8	0.9	1.3	1.0	1.3	1.1	73	62	61,000	173,000	Fow through system
7/18	11:08 AM	1.8	2.1	0.7	0.3	1.1	1.8	1.0	1.2	36	56	24,000	613,000	Flow through system, overflow may have occurred
7/31	9:44 AM	1.1	0.6	0.3	0.2	0.8	0.4	0.7	0.2	26	10	1,300	100	Flow into gravel wetland
7/31	4:52 PM	1.4	0.6	0.5	0.2	0.9	0.4	0.7	0.2	19	12	4,100	200	Flow into gravel wetland just before flow into outlet pond
7/31	7:25 PM	1.3	0.6	0.4	0.1	0.8	0.5	0.6	0.2	24	9	7,700	200	Flow through system
8/2	7:24 PM	1.8	1.8	1.1	1.0	0.8	0.8	0.8	0.7	90	132	461,000	613,000	Flow through system, overflow observed
8/3	7:55 PM	2.3	2.1	1.0	1.2	1.3	1.0	1.3	1.0	126	102	1,410,000	345,000	Flow through system
8/11	8:20 PM	1.3	0.9	0.4	0.1	0.9	0.7	0.7	0.6	34	21	14,100	5,200	Flow into gravel wetland
8/12	8:00 AM	1.5	0.8	0.5	0.2	1.0	0.6	0.9	0.6	39	13	249,000	2,900	Flow into gravel wetland just before flow into outlet pond
9/23	6:11 PM	0.2	0.1	0.1	0.1	0.0	0.0	0.1	0.0	14	24	800	5,200	Flow into gravel wetland
9/28	10:09 PM	1.1	0.2	0.1	0.1	1.0	0.1	1.1	0.2	44	26	58,000	20,000	Flow through system, overflow probably occurred
9/29	9:54 AM	1.0	0.2	0.1	0.1	0.9	0.1	1.0	0.2	40	24	20,000	17,000	Lower flow through system than at previous sampling
9/29	4:25 PM	1.1	0.3	0.3	0.2	0.9	0.1	1.0	0.2	32	20	13,000	12,000	Lower flow through system than at previous sampling
10/7	9:06 AM	1.2	0.2	0.8	0.2	0.4	0.0	0.5	0.0	27	25	1,000	100	Low flow into gravel wetland
10/25	6:52 PM	1.0	0.3	0.4	0.2	0.6	0.0	0.8	0.1	36	14	13,000	1,000	Flow through system
10/31	5:20 PM	1.5	0.2	1.0	0.2	0.6	0.0	0.8	0.2	30	13	3,300	200	Flow into outlet pond
11/14	6:45 PM	1.7	0.4	-	-	-	-	-	-	159	30	-	-	Flow into outlet pond
11/14	10:30 PM	1.8	1.1	-	-	-	-	-	-	76	48	-	-	Peak flow through system, overflow observed
11/15	7:00 AM	1.9	0.6	-	-	-	-	-	-	42	33	-	-	Flow through system
12/3	9:29 PM	1.9	1.1	-	-	-	-	-	-	87	55	36,000	16,000	Flow through system, overflow observed at 12:40 PM on 12/3/09
Max		2.1	2.1	1.0	1.1	1.1	1.8	1.1	1.2	108	117	937,000	613,000	
Median		1.5	0.7	0.6	0.2	0.9	0.3	0.8	0.2	36	25	24,000	5,200	
Mean		1.4	0.8	0.6	0.3	0.7	0.5	0.8	0.4	50	37	116,600	115,700	
Min		0.1	0.1	0.1	0.0	0.0	0.0	0.1	0.0	14	10	800	100	
St. Dev.		0.6	0.7	0.3	0.3	0.3	0.6	0.3	0.4	31	31	276,000	219,000	
C.V.		0.39	0.87	0.54	1.08	0.46	1.27	0.39	1.07	0.62	0.82	2.37	1.89	
Median Reduction (%)		55		67		71		75		32		78		
Mean Reduction (%)		43		47		37		52		25		1		
***p*-value**		0.0003		0.0036		0.0289		0.0015		0.0252		0.2065[a]		

All summary statistics are based on storm averages and not on individual grab samples.

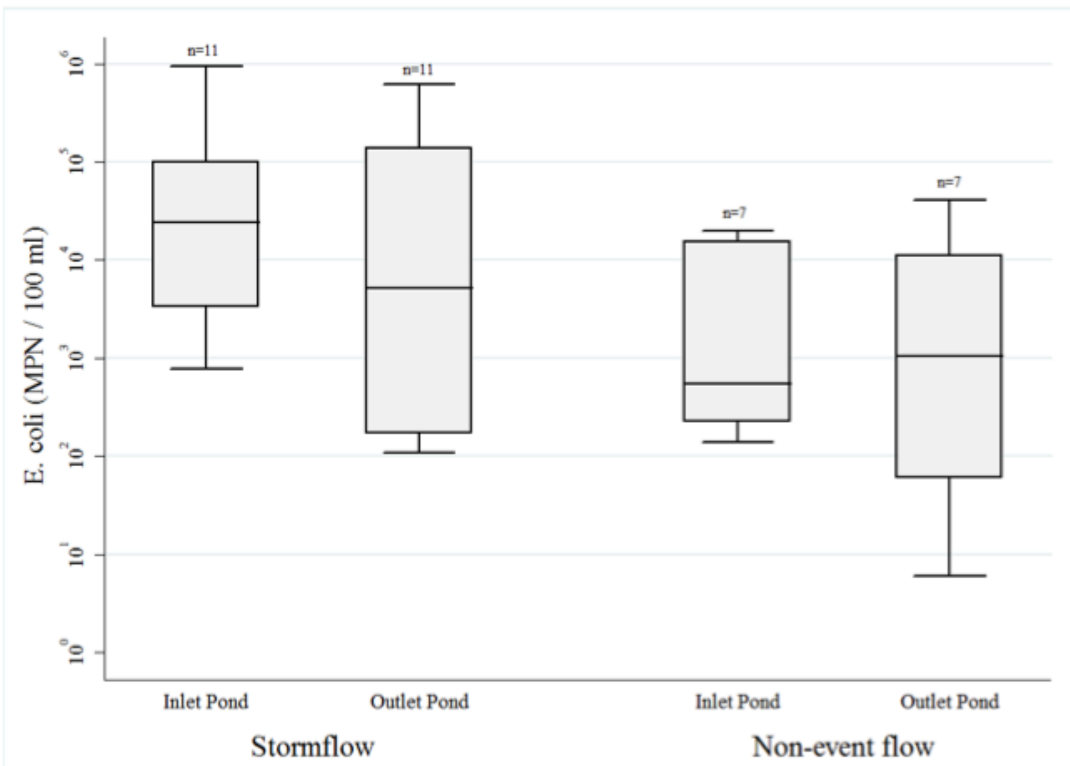
The bimodal storm hydrograph had an earlier peak that was greater in magnitude than the later peak, which occurred several hours later. Storm events on 14 November and 3 December 2009 both resulted in overflow and thus represented high throughput flows through the treatment system. For both storm events, gravel wetland inflows and outflows were comparable despite differences in rainfall amounts, and the duration of gravel wetland inflows was longer than outflows. Gravel wetland outflows on 14 November occurred approximately two hours after inflows began, because the gravel wetland first needed to fill up before there could be flow out. Under wet soil conditions, rainfall increases can translate into a rapid runoff response within the catchment. Flows into and out of the gravel wetland occurred almost simultaneously as a result of the rain event on 3 December 2009. This occurred because the gravel wetland was still flooded from a significant rain event (18.4 mm) four days earlier.

During the study period, seven non-event flows were sampled and were characterized by little or no flow into the gravel wetland. Non-event flows were sampled between one and ten days after storm events.

Storm flow mean outlet pond concentrations were significantly lower ($p < 0.05$) than at the inlet pond for TP, PP, TDP, DRP, and TSS, suggesting that the treatment system reduced pollutant concentrations in agricultural stormwater during the study period. Mean and median concentration reductions between the inlet and outlet pond were generally comparable. However, median concentration reductions were always greater than mean concentration reductions, because phosphorus and TSS distributions tended to be left-skewed for the inlet pond and right-skewed for the outlet pond. TP concentration reductions observed in this study were comparable to mean and median TP reductions (49 and 48%) for twenty-one pond-wetland systems (Kadlec and Wallace, 2008). However, Kadlec and Wallace (2008) reported much higher mean and median TSS concentration reductions for the pond-wetland systems than in this study.



Storm flow outlet *E. coli* concentrations were not significantly lower (p = 0.2065) than at the inlet. Inlet and outlet pond *E. coli* concentrations were extremely variable. Inlet and outlet storm flow *E. coli* concentrations both spanned three orders of magnitude and had coefficients of variation that were 2.37 and 1.89, respectively. Storm flow mean and median concentration reductions for *E. coli* were 1 and 78%, respectively.



2. Intensive Sampling of Gravel Wetland

Automatic sampling revealed that for storm events on 14 November and 3 December 2009, the gravel wetland retained, respectively, 130 and 80 g of P and 7.2 and 9.2 kg of TSS, which represented P removal efficiencies of 39 and 13% and TSS removal efficiencies of 42 and 38%. Results for P were generally comparable to those of (Raisin et al., 1997), who reported P removal efficiencies between 0 and 63% for a small storm event driven constructed wetland in an agricultural watershed. The gravel wetland's treatment performance for TSS was also comparable to reported values in the literature. Average outflow TSS concentrations for the first and second storm flows were 28.0 and 40.6 mg L^{-1}, respectively. Kadlec and Wallace

(2008) reported that for twenty-six horizontal subsurface flow wetlands spanning 130 years of system operation, the average effluent TSS concentration was 22.5 mg L^{-1} and that the 90th percentile limit was 42 mg L^{-1}.

Table 4.4. Storm event flow and phosphorus and suspended solids load data for gravel wetland during intensively sampled storms

		Storm Event	
		11/14	12/3
Rainfall	**Amount (mm)**	25.4	15.0
	Duration (h)	13	11
Flow (m^3)	**In**	360	330
	Out	350	310
P Load (g)	**In**	330	600
	Out	200	520
P Retained (g)		130	80
TSS Load (kg)	**In**	17.1	24.2
	Out	9.9	15.0
TSS retained (kg)		7.2	9.2
P Removal Efficiency (%)		39	13
TSS Removal Efficiency (%)		42	38

Results from this study demonstrated that concentrations of TP, PP, TDP, DRP, TSS, and *E. coli* were frequently lower at the stormwater treatment system's outlet than at its inlet. Additionally, intensive sampling during two high throughput storm flows showed that the gravel wetland retained a portion of the P and TSS load from the small dairy barnyardcatchment. Results also seem to suggest that longer inter-event periods may result in lower pollutant loading rates into the gravel wetland and better treatment. Together these results suggest that the recently constructed stormwater treatment system was able to reduce pollutant concentrations during its first five months in operation. However, the results also indicated that treatment performance for *E. coli* was variable and that storm flows resulting in overflow are likely to reduce the overall performance of the treatment system. Observations in the field during the study indicate that minimizing post- construction erosion of treatment structures is likely important for protecting downstream water quality and maintaining proper flows through the treatment system. Because treatment observed during start-up is not representative of long-term performance, the results from this study provide promising evidence that performance will improve as the system re-vegetates and matures

REFERENCES

Cronk J.K. (1996) Constructed wetlands to treat wastewater from dairy and swine operations: A review. Agriculture Ecosystems & Environment 58:97-114.

Eaton A.D., Clesceri L.S., Greenberg A.E. (1998) Standard methods for the examination of water and wastewater. 20th ed. American Public Health Association, Washington, D.C.

Kadlec R.H., Wallace S.D. (2008) Treatment Wetlands. 2nd ed. CRC Press, Boca Raton, FL.

Knight R.L., Payne V.W.E., Borer R.E., Clarke R.A., Pries J.H. (2000) Constructed wetlands for livestock wastewater management. Ecological Engineering 15:41-55.

Raisin G.W., Mitchell D.S., Croome R.L. (1997) The effectiveness of a small constructed wetland in ameliorating diffuse nutrient loadings from an Australian rural catchment. Ecological Engineering 9:19-35.

Rekolainen S., Posch M., Kamari J., Ekholm P. (1991) Evaluation of the accuracy and precision of annual phosphorus load estimates from two agricultural basins in Finland. Journal of Hydrology 128:237-255.

Tanner C.C., Nguyen M.L., Sukias J.P.S. (2005) Nutrient removal by a constructed wetland treating subsurface drainage from grazed dairy pasture. Agriculture Ecosystems & Environment 105:145-162. DOI: 10.1016/j.agee.2004.05.008.

Bishop P.L., Rafferty M.R., Lojpersberger J.L. (2003) Event-based water quality monitoring to determine effectiveness of agricultural BMPs, *In* Proc. of the American Water Resources Association (AWRA) Int. Congress on Watershed Management for Water Supply Systems, AWRA, Middleburg, VA.

Carpenter S.R., Caraco N.F., Correll D.L., Howarth R.W., Sharpley A.N., Smith V.H. (1998) Nonpoint pollution of surface waters with phosphorus and nitrogen. Ecological Applications 8:559-568.

Easton Z.M., Walter M.T., Steenhuis T.S. (2008) Combined monitoring and modeling indicate the most effective agricultural best management practices. Journal of Environmental Quality 37:1798-1809. DOI: 10.2134/jeq2007.0522.

Eaton A.D., Clesceri L.S., Greenberg A.E. (1998) Standard methods for the examination of water and wastewater. 20th ed. American Public Health Association, Washington, D.C.

Gitau M.W., Gburek W.J., Jarrett A.R. (2005) A tool for estimating best management practice effectiveness for phosphorus pollution control. Journal of Soil and Water Conservation 60:1-10.

Hively W.D., Bryant R.B., Fahey T.J. (2005) Phosphorus concentrations in overland flow from diverse locations on a New York dairy farm. Journal of Environmental Quality 34:1224-1233.

Jamieson R., Gordon R., Joy D., Lee H. (2004) Assessing microbial pollution of rural surface waters - a review of current watershed scale modeling approaches. Agricultural Water Management 70:1-17. DOI: 10.1016/j.agwat.2004.05.006.

Jamieson R.C., Gordon R.J., Sharpies K.E., Stratton G.W., Madani A. (2002) Movement and persistence of fecal bacteria in agricultural soils and subsurface drainage water: a review. Canadian Biosystems Engineering 44:1-9.

Jokela W.E., Clausen J.C., Meals D.W., Sharpley A.N. (2004) Effectiveness of agricultural best management practices in reducing phosphorus loading to Lake Champlain, in: T. O. Manley, et al. (Eds.), Lake Champlain: partnerships and research in the new millenium, Kluwer Academic/ Plenum Publishers, New York. pp. 39-52.

LCBP. (2003) Opportunities for Action: An Evolving Plan for the Future of the Lake Champlain Basin, Lake Champlain Basin Program, Grand Isle, VT. pp. 1-144.

LCBP. (2008) State of the Lake and Ecosystem Indicators Report - 2008, Lake Champlain Basin Program, Grand Isle, VT. pp. 1-32.

McDowell R., Sharpley A., Folmar G. (2001) Phosphorus export from an agricultural watershed: linking source and transport mechanisms. Journal of Environmental Quality 30:1587-1595.

Meals D.W. (1989) Bacteriological water quality in Vermont agricultural watersheds undergoing land treatment. Lake and Reservoir Management 5:53-62.

Meals D.W. (1996) Watershed-scale response to agricultural diffuse pollution control programs in Vermont, USA. Water Science and Technology 33:197-204.

Meals D.W. (2001) Lake Champlain Basin agricultural watersheds section 319 national monitoring program project, final project report: May, 1994 - September, 2000, Vermont Dept. of Environmental Conservation, Waterbury, VT. pp. 1-19.

Meals D.W., Budd L.F. (1998) Lake Champlain Basin nonpoint source phosphorus assessment. Journal of the American Water Resources Association 34:251-265.

Michaud A.R., Laurzier R., Laverdiere M.R. (2004) Temporal and spatial variability in non-point source phosphorus in relation to terrestrial indicators: the Beaver Brook case study, Pike River Basin, Quebec, in: T. O. Manley, et al. (Eds.), Lake Champlain: partnerships and research in the new millenium, Kluwer Academic/Plenum Publishers, Boston.

Noll M.R., Magee E.A. (2009) Quantification of phosphorus sources to a small watershed: A case study of Graywood Gully, Conesus Lake, NY. Journal of Great Lakes Research 35:50-55.

Schellinger G.R., Clausen J.C. (1992) Vegetative filter treatment of dairy barnyard runoff in cold regions. Journal of Environmental Quality 21:40-45.

Sharpley A.N., Chapra S.C., Wedepohl R., Sims J.T., Daniel T.C., Reddy K.R. (1994) Managing Agricultural Phosphorus for Protection of Surface Waters - Issues and Options. Journal of Environmental Quality 23:437-451.

Simon R.D., Makarewicz J.C. (2009a) Storm water events in a small agricultural watershed: characterization and evaluation of improvements in stream water microbiology following implementation of best management practices. Journal of Great Lakes Research 35:76-82.

Simon R.D., Makarewicz J.C. (2009b) Impacts of manure management practices on stream microbial loading into Conesus Lake, NY. Journal of Great Lakes Research 35:66-75.

Sims J.T., Kleinman P. (2005) Managing agricultural phosphorus for environmental protection in: J. T. Sims and A. N. Sharpley (Eds.), Phosphorus: Agriculture and the environment, American Society of Agronomy, Madison, WI.

Smeltzer E., Dunlap F., Simoneau M. (2009) Lake Champlain phospohrus concentrations and loading rates, 1990-2008, Lake Champlain Basin Program, Grand Isle, VT. pp. 1-44.

Troy A., Wang D., Capen D. (2007) Updating the Lake Champlain Basin land use data to improve prediction of phosphorus loading. Technical Report No. 54, Lake Champlain Basin Program, Grand Isle, VT. pp. 1-121.

USEPA. (1986) Quality citeria for water, 1986 U.S. Environmental Protection Agency, Washington, DC.

Vermont Agency of Agriculture Food and Markets. (2008) Act 78 - section 16 annual report, 2008, Vermont Agency of Agriculture, Food, and Markets, Montpelier, VT.

Vermont Natural Resources Board. (2008) Vermont water quality standards, Montpelier, VT.

Improvement of Phosphorus Load Estimates through the use of Enzyme-Hydrolysis Measures of Phosphorus Bioavailability

Basic Information

Title:	Improvement of Phosphorus Load Estimates through the use of Enzyme-Hydrolysis Measures of Phosphorus Bioavailability
Project Number:	2008VT36B
Start Date:	3/1/2009
End Date:	2/28/2010
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Focus Category:	Sediments, None, None
Descriptors:	
Principal Investigators:	Jane Hill

Publications

1. Johnson, Nicholas R., and J.E. Hill, August 2009. Phosphorus composition of wet and dried poultry litter-amended soil by enzyme hydrolysis and solution 31P-NMR. 238th ACS National Meeting Presentation.
2. Johnson, N.R. and Hill, J.E. 2010 (accepted) Phosphorus composition of a poultry manure-amended soil via enzymatic hydrolysis: demonstration of a high-throughput method and hints on enzyme-labile P Soil Science Society of America Journal
3. Giles, C.D., Cade-Menun, B., and Hill, J.E. (under review) The Inositol Phosphates in Soils and Manures: Abundance, Cycling, and Measurement.
4. Hill, J.E., 2009, Phytate: Movement and Transformation in the Landscape, Great Lakes Phosphorus Forum,Poster, July.
5. Giles, Courtney D., Barbara Cade-Menun, and J.E. Hill, 2009, Phosphorus mobility and transformation in a poultry manure-amended soil tracked over time and depth, Presentation, August.
6. Johnson, Nicholas, Barbara Cade-Menun, and J.E. Hill, 2009, Hydrolysis as a Tool for Measuring Bioavailable P in Dairy Manure Storage and Treatment Systems, Presentation, November.

Title: Improvement of Phosphorus Load Estimates through the use of Enzyme-Hydrolysis Measures of Phosphorus Bioavailability

PI: Jane Hill (University of Vermont, School of Engineering)

Notable Accomplishments Narrative

Microorganisms alter the forms of phosphorus in soils and sediments over time. Some forms, such as orthophosphate, are more available to cyanobacteria and crop plants. We need to be able to measure such bioavailability in order to improve crop soil fertility as well as decrease the phosphorus in runoff from agricultural fields. Our present soil analysis methods for phosphorus forms are either very expensive (e.g. ^{31}P-NMR) or do not reveal the total amount of bioavailable phosphorus in the sample (e.g. Modified Morgan P). This lack of knowledge hinders our ability to manage our agricultural soils and thus the watershed. In the past decade, pioneering research conducted at the USDA Plant, Soil and Water Laboratory in Orono, Maine studying animal manures has lead to the development of a method for analyzing forms of bioavailable phosphorus using enzymes. The first objective of this study is to modify this enzymatic method so that it can be applied to characterize Vermont soil systems. The second objective of this study is to employ the modified enzymatic method to Vermont soil systems primarily from the Lake Champlain Watershed area, where we are most concerned about phosphorus pollution entering the Lake.

We have successfully modified and employed a robust, efficient and sensitive phosphohydrolase based assay of soil P forms on a time series of manure-amended Vermont soil samples. We assessed the substrate specificity of several commercially available phosphohydrolases against 13 P compounds commonly found in soil. Knowledge of this specificity allowed us to select a cocktail of enzymes that facilitated the classification of soil P in into three categories: inorganic P, enzyme labile simple monoester P + phytate-like P, and enzyme labile nucleic acid P. Furthermore, we improved the robustness and efficiency of this assay by adapting it to a microplate reader format which allowed us to process a large number of samples quickly. Using this adapted tool we looked at a poultry manure-amended Vermont soil over a period of 10 weeks. We were able to both track three P forms over time and confirm observed proportions of P with ^{31}P-NMR spectroscopy. This has resulted in an accepted publication to the Soil Science Society of America Journal and five presentations at national meetings (Great Lakes Phosphorus Forum, ASA-SSSA-CSSA, and ACS).

We have also applied the method to measure the potential for Vermont soils to release orthophosphate under saturated and anoxic conditions. The data for this work has been collected and is presently being assessed for presentation and publication in a peer-reviewed journal. Knowledge gleaned from this study will affirm the usefulness of this assay to track enzyme labile P forms and provide a foundation for future work identifying specific mechanisms facilitating the release and microbial modification of labile soil P. Students supported by this project include a Ph.D. candidate, an MS candidate, and an undergraduate who recently transitioned to the MS program. All students are part of the Civil and Environmental Engineering Program at the University of Vermont.

Quantifying Sediment Loading due to Stream Bank Erosion in Impaired and Attainment Watersheds in Chittenden County, VT Using Advanced GIS and Remote Sensing Technologies

Basic Information

Title:	Quantifying Sediment Loading due to Stream Bank Erosion in Impaired and Attainment Watersheds in Chittenden County, VT Using Advanced GIS and Remote Sensing Technologies
Project Number:	2009VT44B
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Focus Category:	Non Point Pollution, Sediments, Geomorphological Processes
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Principal Investigators:	Leslie Morrissey, Donna Rizzo, Donald Ross, Eric Young

Publications

1. Garvey, K.M., L. A. Morrissey, D. Rizzo, and M. Kline, 2010, Streambank Erosion in Chittenden County, VT: Application of Very High Resolution Remote Sensing and GIS Modeling, Lake Champlain 2010 Conference: Our Lake, Our Future, Lake Champlain Research Consortium, June 7-8, 2010, Burlington, VT.
2. Garvey, K.M., L. A. Morrissey, D. Rizzo, and M. Kline, 2010, Quantifying Sediment Loading due to Streambank Erosion in Impaired and Attainment Watersheds in Chittenden County, VT, Vermont Geological Society Winter Meeting, Feb. 6, 2010, Norwich, VT.

Annual (Interim) Report
March 1, 2009 – February 28, 2010 (Year 1)

Title: Quantifying Sediment Loading due to Stream Bank Erosion in Impaired and Attainment Watersheds in Chittenden County, VT

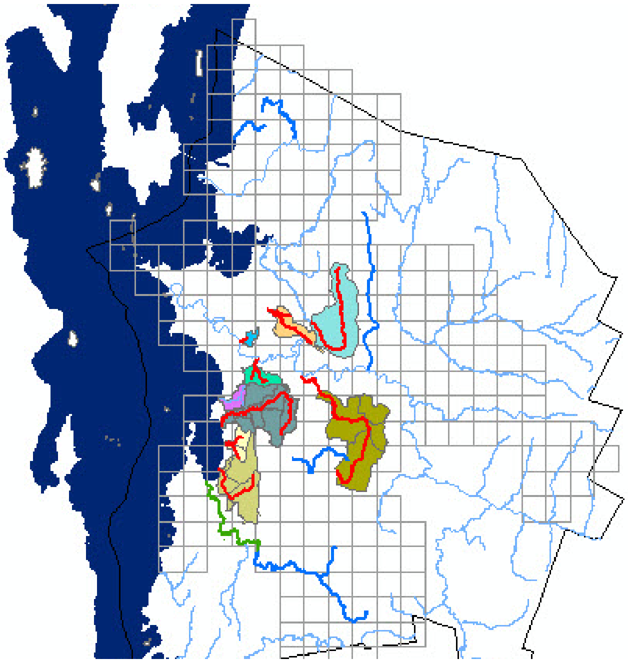
Focus Categories: Pollution, Sediments, Geomorphic Processes
Research Category: Water Quality
Start Date: March 1, 2009 End Date: February 28, 2011
Principal Investigators:

Leslie A. Morrissey, Assoc. Professor, RSENR/UVM
Donna Rizzo, Assoc. Professor, CEMS/UVM

Introduction: Streambank erosion is one of the most important but least understood nonpoint sources of sediment and phosphorus threatening the impairment of surface waters within the Lake Champlain Basin. High spatial and temporal variability and the difficulties of measuring erosion rates at watershed scales limit our understanding or the ability to quantify the contribution of streambank erosion to water quality degradation. Previous research has not provided the quantitative basis required to weight the importance of stream bank erosion relative to other sediment and P sources at watershed scales or the information needed to address within watershed variability in streambank erosion over time.

To address these issues, we have combined field data collection and remote sensing approaches to quantify sediment loading mobilized by streambank erosion in 15 Chittenden County watersheds. Three key subtasks were required to address our goal: 1) mapping of *erosion areas* due to channel migration over time with multidate imagery, 2) analysis of LiDAR-derived DEMs to quantify *streambank heights* that in turn will be used to estimate soil volume loss, and 3) estimating sediment loading per eroded feature, reach, and stream. These analyses in turn will allow us to identify critical source areas that contribute a disproportionate amount of the total sediment load to streams.

Study Area **-** Our research focused on 15 watersheds (Figure 1) in Chittenden County, VT, of which ten are on the state of Vermont's 303d list of impaired waters [VT DEC, 2008] due to urban stormwater or agricultural runoff and six, including the area draining to the non-impaired reaches of the LaPlatte River, are identified *attainment watersheds* i.e., watersheds that can be used to establish TMDL target flows for stormwater impaired watersheds having similar hydrologic and ecological characteristics. The watersheds were selected because of long-standing federal, state and public focus on in-stream sediment, phosphorus, or fecal contamination and their contribution to water quality in Lake Champlain. These watersheds were also selected to leverage available aircraft and satellite imagery, LIDAR data, VT ANR RMP fluvial geomorphic assessments, USGS and UVM stream gage stations, and our previous channel migration mapping efforts in Allen Brook and Indian Brook watersheds.



Impaired watersheds
Allen Brook
Bartlett Brook
Centennial Brook
Englesby Brook
Indian Brook (south)
LaPlatte River (west)
Morehouse Brook
Munroe Brook
Potash Brook
Sunderland Brook

Attainment watersheds
Alder Brook
LaPlatte River (east)
Patrick Brook
Streeter Brook
Sucker Brook
Trout Brook

Figure 1. Chittenden County, VT study area showing 15 watersheds under study. Stormwater impaired watersheds are shown in red, the agriculturally-impaired LaPlatte River in green, and attainment streams in bold blue. The watershed areas associated with the stormwater impaired streams are also shown. The overlying grid indicates geographic coverage of CCMPO LiDAR data (acquired in 2004).

Results: In support of efforts to map stream migration over time, USDA National Agriculture Imagery Program (NAIP) imagery and LiDAR data were acquired and compiled for all 15 streams in Chittenden County. Overhanging forest cover unfortunately precluded mapping stream centerlines with the 2008 NAIP imagery (mid-summer coverage) for all but the LaPlatte River. The remaining stream centerlines were thus mapped using available orthophotography collected during the spring leaf off period (e.g. CCMPO 1:1250 acquired in 2004). Preliminary channel migration estimates were computed as the lateral shift in stream centerlines between any two dates of observation (Figure 2) corrected for errors in image registration. Initial estimates were based on automated detection of eroded features due to lateral channel shift using ArcGIS ModelBuilder. Final estimates will require manual editing and updating of the preliminary ArcGIS model.

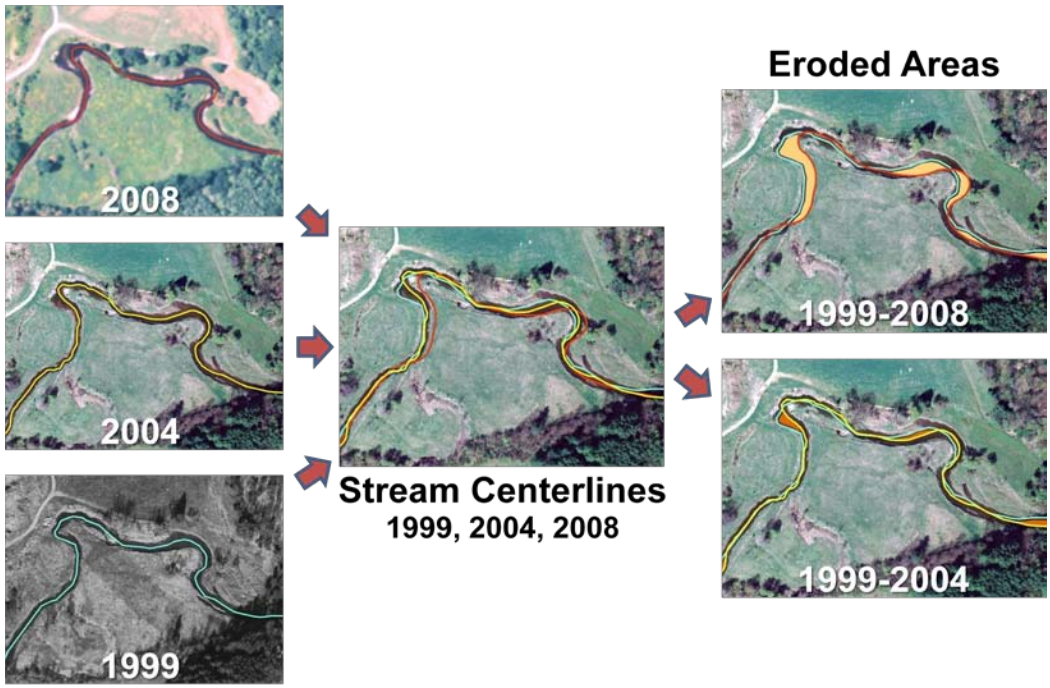


Figure 2. Stream centerlines were digitized for each image date and then overlaid to map stream migration over time (1999 – 2008).

Large spatial and temporal variability in stream migration was observed over the 1999-2008 study period as shown for the LaPlatte River (Figure 3). The number of erosion features for each reach varied from 0-65 with high variability among reaches and time intervals. The number of eroded features was highest (556) for the 2004-2008 time period, lowest (370) for 1999-2008, and intermediate (403) for the 1999-2004, respectively.

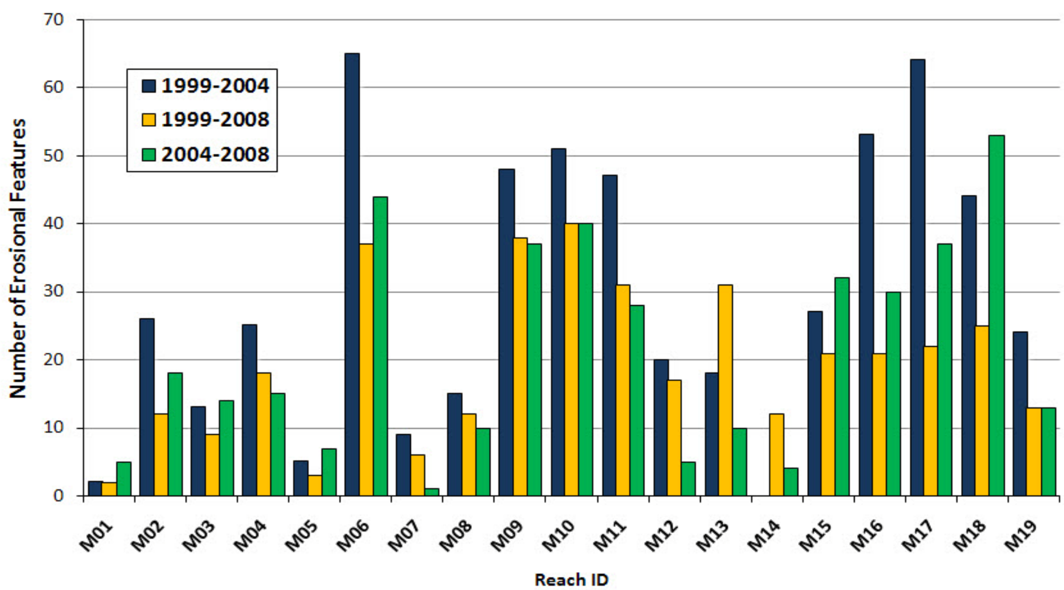


Figure 3. Number of eroded areas due to lateral stream migration summarized by reach for the LaPlatte River watershed over three time intervals (1999 – 2008).

Soil volume loss for eroded areas was calculated using LiDAR data to derive streambank and stream channel heights. For these calculations, we employed 3.2m posting bare earth (BE) and reflective surfaces (RS) LiDAR data collected over our study areas in May 2004. We derived DEMs and DSMs based on Natural Neighbor spatial interpolation and by combining BE systematic point grids with additional low lying RS points to derive the enhanced DEMs used in our subsequent processing and analyses. We then calculated an upper soil volume loss estimate as the product of the eroded area polygons derived from the multidate imagery and streambank height derived from the LiDAR elevation data.

Areal and volume estimates of soil loss differed greatly by reach within each watershed, between watersheds, and over time. Area of soil loss due to stream migration differed greatly between watersheds (Figure 4). Five of the impaired watersheds and one attainment watershed (Trout Brook) had the highest erosion rates (>10% of watershed area). Low erosion rates (<10%) were noted for the remaining impaired and attainment streams.

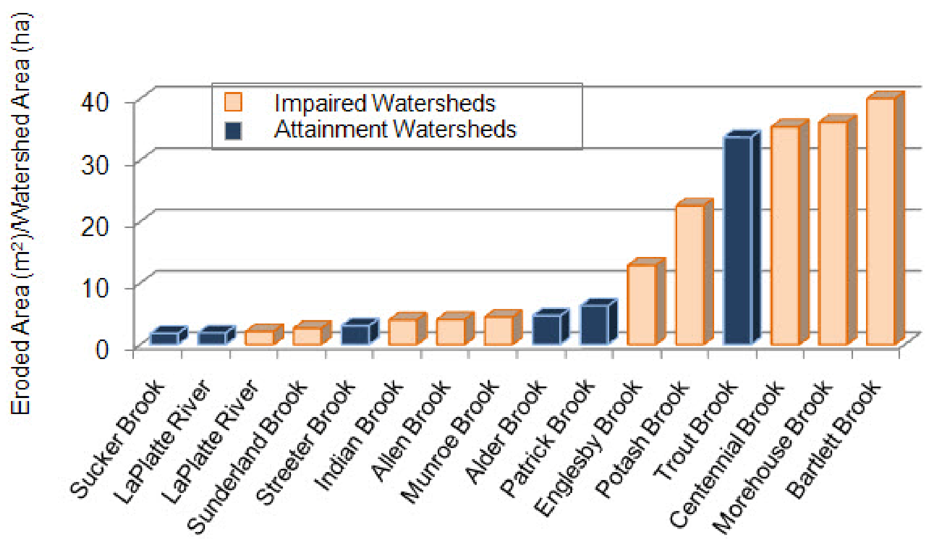


Figure 4. Streambank eroded area (1999-2004) normalized by watershed area for 15 streams in Chittenden County, VT.

The average annual rate of sediment loading (MT yr^{-1}) due to streambank erosion within each watershed over the period of study was estimated by combining measures of the volume of sediment loss derived from the remote sensing and GIS analyses with field observed soil bulk density. Soil sampling and field measures were completed in the summer of 2009 for Allen Brook at selected erosion sites as determined from the multidate imagery. Soil data included bulk density, organic matter, composition, texture and phosphorus content. In concert with D. Ross (Plant and Soil Science, UVM) and Carolyn Alves (USDA NRCS), field teams sampled 31 randomly located erosion sites (with replicates) along Allen and Indian Brooks. Additional sampling for Indian Brook will continue during the summer of 2010. Sampling along Alder Brook and LaPlatte River is also scheduled for next summer.

Preliminary estimates of sediment loading due to stream migration generated for Allen Brook and Indian Brook over the period 1999-2004 are shown in Table 1. Estimates were derived based on estimated soil volume loss and measured soil bulk density (mean 1.2, n=62). When compared to SWAT modeling to predict sediment loading in Allen Brook (Barg et al., 2003), streambank erosion accounted for approximately 13% of the total sediment loading.

Table 1. Sediment loading estimates for Allen and Indian Brooks.

Stream	Number of Reaches	Reach ID	Number of Erosion Features	Sediment Loading (MT/yr^{-1})
Allen Brook	9	M01 – M09	355	1228
Indian Brook	8	M09 - M16	244	1003

Conclusions: These preliminary results demonstrate the potential value of remote sensing to augment field surveys to quantify stream geomorphic change and sediment loading over time at watershed scales and to map and monitor stream channel changes throughout the watershed consistently, accurately, and at relatively low cost. These analyses also serve as a baseline against which future estimates of sediment loading can be evaluated and as a means to constrain subsequent P loading estimates due to streambank erosion. More importantly, this effort represents not only a significant step toward the development of a systematic approach to quantify sediment (and P) loading due to streambank erosion throughout the Lake Champlain basin and elsewhere, but also a watershed-scale approach that could greatly aid adaptive management efforts.

Student Supported: Graduate student, Ms. Kerrie Garvey, joined the project team in July 2009 under the direction of Leslie Morrissey and Donna Rizzo (anticipated graduation May 2011, M.S., Natural Resources Program, RSENR/UVM).

Conference Presentations: -

Garvey, K.M., L. A. Morrissey, D. Rizzo, and M. Kline, Streambank Erosion in Chittenden County, VT: Application of Very High Resolution Remote Sensing and GIS Modeling, *Lake Champlain 2010 Conference: Our Lake, Our Future,* Lake Champlain Research Consortium, June 7-8, 2010, Burlington, VT.

Garvey, K.M., L. A. Morrissey, D. Rizzo, and M. Kline, Quantifying Sediment Loading due to Streambank Erosion in Impaired and Attainment Watersheds in Chittenden County, VT, *Vermont Geological Society Winter Meeting*, Feb. 6, 2010, Norwich, VT.

Estimating Soil Phosphorus Concentrations along Erodible Stream Corridors in Chittenden County, Vermont

Basic Information

Title:	Estimating Soil Phosphorus Concentrations along Erodible Stream Corridors in Chittenden County, Vermont
Project Number:	2009VT45B
Start Date:	3/1/2009
End Date:	2/28/2010
Funding Source:	104B
Congressional District:	First
Research Category:	Water Quality
Focus Category:	Nutrients, Non Point Pollution, Water Quality
Descriptors:	None
Principal Investigators:	Donald Ross, Leslie Morrissey, Eric Young

Publications

1. Garcia, Angel, 2010, Understanding the Relationships between Beaver Dams and the Movement of Phosphorus through Allen Brook, Chittenden County, VT, Universidad Metropolitana 2nd Annual Vermont EPSCoR Streams Project Symposium, Apr 19, 2010 Burlington, VT.
2. Thomas, Maya, 2010, Riparian soil phosphorus and stream channel migration at Allen Brook in Chittenden County, VT, UVM Student Research Conference, April 22, 2010, Burlington, VT.
3. Alves, Caroline, 2010, Examining phosphorus contributions from alluvial soils - a comparison of three Vermont river corridors, (USDA-Natural Resources Conservation Service). Lake Champlain 2010 Conference: Our Lake, Our Future, Lake Champlain Research Consortium, June 7-8, 2010, Burlington, VT.
4. Young, Eric, Don Ross, Caroline Alves, and Thomas Villars, 2010, Spatial variability of riparian soil phosphorus at a site along the Rock River, Vermont, Lake Champlain 2010 Conference: Our Lake, Our Future, Lake Champlain Research Consortium, June 7-8, 2010, Burlington, VT.

Interim Progress Report

Title: Estimating Soil Phosphorus Concentrations along Erodible Stream Corridors in Chittenden County, Vermont

Project Type: Research

Focus Categories: Nutrients, Nonpoint source pollution, water quality

Research Category: Water Quality

Keywords: soil phosphorus, soil mapping, spatial variability, soil-landscape, P transport

Start date: March 6, 2010

End date: March 5, 2011

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Congressional District: Vermont-at-large

Abstract

Phosphorus (P) loss from stream bank erosion is thought to be a major and underestimated contributor of P loading to Lake Champlain. Soil variability strongly influences the chemical and physical properties of riparian areas. Results from our recent research funded by the UVM Water Resources and Lake Studies Center demonstrated that riparian soil P concentrations varied significantly by soil type, texture (e.g., sand, silt, and clay distribution), and drainage at three riparian sites in the Lake Champlain Basin (Lewis Creek, Rugg Brook, and Rock River), suggesting that detailed soil maps may be used to estimate P concentrations. Parent material and drainage vary widely in Vermont's riparian landscapes, making it difficult to produce accurate soil maps. Since drainage and texture are the two main factors that determine soil types, traditional and novel mapping techniques show promise for estimating riparian soil P availability. Building on our previous research, this project will combine high-order soil mapping and soil testing to estimate P levels at riparian sites in Chittenden County, VT. This approach will generate soil-specific P concentrations for each of the study sites. Year one of the project focused on sampling along Allen Brook and Indian Brook, where historical channel migration measurements have occurred. In year two, we will sample along two attainment streams, Alder Brook and the upper reaches of the LaPlatte River. Both are undergoing detailed stream bank erosion mapping by co-investigators Morrissey and Rizzo. We will target two types of erosion features: i) those with the same soil series as the year-one samples and ii) other important stream corridor soil series that were underrepresented in year-one sampling. Using our accumulated dataset, we will evaluate the applicability of our approach to other stream corridors in VT by how well soil type and other properties predict P concentrations in the year-two samples from the same soil series. When coupled to historical measurements of streambank erosion, results from this project will provide improved estimates of P mobilized by fluvial systems and contribute to a greater understanding of P dynamics in the Lake Champlain Basin.

Results from Year 1.

During the first field season, sampling was performed along two streams in Chittenden County that had been identified as impaired. Areas of active erosion were identified via remote sensing by co-investigator Morrissey. On each stream, 25 locations were randomly selected for sampling. All remotely identified features were first verified by a site visit. We then sampled the selected features 1.5 m in from the 'outer' (non-eroded) bank. At each site, three soil corings were taken 1 m apart, with four depths collected: 0-15 cm, 15-30 cm, 30-60 cm and 60-90 cm. These depths were selected to provide P concentrations for the upper soil layers that may reflect

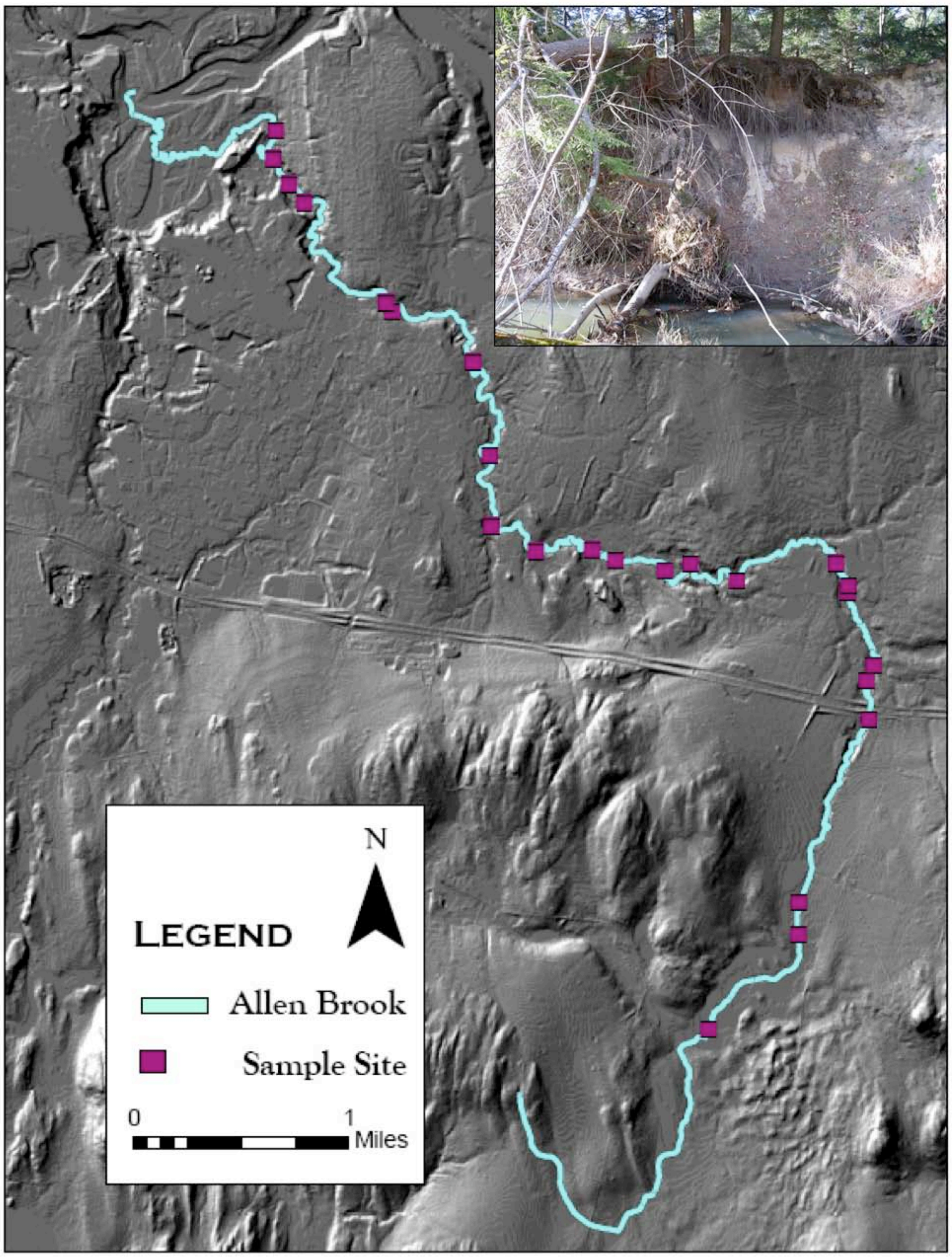

Figure 1. Map of Allen Brook sample sites. 24 out of 25 sampled. (Figure prepared by Eulaila Ishee.)

historical land use and also for lower soil layers that are representative of soil parent material. This approach resulted in 12 samples per feature unless sampling was impeded by coarse fragments or bedrock. Bulk density cores were also taken with a Uhlander device at two depths (0-15 and 15-30 cm) adjacent to each coring. All soil sampling locations were georeferenced to ensure a match with the remote sensing data. As of 05-12-10, 24 sites have been sampled along Allen Brook (Fig. 1) and 14 sites sampled along Indian Brook (Fig. 2) for a total of about 470 soil samples for chemical tests and 228 samples for bulk density and coarse fragment measurements. In addition to this sampling, we dug five classification soil pits along Allen

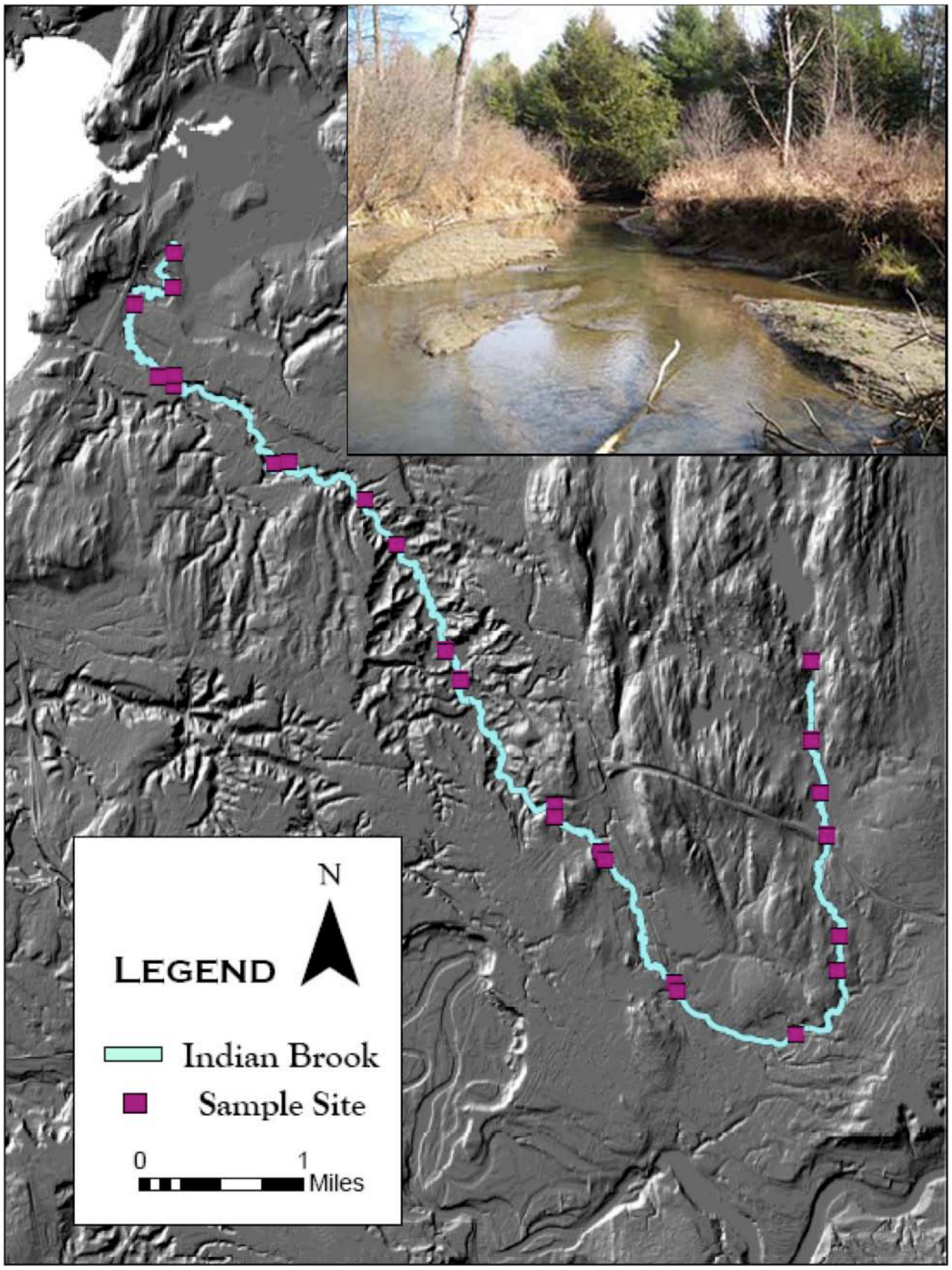

Figure 2. Map of Indian Brook sample sites. 14 out of 25 sampled. (Figure prepared by Eulaila Ishee.)

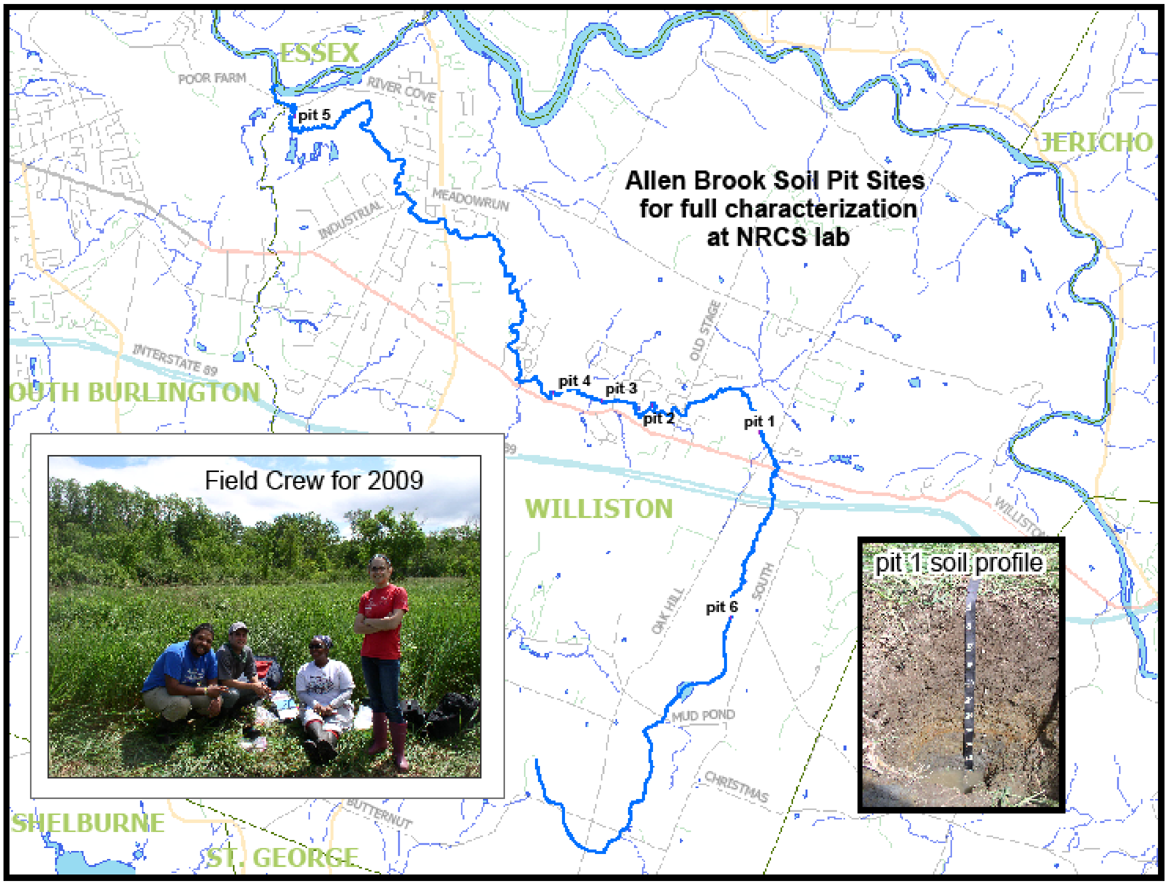

Figure 3. Location of the characterization soil pits. Field crew for the summer of 2009, left ot right, Angel Garcia, Edward Garcia, Maya Thomas and Rebecca Bourgault. (Figure prepared by Caroline Alves, Vermont NRCS.)

Brook in collaboration with cooperator Caroline Alves of the USDA NRCS (Fig. 3). Samples from these pits have been sent to the National Soil Survey Lab for complete physical and chemical analysis, and the data will be used to definitively classify the sampled soils. In these pits, we also obtained bulk density samples from the lower depth increments that are being analyzed at UVM. Finally, at locations where the streambank exceeded 1 m in height and was exposed, we took additional depth increments by digging directly into the bank. These samples will be used to determine if soil changes take place at these greater depths.

Laboratory analyses. For samples analyzed to date, Tables 1 and 2 give the mean and range of chemical characteristics. The range in soil-test or 'available' P, which has been found to correlate well with algal-available P, was relatively broad but the means for each depth were below the optimum range for crop growth (4-7 mg/kg colorimetric P). We found similar low soil-test P in our previous USGS-funded studies of stream corridor soils in Franklin and Addison counties. In our initial Allen Brook results, soil pH was usually somewhat acidic and, coupled with the moderate amounts of available Al, it is likely that these soils would be P sinks if not eroded. Total P has not yet been determined but, based on our previous studies, will be at least two orders of magnitude higher. The highest Ca, pH and Mn values were all deep in the profile and probably reflect a partially weathered limestone parent material.

Depth cm	P-ICP[1] mg/Kg	P-color[2] mg/Kg	pH mg/Kg	% LOI[3] mg/Kg	Ca mg/Kg	Al mg/Kg	Fe mg/Kg	Mn mg/Kg
0-15	4.4	2.9	5.7	4.3	1206	45.6	19.4	16.5
15-30	2.5	1.5	5.7	2.7	1222	77.3	19.6	13.8
30-60	1.7	1.2	5.8	1.7	1304	47.7	13.4	13.8
60-90	2.4	1.8	5.8	1.6	451	34.0	12.8	7.9
Overall average[4]	2.8	1.9	5.8	2.7	1100	52.7	16.6	13.5
min[5]	0.5	0.4	4.0	0.2	71	4.2	1.8	0.9
max	11.9	9.9	7.6	8.8	6504	323.3	111.2	75.4

[1] 'Available' phosphorus by ICP-OES (includes inorganic and organic)

[2] Colorimetric 'available' phosphorus (inorganic)

[3] Estimate of organic matter by weight loss on ignition

[4] Overall averages are from the means of each sample site

[5] Min and max of averaged values

Table 1. Summary of soil test results from the Allen Brook sampling ($n = 153$). The extractant was pH 4.8 ammonium acetate (Vermont's soil test procedure).

Soil texture of soils along the erodible features on Allen Brook was a mixture of sandy loams and loamy sands (Tables 2 and 3). There was often a general increase with sand at depth in the profile. Both the texture and the texture change are typical of the soil series mapped in this area. Not all sites were sandy however—one erosion feature had silty clay loam soils, giving the minimum value for sand (22.3%) and the maximum for clay (28.9%) and near the maximum for silt (48.8). More than half the samples analyzed to date have been sandy loams (Table 3).

Sample Depth cm	Sand %	Silt %	Clay %	Bulk Density mg/m^3	Coarse Fragments vol%
0-15	56.5	34.6	8.9	1.01	2.8
15-30	57.4	33.2	9.5	1.20	2.0
30-60	64.6	27.5	7.9	nd[1]	Nd
60-90	64.1	34.6	8.9	nd	Nd
overall average[2]	60.3	31.3	8.4	1.41	2.4
min[4]	22.3	4.8	2.4	0.48	0
max	91.9	49.8	28.9	1.72	18.1

[1] Not determined

[2] Overall averages are from the mean of each erosion site

[3] Coarse fragment overall average is the mean of all values

[4] Min and max of averaged values

Table 2. Physical characteristics from initial soil analysis of the Allen Brook samples ($n = 97$).

Texture Class	#	%
loam	19	0.20
loamy sand	16	0.16
sand	6	0.06
sandy loam	52	0.54
silt loam	2	0.02
silty clay loam	2	0.02
total (n)	97	1.00

Table 3. Number and percent of individual samples by texture class (n = 97).

Ongoing schedule

In year two, we will finish the Indian Brook sampling in late spring and, between June and August, sample an additional remotely-sensed erosion features from Alder Brook and the LaPlatte River. Additional characterization soil pits will be located along Indian Brook and at other locations that match the needs of the NRCS (specific soil series). The final six months of the project will focus on laboratory analysis, statistical analysis and soil map updating.

In an associated project, co-investigators Morrissey and Garvey (and collaborator Rizzo) are performing the remote sensing analyses of channel migration for streams in Chittenden County. As it becomes available, we will supply phosphorus and bulk density data so that historical P loading into the streams can be calculated. Calculation of P loading in other Chittenden County streams will follow once we better understand the variability of bulk density of P content, and their relationship to soil series characteristics, such as texture and drainage.

Training

This project is training a M.S. candidate (Eulaila Ishee) in all aspects of the proposed research. In additional, the project is providing valuable training for a number of undergraduate students majoring in Environmental Sciences and student interns in UVM STREAMS program. During the first field season we had the help of two students (Edward Garcia and Angel Garcia) from Universidad Metropolitana of Puerto Rico as part of the UVM STREAMS internship program. We also had the assistance of a UVM McNair scholar from the Rubenstein School, Maya Thomas. These three students have already given presentations on the research they performed last summer. Most recently, Angel Garcia presented at the annual STREAMS conference and Maya Thomas at the UVM Student Research Conference (citations below). In addition, Angel has been admitted to UVM's graduate program in the Geology Dept. and will commence studies in the fall of 2010. For the second field season (2010), we will again have the assistance of two students from Universidad Metropolitana and one UVM Environmental Sciences undergraduate.

Conference Presentations

Two of these were student presentations and two will be presented at the upcoming Lake Champlain conference. The latter two are focused on earlier, related work in Lake Champlain stream corridors funded by the USGS Water Center and the VT ANR.

Understanding the Relationships between Beaver Dams and the Movement of Phosphorus through Allen Brook, Chittenden County, VT. Angel Garcia. Universidad Metropolitana 2nd Annual Vermont EPSCoR Streams Project Symposium, Apr 19, 2010 Burlington, VT.

Riparian soil phosphorus and stream channel migration at Allen Brook in Chittenden County, VT. Maya Thomas. UVM Student Research Conference, April 22, 2010, Burlington, VT.

Examining phosphorus contributions from alluvial soils - a comparison of three Vermont river corridors - Caroline Alves (USDA-Natural Resources Conservation Service). *Lake Champlain 2010 Conference: Our Lake, Our Future,* Lake Champlain Research Consortium, June 7-8, 2010, Burlington, VT.

Spatial variability of riparian soil phosphorus at a site along the Rock River, Vermont - Eric Young (University of Vermont), Don Ross, Caroline Alves, and Thomas Villars. *Lake Champlain 2010 Conference: Our Lake, Our Future,* Lake Champlain Research Consortium, June 7-8, 2010, Burlington, VT.

Information Transfer Program Introduction

The Information Transfer Program for the Vermont Water Resources and Lake Studies Center for FY2009 is described in the following project report.

Information Transfer Activities

Basic Information

Title:	Information Transfer Activities
Project Number:	2008VT39B
Start Date:	3/1/2009
End Date:	2/28/2010
Funding Source:	104B
Congressional District:	First
Research Category:	Water Quality
Focus Category:	Education, Management and Planning, Methods
Descriptors:	None
Principal Investigators:	Breck Bowden

Publications

There are no publications.

The Vermont Water Resources and Lake Studies Center facilitates information transfer in a variety of ways. The Center produces a web-based newsletter that highlights emerging research funded by the Center or relevant to water resources management in Vermont. The Vermont Water Center partially funds one staff position to produce this newsletter and to manage the center's website. The website is used to disseminate information about water research that is of interest to the water resources management community in state.

The Director of the Water Center sits on the Lake Champlain Basin Program's Technical Advisory Committee (TAC) and in September 2010 will assume the Chair of this committee. In this capacity the Director regularly brings information from Center-funded projects to the attention of the TAC. The Director also participates in a number of other state-level initiatives, especially those related to stormwater management. In this capacity he has the opportunity to contribute to and guide policy with respect to this critical area of water research and management in the state.

The Center regularly supports seminars, workshops, and conferences relevant to water resources management issues in Vermont. Examples include specialty workshops designed to showcase emerging results from Center-funded projects. At other times the Center supports meetings that address topics that are directly relevant to the Center's mission. An important example of this type of meeting is the upcoming conference on Lake Champlain entitled "Our Lake, Our Future", which will be held June 7-8, 2010 at the University of Vermont Davis Center. This conference is the second in a series which focuses on current research that addresses key issues facing sustainable management of Lake Champlain and its basin. This new conference series revives an older series of research conferences on Lake Champlain that stopped several years ago. The Vermont Water Center is a major supporter for this conference. Planning for this conference took place during this reporting period. A more detailed report of the conference outcomes will be provided in the 2010-2011 Annual Reporrt.

USGS Summer Intern Program

None.

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	4	0	0	0	4
Masters	4	0	0	0	4
Ph.D.	1	0	0	0	1
Post-Doc.	0	0	0	0	0
Total	9	0	0	0	9

Notable Awards and Achievements

The Director of the Vermont Water Center delivered a major report on the Vermont Flow Monitoring Project results from 2006-2008 to the Vermont Agency of Natural Resources. This report summarizes results of precipitation and discharge monitoring on 26 previously ungaged urban and reference streams throughout the state. All data from the project have been posted on a publicaly-accessible website, for future use (http://www.uvm.edu/bwrl/vermontflow/). The report concludes that hydrological metrics can be used successfully to identify stormwater impaired streams. These metrics may be used to identify progress towards restoration of unimpaired conditions. Data for the 2009 monitoring year will be reported to VTANR shortly. This project has lead to a new partnership among VTANR, UVM, and the New Hampshire/Vermont USGS Water Science Center to develop draft standard operating procedures for flow monitoring that may become a part of the monitoring requirements in permits for Municipal Separate Stormwater Sewer Systems (MS4's) in the state.

Publications from Prior Years