LaPlatte Watershed Partnership

Shelburne Bay Tributaries - LaPlatte River

(Background and Interpretation of Results: 2004-2007)

Prepared for:

The Town of Shelburne, Vermont
Lewis Creek Association

August, 2008

PREFACE

The LaPlatte Watershed Partnership was established in 2003 to:

i. Work for the continuous improvement of WATER QUALITY in the LaPlatte River, its tributaries, and Shelburne Bay for the protection of healthy macro-invertebrate and fish populations and other wildlife, for the maintenance of healthy and diverse aquatic and terrestrial flora, and for the protection of the water resource for human use, including drinking water supply and recreation.

ii. Work for the continuous improvement of NATURAL SYSTEMS, including habitat, wildlife corridors, riparian and other natural areas in the watershed, especially those associated with the LaPlatte River, its tributaries, and nearby wetlands.

The Partnership, in collaboration with Lewis Creek Association, the towns of Hinesburg, Charlotte, and Shelburne, with the Champlain Water District serving over 68,000 customers in the area surrounding Burlington, Vermont, and the Vermont Department of Environmental Conservation which provides laboratory support through the LaRosa Grants Program, has been monitoring water quality in two streams discharging into Shelburne Bay. Coordination of the monitoring program and collection, transport, and preparation of water samples is carried out by trained volunteers. Quality assurance is provided according to a protocol developed by the State of Vermont and approved by the U.S. Environmental Protection Agency.

The present report presents a review of data collected over the first four years of monitoring in the LaPlatte River watershed. It was funded in part by the Town of Shelburne through a Special Environmental Project.

EXECUTIVE SUMMARY

The LaPlatte River watershed is the largest sub-basin discharging into Shelburne Bay, Lake Champlain. The watershed drains about 57 $mi.^2$ in the towns of Hinesburg, Charlotte, and Shelburne,Vermont. The river corridor is a valuable resource providing wildlife habitat and corridors, and recreation, and it is an important feature of the landscape.

Two sewage treatment plants discharge within the watershed: to the LaPlatte River in Hinesburg, and McCabe's Brook in Shelburne. In recent years, farming has decreased within the watershed, although it continues on land draining into the upper reaches of Mud Hollow and Bingham brooks and into McCabe's Brook.

The LaPlatte River is a class B stream and is designated as habitat for warm water fish during the summer months. The LaPlatte River and Mud Hollow Brook are designated by the State of Vermont as impaired waters in need of TMDLs as a result of agricultural runoff.

Water quality has been monitored on a monthly basis from June through November beginning in 2004 within the LaPlatte watershed, and is reviewed in the present report in relation to related studies and monitoring activities. Monitoring activities include analysis of turbidity and concentrations chloride, total and dissolved phosphorus, total nitrogen, and nitrate plus nitrite. In addition, limited analysis of particle size distribution is carried out at one sampling site.

Water quality in the LaPlatte River is significantly impacted by erosion mobilizing solids from stream banks and bottom sediments. Solids are currently monitored as turbidity. Turbidity was monitored in conjunction with total suspended solids (TSS) concentrations between 2004 and 2006. Mean ratios of turbidity to TSS varied from 1.09 in 2007 to 1.22 in 2004 and 2005.

Along the main stem of the LaPlatte River, turbidity increased dramatically over reaches characterized by significant erosion. Under normal flow conditions, turbidity values exceeded the state water quality standard of 25 NTU in over half the samples examined in these reaches, after which they decreased steadily downstream. When flows were high, solids concentrations increased steadily downstream, reaching values approaching 250 NTU at downstream stations.

In McCabe's Brook, turbidity values generally fall well below the state standard, but tend to increase when flows increase, particularly downstream from farming activities in Charlotte, where increases to as high as 350 NTU have been observed.

Particle sizes were determined in samples collected at the site of the USGS gaging station on the LaPlatte River from 2005 through 2007. Initial results based on these limited results suggested that concentrations of particles in size classes less than 7 μ (clay and very fine silt) remain relatively independent of turbidity values. Larger fine to medium silt (particles greater than 7 μ) tended to increase in proportion to turbidity. Similarly, in relation to flow rate, concentrations of very fine particles <7μ again appeared to be relatively independent of flow or to increase only slowly with flow. Concentrations of larger fine to medium silt appeared to remain fairly constant at flow rates below a threshold of approximately 75 cfs. At higher flow rates, concentrations increased in proportion to flow.

Suspended sediment is important because it can degrade habitat of macroinvertebrates and spawning areas for fish. It is also important as a vehicle for the transport of phosphorus, heavy metals, and toxic organic compounds.

Phosphorus in streams exists in either dissolved form or associated with particulate matter, primarily suspended sediment. In general, particulate phosphorus concentrations in the LaPlatte River watershed have been strongly correlated with TSS concentrations and turbidity. In contrast, while dissolved phosphorus concentrations are variable, they tend to be relatively independent of solids concentrations or flow. Concentrations of particulate phosphorus tend to exceed those of dissolved phosphorus except when solids concentrations are very low. As a result, profiles of total phosphorus concentrations reflect those of TSS concentrations and turbidity.

Because in the LaPlatte River watershed particulate phosphorus concentrations tend to define the phosphorus profile, at times of high flow when sediments are mobilized from stream banks and stream beds, as well as cultivated fields, total phosphorus concentrations can increase steadily downstream, at times exceeding 350 μg/l..

An examination of data from the LaPlatte River at the USGS gaging station collected under both the Volunteer Monitoring Program and the Long Term Tributary Monitoring Program show that when suspended sediment concentrations are low, the phosphorus load per gram of solids tends to be high, at times approaching 7 mg P/gram solids. The highest loads of phosphorus associated with sediment were observed when flows were below a 70 cfs threshold. Whereas this threshold was exceeded only about 20% of the time, the major phosphorus discharge to Shelburne Bay occurred when flows exceeded 70 cfs.

On the other hand, larger particles consisting of fine to medium silt discharged into Shelburne Bay during high flows may settle to the bottom near to shore, and the finer clay and very fine silt particles <7μ as well as dissolved phosphorus, concentrations of which vary generally around 50 μg/l, may have a greater impact in the open water.

Phosphorus concentrations in McCabe's Brook are significantly impacted by storm runoff from agricultural land and large impervious surfaces, as well as by stormwater runoff from urban/semi-urban areas in downstream stations.

Nitrogen profiles and behavior in the LaPlatte River watershed differ from those of phosphorus. Nitrogen concentrations are generally low and well below the state standard for nitrate (5 mg/l as N). The primary source of nitrogen to the LaPlatte River is the Hinesburg treated waste outfall, although at the upstream station, concentrations tend to equal those observed below the treated waste discharge. In both locations median total nitrogen concentrations exceeded 1 mg/l as N. At the upstream station, nitrate plus nitrite constituted about 90% of the nitrogen present. Below the waste discharge, less than 20% of the nitrogen was mineralized. Nitrogen concentrations below the waste discharge decreased in proportion to chloride concentrations, indicating that there were no significant sources along the stream and that the decline was wholly a result of dilution, although an increase at the downstream stations during rain events can be attributed to urban runoff.

In McCabe's Brook, total nitrogen concentrations fell fairly consistently between 0.6 and 0.8 mg/l as N. During one rain event in early summer following manure application to an adjacent cornfield, the total nitrogen concentration rose from about 4 mg/l to about 11 mg/l, and the nitrate plus nitrite from about 3 mg/l to about 8 mg/l, exceeding the state standard.

Of interest in the discussions of nutrients discharged into Shelburne Bay are molar TN:TP ratios which, based on Long term tributary monitoring data at the USGS gaging station, tend to be low (<20) about 70% of the time, and about 90% of the time during the summer and fall months, exceeding 50 on only 2 occasions, and suggesting that nitrogen may be more significant than it is often given.

INTRODUCTION

Shelburne Bay is an important recreational resource and is the source of water supplying the Champlain Water District. The purpose of the monitoring program is to improve public understanding of issues related to water quality in the bay and in the streams tributary to it. By monitoring water quality parameters within two watersheds, one primarily rural, the other draining semi-urban areas, it is meant to complement related monitoring programs implemented by the States of Vermont and New York which focus on nutrient discharges into Lake Champlain.

Shelburne Bay

Shelburne Bay is situated on the eastern side of Lake Champlain just south of Burlington, Vermont. The bay has an area of 9 km^2 (3.5 mi^2) and has an elongated shape with a north-south orientation. The bay is shallow at its southern extremity, increasing in depth gradually for about 300 meters north of the mouth of the LaPlatte River just south of Allen Hill. North of Allen Hill, the depth increases steadily forming a trough extending to the north reaching a depth of about 120 feet at the mouth of the bay, and continuing into Burlington Bay.

Shelburne Bay receives drainage from five tributary streams. The total area drained by these streams is approximately 185 km^2 (71.6 mi^2) and is characterized by a variety of land uses, including agriculture (McCabe's Brook, tributary to the lower LaPlatte River), forests and open land (LaPlatte River, 147 km^2/57 $mi.^2$), sub-urban residential development (Munroe Brook, 13.5 km^2/ 5 mi^2), and urban commercial and residential development (Bartlett Brook, 4 km^2 /1.5 mi^2, and Potash Brook, 21 km^2 /8.1 mi^2). The bay and its tributary streams receive treated sewage and from four waste treatment plants as well as storm runoff from residential and commercial areas.

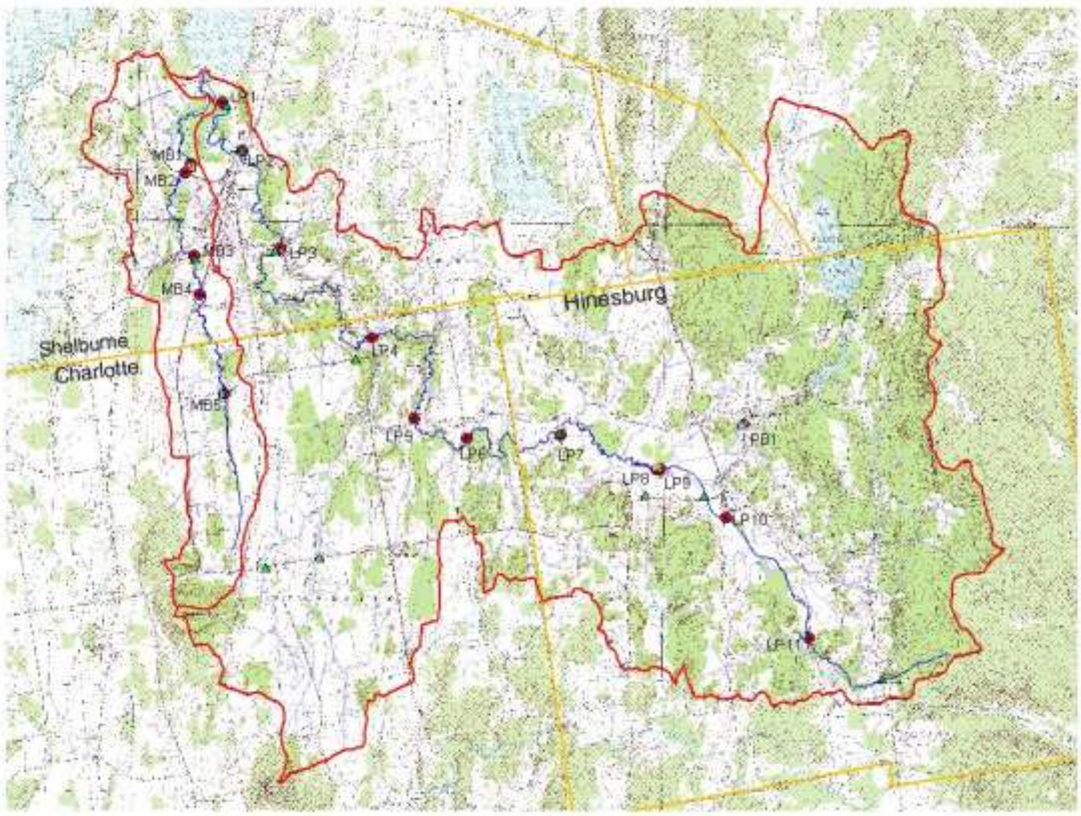
The bay itself provides a number of benefits, including swimming, boating, and year around fishing and it is host to a small boat marina, yacht club, public boat launching area, and mooring areas. The shoreline of the bay, particularly on the eastern and southern shores, is residential. The western shore is protected from the mouth of the LaPlatte River to just north of Allen Hill, but is developed for residential and recreational purposes north from Allen Hill.

The bay is also the source of water for the Champlain Water District which serves more than 65,000 customers and major corporate entities in the Burlington area. It is listed also by the State of Vermont as impaired water as a result of mercury and PCBs which find their way into game fish, and phosphorus which supports the growth of algae and aquatic plants in the bay and around its margins and create nuisance conditions, including blooms of potentially toxic blue-green bacteria.

LaPlatte River

The LaPlatte River watershed is the largest sub-basin discharging into Shelburne Bay. The watershed has gone through changes which have affected the dynamic of pollution sources. The LaPlatte River arises in Hinesburg, and drains about 57 $mi.^2$ in the towns of Shelburne, Charlotte, Hinesburg, Richmond, Williston, and St. George. Its major tributaries are Patrick Brook in Hinesburg, Mud Hollow and Bingham Brooks in Charlotte, and McCabe's Brook in Charlotte and Shelburne. The River is a valuable resource, particularly in the towns of Hinesburg, Charlotte and Shelburne, where it provides wildlife habitat and corridors, recreation, and is an important feature of the landscape. Its drainage also includes important wetlands, particularly in the lower LaPlatte River and McCabe's Brook area.

With major improvements in two sewage treatment facilities discharging to the LaPlatte River in Hinesburg and McCabe's Brook in Shelburne, the phosphorus loading on Shelburne Bay has been significantly reduced. At the same time, with the decrease in farming in some areas, urbanization has proceeded, increasing the extent of impervious surfaces. As a result, storm runoff from urban/developed areas and farm land has increased in relative importance as a source of phosphorus and other nutrients, and as a source of sediment load. Farming continues along McCabe's Brook and on land draining to the headwaters of Mud Hollow and Bingham Brooks, and access of cows to drainages as well as manure spreading on fields and the application of fertilizer increase the potential for pollution of surface waters with nutrients and *E. coli.*



Water Quality. The LaPlatte River is a Class B stream and is designated as habitat for warm water fish between the confluence with Patrick Brook and Spear Street during summer months and which is designated as habitat for cold water fish from October through May. This classification requires that turbidity, nutrients, and other related water quality parameters meet appropriate standards.

Water quality in the LaPlatte River has been monitored by the State of Vermont at Falls Road in Shelburne under the Long Term Tributary Monitoring Program conducted by the States of Vermont and New York since 1991. Whereas the Long Term Tributary Monitoring Program provides data on nutrient loadings to Shelburne Bay from the LaPlatte River, few data have been collected since the 1980s within the watershed or on McCabe's Brook to monitor or assess the long term impacts and sustainability of initiatives taken in the 1980s to implement BMPs for the control of nutrients and sediments reaching the waters of the LaPlatte watershed. The LaPlatte Watershed Volunteer Monitoring Program is intended to provide a basis for assessing impacts of fundamental change in land use and management practices, and inform establishment of priorities for improving the condition of the LaPlatte River system and Shelburne Bay.

The 2006 Vermont 303(d) Part A list of impaired waters in need of TMDL development includes two sections of the LaPlatte watershed which fail to meet state water quality standards and are designated as impaired waters. These are:

- LaPlatte River, Hinesburg to mouth – Impaired for contact recreation as a result of high fecal coliform counts caused by agricultural runoff
- Mud Hollow Brook, mouth to 3 miles upstream – Impaired for contact recreation as a result of high fecal coliform counts caused by agricultural runoff
- Shelburne Bay – Impaired for fish consumption as a result of high PCB concentrations in Lake Trout and high mercury concentrations in Walleyes

Under the State draft 303(d) Part C, nutrients in the LaPlatte River at its mouth are designated as in need of further assessment.

Point Source Phosphorus Loadings to Shelburne Bay Watershed. Point source phosphorus loadings to the Shelburne Bay watershed were estimated as early as 1975/1976 when the first studies of Lake Champlain were undertaken to establish the status of the lake and to set guidelines and strategies for its preservation. Point source loadings have declined since the early assessments as a result of improvements in treatment at four sewage treatment plants discharging to the Bay and its drainage.

Two sewage treatment plants discharge within the LaPlatte watershed:

Treatment Plant	Capacity (mgd)	Process	Receiving Stream	Year of Up-Grade	Design Life (yrs)
Hinesburg	0.25	Aerated Lagoons	LaPlatte R.	1990	-
Shelburne Plant No. 2	0.66	Sequencing Batch Reactors	McCabe=s Brook	2001	20

Improvements at the Hinesburg waste treatment plant discharging to the LaPlatte River were completed in 1991 and resulted in a reduction in the total phosphorus loading to the bay from about 5,000 kg P to about 700 kg P between 1991 and 1995. However, the loading from the Hinesburg plant increased again in 2000 following the resumption of full operation of the cheese plant in Hinesburg which discharges to the Hinesburg treatment plant following primary treatment. Based on permitted flows and phosphorus loadings from the Hinesburg and Shelburne plants discharging into the LaPlatte River and McCabe's Brook, point source loadings within the watershed amount to 346.8 kg/year from Hinesburg, and 496.4 kg/year from Shelburne Plant No. 2, or about 40.7 % of a total of 2,074 kg/year from the four plants discharging into the bay.

The Hinesburg sewage treatment plant, first constructed in 1967, consists of four aerated lagoons operated in series and preceded by a comminution step. The plant has been up-graded twice; first in 1988 when the air distribution system was up-graded, and more importantly in 1991 when alum addition was provided prior to the final pond to remove phosphorus. The ponds are of equal size totaling 8 acres and are 12 feet deep.

Mean retention time is 32 days. Settleable solids in the influent are removed in the first pond which must be dredged from time to time. Alum floc settles out in the fourth pond and also must be dredged periodically. The effluent from the final pond is discharged directly to the LaPlatte River approximately 17.7 km upstream from its mouth. The plant serves about 300 connections within a service area of about 2 km^2. The cheese factory currently utilizes slightly more than half of a 20,000 gpd allocation

Monthly mean daily discharges from the Hinesburg waste treatment plant vary widely from zero especially during hot, dry months to over 250,000 gpd.

Shelburne=s waste treatment plant No.2 is located off Harbor Road and discharges to McCabe's Brook approximately 2.45 km upstream from its confluence with the LaPlatte River and about 3 km upstream from Shelburne Bay.

Until early 2001, Plant No. 2 operated as an activated sludge plant with chlorine disinfection. Renovations completed in early 2001 were carried out to convert the treatment process to a sequencing batch reactors with ultraviolet disinfection. The plant is operated on a 6 hour reaction cycle. Alum is added at the reaction stage for phosphorus removal. The plant is currently operated to optimize denitrification. Pre-treatment includes fine rotary screens, aerated grit chamber, and settling. The effluent from the sequencing batch reactors passes through cloth disc filters and a UV disinfection step before discharge to Shelburne Bay.

Treatment plant No. 2 serves about 1014 connections, about 931 of which are residential customers, 83 of which are commercial and industrial customers in an area of about 11.9 km^2 including the town center, and a number of residential developments.

The State of Vermont has established discharge permits for point sources. The general policy contained in the Vermont Water Quality Standards effective July 2, 2000 states that Atotal phosphorus loadings shall be limited so that they will not contribute to the acceleration of eutrophication or the stimulation of the growth of aquatic biota in a manner that prevents the full support of uses.@ More specifically, in the Lake Champlain watershed it is the policy of the State to accomplish net reductions in phosphorus loadings that are necessary to achieve defined in-lake phosphorus concentrations. In the case of Shelburne Bay, this concentration is 0.014 mg P/l.

Basin-wide phosphorus limits of 0.8 mg P/l applicable to plants treating more than 0.2 mgd were established by the State of Vermont in 1992 (10 V.S.A. ' 1266a). The statute also requires that there be no significant increase over current loadings. Increases can be incorporated in basin plans or permit limits only when there is a corresponding reduction in loadings from other sources within the watershed of the same lake segment. Aerated lagoons were exempted from the 0.8 mg/l limit.

Other permitted parameters include BOD_5, total suspended solids, and thermotolerant *Escherichia coli*. Effluent nitrogen is not limited in permits. Permitted discharge limits established for the two treatment plants discharging within the LaPlatte watershed are as follows:

Treatment Plant	Flow (mgd)	Total Phosphorus Conc. (mg/l)	Total Phosphorus Load (lbs/day)	Total Phosphorus Load (kg/day)	5-Day BOD Load (lbs/day) Mo. Mean	5-Day BOD Load (lbs/day) Weekly Mean	E. coli Max. No./100ml	Tot. Suspended Solids Loading (Mo. Mean) (Lbs/day)
Hinesburg	0.25	0.8	2.1	0.95	63	94	77	94
Shelburne Plant No. 2	0.66	0.8	3.0	1.36	113	169	77	113

Stormwater. Minimum control measures proposed by the Town of Shelburne to meet its MS4 requirements include specific roles for the LaPlatte Watershed Partnership through public involvement and education. The sampling program contributes to an understanding of the sources of suspended solids, nutrients, and salts, and is helping to put management requirements and priorities into perspective.

Land Use/Land Cover. The LaPlatte watershed is predominantly rural, however, there are differences between the areas draining into the LaPlatte and its upstream tributaries and the areas draining into McCabe's Brook which impact on the water quality in these watersheds.

Watershed	Major Land Use/Land Cover (%) Urban/ Residential	Commercial & Industrial	Forest	Pasture & Row Crops	Utilities
LaPlatte River	10.24	0.81	39.19	36.53	4.44
McCabe's Brook	8.57	5.24	23.85	43.4	7.10

Particularly important are pasture and cornfields which impact significantly on McCabe's Brook, but the effects of which are less visible in the LaPlatte River itself.

The watershed has gone through changes which have affected the dynamic of pollution sources. With major improvements in the Hinesburg and Shelburne sewage treatment facilities discharging to the LaPlatte River and McCabe's Brook, respectively, storm runoff from urban/developed areas and farm land has increased in relative importance as a source of phosphorus and other nutrients as well as a source of sediment load. In addition, there is a trend towards larger dairy farms, as well as the potential for movement towards more concentrated animal feeding operations. Farming is more intense along McCabe's Brook, and on land draining to the headwaters of Mud Hollow and Bingham Brooks. At the same time, manure is still spread on fields and fertilizer use increases the potential for pollution of surface waters with nutrients and *E. coli*. With the decrease in farming in some areas, urbanization has proceeded, increasing the extent of impervious surfaces.

Fluvial Geomorphology. With funding from the Town of Shelburne under a Special Environmental Project, the LRP undertook a Phase I fluvial geomorphic assessment of the LaPlatte watershed[1]. In 2005, with funding from the State of Vermont,

[1] LaPlatte Watershed Partnership (2004). Phase I Geomorphic Assessment: LaPlatte River Watershed.

the LaPlatte Watershed Partnership undertook a Phase II assessment within the town of Hinesburg[2]. Whereas sections of stream defined by water quality sampling locations do not coincide with reaches employed in the geomorphic assessment, together the results can contribute to an understanding of processes within the watershed and its application to planning and initiatives to protect the river and the bay.

Of particular interest are four reaches of the LaPlatte River including the stretch of the river extending from the Hinesburg treated waste discharge to the Hinesburg-Charlotte town line.

Reach	Location	Description
M12	Extends from Hinesburg-Charlotte line about 0.98 mi. upstream. Sampling station LP 07 is located about 0.65 mi. upstream from the town line, and LP 06 is located about 1.4 mi. downstream from M12.	Low gradient Stable condition Sinuosity 1.34 with gradual curves Bed material fine sand and silt Stream bank erosion: Left bank = 7% Right bank = 13% Two beaver dams affect 52% of Channel length
M13	Extends upstream from M12 for a distance of about 1.15 miles	Low gradient Sinuosity 1.6 with sharp curves Bed material fine sand and silt with some clay Stream bank erosion: Left bank = 40% Right bank = 40%
M14	Extends upstream fro M13 for a distance of about 0.3 mi. Sampling station LP 08 is located about 0.73 mi. upstream fro M14.	Low gradient Sinuosity 2.0 with sharp curves Bed material fine sand and silt with Some clay Stream bank erosion: Left bank = 36% Right bank = 28%
M15a	Extends upstream from M14. Sampling station LP 08 just down-stream from the Hinesburg treated waste discharge is located about 0.4 mi. upstream from the start of M15a	Low gradient Evidence of previous straightening Stream bank erosion: Left bank = 63% Right bank = 36%

[2] LaPlatte Watershed Partnership (2006). LaPlatte River Phase 2 Geomorphic Assessment: Hinesburg Reaches.

It is noted that the report *Lake Champlain Phosphorus TMDL*[3] calls for long-term research to relate stream geomorphic assessment data to sediment loading expected in each major tributary watershed by measuring sediment loss and phosphorus inputs in selected stream reaches across a variety of conditions.

Phosphorus Export. It is useful to consider results of water quality sampling in the context of phosphorus export loadings from the LaPlatte Watershed predicted using the SPARROW (Spatially Referenced Regressions on Watershed Attributes) model developed by the USGS in cooperation with the USEPA and the New England Interstate Water Pollution Control Commission. This is a statistical model that uses regression equations to predict total nitrogen and total phosphorus loads from sub-watersheds, or catchments, based on spatially referenced watershed characteristics, including physical characteristics (drainage area, stream flow, time of travel, mean slope, soil permeability, stream density), nutrient sources (waste outfalls, cultivated land, forested land, urban and suburban areas), and nutrient sinks (water bodies and wetlands). Nutrient sources are evaluated as a function of location, magnitude, and interaction with watersheds characteristics and in-stream processes in water bodies. The model has been applied to estimate phosphorus export from the LaPlatte watershed

The input data date from the early 1990s, and in the case of point source treated sewage discharges, consist of data dating from 1992 or earlier. Following up-grading of the Hinesburg treatment plant in 1991, the estimated total point source loading to Shelburne Bay was reduced by over 80%. Further reductions were achieved at the Shelburne plant in 2001. Whereas changes in land use may have impacts on the results of the SPARROW analysis as well, the reduced loadings from the sewage treatment plants result in a significant change in predicted loadings within the middle LaPlatte and McCabe's Brook catchments.

Overall, the SPARROW model predicted a total phosphorus loading of 16.4 metric tons per year from the LaPlatte watershed. This loading by itself far exceeds the total estimated phosphorus export of 11.8 metric tons to Shelburne Bay from all sources[4]. Changing the point source inputs to the middle LaPlatte and McCabe's Brook catchments reduces the total loadings to 9.8 metric tons based on permitted discharges, and 9.17 metric tons based on very rough estimates of 2004 discharges from the Hinesburg and Shelburne sewage treatment plants, respectively. These reductions result in a dramatic change in the relative importance of phosphorus sources. Waste discharge loadings constituting 45% of the total loading employed during the original application of the model, dropped to 8.6% and 2.2%, respectively, when permitted and estimated current discharge loadings were used. Under these scenarios, "cultivated land," would contribute 81.5% and 87.2% of the total loadings, respectively.

---

[3] Vermont and New York State Departments of Environmental Conservation, 2002. *Lake Champlain Phosphorus TMDL*

[4] Lake Champlain Basin Atlas, http://www.anr.state.vt.us/champ/Atlas/PDFmaps/is_pload.pdf

CHLORIDES

Chloride is a non-reactive, biologically inactive, conservative ion, in contrast to inorganic ions or organic compounds which react chemically or can be acted on biologically, and which are non-conservative in nature.

In the context of the volunteer monitoring effort, chloride concentrations are primarily of interest as they impact streams or indicate sources of pollution and dilution. A 1988 study commissioned by the Vermont Department of Environmental Conservation (*op. cit.*) examined chloride loadings from the LaPlatte River (including McCabe's Brook) into Shelburne Bay. Smeltzer (*op. cit.*) reported chloride loads of 2,570 kg/d during the mid-summer months. He concluded that the LaPlatte River was the most significant source of chloride reaching Shelburne Bay, contributing 72% of the total load.

Sources

Chlorides can enter surface waters with industrial or domestic wastewater, runoff from salted roads, salt storage areas, or groundwater exposed to salt deposits or seepage from the surface of the ground.

Importance

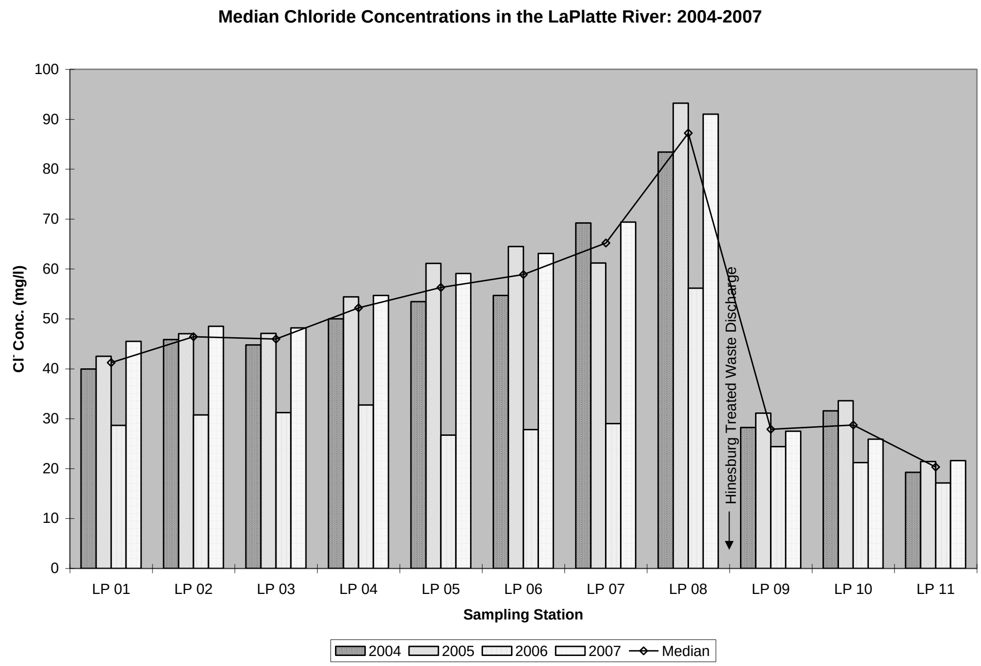
Chlorides can impact on aquatic organisms, and the United States Environmental Protection Agency has recommended a maximum concentration of 860 mg/l, and a continuous concentration limit of 230 mg/l in surface waters. A study undertaken to establish water quality criteria for the Santa Clara River in California based on effects of chlorides on resident species established chronic and acute threshold levels of 278 mg/l and 544 mg/l, respectively. Currently, the State of Vermont has not adopted criteria for chloride ion in surface waters.

Because it is present in waste discharges, and because it is not influenced by chemical reactions or biological processes, chloride ion can be a useful indicator of pollution sources and dilution in streams. Furthermore, the application of salt to roadways in winter can result in high chloride concentrations. Studies in the New England area have shown spikes in chloride concentrations far exceeding acute toxicity levels.

Monitoring Results

Monthly sampling of streams in the summer and fall months can give a general picture of sources, levels, and behavior of chlorides in the LaPlatte River which support interpretation of other monitoring data. But the picture they can provide is limited since they cannot provide an understanding of extreme concentration levels, especially during high winter and spring flows fed by runoff from roads carrying salt.

The LaPlatte River watershed is essentially rural with limited farming at the present time, although cows have access to the stream in some places. Baseline chloride concentration levels in the watershed are generally around 20 mg/l, although lower levels are characteristic of the upper reaches of many of its tributaries. Chloride concentrations generally exhibit a substantial increase below the Hinesburg waste



treatment plant outfall between sampling stations LP 09 and LP 08, followed by a steady decrease as flow increases downstream. The general pattern may vary with flow, but appears fairly consistent from year to year. The effects of flow on any given day may be substantial, however. For example, at times of very high flow, chloride concentrations may be lower than normal. More importantly, however, during periods of very low flow when the waste discharge is high in relation to the flow in the stream, chloride concentrations may reach levels approaching or exceeding the EPA recommended maximum limits for acute toxicity. For example, below the treatment plant outfall at LP 08:

Date	Cl^- Conc
November 16, 2004	214 mg/l
July 5, 2005	222 mg/l
September 11, 2007	354 mg/l

While in general concentrations decreased by a factor of about 2 between the station LP 08 and LP 01 approximately 0.55 miles upstream from the mouth of the river, the decrease can vary as on September 11, 2007 when the concentration decreased by a factor of 5 between the two locations.

SUSPENDED SOLIDS

Suspended solids are important in streams and lakes where they can impact directly on aquatic life and where they play a role in the mobilization and transport of phosphorus, as well as determining the clarity and esthetic quality of water.

Total suspended solids (TSS) in water include both organic and inorganic solids. Inorganic solids comprise the main component of suspended solids discharging into Shelburne Bay from the LaPlatte River, and consist of clay, silt, and fine to medium sand.

Classification of Sediments

Sediment Class	Size (mm)
Sand:	
Very Coarse	1.5
Medium	0.375
Very Fine	0.094
Silt:	
Very Coarse	0.047
Medium	0.0117
Very Fine	0.0049
Clay	<0.00195

At high flow rates, medium and coarse silt as well as fine sand can be carried in suspension, but settle to the bottom during periods of low flow and in still lake waters, leaving only clay and fine silt in suspension.

Orthophoto showing typical discharge of suspended sediment into the southern end of Shelburne Bay from the LaPlatte River during spring runoff.

Concentrations of suspended solids can be determined directly (gravimetrically), and expressed as mg/l, or indirectly as turbidity which measures the degree to which light is scattered as it travels through a water sample, in which case it is expressed as nephelometric turbidity units (NTU).

Sources

Suspended solids carried by streams may originate as a result of the mobilization of clay, silt, and fine sand in soils. This may result from stream bank erosion and scour, particularly during high flows. It may also occur at construction sites or on cultivated fields during rain storms. Other sources may include point sources of municipal or industrial wastes.

Importance

Suspended sediment and turbidity impact on the esthetic quality of surface waters and their attractiveness as recreational resources. They also can create a hazard for swimmers and boaters if visibility is seriously impaired. Generally, a turbidity limit of 5 NTU is considered acceptable for recreational uses.

Suspended sediment also can impact on aquatic organisms by interfering with light penetration and as a result, reducing photosynthetic activity. When sediment settles, it can degrade the habitat of invertebrates and spawning areas for fish. While turbidity values of up to 50 NTU may be acceptable for very brief periods of exposure, 25 NTU is generally regarded as the maximum allowable level of turbidity for non-trout waters, and has been established as the limit for Vermont's class B waters designated as habitat for warm water fish.

In raw water sources for drinking water supplies, solids can cause increases in the cost of treatment by shortening filter runs.

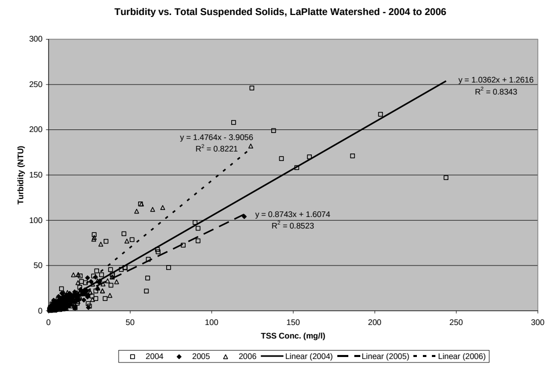
Finally, sediment can play a role in the transport of toxic organic substances or heavy metals adsorbed on their surfaces. Particularly important in the Lake Champlain Basin is the role of suspended sediment in the transport of phosphorus. Phosphorus reacts at surface sites on soil particles, especially clay and fine glacial lake sediments and till. Soils farmed over many years may be particularly rich in phosphorus. Runoff from eroded soils can transport sediment and associated phosphorus to streams which eventually carry it to the receiving water body.

Monitoring Results

Results obtained during monitoring in the LaPlatte River watershed provide insights into the relationship between turbidity and TSS concentrations, and the nature, sources, and behavior of suspended solids in these watersheds.

Measurement of Suspended Sediment Concentrations. Suspended solids loads in the LaPlatte River watershed have been measured both directly and as turbidity. Both methodologies were employed in the LaPlatte watershed from 2004 through 2006. After 2006, turbidity only was determined and will be the only analysis employed in the future. This has the advantage of reducing costs while providing data related to water quality standards. It has the disadvantages i) of a surrogate indicator that may vary in relation to actual solids concentrations, and ii) of not being consistent with data collected under the Long Term Tributary Monitoring Program which includes TSS only.

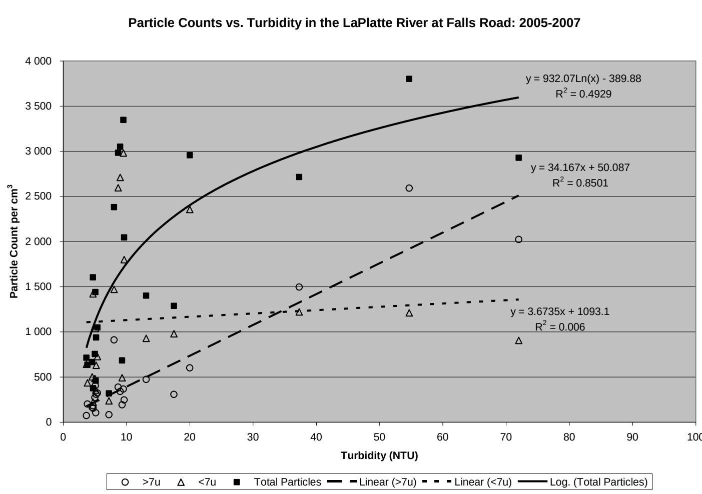
That turbidity levels determined in surface waters are related to TSS concentrations is illustrated by comparisons of these measures in the LaPlatte River watershed:



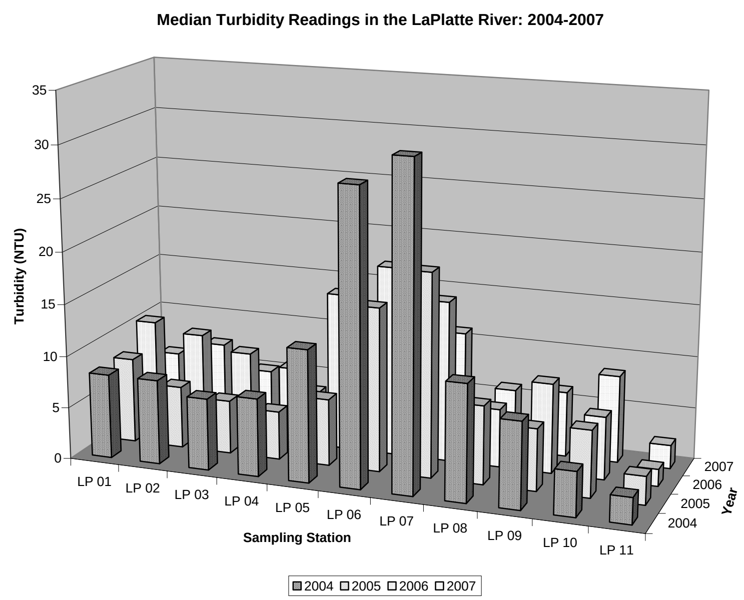
Analysis of data from the LaPlatte watershed suggests that the relation of turbidity to TSS is on average fairly consistent, although there is considerable variability among individual samples:

Watershed	Mean Turbidity:TSS Ratio	Standard Deviation
LaPlatte, 2004	1.22	0.69
LaPlatte, 2005	1.22	0.64
LaPlatte, 2006	1.09	0.57

Characteristics of Suspended Sediment. Since 2005, the CWD has determined particle counts on samples collected by them and on samples provided under the Volunteer Monitoring Program. Of interest are the characteristics of suspended sediment based on limited results obtained between 2005 and 2007 from the LaPlatte River at Falls Road which suggest that counts of particles of size less than 7μ consisting of clay and very fine silt are highly variable and predominate when turbidities are below about 35 NTU. Their concentrations appear to be independent of turbidity, and vary over a wide range when turbidities are low, but remain relatively constant as turbidity increases. In contrast, counts of particles exceeding 7μ in size consisting of fine to medium silt increase steadily from less than 500 per cm^3 in direct proportion to turbidity.



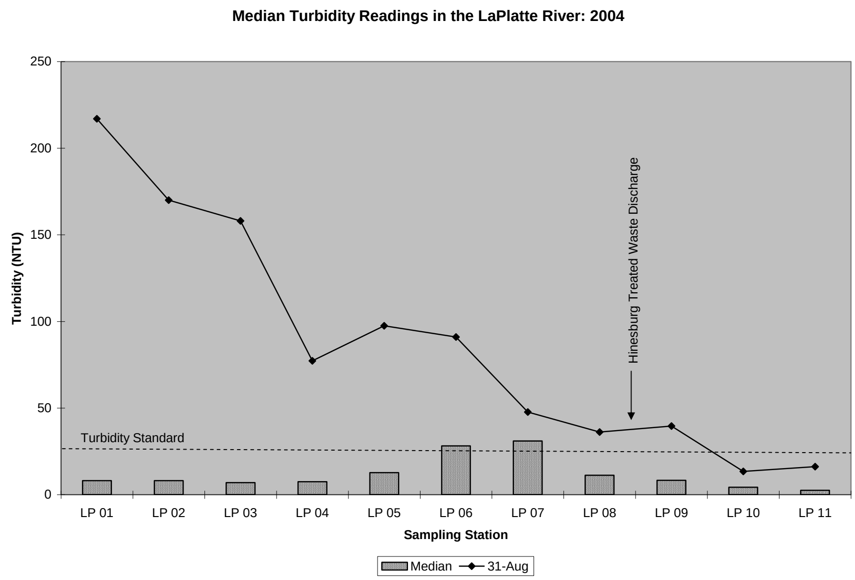
Suspended Sediment in the LaPlatte River and McCabe's Brook Watersheds. Suspended sediment loads in the LaPlatte River at times of normal flow follow a regular pattern, increasing gradually as the river passes through the town of Hinesburg to a point just downstream the Hinesburg treated waste outfall (LP 08), subsequently rising rapidly to LP 07 or LP 06, then decreasing as a result of dilution and settling to Falls Road (LP 03) in Shelburne, after which they increase somewhat to the downstream station upstream from Bay Road (LP 01).



While this pattern is consistent from year to year, the levels detected reflect flow conditions on the days sampled. Of particular interest is the increase in sediment load between LP 08 and LP 07 where the impact of extensive bank erosion is striking.

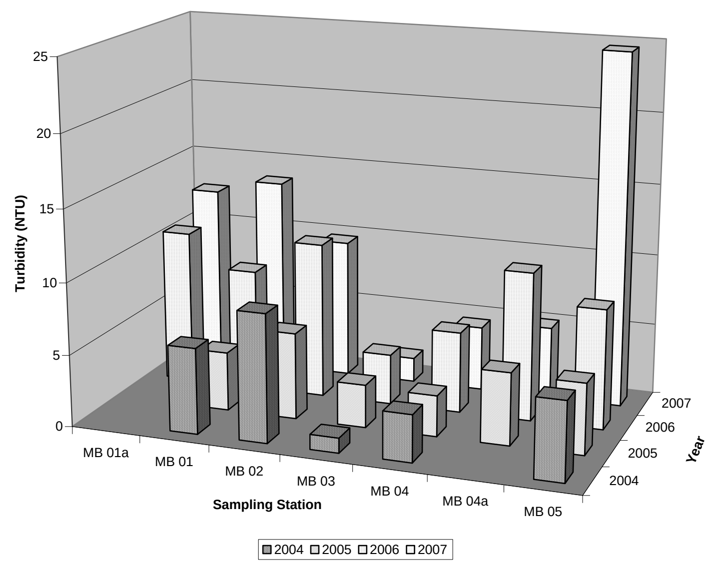
Increases downstream from Falls Road (LP 03) appear to reflect runoff, scour, and bank erosion.

The picture can look quite different at times of high flow when sediment loads typically increase, and the turbidity standard typically exceeded. At times of high stream flow when runoff from adjacent lands mobilize and contribute heavy sediment burdens of solids, suspended sediment loads in the river typically increased steadily downstream, as during exceptionally high flows on August 31, 2004.



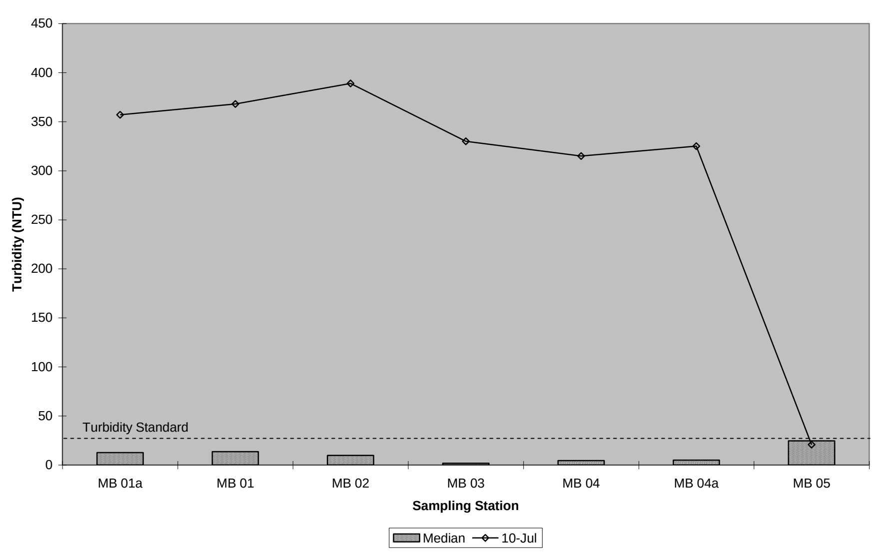
The picture in the much smaller McCabe's Brook which joins the LaPlatte River before it discharges into Shelburne Bay is less consistent. Typically, sediment loads

Median Turbidities in McCabe's Brook: 2004-2007

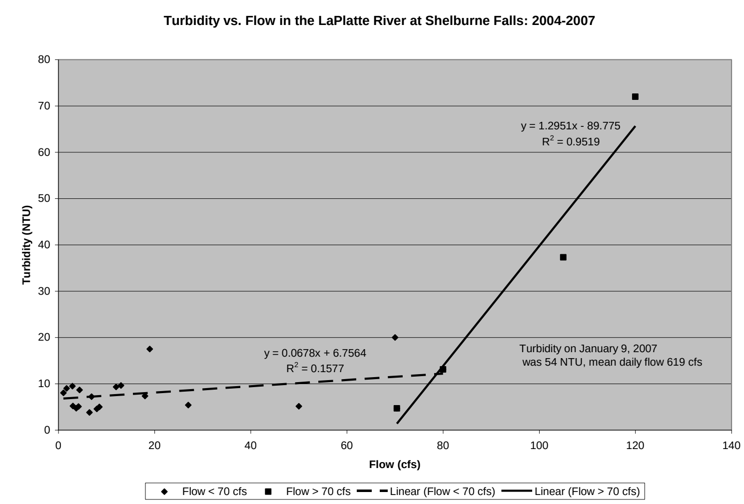


increased somewhat as the stream flows north from Lime Kiln Road in Charlotte (MB 05) receiving drainage from farmed areas and impervious areas as it flows to Bostwick Road in Shelburne (MB 03), and then increased substantially between Bostwick Road and Harbor Road (MB 02) as a result of erosion. As with the LaPlatte River, suspended sediment can increase dramatically at times of very high flows, as on July 10, 2007 when runoff from farmed areas contributed to heavy loads.

Turbidity in McCabe's Brook: June-November, 2007



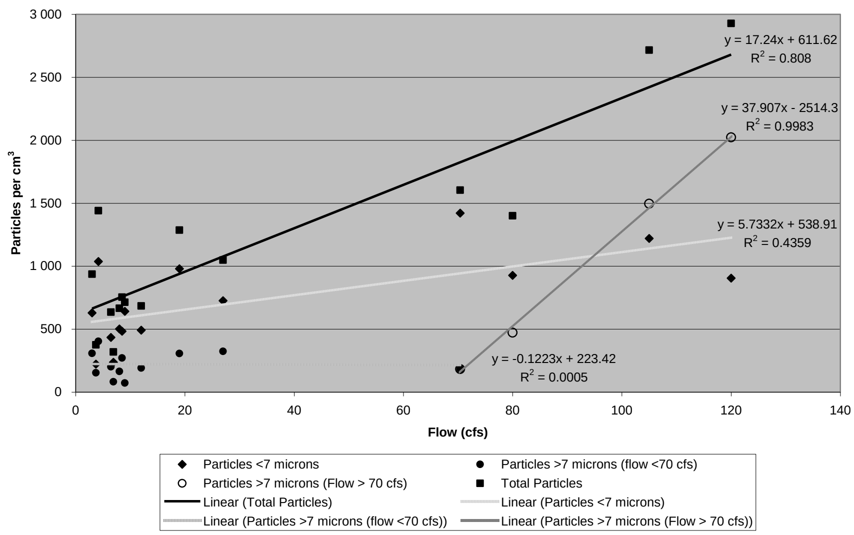
Relation between Suspended Sediment and Flow. With increasing flow carrying solids into streams from the land surface and erosion of stream banks and beds during high flows, suspended sediments are maintained in suspension and transported downstream. That TSS concentrations and turbidity increase with increasing flow is illustrated by analyses carried out on samples from the LaPlatte River at Falls Road where flows are measured on a continual basis by the U.S.G.S. An examination of turbidity values obtained for samples collected at Falls Road from 2004 through 2007 demonstrate the effect of flow rate on suspended sediment load, and the role of flow in mobilizing and maintaining solids in suspension. Of particular interest, however, is an apparent absence of a significant relationship between suspended sediment load and flow at flow rates below about 70 cfs. Thus, baseline levels of solids and their characteristics appear to exist up to a flow of about 70 cfs, above which solids are mobilized by runoff and rising stream flow and are carried in suspension by the high flows. It is noted that between March, 1990 and mid-April, 2008, mean daily flows were less than or equal to 70 cfs 81.6% of the time.



Based on very limited data, it appears that at flow rates above 70 cfs, suspended sediment loads appear to increase in proportion to flow rate, at least up to a flow of about 120 cfs.

Characteristics of Suspended Sediments and Relation to Flow. The pattern of suspended solids loads in relation to flow at Falls Road appears to be clearly reflected in counts of suspended particles. Overall, concentrations of particles less than a nominal 7μ size (clay and fine silt) rise gradually but consistently as flow increases. In contrast, concentrations of particles greater than a nominal 7μ size appear to remain constant at a low level at flows below 70 cfs, but to increase in proportion to flow as flow exceeds 70 cfs, the rate of increase being greater the larger the particle size. Thus, as might be anticipated, there appears to be a baseline suspended sediment concentration consisting primarily of fine particles which do not settle characteristic of flows less than 70 cfs. Concentrations associated with flow above 70 cfs are characterized by an increasing predominance of larger particles.

Particles Counts vs. Flow in the LaPlatte River at Shelburne Falls: 2005-2007



As we will see, the characteristics and behavior of suspended sediments can contribute to, and reinforce, our interpretation and understanding of phosphorus loadings to Shelburne Bay and Lake Champlain.

PHOSPHORUS

Phosphorus is an element required by all living organisms and is a component of all proteins, nucleic acids, and many molecules essential to energy metabolism and other cellular functions. In the environment, it occurs in both dissolved and particulate organic and inorganic forms. Of particular importance in the context of surface waters discharging into Shelburne Bay and Lake Champlain are dissolved phosphorus, primarily in the form of inorganic phosphate, when flows are low, and phosphorus associated with particulate matter, at times of high flow. Review of the results of the Long Term Tributary Monitoring Program of the State of Vermont and the Volunteer Monitoring Program shed light on sources and implications of phosphorus mobilized in the LaPlatte River watershed and discharging into Shelburne Bay.

Sources

Phosphorus is an important nutrient essential to all living animals and plants. It can occur dissolved in surface waters as phosphate and as a constituent of dissolved organic molecules, as or it can occur in particulate form as organic particles or sorbed on suspended sediment. It can reach surface waters from waste outfalls or with storm runoff from urban areas, including lawns, from agricultural lands where it may originate with fertilizers or manure spread on the soil, or with grazing animals. Sediments may also be mobilized as a result of earth work at construction sites which can be carried into streams by runoff during storms, or of erosion of exposed soils and stream banks.

Historical Assessments of Phosphorus Discharges to Shelburne Bay. In a 1976 study by the State of Vermont,[5] it was estimated that the LaPlatte River itself contributed 24.4% of the total phosphorus loading to Shelburne Bay of 4,053 kg/yr, or 11.1 kg/day. A decade later, Smeltzer[6] reported mean phosphorus loadings of 16.98 kg/d during the summer months, and concluded that the LaPlatte River was the most significant source of phosphorus entering the bay, contributing 62% of the total loading. In a 1998 status report on the Long-Term Water Quality and Biological Monitoring Project for Lake Champlain,[7] results indicated that total phosphorus concentrations in the river were decreasing significantly. It was concluded that the stream was responding to upstream measures taken in 1992 to reduce phosphorus loadings, including upgrades to the Hinesburg sewage treatment plant. This plant, first constructed in 1967, has been up-graded twice, in 1988 and again in 1991. Up-grading of the treatment plant in 1991 was largely responsible for the reduction in the loading to from about 4,811 kg in 1991 to about 186 kg in 1995. This loading decreased to a low of 76 kg. in 1999, but increased to

[5] K. Little, Nutrient Loadings to Shelburne Bay and St. Albans Bay, Lake Champlain, Vermont, 1975-1976, Vermont Department of Water Resources, 1976

[6] E. Smeltzer, A Summertime Phosphorus Model for Shelburne Bay, Vermont Department of Environmental Conservation, 1988

[7] Vermont Department of Environmental Conservation and the New York State Department of Conservation, Long-Term Water Quality and Biological Monitoring Project for Lake Champlain: Cumulative Report for Project Years 1992-1996, 1998

163 kg. in 2000 following the resumption of full operation of a cheese plant in Hinesburg which discharges to the Hinesburg sewage treatment plant following primary treatment. The cheese plant utilizes about one half of the plant's 20,000 gpd allocation. The Hinesburg sewage treatment plant is currently permitted to discharge up to 0.95 kg/d of phosphorus.

Smeltzer,[8] estimated the mean phosphorus loadings during the summer months from McCabe's Brook were 0.27 kg/d, and concluded that the stream was not a significant source of phosphorus to Shelburne Bay. Shelburne's Waste Treatment Plant No. 2 is currently permitted to discharge up to 1.35 kg/d of phosphorus.

Factors Affecting the Mobilization and Transport of Phosphorus. Phosphorus in surface waters may exist in a variety of forms and reacts in ways which affect its mobilization, transport, and fate in streams and receiving water bodies. It occurs in water as dissolved phosphorus, mainly in the form of phosphate, or associated with small particles, including clay and fine silt, as well as associated with medium silt particles. It also can be a constituent of dissolved and particulate organic matter.

Under aerobic conditions, phosphates form insoluble products with iron or aluminum and become associated with soil particles. As a result, there is a relationship between total phosphorus concentrations and concentrations of total suspended solids (TSS) in surface waters.

Phosphorus applied as fertilizer reacts with calcium in soil to form stable precipitates. Both inorganic and organic phosphorus also react with iron and aluminum minerals. It is generally considered that most phosphorus lost from agricultural lands is carried by runoff as either soluble or particulate organic particles, particles being most important. Humic compounds containing iron or aluminum, are able to form complexes with orthophosphate. Furthermore, soil particles can provide a long lasting source of phosphorus. It has been said that particles generally carry 100-3,000 mg phosphorus/kg solids (0.1 – 3.0 mg P/gm suspended sediment).

It should be noted that the distribution of phosphorus in soils is determined by sorption/desorption and precipitation/dissolution processes, and their exchange characteristics and solubility products.

Larger sediment particles carrying phosphorus as they discharge into receiving water bodies might be expected to settle out in near shore (littoral) areas of a receiving water body, providing a rich substrate for nuisance rooted aquatic plants. Dissolved inorganic phosphorus and organic compounds containing phosphorus, as well as clay or fine silt particles, might be expected to reach deeper open waters where they would be available to support algal populations. Soluble phosphorus is most readily available to algae.

Importance

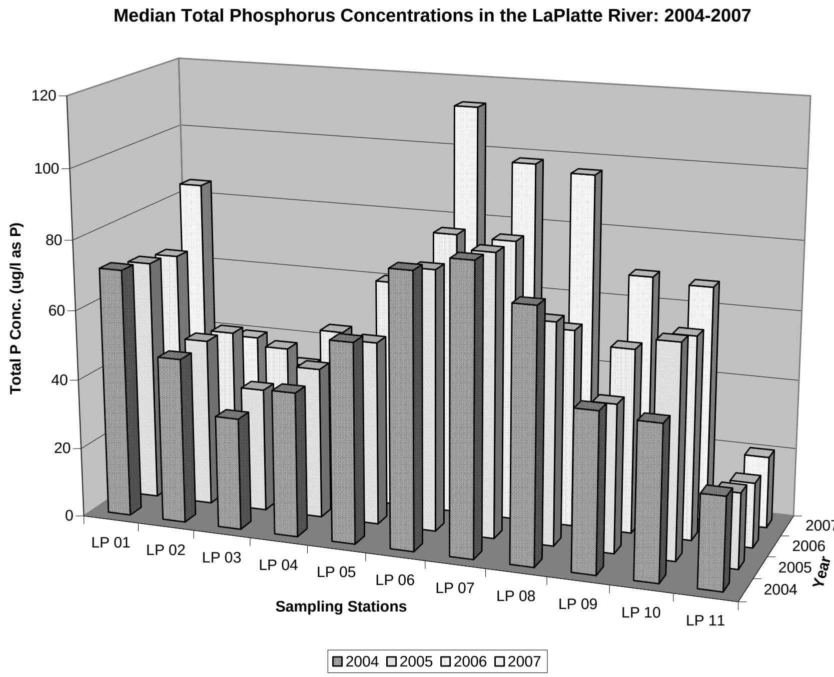
[8] Smeltzer *op. cit.*

Phosphorus is important as it is a nutrient essential to nuisance plants and algae, and thus contributes to their growth in aquatic habitats. In shallow margins of lakes, phosphorus can contribute to the growth of rooted aquatic plants and blooms of algae. In some instances, blooms of toxic blue-green algae may occur. Particularly susceptible to the development of nuisance conditions are areas where rivers discharge sediments carrying with them phosphorus which settles to the bottom in near shore areas. It is generally considered that production in open waters of Lake Champlain is limited by the availability of phosphorus, and thus that increases in the phosphorus loading may be expected to result in algal blooms and a general deterioration in water quality. The State of Vermont has established a total phosphorus limit of 0.014 mg/l for open water in Shelburne Bay. A review of Lay Monitoring data for the bay indicates that this limit is exceeded during the summer months.

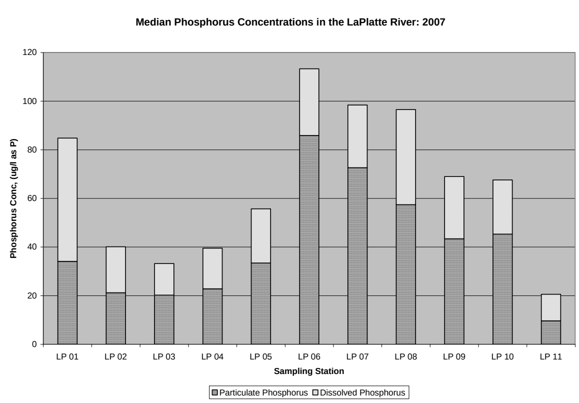
Monitoring Results

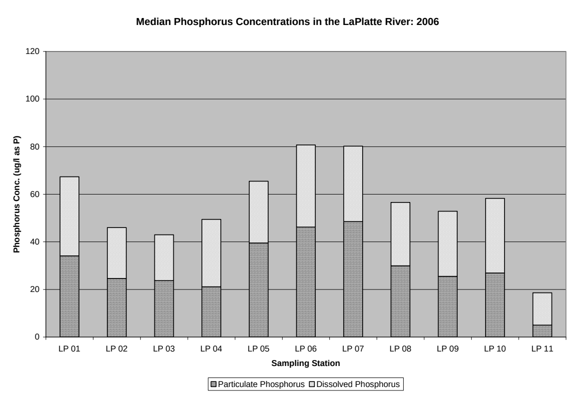
Monitoring in the LaPlatte Watershed initially included determination of total phosphorus concentrations. It soon became evident, in view of the relationships between phosphorus and TSS concentrations, that further distinction between particulate and dissolved fractions of the phosphorus load was important to our understanding and interpretation of nutrient data and their implications. As a result, determination of phosphorus in filtered samples (dissolved phosphorus) was begun in 2006. This has led to a better understanding of sources, and has made it possible to address more effectively questions related to transport and the fate of phosphorus in the river and the receiving waters.

***Phosphorus Concentrations*.** In general, total phosphorus concentrations follow a consistent pattern from one year to the next, increasing from about 20 μg/l as P at Gilman Road (LP 11) to around 60 – 70 μg/l at Silver Street in Hinesburg (LP 10). This appears to be attributable largely to an increase in particulate phosphorus originating from erosion (see discussion of the Association of Phosphorus with Sediment). A further increase below the Hinesburg Treated Waste outfall appears in general to occur primarily in the particulate fraction in the waste discharge. Downstream from the treatment plant, the phosphorus concentration continues to increase as a result of stream bank erosion between the point of discharge and continuing to Leavenworth Road (LP 07), and at times to Dorset Street Extension (LP 06). This is consistent with results of fluvial geomorphic analyses which demonstrate the importance of stream bank erosion in this section of the stream which is characterized by sharp curves. Below LP 06,



particulate phosphorus concentrations decrease rapidly, causing a decrease in total phosphorus concentrations to Falls Road (LP 03). Below Falls Road, and especially through the Lower LaPlatte Nature Reserve, concentrations of phosphorus tend to increase substantially, interestingly, primarily in the dissolved fraction. It is noted, however, that under very high flow conditions, phosphorus, and in particular phosphorus associated with sediment may increase steadily over the full length of the river (see discussion of Phosphorus in Relation to Flow below).





It is noted that in general particulate phosphorus concentrations appear to decrease more rapidly between Leavenworth Road (LP 06) and Spear Street (LP 04) than might be accounted for by dilution as indicated by ratios of upstream to downstream chloride concentrations, suggesting that under normal flow conditions, sediment is removed as a result of settling.

Reduction in Median Particulate Phosphorus and Chloride Concentrations
In the LaPlatte River, 2004-2007

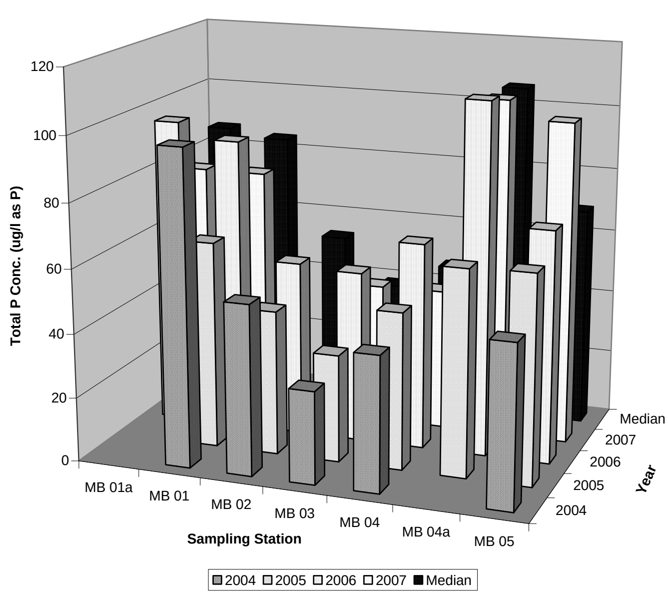
Reach	$Cl_{upstream}/Cl_{downstream}$	$PP_{upstream}/PP_{downstream}$	$Turbidity_{upstream}/Turbidity_{downstream}$
LP 06-LP 05	1.05	1.81	2.36
LP 05-LP 04	1.08	1.66	1.35

This portion of the stream is wider, less sinuous, and less subject to stream bank erosion, and appears to act as a sink for sediment and its associated particulate phosphorus.

As discussed further below (see discussion of Partition of Phosphorus between Solid and Dissolved Phases), dissolved phosphorus concentrations, while variable, tend to remain relatively constant in the river system regardless of flow rate.

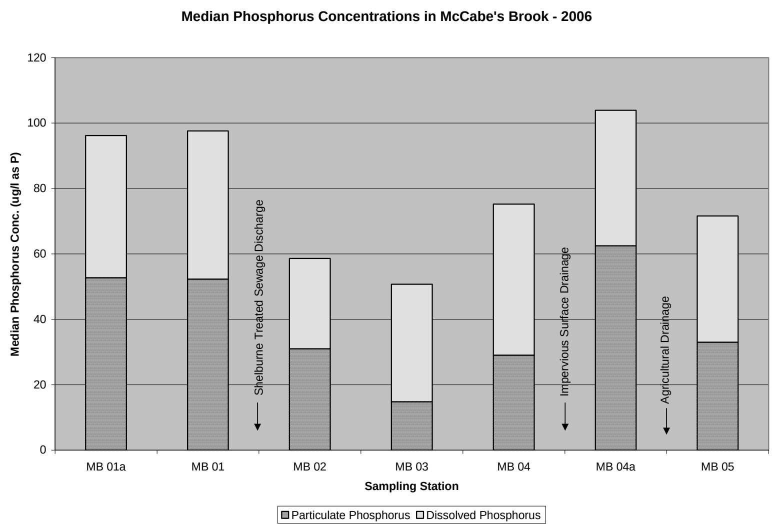
The pattern exhibited by phosphorus concentrations in McCabe's Brook, while fairly consistent on average, at times appears to illustrate particular responses to current and recent histories of flow and land use. In general, the total phosphorus concentration is observed to increase between Lime Kiln Road (MB 05) and the Vermont Teddy Bear access road (MB 04a) where pastures and cultivated fields represent potential sources of phosphorus. Phosphorus concentrations tend to decline downstream to Route 7 (MB 04) and again to Bostwick Road (MB 03). Below Bostwick Road phosphorus concentrations increased as the stream continues downstream and passes through wetlands before

Median Total Phosphorus Concentrations in McCabe's Brook: 2004-2007



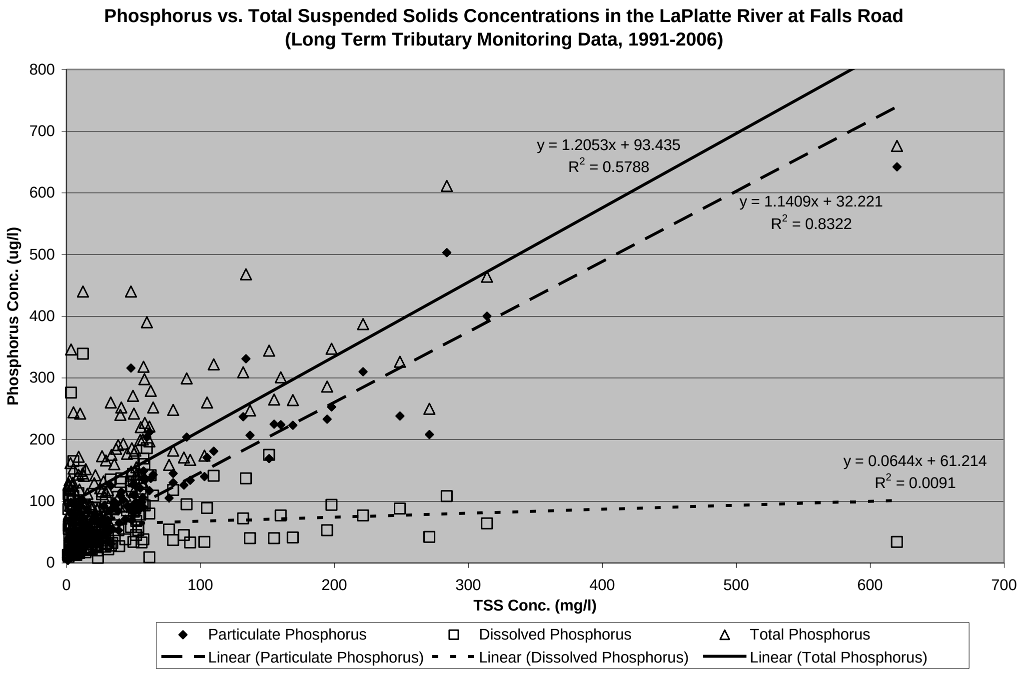
reaching Harbor Road (MB 02). The increase between MB 03 and MB 02 was particularly evident during the summer of 2007 when flows were generally low during the summer months. Median particulate phosphorus concentrations during the summer and fall of 2007 reached nearly 200 μgm/l. As a rule, a further increase occurred below the Shelburne treated waste discharge, the extent of which depended on whether the plant was discharging at the time samples were taken.

The general behavior of phosphorus in McCabe's Brook is illustrated in the following representation which is characterized by fairly consistent dissolved phosphorus concentrations with a total phosphorus profile defined primarily by particulate phosphorus concentrations.

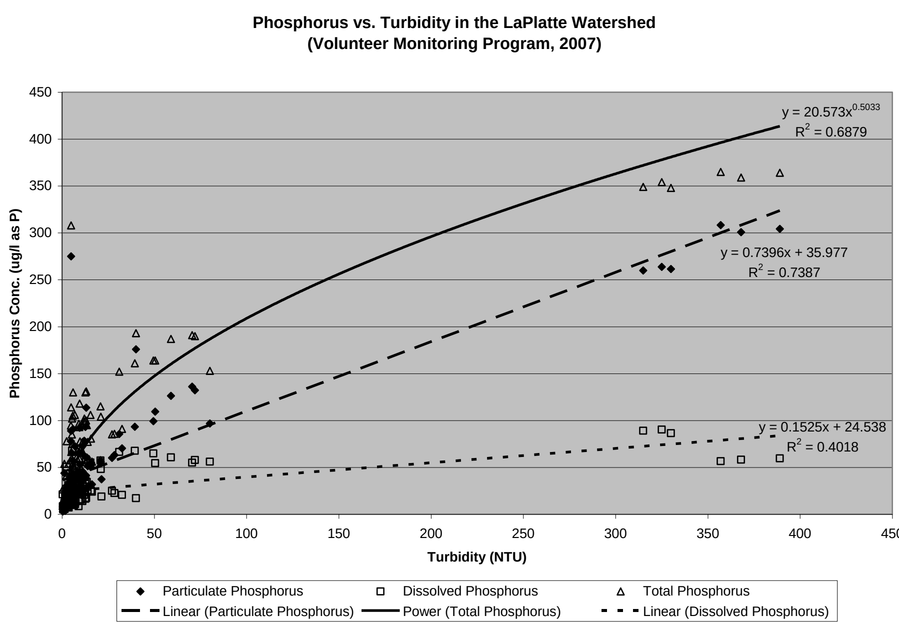


Association of Phosphorus with Solids. We have seen that concentrations of particulate phosphorus tend to reflect concentrations of suspended sediment and turbidity in the streams discharging into the southern end of Shelburne Bay. Closer examination of total phosphorus concentrations and their component particulate and dissolved phases is instructive and has implications with regard to potential impacts on the bay.

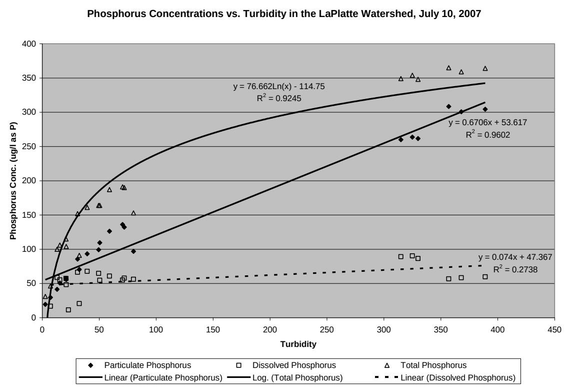
Examination of results of phosphorus monitoring on the LaPlatte River at Falls Road in Shelburne provided by the Long Term Tributary Monitoring Program illustrates the close direct relationship between particulate phosphorus and suspended sediment.

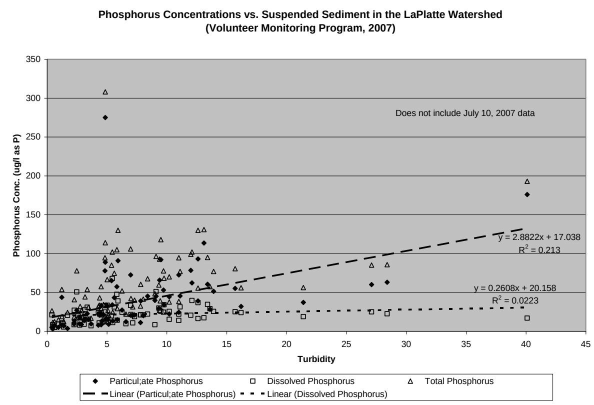


Of note is the relatively consistent level of dissolved phosphorus which appears to be fairly independent of the concentration of suspended sediment (see discussion of Dissolved Phosphorus below). Often, as illustrated by the Long Term Tributary Monitoring data, where dissolved phosphorus concentrations are low compared with those of particulate phosphorus, total phosphorus concentrations appear to be directly related to suspended sediment.



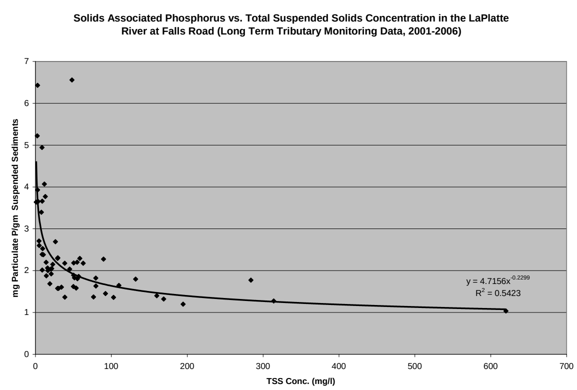
When data collected on a single day when flow conditions are relatively consistent within the watershed, as on July 10, 2007, the picture tends to be clearer than that presented by longer term sampling carried out under more variable conditions. However, high particulate phosphorus concentrations associated with high suspended sediment concentrations usually associated with high flow events may distort the overall





picture. For example, when the July 10, 2007 data are removed from the analysis, the picture is quite different and it can be seen that the relationship between particulate phosphorus and suspended sediment may become less clear.

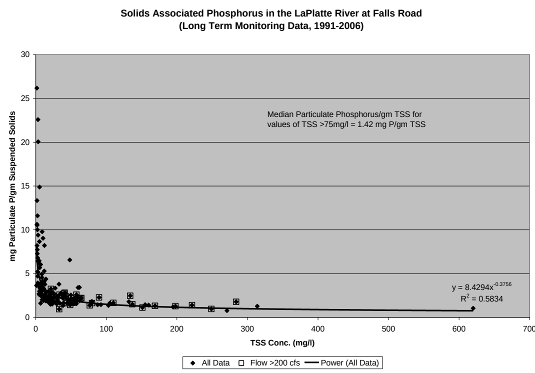
Some insight into the reasons that the relationship between particulate phosphorus and suspended sediment is not as straight forward as it appears when longer term data are viewed as a whole may be gained by considering the phosphorus load associated with suspended sediment in relation to the sediment load. When this is done, it is evident that at low concentrations of suspended sediments, the phosphorus load associated with them may be very high, much higher than the normal range of 0.1 to 3 mg P/gm TSS reported

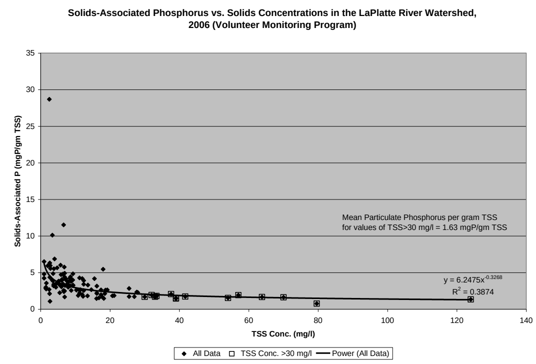


Cassell *et al.*[9] The high load of phosphorus associated with sediment at very low suspended sediment concentrations may have significant implications with regard to the transport and fate of phosphorus in Shelburne Bay. Furthermore, it might be noted that the threshold below which phosphorus associated with suspended sediments increases relates well with the level below which clay and fine silt particles predominate, and

[9] E.A. Cassell, R. Kort, T. Menees, and D. Newman. Sediment and Phosphorus Storage and Dynamics in the Winooski River System, PowerPoint Presentation (no date)

above which larger silt particles begin to increase in proportion to flow (see discussion of Implications of Monitoring Results below).





The findings of Menees (2001)[10] and Cassell *et al*.[11] based on investigations in the Winooski River watershed are interesting in the context of the present discussion and should be highlighted. Menees investigated total phosphorus associated with fine sediment (clay and fine silt) content of streambank and floodplain soils and sediment. He found that total phosphorus and the percentage of fine particles were greater in floodplain soils than in in-stream sediments in free flowing reaches of streams with steeper slopes and lower sinuosity (category I reaches), suggesting that these represent zones of particulate phosphorus transport. In contrast, where reaches were characterized by shallower slopes, higher sinuosity, and with downstream impoundments, i.e., within the backwater curve (category II reaches), differences between the floodplain soil and in-stream sediments were not significant, suggesting that these reaches represent zones of greater particulate deposition.

Reach Category	Median % Fines Floodplain	Median % Fines Sediments	Median Total P (mg TP/kg dry wt) Floodplain	Median Total P (mg TP/kg dry wt) Sediments
I	36	14	804	422
II	56	61	849	638

Of interest also were the mean residence times of phosphorus and sediment in the flow corridor estimated from their model (Cassell *et al*.[8]):

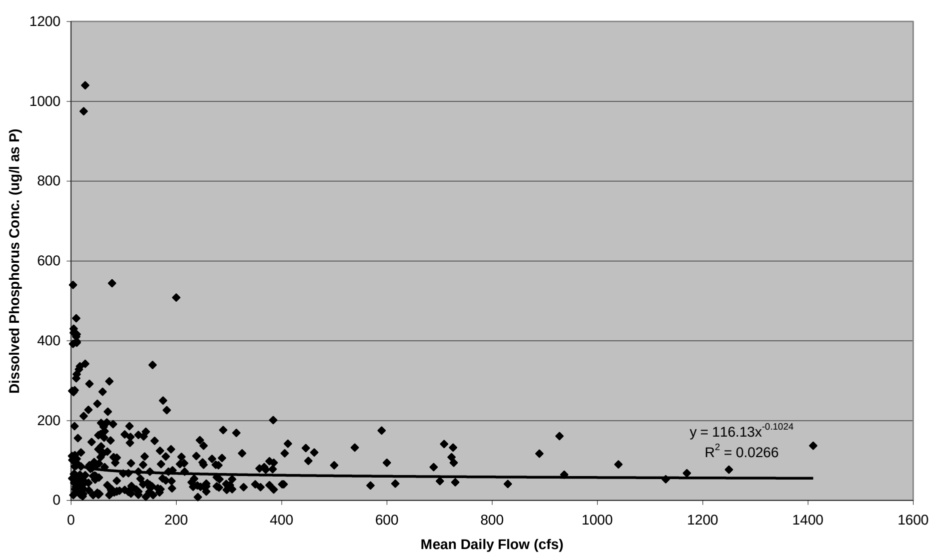
Parameter	Residence Time (Years)
Total P	1,050
Sediment	5,270

[10] Menees, T.T. (2001). The Distribution of Fine-Grained Particulates and Total Phosphorus in the Winooski River Flow Corridor. M.S. Thesis, University of Vermont.
[11] Cassell, E.A. *et al*.(no date) *op. cit*.

A reason for this may be suggested by very high particulate phosphorus loads associated with suspended sediment when TSS concentrations are low.

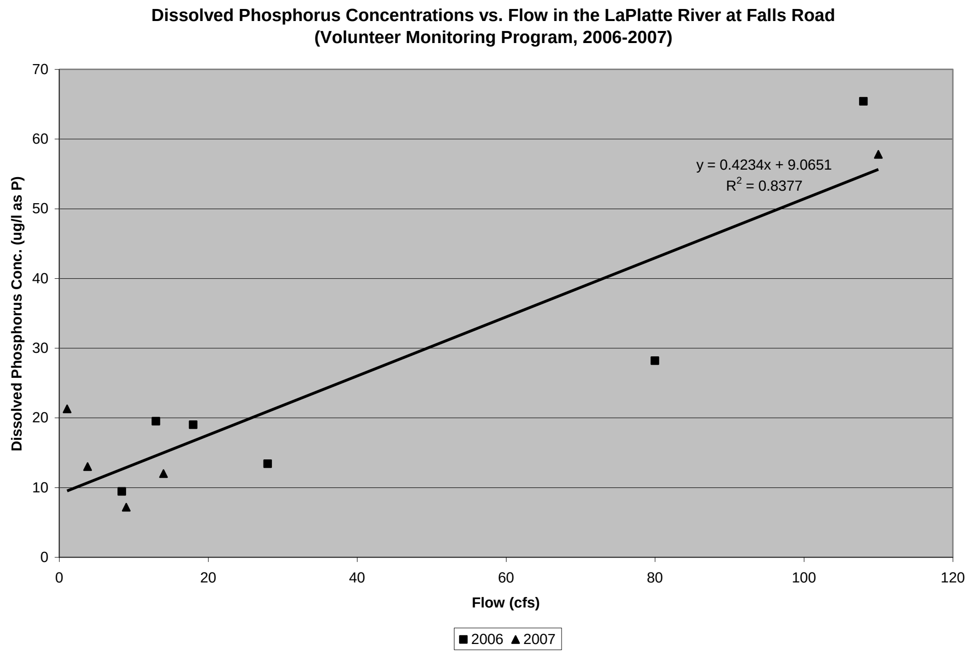
Dissolved Phosphorus. As noted in the previous paragraphs, concentrations of dissolved phosphorus, while exhibiting some variation, appear to remain fairly constant and independent of both flow rate and concentration of phosphorus associated with suspended sediment. In general, dissolved phosphorus concentrations are lower than particulate phosphorus concentrations in the LaPlatte and Munroe Brook watersheds discharging to Shelburne Bay except at very low flow rates when, on average, they exceed concentrations of particulate phosphorus (see discussion of flow below). On the other hand, concentrations of dissolved phosphorus in the LaPlatte River at Falls Road exceeded the standard for total phosphorus in Shelburne Bay (14 μg/l as P) in over 90% of 246 samples analyzed under the Long Term Tributary Monitoring Program between 1991 and 2006. Similarly, concentrations observed in samples collected from McCabe's Brook, as well as the LaPlatte watershed, under the Volunteer Monitoring Program in 2006 and 2007 in general exceeded the standard for open water in the bay, although concentrations exceeding 200 μg/l were not observed. Very high dissolved phosphorus

Dissolved Phosphorus Concentrations vs. Flow in the LaPlatte River at Falls Road (Long Term Monitoring Program, 1991-2006)



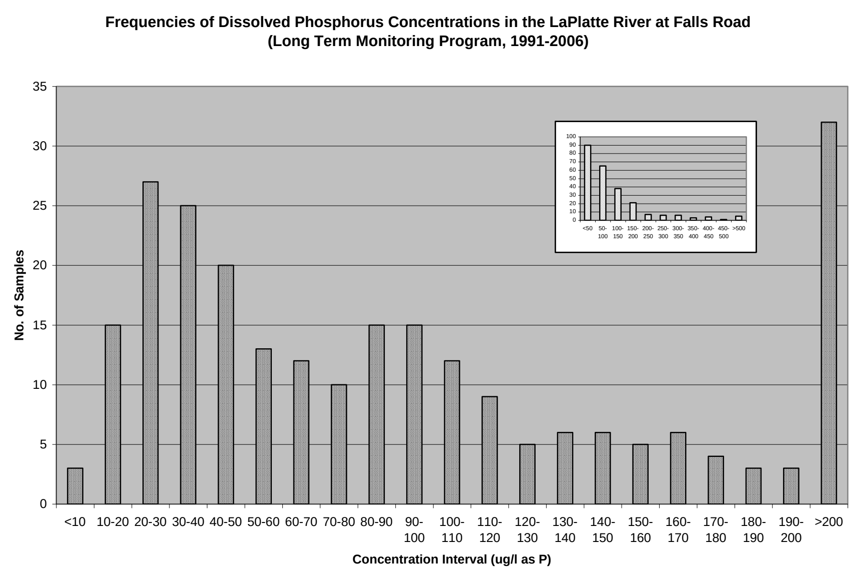
concentrations greater than about 200 ug/l observed in samples from the LaPlatte River at Falls Road (LP 03) analyzed under the Long Term Tributary Monitoring Program over the period 1991-2006 tended also to be associated with flow rates less than 70 cfs and were never reported at flow rates greater than about 200 cfs (see discussion of flow and implications of monitoring data below). Concentrations of dissolved phosphorus exceeding 200 μg/l have not been observed in samples collected under the Volunteer Monitoring Program.

Interestingly, the limited dissolved phosphorus concentration data for samples collected from the LaPlatte River at Falls Road under the Volunteer Monitoring Program appear to be directly proportional to flow, but this relation may break down as the number of samples is increased.



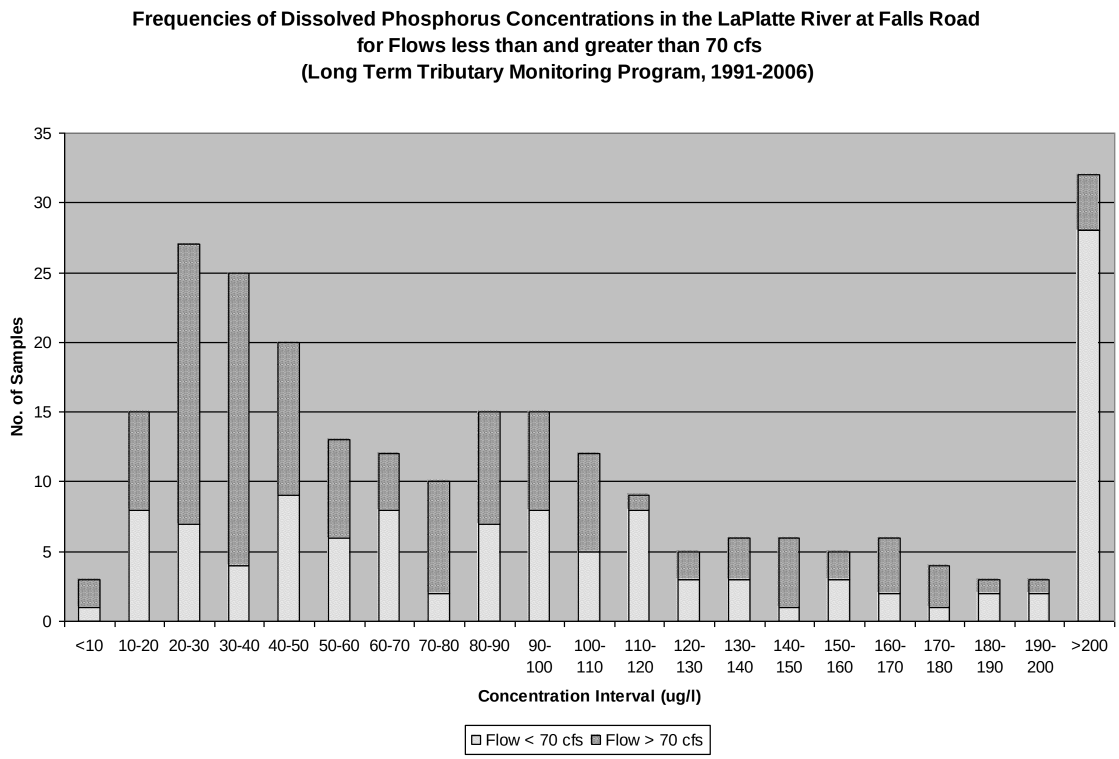
Of potential significance based on the limited data collected under the Volunteer Monitoring Program during 2006 and 2007, is an apparent doubling of dissolved phosphorus concentrations between Falls Road (LP 03) and LP 01 located approximately 3.5 miles downstream.

An examination of the frequencies distributions of dissolved phosphorus concentrations in the LaPlatte River at Falls Road (Long Term Tributary Monitoring Program) and within the LaPlatte watershed (Volunteer Monitoring Program) suggests anomalies which might be investigated further to elucidate factors operating within the watershed to influence loadings on Shelburne Bay. Looking first at the Long Term

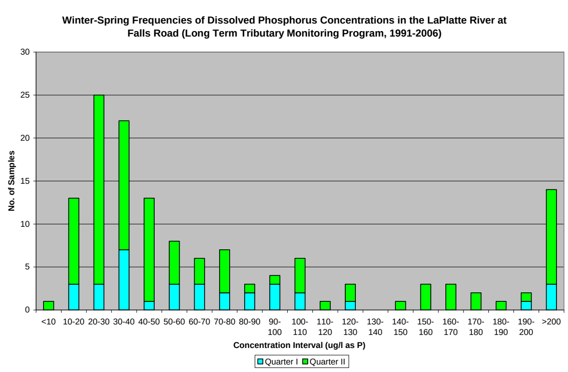


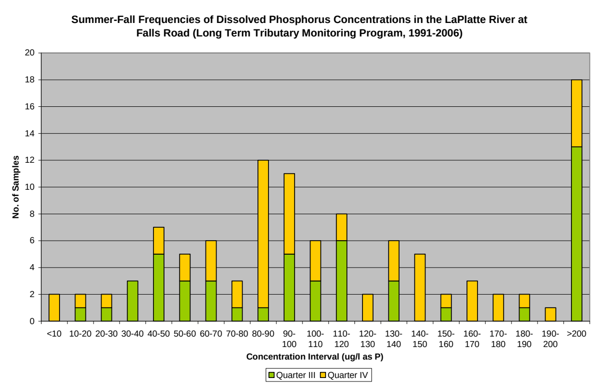
Tributary Monitoring data, it appears that there is first of all a primary distribution around the 20-30 µg/l concentration interval, and a secondary distribution around the 80-90 µg/l and the 90-100 µg/l intervals, with perhaps a third around 160-170 µg/l.

When the data are separated into two groups, one for flows of less than 70 cfs, and one for flows of greater than 70 cfs, the distribution around 20-30 µg/l appears to be associated with flows greater than 70 cfs, and the secondary distribution around 90-100 µg/l appears to be associated primarily with flows less than 70 cfs.

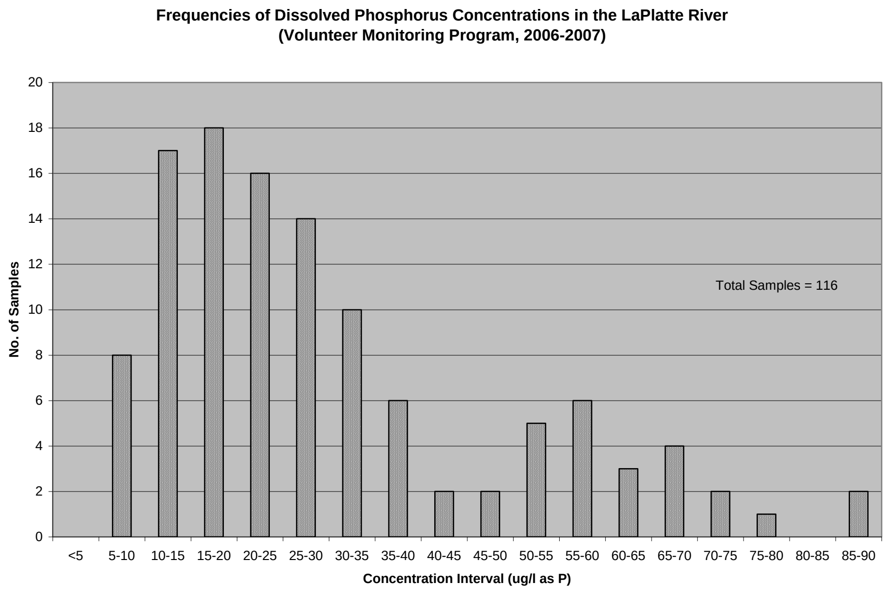


While on the one hand, there is some bias built into the sampling program, separation of the results into winter-spring and summer-fall groupings suggests seasonal differences which explain the two primary distributions, apparently related to flows.





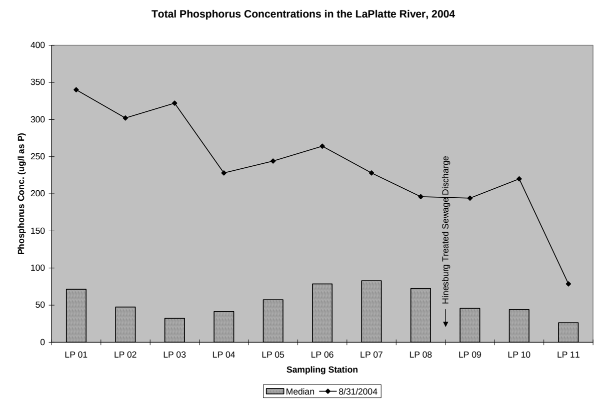
It is noted once again that, while on the one hand summer and fall data collected for all LaPlatte River sampling sites under the Volunteer Monitoring Program exhibit primary and secondary distributions, and the clusters around 50 μg/l are common to both the Long Term Tributary Monitoring and the Volunteer Monitoring Program data, the primary clusters differ substantially from one another. In part, the lower concentration cluster

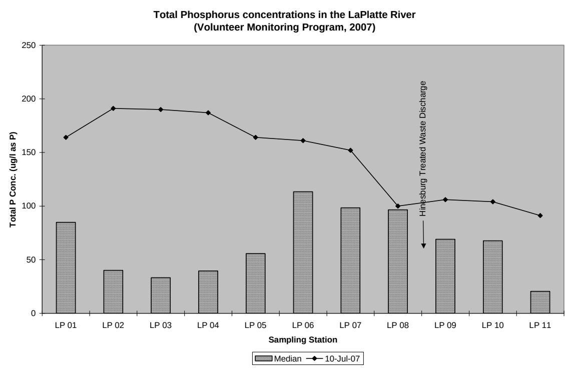


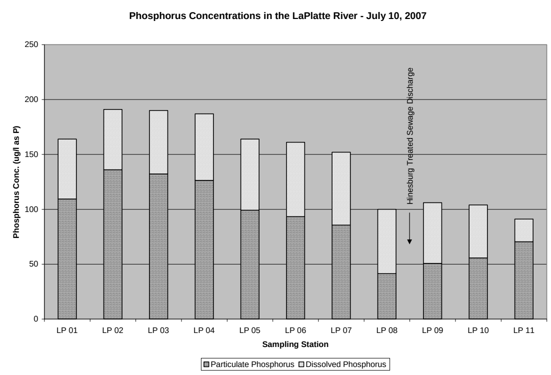
at the watershed level reflects lower dissolved phosphorus concentrations detected in the upper part of the watershed. Other factors operating at the watershed level are at times relatively high dissolved phosphorus concentrations below the Hinesburg treated waste outfall and at LP 01.

Of interest in relation to dissolved phosphorus concentrations would be the importance of the buffering influence of chemical equilibrium reactions.

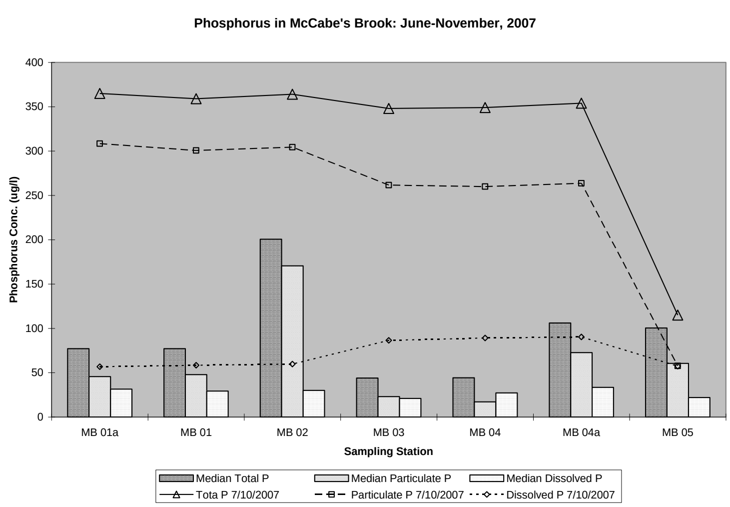
Phosphorus in Relation to Flow. Flow, and in particular high flows associated with rainfall events, may have a profound impact on the phosphorus loading from tributary streams discharging into Shelburne Bay. The impact of high flow events on phosphorus concentrations is illustrated clearly by total phosphorus results for the LaPlatte River obtained on August 31, 2004 and July 10, 2007, and for McCabe's Brook on July 10, 2007. The increases observed in the LaPlatte River on these dates appear to have been largely the result of increases in suspended solids concentrations associated with stream bank erosion and the mobilization of bottom sediments which appear also to have occurred along the full length of the river in contrast to its localization particularly between LP 08 and LP 06 during normal flows.



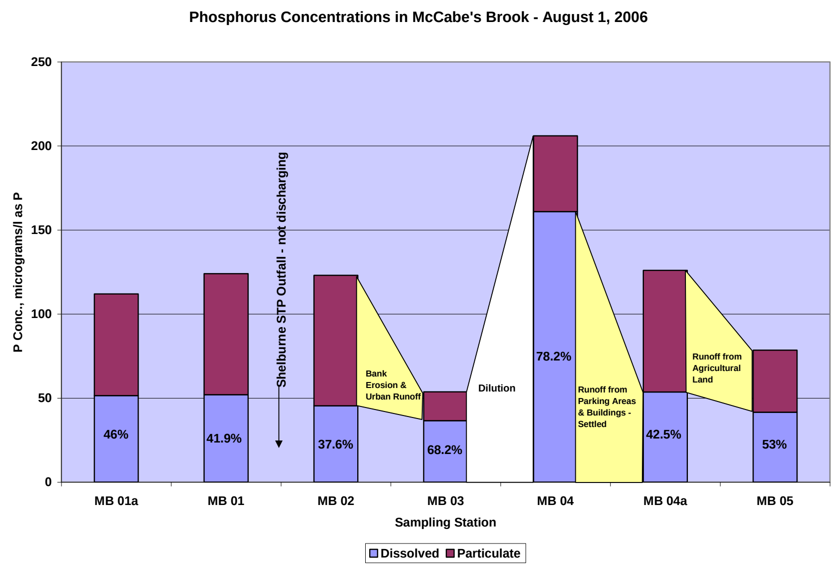




Results for McCabe's Brook during the rain event on July 10, 2007 present a different picture. On this date, the total phosphorus concentration increased dramatically between sampling points MB 05 and MB 04a and remained constant downstream. This reach of the stream receives drainage from several pasture areas, and a cornfield to which manure is applied. Dramatic increases on this date appear to be attributable primarily to solids carried by storm runoff from the cultivated field. A small increase in the concentration of dissolved phosphorus in excess of usual concentrations also occurred along the same reach, decreasing somewhat downstream, but remaining above the median at all at all downstream stations.

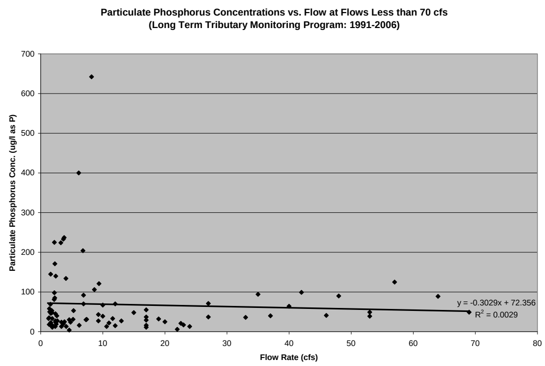


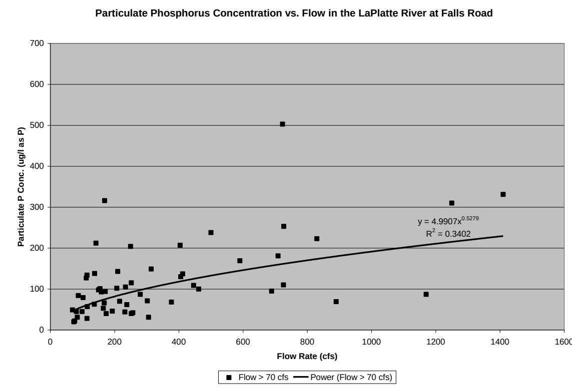
The pattern of phosphorus concentrations in McCabe's Brook on August 1, 2006 is also instructive. On that date, the total phosphorus concentration followed its normal pattern, increasing between Lime Kiln Road (MB 05) and the Vermont Teddy Bear access road (MB 04a), driven largely by an increase in the particulate phosphorus



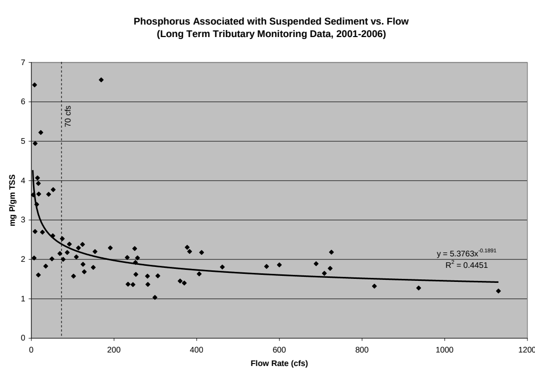
fraction. A further increase in the total phosphorus concentration occurred in the reach downstream of the Vermont Teddy bear access road and upstream from Route 7 (MB 04) driven by a dramatic increase in the dissolved phosphorus fraction, apparently originating in runoff from a large impervious area. After a decrease in the phosphorus concentration apparently resulting from dilution between Route 7 and Bostwick Road (MB 03), the concentration again increased following the normal pattern to Harbor Road (MB 02) driven by an increase in the particulate fraction.

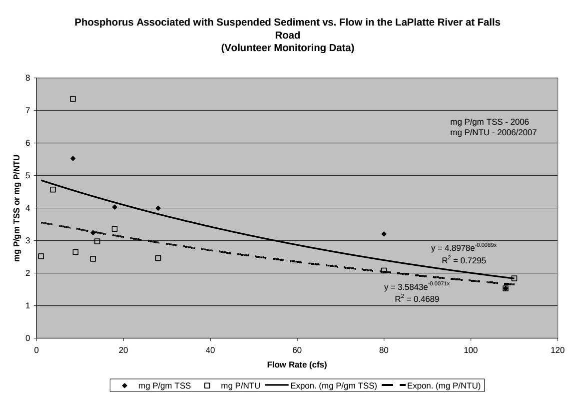
Whereas concentrations of phosphorus, particularly phosphorus associated with suspended soil and sediment, may increase dramatically during certain storm events, particulate phosphorus concentrations do not appear to be directly related to flow rates, consistent with the behavior of suspended sediment in relation to flow (see discussion of suspended sediment above).



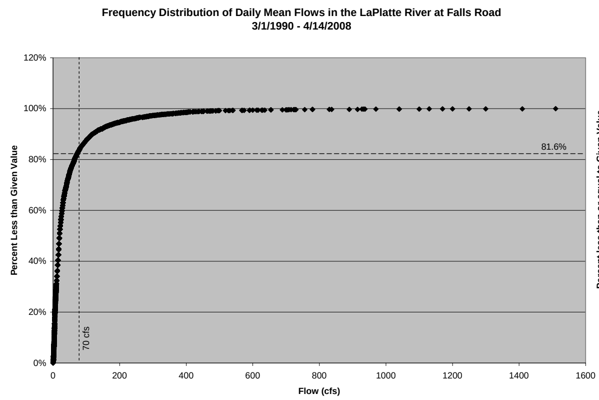


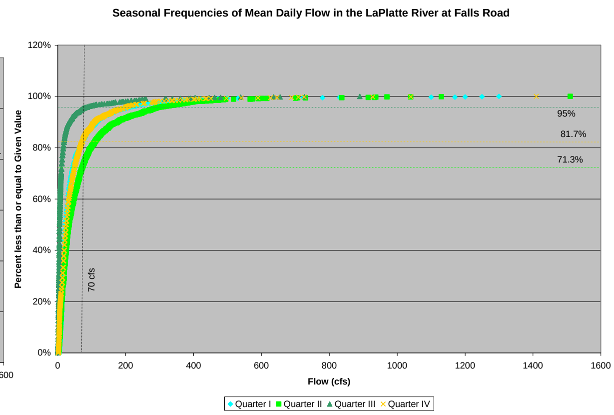
As was noted in the previous paragraphs, the load of phosphorus associated with suspended sediment tends to be greatest at low suspended sediment concentrations. Furthermore, under the discussion of suspended solids in the LaPlatte River, it was noted that results of analyses at Falls Road suggest that turbidity remains relatively constant at flows below about 70 cfs. Similarly, particle sizes appear to be primarily in the range of clay and fine silt at flows below about 70 cfs. Particles of size 7μ or more begin to increase in number at flows greater than 70 cfs. As indicated above, this suggests that at low flows (<70 cfs), high phosphorus loads carried by suspended sediments are associated primarily with clay and fine silt. Examination of records of phosphorus associated with suspended sediment in relation to flow tends to support this interpretation. The potential contribution of clay and fine silt to the overall phosphorus loading to Shelburne Bay is evident when it is realized that daily mean flows are under 70





cfs on about 8 out of 10 days each year. During the summer months, flows exceed 70 cfs only 5% of the time, and during the spring about 29% of the time.





As pointed out by Cassell et al.[12], "additional studies are needed to define the relationships among particle size categories and their phosphorus content for the common soils within the Lake Champlain basin."

***Implications of Monitoring Results*.** Whereas there are few data available with regard to particle size, and the data collected under the Volunteer Monitoring Program are seasonal and have been collected only monthly over a period of 4 years, together with results provided under the Long Term Tributary Monitoring Program they are instructive and suggest conclusions and questions which may deserve to be investigated further:

1. A review of phosphorus and suspended sediment data for the LaPlatte River at Falls Road suggests that **phosphorus can be thought of as occurring in 3 fractions**:

   Fraction I: Dissolved phosphorus
   Fraction II: Particulate phosphorus associated with clay and fine silt
   Fraction III: Particulate phosphorus associated with particles >7μ (medium silt)

2. **Clay and fine silt (Fraction II) predominant at flows less than 70 cfs appear to carry about twice as much phosphorus per gram sediment as does medium silt (Fraction III) predominant at flows greater than 70 cfs**.

[12] Cassell, E.A., W.P. Roberts, E.M. Clapp, and R.L. Kort (1995). Dynamic Simulation Modeling for Analyzing Sediment Transport and Storage in Stream Corridors. Report to USDA natural Resources Conservation Service, Winooski, Vermont.

Seasonal Comparisons of Phosphorus Associated with Suspended Sediment Particles (Long Term Tributary Monitoring Data, 1993-2006)

Mean Daily Flow (cfs)	Mean mg P/gm TSS			
	Jan.-March	April-June	July-Sept.	Oct.-Dec.
<70 cfs	4.14	4.12	5.69	7.35
>70 cfs	2.40	2.01	2.14	3.86
	Median mg P/gm TSS			
<70 cfs	2.46	3.33	3.79	5.23
>70 cfs	1.89	1.87	2.27	2.51

3. It might be anticipated that:

    a. **Phosphorus in Fraction I and Fraction II contributes to the phosphorus loading reaching deeper open waters of Shelburne Bay**
    b. **Phosphorus in Fraction III settles in the littoral zone where it could support rooted aquatic plants and algae**

4. In general, phosphorus in Fraction I and Fraction II each exceed 14 µg/l at Falls Road (LP 03) in Shelburne, thus potentially contributing to total phosphorus concentrations in the open water of Shelburne Bay in excess of the State standard.

5. Since i) concentrations of clay and fine silt appear to remain fairly constant and independent of flow rate, increasing only gradually as flow increases, and ii) dissolved phosphorus concentrations, while highly variable, appear to be fairly independent of flow rate, at least seasonally, it might be expected that the **phosphorus loading on the open water of Shelburne Bay should be roughly proportional to flow into the bay**.

6. If concentrations of particles greater than 7 µ in fact begin to increase only when flows exceed about 70 cfs, and if they settle primarily in the littoral zone, then **the contribution of the larger silt component associated with high suspended solids concentrations discharged to the open waters of the bay over and above that contributed by the dissolved and the fine particulate phosphorus fractions might be expected to constitute only a minor part of the overall phosphorus loading on the bay.**

7. Since concentrations of both dissolved and particulate phosphorus determined under the Volunteer Monitoring Program at LP 01 on average exceed concentrations at LP 03, **calculations of phosphorus loadings on Shelburne Bay based on concentrations determined at Falls Road (LP 03) may underestimate actual loadings**. Although it is recognized that the downstream stations LP 02 and LP 01 are in the backwater of the lake, the source and importance of this increase should be investigated.

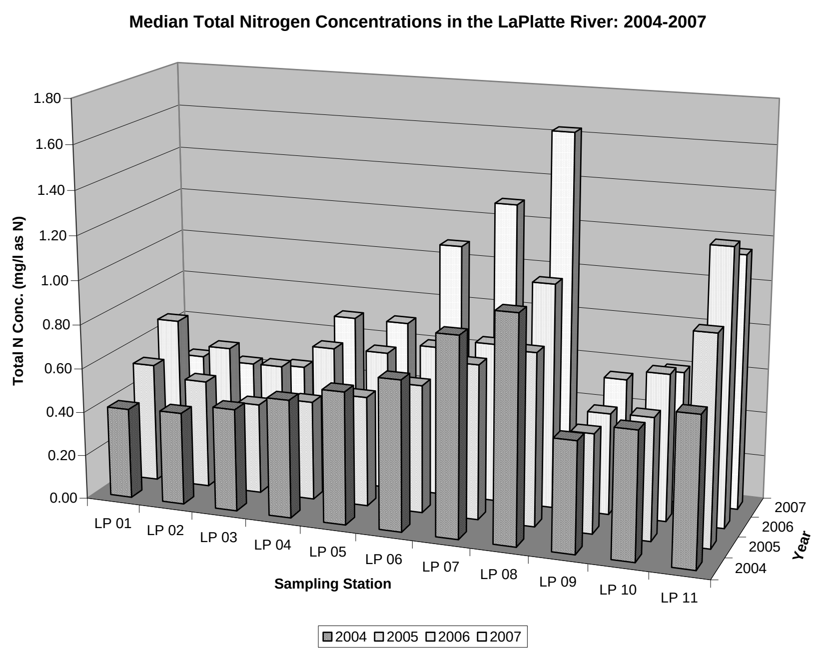
NITROGEN

Nitrogen is an essential, and at times, limiting, nutrient required by aquatic plants and algae. With the exception of leguminous plants and certain cyanobacteria which are able to fix atmospheric nitrogen, nitrogen must be derived from the water or sediments. The State of Vermont has established a limit of 5 mg nitrate-N/l in Class B streams.

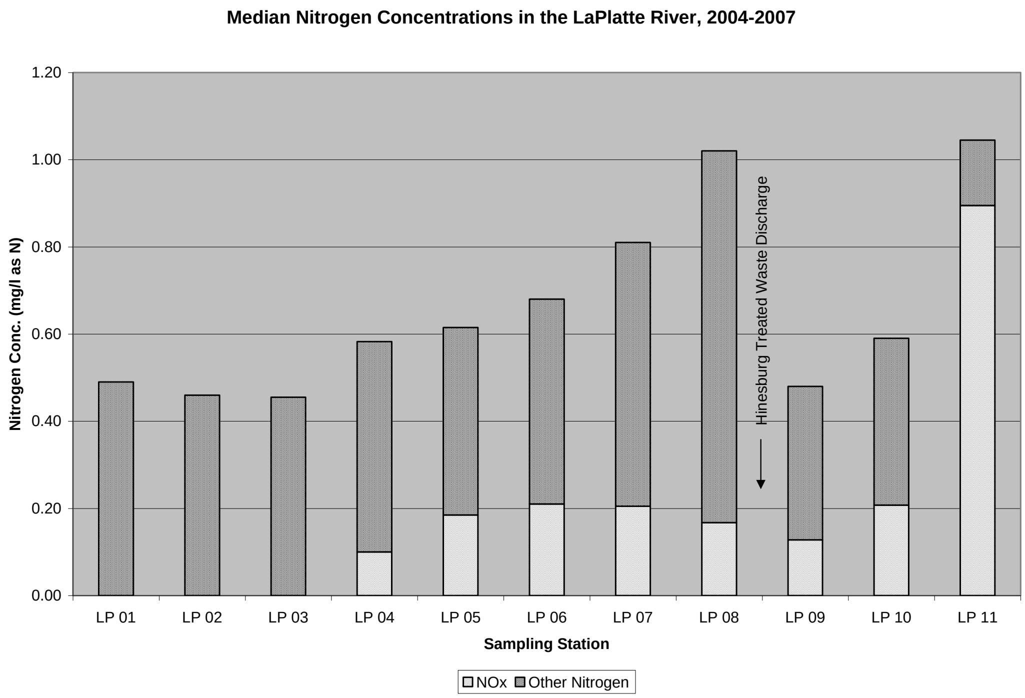
Nitrogen can be present in the water as nitrate, nitrite, ammonium ion, or in the form of dissolved or particulate organic matter. In well aerated stream water, nitrite is usually absent, as is ammonium ion. Nitrogen can enter surface waters in the form of nitrate or nitrite with rain, ground water, runoff from urban or agricultural areas, or waste discharges. Similarly, organic nitrogen can enter with runoff from agricultural land, urban areas, or waste discharges, as well as polluted ground water. Ammonium ion, essentially absent from aerated waters, can originate primarily from waste discharges. In the well aerated water of the LaPlatte River and its tributaries at the locations sampled, ammonium ion and nitrite concentrations were probably negligible, and nitrogen was probably present primarily as nitrate ion, measured as $NO_3 + NO_2$, and organic nitrogen.

Monitoring Results

Total nitrogen concentrations in the LaPlatte River present a consistent pattern from year to year. Concentrations are relatively high at Gilman Road (LP 11), although they have never been observed to approach the State water quality standard. They are highest at this location during drier years. Under normal conditions they decrease as a result of dilution to the Hinesburg Treated Waste Discharge after which they increase to higher levels, decreasing progressively downstream as a result of dilution, rising slightly as the river passes through the Lower LaPlatte Nature Reserve.



The high nitrogen concentrations observed at Gilman Road are of interest. They consist largely of nitrate plus nitrite, concentrations of which decrease rapidly, but persist to Spear Street (LP 04) and are detected in less than half the samples collected at and below Route 7 (LP 03). There are potential sources of nitrate upstream from LP 11, and these should be investigated.

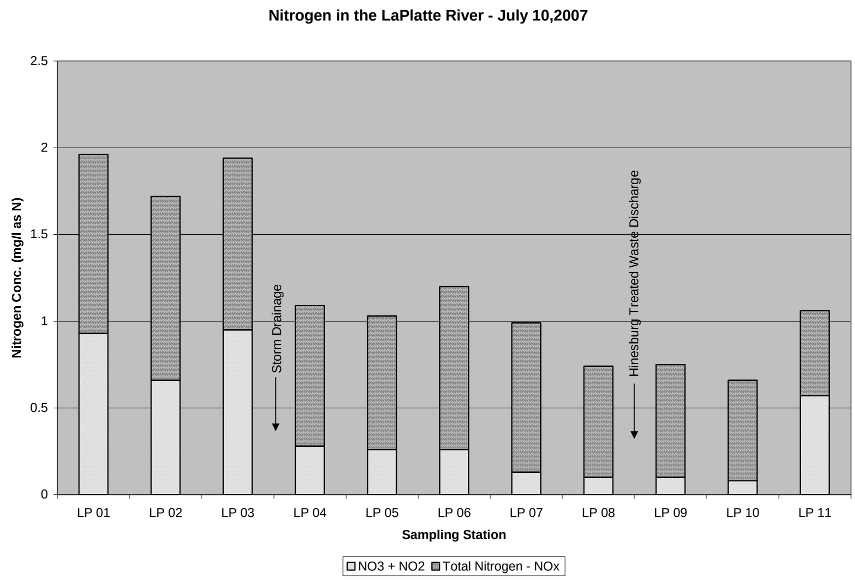


The Hinesburg Treated Waste Discharge is the major source of nitrogen entering the LaPlatte River, causing a large jump in the concentration of total nitrogen between LP 09 and LP 08 located immediately upstream and downstream of the outfall, respectively. Nitrogen entering the river from the waste discharge does not appear to be highly nitrified, but a slight increase in nitrate plus nitrite concentrations for a distance downstream from the outfall could suggest some nitrification in the stream. In general, total nitrogen concentrations decreased in direct proportion to dilution as indicated by a comparison with decreases in chloride concentrations between the outfall (LP 08) and Route 7 in Shelburne (LP 03):

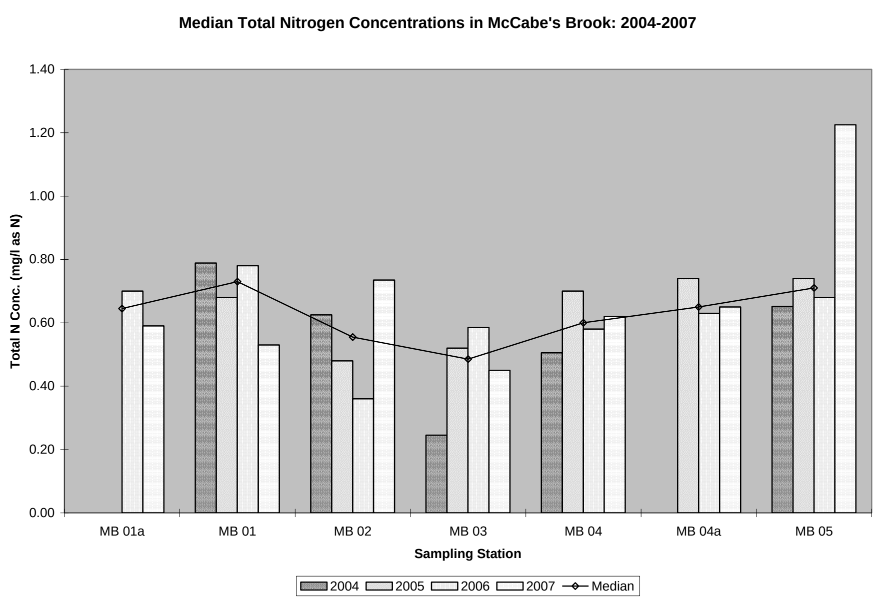
Reduction in Median Total Nitrogen and Chloride Concentrations
In the LaPlatte River, 2004-2007

Reach	$Cl_{upstream}/Cl_{downstream}$	$TN_{upstream}/TN_{downstream}$
LP 08-LP 07	1.34	1.26
LP 07-LP 06	1.11	1.19
LP 06-LP 05	1.05	1.11
LP 05-LP 04	1.08	1.06
LP 04-LP 03	1.14	1.28

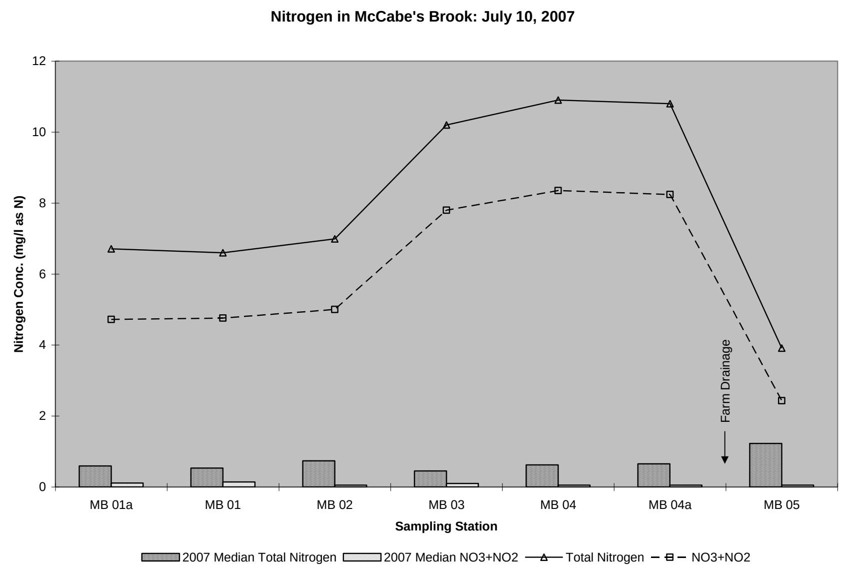
Under high flow conditions, such as existed on July 10, 2007, whereas the waste discharge in Hinesburg had no noticeable impact on concentrations of total nitrogen in the river, concentrations were observed to increase somewhat downstream to Dorset Street Extension (LP 06) and then remain fairly constant to Falls Road in Shelburne (LP 04). But at Route 7 in Shelburne (LP 03) storm drainage enters the river, nearly doubling the total nitrogen concentration, about half of which is in the form of nitrate plus nitrite.



The picture in McCabe's Brook is in general unremarkable. Total nitrogen concentrations were generally below 1.0 mg/l, well below the State limit of 5 mg NO_3/l as N. Concentrations decreased steadily below Lime Kiln Road (MB 05), at times increasing between Bostwick Road (MB 03) and Harbor Road (MB 02), perhaps as a result of inputs of storm drainage, and then a further increase below the Shelburne treated waste discharge.



However, storm events have been observed to impact significantly on nitrogen concentrations in McCabe's Brook where farm runoff entering between Lime Kiln Road (MB 05) and the Vermont Teddy Bear access road (MB 04a) can contribute significantly to nitrogen loadings on the stream. Such an event occurred on July 10, 2007 when the



flow was peaking following heavy rains. Total nitrogen concentrations already at a level of nearly 4 mg/l at Lime Kiln Road, increased to 10.8 mg/l at the Vermont Teddy Bear access road. Nitrate plus nitrite alone reached a concentration of 8.24 mg/l, far in excess of the Vermont State Standard. Concentrations decreased downstream somewhat as a result of dilution, but remained in excess of the State Standard at all downstream stations.

***Implications of Monitoring Results*.** The Volunteer Monitoring Program represents the primary source of current nitrogen data on the LaPlatte River and McCabe's Brook watersheds. Based on these data, the following conclusions may be drawn:

- **Nitrogen is an essential nutrient which should be included in volunteer water quality monitoring programs**.
- **Concentrations of total nitrogen in streams tributary to the southern end of Shelburne Bay are generally well below the Vermont State water quality standard of 5 mg NO_3-N/l**.
- **Very high nitrogen concentrations greatly exceeding Vermont State standards in McCabe's Brook can occur during rain events where the stream receives runoff from cultivated fields following application of manure**.
- In the Laplatte River, concentrations of nitrogen exceeding 1.0 mg/l at Gilman Road and below the Hinesburg treated waste discharge decrease downstream in direct proportion to dilution:
  - Nitrate plus nitrite predominate at Gilman Road
  - The non-nitrified fraction predominates below the waste outfall.

- **Investigations should be undertaken to determine the source of nitrate plus nitrite in the LaPlatte River at Gilman Road**.

NUTRIENT RELATIONSHIPS – LIMITING NUTRIENTS

The concept of limiting nutrients has long been central to efforts to control productivity and the development of nuisance conditions in water bodies. Whereas a number of trace elements have been shown to limit the growth of algae and rooted aquatic plants in various special situations, nitrogen and phosphorus are generally the major requirements for growth, and either may limit growth. A sense of which nutrient may be limiting in lakes can be derived from the molar ratio of TN:TP. In general, it has been found that when the TN:TP ratio is <20, nitrogen tends to limit growth, and when the ratio is >50, phosphorus deficient growth may be anticipated. At intermediate ratios, either nitrogen or phosphorus may limit growth.[13]

It is noted that Levine *et al.*,[14] based on work on Lake Champlain, noteded that although TN:TP ratios were always indicative of severe phosphorus limitation in the lake (68:1 to 139:1), phosphorus sufficiency was suggested by physiological indicators and mixed phosphorus and nitrogen limitation growth assays. These authors found that phosphorus alone was not limiting at all times, and concluded that while on the one hand, phosphorus was an important factor limiting growth of phytoplankton in Lake Champlain, phosphorus deficiency was not consistent, nitrogen apparently also played an important role. At times, addition of phosphorus yielded very little increase in the biomass of phytoplankton, and increased nitrogen loadings in the absence of reductions in phosphorus loadings could lead to increased productivity. In many of her experiments using *Selenastrum capricornatum* as a test organism, growth was always greater when nitrogen and phosphorus were added in combination than when phosphorus was added alone.

It is often considered that the N:P ratio plays a role in determining the presence or absence of nitrogen fixing blue green bacteria. However, the situation may be more complex. For instance, an exceptional bloom of *Aphanizomenon ovalisporum* in Lake Kinneret in 1994 was shown to derive most of its nitrogen from dissolved organic nitrogen rather than from nitrogen fixation.

---

[13] S.J. Guildford and R.E. Hecky (2000).). Total nitrogen, total phosphorus, and nutrient limitation in lakes and oceans: Is there a common relationship. Limnol. Oceanogr. *45*, 1213-1223.

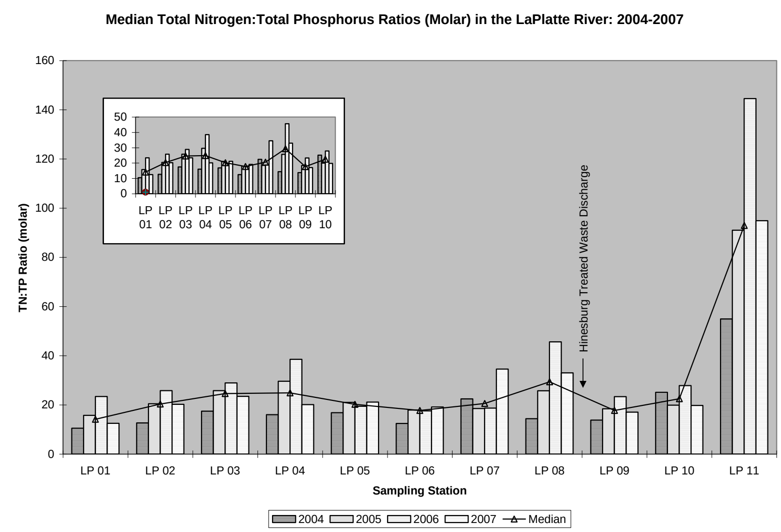
[14] Levine, S., A. d. Shambaugh, S.E. Pomeroy, and M. Braner (1997). Phosphorus, nitrogen, and silica as controls on phytoplankton biomass and species composition in Lake Champlain (USA-Canada). J. Great Lakes Res., *23*, 131-148

In contrast to open water bodies, research on artificial streams fed stream water[15] have indicated that the structure of the periphyton community is more sensitive to the N:P ratio as well as total nutrient concentrations than is periphyton biomass.

As is suggested by the results by the results of the Volunteer Monitoring Program, the TN:TP ratio may inform the interpretation of both nitrogen and phosphorus results as well as suggesting that nitrogen may be of greater significance than is generally recognized, consistent with the observations of Levine *et al*.

Monitoring Results

TN:TP ratios in the LaPlatte River provide a picture which first of all, highlights contrasts between sources of nitrogen and phosphorus in the river. The dynamics of forces affecting nutrient relationships in the river suggest the existence of 5 zones:



- LP 11 – LP 09: The TN:TP ratios were extremely high at LP 11 (in general greater than just over 90, but at times exceeding 150), and declined steadily to LP 08. While there occurred an increase in the total phosphorus concentration between LP 11 and LP 10 from a low of around 20 µg/l at LP 11 to over 50 µg/l at LP 10 and LP 09, total nitrogen concentrations decreased steadily from greater than 1 mg/l as N at LP 11 to less than 0.5 mg/l as N at LP 09. Whereas the concentrations of total nitrogen are not exceptionally high, their relationship to phosphorus concentrations suggests the existence of a source of nitrate entering the stream upstream of LP 11.

- LP 09 – LP 08: The TN:TP ratio in this short reach of the river is impacted by the treated waste discharge which, while it contributes both nitrogen (non-nitrified) and phosphorus (both particulate and dissolved), is relatively rich in

[15] R.S. Stelzerand and G.A. Lamberti, (2001). Effects of N:P ratio and total nutrient concentration on stream periphyton community structure, biomass, and elemental composition. Limnol. Oceanogr. *46,*: 356-367.

nitrogen. This is reflected in an increase in the TN:TP ratio from about 17 (nitrogen poor) upstream from the treated waste discharge to about 29 (balanced with respect to nitrogen and phosphorus) below the point of discharge.

- LP 08 – LP 06: Over this reach, the dominant source of nutrient species appears to be stream-bank erosion, resulting in the mobilization of particulate phosphorus (with little change in the concentration of dissolved phosphorus). At the same time, total nitrogen concentrations decrease steadily as a result of dilution, with no evident source of nitrogen over and above a low base level.[16]

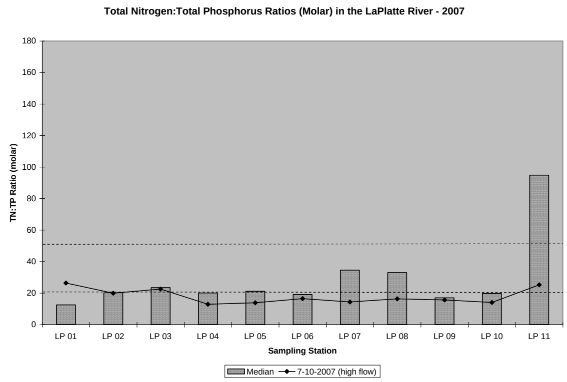
- LP 06 – LP 04: Between LP 06 and LP 04 both total nitrogen and total phosphorus concentrations decline. An increase in the TN:TP ratio, reflects a simultaneous decrease in the total nitrogen concentration in proportion to dilution,[17] and more rapid decrease in the total phosphorus concentration attributable almost entirely to deposition of particulate phosphorus.[18]

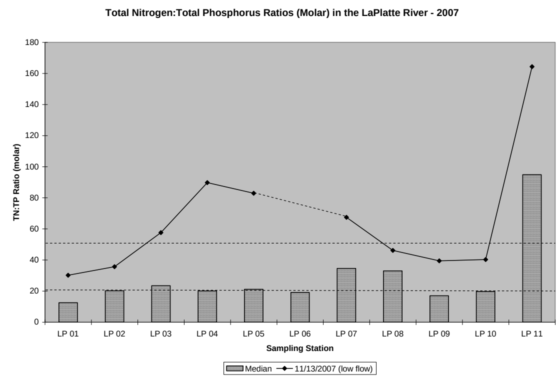
- LP 04 – LP 01: Downstream of LP 04, oxidized inorganic nitrogen rapidly becomes undetectable within the limits of the test procedure and the concentration of total nitrogen becomes relatively constant. In contrast, concentrations of total phosphorus increase downstream of LP 03, primarily as a result of increases in dissolved phosphorus concentrations, especially noticeable as the river passes through the Lower LaPlatte Nature Reserve.

It should be noted, however, that TN:TP ratios may vary with different flow conditions, again reflecting factors affecting both nitrogen and phosphorus in the river. Thus at very high flows, as on July 10, 2007, concentrations of total nitrogen remain at fairly constant levels generally lower than normal throughout the length of the river, whereas at very low flows, ratios may be considerably higher reflecting low levels of erosion and thus low levels of particulate phosphorus. In any event, based on ratios observed throughout the river seldom indicate that phosphorus should be definitively limiting (>50).

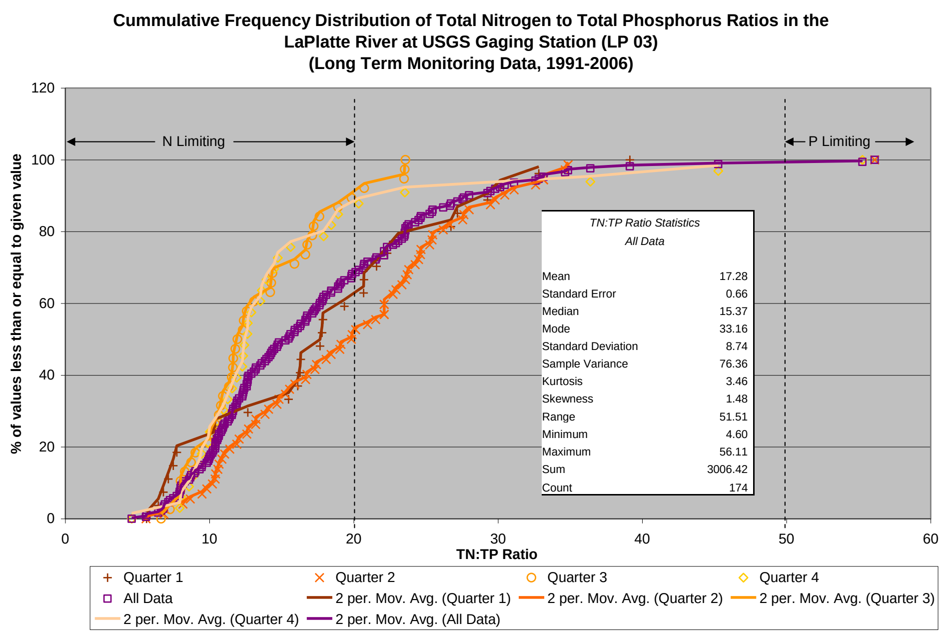
---

[16] $Cl_{LP\ 08}/Cl_{LP\ 06} = 1.4807$ compared to $TN_{LP\ 08}/TN_{LP\ 06} = 1.5$.
[17] $Cl_{LP\ 06}/Cl_{LP\ 04} = 1.1282$ compared to $TN_{LP\ 06}/TN_{LP\ 04} = 1.1724$
[18] $PP_{LP\ 06}/PP_{LP\ 04} = 2.977$ (ave. 2 years); $DP_{LP\ 06}/DP_{LP\ 04} = 1.4303$ (ave. 2 years)

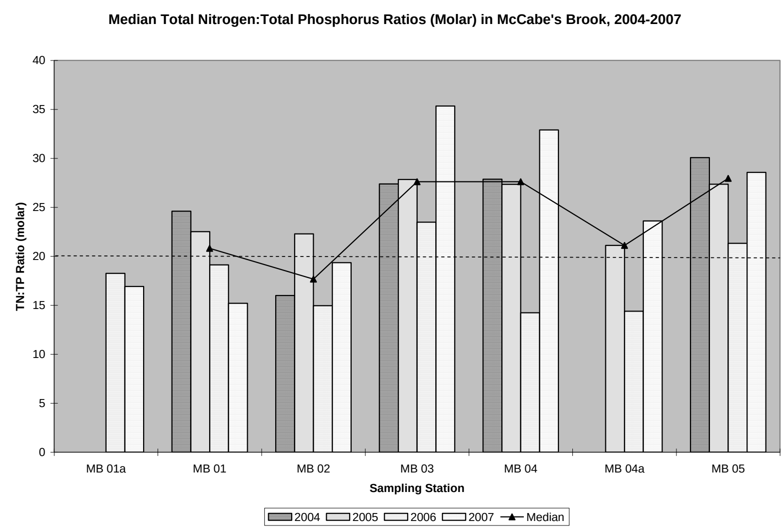




A final point of interest is the generally low ratio of TN:TP as the river discharges into Shelburne Bay (generally <20) suggesting an excess of phosphorus relative to nitrogen, and a possibility of nitrogen limiting conditions. Although nitrogen limitation could shift to phosphorus limitation as a result of settling, especially when sediment loads are high and the burden of larger silt particles is high, it also might be anticipated that, since in general dissolved phosphorus constitutes between 40% and 50% of the total phosphorus, and can exceed 65% during periods when sediment loads are low as occurred during the summer of 2007, and since the phosphorus load carried by clay and fine silt particles which predominate in the river during periods of low flow tend to be very high, nitrogen could be limiting in LaPlatte River waters discharging to Shelburne Bay during much of the summer. This picture is reinforced by data collected under the Long Term Tributary Monitoring Program which indicate that during the summer and fall months, the TN:TP ratios are less than 20 about 90% of the time. On only 2 occasions did the ratio exceed 50.



The picture presented by McCabe's Brook is one of variability, yet at the same time consistency in overall pattern. Ratios decreased between lime Kiln Road (MB 05) and the Vermont Teddy bear access road (MB 04a) as a result of (particulate) phosphorus inputs between these stations relative to nitrogen, and increased between MB 04a and Route 7 (MB 04). They decreased again between Bostwick Road (MB 03) and Harbor Road (MB 02) as a result of increases in phosphorus loading, apparently resulting from erosion. Below the Shelburne treated waste outfall, the pattern varied as a result of timing of samples in relation to discharge, but in general, increased suggesting high concentrations of nitrogen relative to phosphorus in the discharge. A review of treatment plant operational data indicated that whereas the TN:TP ratio in the effluent from the plant can be as high as 75, ratios are in general low (mean = 12.08, median = 8.6) reflecting the operational objective of reducing the discharge of nitrogen. It is notable, however, that ratios generally were between 20 and 35, although at the downstream station (MB 01a), and at all stations below Lime Kiln Road (MB 05) during 2006, ratios fell below 20.



***Implications of Monitoring Results*.** The Volunteer Monitoring Program represents the primary source of current nitrogen data on the LaPlatte River and McCabe's Brook watersheds. Based on these data, the following conclusions may be drawn:

- **TN:TP ratios can be useful analytical tool to:**
  - **Indicate the relative importance of nitrogen and phosphorus deficiencies and potential as limiting nutrients**
  - **Highlight the dynamics and sources of nutrients**
- The rural **LaPlatte watershed, which is not highly developed, is rich in phosphorus contributed by erosion (LaPlatte River) or farm runoff (McCabe's Brook) relative to nitrogen**
- **The TN:TP ratios common in the discharge from the LaPlatte River into Shelburne Bay suggest a deficiency of nitrogen relative to phosphorus particularly during the summer and fall months**.
- **TN:TP ratios should be calculated and employed in the analysis and interpretation of data collected by volunteer water quality monitoring programs**

- **Sources of NOx should be investigated upstream of station LP 11 in the LaPlatte River**

ANNEXES

ANNEX I	Sampling Station Locations
ANNEX II	Quality Assurance
ANNEX III	Flows
ANNEX IV	Tributary Streams: Patrick Brook, Mud Hollow Brook
ANNEX V	Fluvial Geomorphology
ANNEX VI	Phosphorus Export (SPARROW)

ANNEX I – Sampling Station Locations

Station No.	River Mile	Coordinates	Town	Description	Remarks
LP 01	LAP	44.39450 -73.22879	Shelburne	LaPlatte River, trail from end of Yacht Haven Drive	
LP 02 (LR 02)	LAP 1.8	44.38707 -73.22515	Shelburne	LaPlatte River, Route 7 bridge north of Shelburne Village. Right bank under bridge.	
LP 03 (LR 04)	LAP 3.46	44.37022 -73.21577	Shelburne	LaPlatte River, intersection of Thomas and Falls Roads. East (right bank), approximately 30 meters south of Falls Rd. bridge.	Dairy farms drain via tributaries below LP4
LP 04	LAP 6.96	44.3550 -73.19382	Charlotte	LaPlatte River, Spear St. bridge (at Gecewicz). Left bank, 3 meters downstream of bridge.	
LP 05	LAP 9.19	44.34176 -73.18383	Charlotte	LaPlatte River, Carpenter Rd. bridge. Left bank, 5 meters upstream from bridge.	Dairy farms drain from right bank downstream from LP4b. Bank erosion upstream.
LP 06	LAP 10.32	44.33839 -73.17097	Charlotte	LaPlatte River, Dorset St. bridge. Right bank, upstream end of bridge.	
LP 07 (LR 09)	LAP 12.37	44.33887 -73.14931	Hinesburg	LaPlatte River, Leavenworth Rd. North bridge. Left bank at downstream end of bridge.	
LP 08	LAP 14.52	44.33319 -73.12618	Hinesburg	LaPlatte River, 15 meters downstream of Hinesburg sewage treatment plant outfall.	
LP 09	LAP 14.54	44.33395 -73.12598	Hinesburg	LaPlatte River, 15 meters upstream of Hinesburg sewage treatment plant outfall.	
LP10 (LR 11)	LAP 15.66	44.32524 -73.11015	Hinesburg	LaPlatte River, Silver St. bridge. Right bank, downstream end of bridge.	
LP 11 (LR 14)	LAP 17.63	44.30492 -73.30492	Hinesburg	LaPlatte River, Gilman Rd. bridge. Left Bank. Downstream discharge from culvert.	Downstream from Cedar Knoll Golf Club
MB 01a	LAP 0.34 MB 1.4	44.38423 -73.23695	Shelburne	McCabe’s Brook, access opposite Shelburne Rescue	Downstream from Shelburne STP discharge

MB 01	LAP 0.34 MB 1.51	44.38423 -73.23695	Shelburne	McCabe's Brook, 20 meters downstream of Shelburne sewage treatment plant #2. East (right) bank.	Intermittent discharge from SBRs. UV disinfection.
MB 02	LAP 0.34 MB 1.68	44.38305 -73.23853	Shelburne	McCabe's Brook, Harbor Rd. bridge. Left bank, 30 meters below bridge.	Surface drain channel enters from right bank about half way between the bridge and the sampling point
MB 03 (LR 03)	LAP 0.34 MB 3.32	44.36892 -73.23586	Shelburne	McCabe's Brook, Bostwick Rd. Bridge. Left bank at downstream discharge from culvert.	
MB 04	LAP 0.34 MB 4.00	44.36230 -73.23461	Shelburne	McCabe's Brook, Route 7 bridge. Right bank at upstream end of bridge.	Upstream bank erosion. Vermont Teddy Bear storm drainage pond overflow immediately upstream on east drainage.
MB 04a	LAP 0.34 MB 4.20	44.36086 -73.23405	Shelburne	McCabe's Brook, Vermont Teddy Bear access road	Upstream Route 7 fill disposal on farm fields on east drainage. Upstream from disposal site, pasture and corn fields with manure spreading on west drainage.
MB 05 (LR 05)	LAP 0.34 MB 6.04	44.34582 -73.22868	Charlotte	McCabe's Brook, Lime Kiln Rd. bridge. Downstream discharge from culvert.	Horses upstream, west (left) bank. Nordic Farm upstream west drainage.
MH 01 (LR 06)	LAP 6.64 MH 0.23	44.35353 -73.19340	Charlotte	Mud Hollow Brook, Spear St. Bridge (at Gecewicz). Entrance to culvert at upstream end.	Upstream drainage from cultivated fields.
PB 01a	LAP 15.09 PB 0.50	44.33566 -73.11286	Hinesburg	Patrick Brook, left bank above Route 116 bridge and above drainage along Route 116 behind Mobil Station	
PB 01	LAP 15.09 PB 1.01	44.34115 -73.10594	Hinesburg	Patrick Brook, Mechanicsville Rd. bridge. Right bank, upstream entrance to culvert.	

ANNEX II – Quality Assurance

Training

Initial activities undertaken to provide a public forum on water quality and the LaPlatte Watershed Volunteer Water Quality initiative, and to assure understanding of, and adherence to, sampling protocols included the following:

- Initial training session attended by the Project Coordinator in Waterbury
- Water Quality Forum sponsored by the LaPlatte River Partnership, Hinesburg Town Library, May 25. Presentations on water quality in the LaPlatte River and Shelburne Bay by Don Meals and by Mike Barsotti.
- Yearly training of volunteers, Shelburne Town Offices. Coordinated by the Project Coordinator and the Water Quality Director, CWD. Discussion of program objectives, water quality parameters, sampling schedule and procedures, sampling station locations, organization of sampling teams, maintenance of records, and quality assurance
- Field training
- Follow-up of sampling. Following each sampling date, the Project Coordinator communicates with all volunteers, providing graphs illustrating important findings and brief interpretations of results, highlighting areas/results of interest, clarifying procedures as well as discussing problems identified during review of field data sheets and data
- Interim Review Meetings with volunteers. Discussion of results received to date, problems and constraints, protocols, and improvement of procedures.
- Site visits with sampling teams. Site visits by the QA Coordinator wave not been possible. Careful review of field data and lab sample sheets followed by communications with samplers has been an important follow-up action.

Review of Data

Data management and analysis were carried out by the Project Coordinator. Data entry in the field and office were reviewed for accuracy through direct checks and checks and analysis of outlying data. Recorded and manipulated data and analyses were also reviewed for accuracy by the QA Coordinator.

2004 Sample Season

Completeness of Sampling and Field Duplicates

	No. of Stations with Flow	No. of Stations Sampled	Number of Samples: TSS	Turbidity	Total N	NO3 + NO2	Total P	Chlorides	*E. coli*
Month									
June	26	25	25	25	25	25	24	25	25
July	26	26	26	26	25	26	25	26	26
August	27	22	22	22	22	20	21	22	20
September	26	26	26	26	26	26	26	26	26
October	26	26	26	26	26	26	26	26	26
November	26	26	26	26	25	26	26	26	26
Total Number	157	151	151	151	149	149	148	151	149
Percent	-	96.18	96.18	96.18	94.90	94.90	94.27	96.18	94.90
Target Percent	-		≥80%	≥80%	≥80%	≥80%	≥80%	≥80%	≥80%
Number of Duplicates			16	15	16	16	15	15	10
Percent of Total			10.60	9.93	10.74	10.74	10.14	9.93	6.71
Target Percent			10%	10%	10%	10%	10%	10%	10%

Summary of Mean Relative Percent Differences

Parameter	Target Precision	Mean RPD
Total Suspended Solids	≤ 10%	9.34%
Turbidity	≤ 10%	15.88%
Total Nitrogen	≤ 15%	14.83%
NO3 + NO2	≤ 10%	2.33%
Total Phosphorus	≤ 15%	7.00%
Chloride	≤ 10%	2.13%
E. coli	≤100%	*

The QA Protocol sets precision targets (mean relative percent differences, MRPDs) for each of the parameters analyzed. These are given in Table 10. Targets were met for all parameters save turbidity which exceeded the target by 50% (15.88% vs. 10% target).

The determination of individual field RPDs for *E. coli* was constrained by the number of samples which equaled or exceeded the maximum limit for the MPN procedure (3 of 10 samples-duplicate pairs) and were recorded as either 2,419 or >2,419 per 100 ml. Whereas both the sample and the duplicate might be ≥2,419 per 100 ml., such counts cannot be taken as equal, and cannot be compared. Of the 10 pairs of samples and field duplicates which could be compared, all were under the 100% MRPD target, and the maximum RPD was 43.0%, well below the 100% target.

2005 Sampling Season

Completeness of Sampling and Field Duplicates

	No. of Stations with Flow	No. of Stations Sampled	Number of Samples						
			TSS	Turbidity	Total N	NO3 + NO2	Total P	Chlorides	*E. coli*
Month									
May	28	28	28	28	28	27	28	28	28
June	27	27	27	27	27	27	27	27	27
July	27	27	27	27	26	27	27	27	27
August	27	27	27	27	27	26	27	27	27
September	27	27	27	27	27	27	27	27	26
October	27	27	27	27	27	27	27	27	27
November	28	28	28	28	28	28	28	28	28
Total Number	191	191	191	191	190	189	191	191	190
Percent	-	100	100	100	99.48	98.48	100	100	99.48
Target Percent	-		≥80%	≥80%	≥80%	≥80%	≥80%	≥80%	≥80%
Number of Duplicates			21	21	21	21	21	20	20
Percent of Total			10.99%	10.99%	11.05%	11.11%	10.99%	10.47%	10.53%
Target Percent			10%	10%	10%	10%	10%	10%	10%

Summary of Mean Relative Percent Differences

Parameter	Target Precision	Mean RPD
Total Suspended Solids	≤ 10%	19.92%
Turbidity	≤ 10%	6.13%
Total Nitrogen	≤ 15%	2.81%
NO3 + NO2	≤ 10%	1.38%
Total Phosphorus	≤ 15%	2.51%
Chloride	≤ 10%	2.30%
E. coli	≤100%	22.50%

2006 Sampling Season

Completeness of Sampling and Field Duplicates

	No. of Stations with Flow	No. of Stations Sampled	Number of Samples: TSS	Turbidity	Total N	NO3 + NO2	Total P	Dissolved P	Chlorides
Month									
June	21	21	21	21	21	21	20	21	21
July	21	21	21	21	20	21	21	19	21
August	21	18	18	18	18	18	18	18	18
September	21	21	21	21	21	21	21	21	21
October	21	21	21	21	21	21	21	21	21
November	21	21	21	21	21	21	21	21	21
Total Number	126	123	123	123	122	123	122	121	123
Percent	-	97.62%	97.62%	97.62%	96.83%	97.62%	96.83%	96.03%	97.62%
Target Percent	-		≥80%	≥80%	≥80%	≥80%	≥80%	≥80%	≥80%
Number of Duplicates			17	17	16	16	15	16	17
Percent of Total			13.82%	13.82%	13.11%	13.01%	12.30%	13.33%	13.82%
Target Percent			10%	10%	10%	10%	10%	10%	10%

Summary of Mean Relative Percent Differences

Parameter	Target Precision	Mean RPD
Total Suspended Solids	≤ 10%	14.93%
Turbidity	≤ 10%	17.19%
Total Nitrogen	≤ 15%	4.27%
NO3 + NO2	≤ 10%	2.90%
Total Phosphorus	≤ 15%	8.58%
Dissolved Phosphorus	≤ 15%	3.86%
Chloride	≤ 10%	1.84%

2007 Sampling Season

Completeness of Sampling and Field Duplicates

	No. of Stations with Flow	No. of Stations Sampled	Number of Samples					
			Turbidity	Total N	NO3 + NO2	Total P	Dissolved P	Chlorides
Month								
June	21	21	21	21	21	21	21	21
July	21	21	21	21	21	21	21	21
August	19	19	19	19	19	19	19	19
September	18	18	18	18	18	18	18	18
October	21*	*	*	*	*	*	*	*
November	21	21	21	21	21	21	20	21
Total Number	121	100	100	100	100	100	99	100
Percent	-	82.6%	82.6%	82.6%	82.6%	82.6%	78.6%	81.8%
Target Percent	-	≥80%	≥80%	≥80%	≥80%	≥80%	≥80%	≥80%
Number of Duplicates			14	14	14	14	14	13
Percent of Total			14	14	14	14	14.14	13
Target Percent			≥10%	≥10%	≥10%	≥10%	≥10%	≥10%

* LaPlatte Watershed not sampled in October

Summary of Mean Relative Percent Differences

Parameter	Target Precision	Mean RPD
Turbidity	≤ 10%	9.45%
Total Nitrogen	≤ 15%	3.72%
NO3 + NO2	≤ 10%	1.73%
Total Phosphorus	≤ 15%	2.84%
Dissolved Phosphorus	≤ 15%	4.41%
Chloride	≤ 10%	1.21%

ANNEX III – Flow Data

Flows* in the LaPlatte River at Falls Road

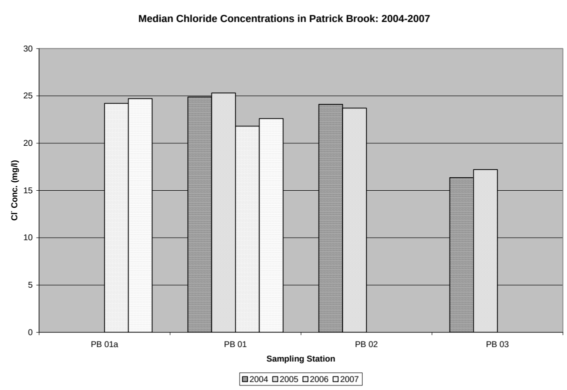
2004	
Date	Flow cfs
22-Jun	8.8
20-Jul	15
31-Aug	500
21-Sep	11.5
19-Oct	6
16-Nov	2.4
2005	
3-May	71
6-Jun	7.05
5-Jul	4.01
2-Aug	19
6-Sep	6.9
4-Oct	8
8-Nov	50
2006	
6-Jun	80
5-Jul	108
1-Aug	13
5-Sep	8.4
3-Oct	18
7-Nov	28
2007	
12-Jun	14
10-Jul	110
14-Aug	1.05
11-Sep	3.8
13-Nov	9

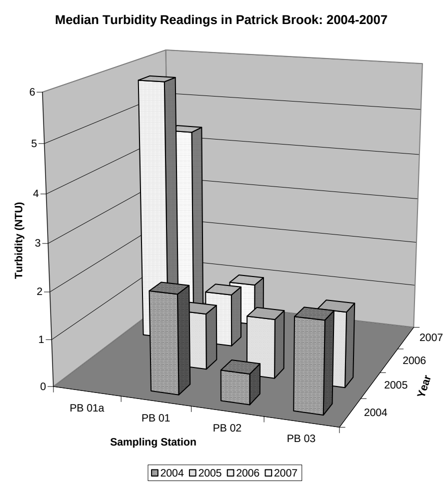
ANNEX IV – Tributary Streams
Patrick and Mud Hollow Brooks

Annex IV-A: Patrick Brook

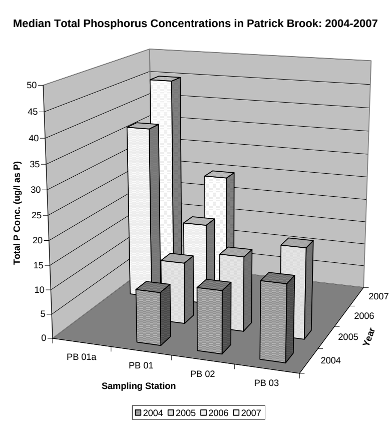
Patrick Brook, was sampled at Pond Road (PB 03), the Hinesburg-Richmond Road (PB 02), and Mechanicsville Road (PB 01) in 2004 and 2005. In general, results were unremarkable over this stretch of the stream, and chloride, suspended sediment, total phosphorus, and nitrogen concentrations were consistently low and indicated no unusual situations. Determination of total suspended solids concentrations was dropped in 2007.

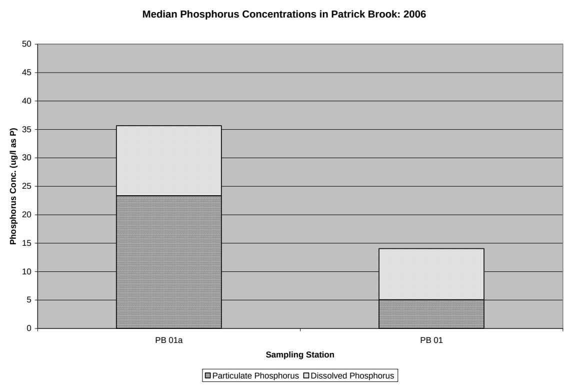
Sampling at the two upstream stations, PB 03 and PB 02, was dropped in 2006, and a new station (PB 01a) was established at Route 16. Land cover/land use (LCLU) between Mechanicsville Road and Route 16 includes vacant land and commercial development. LCLU did influence suspended sediment concentrations measured as

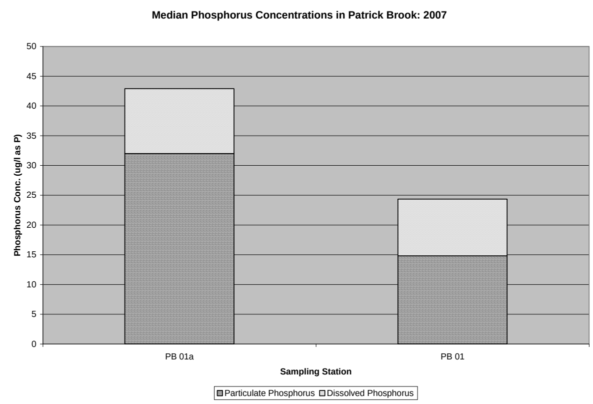




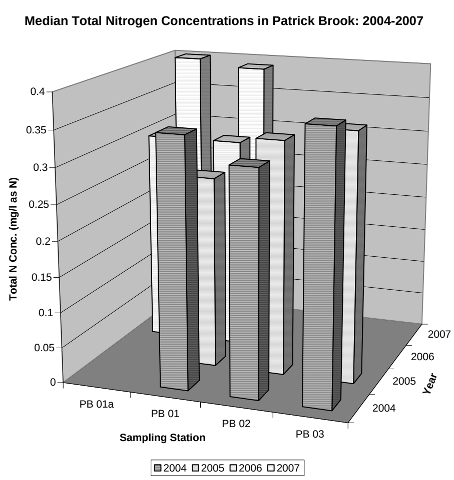
turbidity which increased 4 to 5-fold over this section of the stream. Increases in concentrations of total phosphorus, could be attributed to increases in particulate

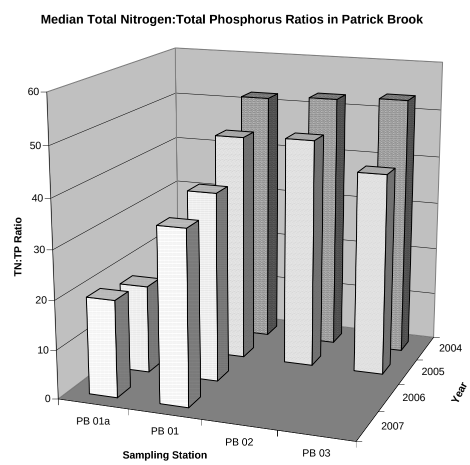






phosphorus concentrations, associated with suspended sediment, but were less pronounced. Nitrogen concentrations were not affected over this section of Patrick Brook. The effect of increasing phosphorus concentrations was a decrease in the TN:TP ratios.





Annex IV-B: Mud Hollow and Bingham Brooks

Mud Hollow Brook and its tributary, Bingham Brook, which enters downstream from station MH 03, were sampled at 4 locations in 2004 and 2005, after which only the downstream station (MH 01) on Mud Hollow Brook was sampled.

Chloride concentrations were generally low (<15 mg/l) except at station MH 03 located below the Charlotte-Hinesburg Road in 2004, a wet summer, when they tended to exceed 15 mg/l. The data appear to suggest a background level of chloride in the range of 10 to 15 mg/l. During high flows (8/31/2004, 7/5/2006, and 7/10/2007), concentrations tended to be lower.

Sampling Station	Yearly Median Chloride Concentrations			
	2004	2005	2006	2007
MH 1	12.75	14.60	11.10	11.40
MH 2	8.99	10.90	-	-
MH 3	21.70	13.50	-	-
BB 1	10.20	9.01	-	-
	8/31/2004*	7/5/2005**	7/5/2006*	7/10/2007*
MH 1	6.19	11.60	7.61	9.51
MH 2	-	7.60	-	-
MH 3	-	12.10	-	-
BB 1	4.03	5.48	-	-

* High flow
** Low flow

Sediment in the Mud Hollow-Bingham Brook watershed tended under normal conditions to increase downstream, and was fairly consistent from year to year at station MH 01 (Spear Street). However, when flows were high (8/31/2004, 7/10/2007), suspended sediment concentrations were high.

Sampling Station	Yearly Median TSS Concentrations			
	2004	2005	2006	2007
MH 1	19.75	20.30	19.05	-
MH 2	6.70	12.90	-	-
MH 3	7.60	4.71	-	-
BB 1	14.30	5.06	-	-
	8/31/2004*	7/5/2005**	7/5/2006*	7/10/2007*
MH 1	138.00	30.00	54	-
MH 2	-	11.80	-	-
MH 3	-	112.00	-	-
BB 1	28.00	24.40	-	-

* High flow
** Low flow

Sampling Station	Yearly Median Turbidity Levels			
	2004	2005	2006	2007
MH 1	25.45	21.4	19.5	21.4
MH 2	7.04	14.9	-	-
MH 3	24.3	8.74	-	-
BB 1	28.1	7.93	-	-
	8/31/2004*	**7/5/2005****	**7/5/2006***	**7/10/2007***
MH 1	199	24.3	110	80.1
MH 2	-	14.9	-	-
MH 3	-	37	-	-
BB 1	84.1	3.5	-	-

* High flow
** Low flow

Total phosphorus concentrations were consistent from year to year at MH 01, but tended to be higher at MH 03. Comparison with sediment loads, which were not high at MH 03, in relation to downstream loads would suggest high dissolved phosphorus concentrations at MH 03. At times of high flow (8/31/2004, 7/5/2006, and 7/10/2007), phosphorus concentrations were high. But at MH 03, the total phosphorus concentration could be high even at low flows (7/5/2005).

Sampling Station	Yearly median Total P Concentrations (µg/l as P)				Yearly median Dissolved P Concentrations (µg/l as P)			
	2004	2005	2006	2007	2004	2005	2006	2007
MH 1	80.79	79.20	84.30	85.30	-	-	38.9	25.1
MH 2	64.27	73.80	-	-	-	-	-	-
MH 3	134.69	123.00	-	-	-	-	-	-
BB 1	81.05	81.50	-	-	-	-	-	-
	8/31/2004*	**7/5/2005****	**7/5/2006***	**7/10/2007***	**8/31/2004***	**7/5/2005****	**7/5/2006***	**7/10/2007***
MH 1	328	79.8	195	153	-	-	112	56.2
MH 2	-	90.5	-	-	-	-	-	-
MH 3	-	382	-	-	-	-	-	-
BB 1	234	159	-	-	-	-	-	-

* High flow
** Low flow

Dissolved phosphorus concentrations, determined only at MH 01 and only in 2006 and 2007, were generally consistent with levels observed throughout the LaPlatte watershed.

Nitrogen concentrations tended to be low (< 1.0 mg/l as N), and nitrate plus nitrite concentrations in general fell below the limit of detection (0.05 mg/l as N). At high flows, total nitrogen concentrations did increase, and on July 10, 2007 exceedeed 3 mg/l as N, while nitrate plus nitrite reached 1.84 mg/l as N at MH 01.

Sampling Station	Yearly Median Total N Concentrations			
	2004	2005	2006	2007
MH 1	0.51	0.60	0.52	0.48
MH 2	0.49	0.61	-	-
MH 3	0.88	0.70	-	-
BB 1	-	0.70	-	-
	8/31/2004*	**7/5/2005****	**7/5/2006***	**7/10/2007***
MH 1	1.40	0.71	1.00	3.19***
MH 2	-	0.73	-	-
MH 3	-	1.52	-	-
BB 1	-	0.93	-	-

* High flow
** Low flow
*** NOx = 1.84 mg/l as N

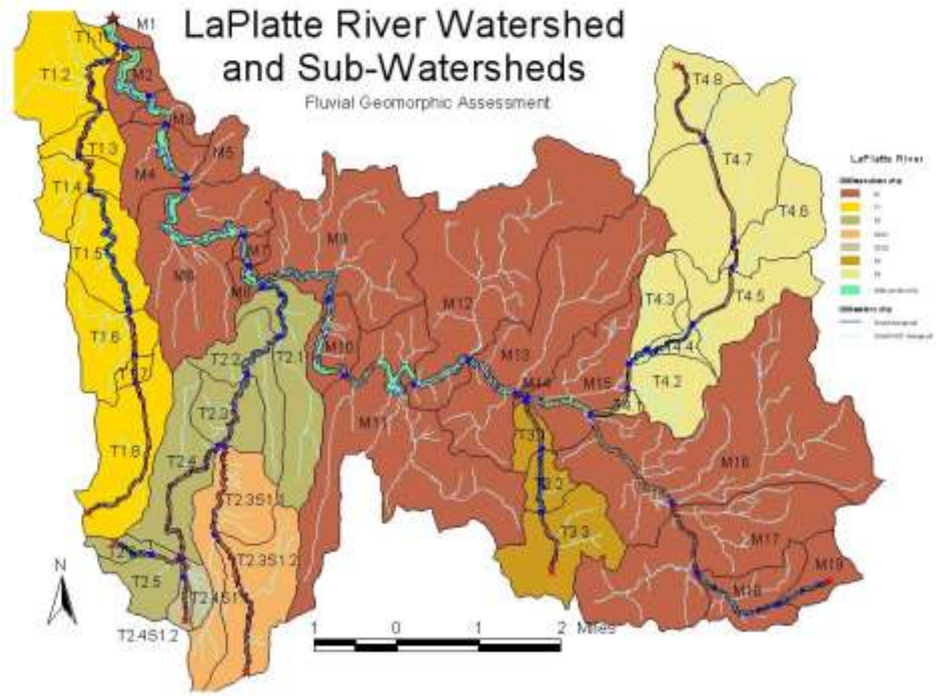
Whereas TN:TP ratios generally fell below 20, the ratio reached 46.1 on July 10, 2007 as a result of the exceptionally high concentration of total nitrogen relative to total phosphorus on that date.

Sampling Station	Yearly Median TN:TP Ratios (molar)			
	2004	2005	2006	2007
MH 1	15.68	16.75	13.23	12.44
MH 2	16.90	17.39	-	-
MH 3	10.27	12.64	-	-
BB 1	13.51	15.55	-	-
	8/31/2004*	**7/5/2005****	**7/5/2006***	**7/10/2007***
MH 1	9.44	19.67	11.34	46.10
MH 2	-	17.84	-	-
MH 3	-	8.80	-	-
BB 1	11.77	12.93	-	-

* High flow
** Low flow

ANNEX V – Fluvial Geomorphology

With funding from the Town of Shelburne under a Special Environmental Project, the LRP undertook a Phase I fluvial geomorphic assessment of the LaPlatte watershed. Whereas sections of stream defined by water quality sampling locations do not coincide with reach points employed in the geomorphic assessment, it can be informative to interpret results in the context of the results of the geomorphic assessment. Thus, although it is not the intent here to discuss the results of the Phase I assessment, the results of that study are summarized in the table for reaches of stream defined by water quality sampling stations. Reaches defined in the fluvial geomorphic assessment are shown below.



In general, the condition of waters within the watershed was fair to good, with portions in poor condition between LP 11 and LP 09, above MB 6, and in Patrick Brook between PB 3 and PB 1. Furthermore, sensitivity was generally medium to high.

It is noted that the report *Lake Champlain Phosphorus TMDL* (Vermont and New York State Departments of Environmental Conservation, *Lake Champlain Phosphorus TMDL*, 2002) calls for long-term research to relate stream geomorphic assessment data to sediment loading expected in each major tributary watershed by measuring sediment loss and phosphorus inputs in selected stream reaches across a variety of conditions.

Summary of Geomorphic Characteristics – LaPlatte Watershed

Sub-Watershed	Geomorphic Reaches	Stream Type	Dominant Adjustment Type	Erodability	Stream Condition	Stream Sensitivity
LP 01-LP 02	M 2, M 1	E, C	Degradation, Degradation	Slight, Slight	Fair, Fair	High, High
LP 02-LP 03	M 3, M 4	C	Degradation, Aggradation	Moderate, Slight	Good, Fair	Medium, High
LP 03-LP 04	M 5-M 8	E, B, C, B	Widening, None, Degradation, Degradation	Slight, Very Severe, Moderate, Very Severe	Fair, Ref., Poor, Good	High, Medium, High, Low
LP 04-LP 05	M 9	B	None	Severe	Good	Medium
LP 05-LP 06	M 9, M 10	C, B	Degradation, None	Moderate, Severe	Fair, Good	High, Medium
LP 06-LP 07	M 11	C	Degradation	Very Severe	Good	Medium
LP 07-LP 08	M 12, M 13	C	Degradation, Aggradation	Slight, Moderate	Good, Fair	Medium, High
LP 08/09-LP 10	M 14-M 16, T 4.1, T 4.2	C, C, E	Aggradation, Planform, None	Slight	Fair, Poor, Good	High, High, Medium
LP 10-LP 11	M 16, M 17	C	Degradation, Aggradation	Slight	Poor, Fair	High
LP 11-LP 12	M 18	B	None	Severe	Good	Medium
LP 12	M 19	A	None	Very Severe	Reference	Low
MB 1/2-MB 3	T 1.3, T 1.4	C, E	Degradation, Degradation	Slight, Slight	Good, Fair	Medium, High
MB 3-MB 4	T 1.5	C	Widening	Severe	Fair	High
MB 4-MB 5	T 1.5	C	Widening	Severe	Fair	High
MB 5-MB 6	T 1.6, T 1.7	C	Degradation, Degradation	Very Severe, Moderate	Fair, Fair	High, Medium
MB 6-MB 7	T 1.8	C	Degradation	Slight	Poor	High
MB 7	T 1.8	C	Degradation	Slight	Poor	High
MH 1-MH 2	T 2.1, T 1.2	C, B	None, Widening	Severe, Severe	Good, Fair	Medium, Medium
MH 2-MH 3	T 2.3, T 2.4	C	Aggradation, None	Moderate, Moderate	Fair, Good	Medium, Medium
MH 3	T 2.4-T 2.6	B, C, C	None, None, Aggradation	Very Severe, Slight, Moderate	Ref., Ref., Fair	Low, Medium, Medium
BB 1	T 2.3 S 1.1, T 2.3 S 1.2	C	Aggradation, Degradation	Slight, Slight	Fair, Fair	High, High
UN 1	T 3.1-T 3.3	C, C, C	Degradation, Degradation, None	Slight, Very Severe, Slight	Fair, Good, Ref.	High, Medium, Medium
PB 1-PB 2	T 4.3, T 4.4	A	Aggradation, Aggradation	Slight, Severe	Poor, Fair	High, Medium
PB 2-PB 3	T 4.5, T 4.6	C	Planform, -	Severe, Slight	Poor, -	High, -
PB 3	T 4.7, T 4.8	C	Degradation, -	Slight, Slight	Fair, -	High, -

ANNEX VI – Phosphorus Export (SPARROW)

It is useful to consider results of water quality sampling in the context of phosphorus export loadings from the LaPlatte Watershed predicted using the SPARROW (Spatially Referenced Regressions on Watershed Attributes) model developed by the USGS in cooperation with the USEPA and the NEIWPCC. This is a statistical model that uses regression equations to predict total nitrogen and total phosphorus loads from sub-watersheds, or catchments, based on spatially referenced watershed characteristics, including physical characteristics (drainage area, stream flow, time of travel, mean slope, soil permeability, stream density), nutrient sources (waste outfalls, cultivated land, forested land, urban and suburban areas), and nutrient sinks (water bodies and wetlands). Nutrient sources are evaluated as a function of location, magnitude, and interaction with watershed characteristics and in-stream processes in water bodies.

The sub-watersheds used in the SPARROW analysis of the LaPlatte watershed are shown in Figures 30a,b, and the results, organized by similar adjacent catchment blocks, are shown in Tables 7 and 8a,b,c (model output results provided by Neil Kamman, Vermont Department of Environmental Conservation). Watershed attributes are provided in Table 7, and export loadings based on three waste discharge scenarios are provided in Tables 8a,b,c and Figures 30a,b.

The input data date from the early 1990s, and in the case of point source treated sewage discharges, consist of data dating from 1992 or earlier. Following up-grading of the Hinesburg treatment plant in 1991, estimated total point source loading to Shelburne Bay was reduced by over 80%. Further reductions were achieved at the Shelburne plant in 2001. Whereas changes in land use may have minor impacts on the results of the SPARROW analysis, the reduced loadings from the sewage treatment plants result in a significant change in loadings within the middle LaPlatte and McCabe's Brook catchments (13562 and 13561, respectively). Table 8a has been adjusted to show point source phosphorus loadings based on permitted discharges (Table 8b), and rough estimates of current discharges (Table 8c). The impact of the adjusted point source loadings on phosphorus export by catchment is illustrated in Figure 30b. The results of the analysis can be interpreted as follows:

Main Stem Patrick Brook (13581, 13583)

P Export Level:- low (<42 kg/km^2)

In spite of moderately steep slopes (9-11%), high permeability (1.7-1.9 in/hr), mostly low stream density, low cultivated area (25-27%), very high forest cover (~60%), and very high water cover (4.57-9.7%) all contribute to reduced sources of P, reduced delivery to the stream system, and effective removal within the catchment area, explaining the low export.

Selected Attributes of Catchments

Value	P Export Kg/Km2	Mean Slope Percent	Mean Perm. in/hr	Stream Density	Total Area Sq. Mi.	Barren Percent	Cultivated Percent	Forest Percent	Wetlands Percent	Water Percent	Urban Percent	Suburban Percent
13581	<42	10.887	1.9193	0.000477	1.354143	0.15	25.74	60.84	2.49	4.57	2.18	4.00
13583	<42	9.327	1.704	0.000199	3.913359	0.37	26.74	60.74	1.74	9.71	0.20	0.48
13582	42-<61	15.1972	1.8015	0.000386	0.417328	1.50	45.05	50.21	2.00	0.00	0.08	1.17
13563	42-<61	11.9569	3.0255	0.000198	9.505063	0.59	37.86	58.69	1.26	0.00	0.89	0.65
13580	42-<61	11.8924	1.8507	0.000666	1.754097	0.73	36.13	54.66	1.25	0.00	3.55	2.97
13562	132-192	7.2671	0.7052	0.000255	17.895747	0.47	54.67	37.42	4.82	0.53	0.94	0.99
13572	61-<99	3.8729	0.5997	0.000535	2.894537	0.12	80.76	13.53	5.02	0.04	0.26	0.28
13579	61-<99	5.1059	0.5846	0.000568	2.147795	0.29	69.83	21.49	7.72	0.00	0.42	0.26
13571	42-<61	5.7092	0.5758	0.000794	2.192968	0.19	39.60	41.94	16.59	0.30	0.63	0.74
13561	99-<132	5.9507	0.5639	0.000357	10.863376	0.17	48.88	32.09	11.49	0.08	2.31	3.46

Phosphorus Export from the LaPlatte Watershed based on SPARROW Model Results

	Area	Treated Waste Discharges			Cultivated Land			Forested Land			Urban Areas			Total P Loadings	
Value	Km2	kgP/ Km2	KgP	%	kgP/ Km2	KgP	%	kgP/ Km2	KgP	%	kgP/ Km2	KgP	%	kgP/ Km2	KgP
13581	3.51	0.00	0	0.0	31.02	109	73.6	8.55	30	20.3	2.59	9	6.1	42.13	147.75
13583	10.14	0.00	0	0.0	32.24	327	78.6	8.54	87	20.8	0.29	3	0.7	41.03	415.88
13582	1.08	0.00	0	0.0	54.30	59	87.8	7.05	8	11.4	0.52	1	0.8	61.84	66.85
13563	24.66	0.00	0	0.0	45.56	1123	83.7	8.24	203	15.1	0.67	16	1.2	54.43	1,342.06
13580	4.54	0.00	0	0.0	43.55	198	80.3	7.68	35	14.2	3.01	14	5.6	54.21	246.30
13562	46.38	120.75	5601	62.7	65.85	3054	34.2	5.25	244	2.7	0.87	40	0.5	192.71	8,938.05
13572	7.51	0.00	0	0.0	97.17	730	97.9	1.90	14	1.9	0.22	2	0.2	99.29	745.60
13579	5.56	0.00	0	0.0	84.16	468	96.2	3.02	17	3.5	0.28	2	0.3	87.45	486.48
13571	5.68	0.00	0	0.0	47.73	271	88.1	5.89	33	10.9	0.57	3	1.1	54.17	307.71
13561	28.14	66.19	1862	49.9	58.91	1658	44.4	4.51	127	3.4	3.02	85	2.3	132.61	3,731.15
Total	137.19		7,462.89	45.4		7,996.40	48.7		797.19	4.9		174.51	1.1		16,427.82

Phosphorus Export from the LaPlatte Watershed Adjusted to Permitted Discharge Loadings

	Area	Treated Waste Discharges			Cultivated Land			Forested Land			Urban Areas			Total P Loadings	
Value	Km2	kgP/ Km2	KgP	%	kgP/ Km2	KgP	%	kgP/ Km2	KgP	%	kgP/ Km2	KgP	%	kgP/ Km2	KgP
13581	3.51	0.00	0	0.0	31.02	109	73.6	8.55	30	20.3	2.59	9	6.1	42.16	147.85
13583	10.14	0.00	0	0.0	32.24	327	78.5	8.54	87	20.8	0.29	3	0.7	41.06	416.16
13582	1.08	0.00	0	0.0	54.30	59	87.8	7.05	8	11.4	0.52	1	0.8	61.87	66.88
13563	24.66	0.00	0	0.0	45.56	1123	83.7	8.24	203	15.1	0.67	16	1.2	54.46	1,342.78
13580	4.54	0.00	0	0.0	43.55	198	80.3	7.68	35	14.2	3.01	14	5.6	54.24	246.44
13562	46.38	7.48	347	9.4	65.85	3054	82.9	5.25	244	6.6	0.87	40	1.1	79.45	3,685.22
13572	7.51	0.00	0	0.0	97.17	730	97.9	1.90	14	1.9	0.22	2	0.2	99.29	745.66
13579	5.56	0.00	0	0.0	84.16	468	96.2	3.02	17	3.5	0.28	2	0.3	87.46	486.55
13571	5.68	0.00	0	0.0	47.73	271	88.1	5.89	33	10.9	0.57	3	1.1	54.20	307.84
13561	28.14	17.64	496	21.0	58.91	1658	70.1	4.51	127	5.4	3.02	85	3.6	84.08	2,365.87
Total	137.19		843.15	8.6		7,996.40	81.5		797.19	8.1		174.51	1.8		9,811.24

Phosphorus Export from the LaPlatte Watershed Adjusted to Estimated 2004 Discharge Loadings

	Area	Treated Waste Discharges			Cultivated Land			Forested Land			Urban Areas			Total P Loadings	
Value	Km2	kgP/ Km2	KgP	%	kgP/ Km2	KgP	%	kgP/ Km2	KgP	%	kgP/ Km2	KgP	%	kgP/ Km2	KgP
13581	3.51	0.00	0	0.0	31.02	109	73.6	8.55	30	20.3	2.59	9	6.1	42.16	147.85
13583	10.14	0.00	0	0.0	32.24	327	78.5	8.54	87	20.8	0.29	3	0.7	41.06	416.16
13582	1.08	0.00	0	0.0	54.30	59	87.8	7.05	8	11.4	0.52	1	0.8	61.87	66.88
13563	24.66	0.00	0	0.0	45.56	1123	83.7	8.24	203	15.1	0.67	16	1.2	54.46	1,342.78
13580	4.54	0.00	0	0.0	43.55	198	80.3	7.68	35	14.2	3.01	14	5.6	54.24	246.44
13562	46.38	1.12	52	1.5	65.85	3054	90.1	5.25	244	7.2	0.87	40	1.2	73.10	3,390.48
13572	7.51	0.00	0	0.0	97.17	730	97.9	1.90	14	1.9	0.22	2	0.2	99.29	745.66
13579	5.56	0.00	0	0.0	84.16	468	96.2	3.02	17	3.5	0.28	2	0.3	87.46	486.55
13571	5.68	0.00	0	0.0	47.73	271	88.1	5.89	33	10.9	0.57	3	1.1	54.20	307.84
13561	28.14	5.29	149	7.4	58.91	1658	82.1	4.51	127	6.3	3.02	85	4.2	71.74	2,018.39
Total	137.19		200.93	2.2		7,996.40	87.2		797.19	8.7		174.51	1.9		9,169.03

Fig. 30a. Phosphorus Export Projections
LaPlatte Watershed
(Projections using SPARROW model)

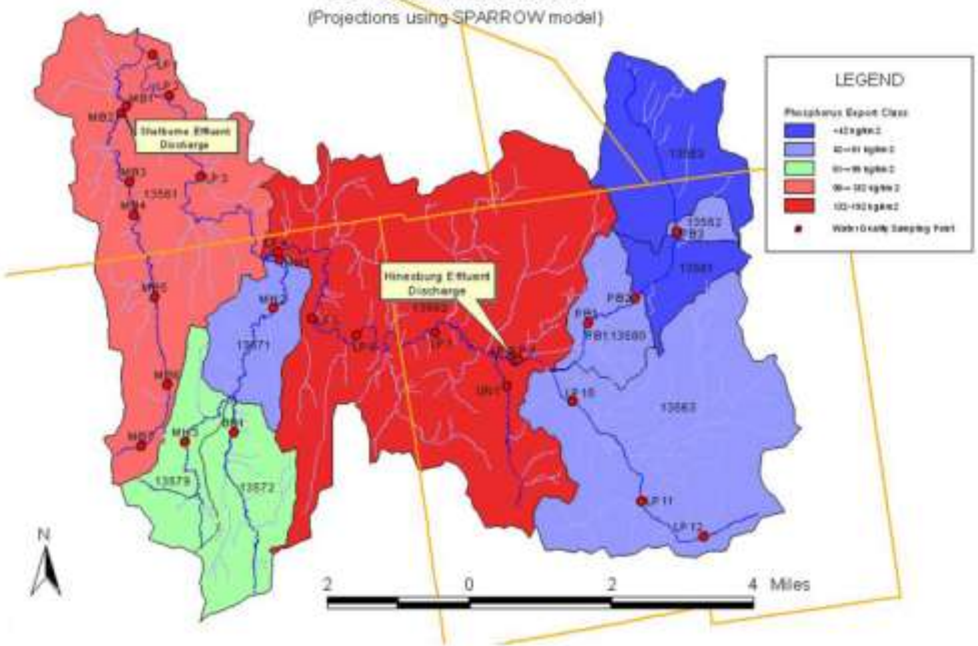
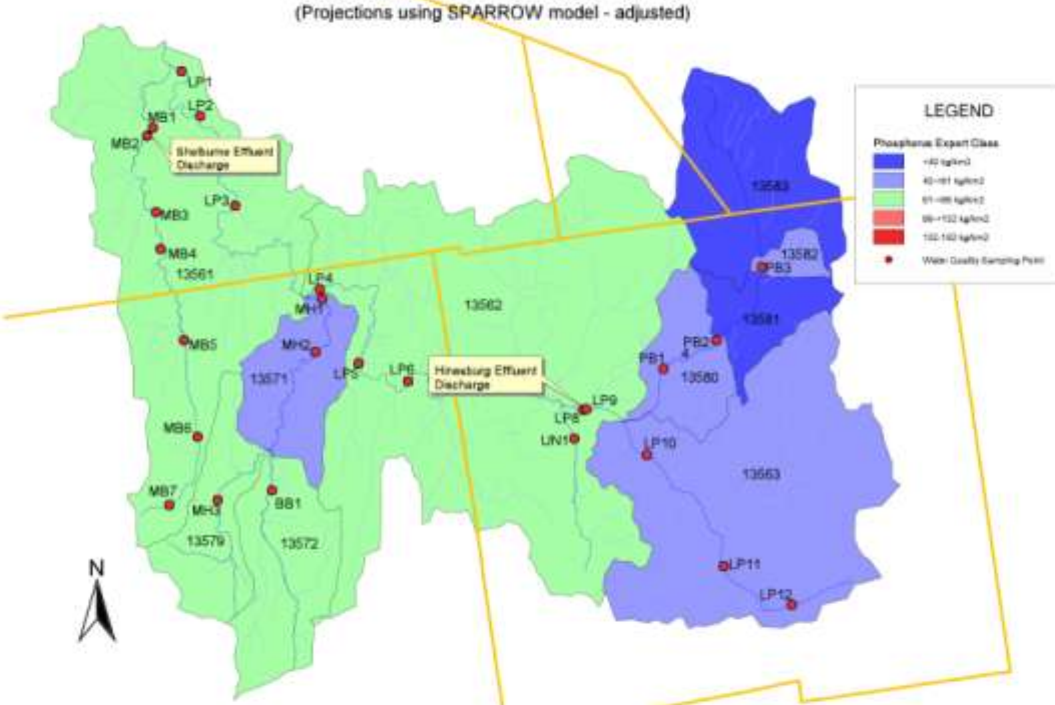


Fig. 30b. Phosphorus Export Projections
LaPlatte Watershed
(Projections using SPARROW model - adjusted)



Eastern Tributaries Patrick Brook (13582)

P Export Level:- low-moderate (42-<61 kg/km^2)

Whereas permeability is high (1.8 in/hr) and stream density is moderate, steep slopes (15%) can bringing runoff more rapidly to water courses, somewhat larger cultivated areas (45%) and lower forested areas (50%), together with the absence water bodies which act as sinks, results in slightly higher export than in the Main Stem of Patrick Brook.

Upper LaPlatte River-Lower Patrick Brook (13563, 13580)

P Export Level:- low-moderate (42-<61 kg/km^2)

Mean slope, stream density, and forested area (54.6-58.7%) are similar to Main Stem Patrick Brook, but permeability is very high, reducing runoff. The increase in P export appears to be the result primarily of greater cultivated area (36-38%).

Middle LaPlatte River (13562)

P Export Level:- SPARROW run, very high (132-192 kg/km^2)
Permitted/current estimate, moderate (61-99 kg/km2)

Physical characteristics are moderately favorable to runoff reaching the river; low-moderate slope (7.27%), low permeability (0.7 in/hr), but low stream density (0.000255). Using inputs employed in running the SPARROW model, moderately high coverage by cultivated areas (54.67%), moderate forest coverage (37.42%), together with low-moderate wetland coverage (4.82%) and low water body area (0.53%), but especially the Hinesburg sewage discharge, explain the very high export of phosphorus from the Middle LaPlatte River catchment. When the loadings from the Hinesburg waste treatment plant were adjusted to permitted and estimated current loadings, cultivated land increased in relative and absolute importance.

Upper Mud Hollow-Bingham Brooks (13572,13579)

P Export Level:- moderate (61-<99 kg/km^2)

This catchment, characterized by low mean slopes (3.9-5.1%), but low permeability (0.57-0.59 in/hr) and high stream density (0.00054-0.00057), included the highest cultivated cover (69.8-80.8%), and the lowest forest cover (13.5-21.5%) of all the LaPlatte River catchments, yet with only moderate wetland coverage (5-7.7%), produced only moderate export levels.

Lower Mud Hollow Brook (13571)

P Export Level:- low-moderate (42-<61 kg/km^2)

The physical characteristics of the Lower Mud Hollow catchment were similar to those of the Upper Mud Hollow-Bingham Brook catchment; mean slope, 5.7%; mean permeability, 0.58 in/hr; stream density, 0.000794. A lower cultivated area (39%), a higher forest cover (42%), and very high wetland coverage (16.6%) explain its lower P export level.

Lower LaPlatte-McCabe's Brook (13561)

P Export Level:- SPARROW run, high-moderate (99-<132 kg/km^2)
Permitted/current estimate, moderate (61-99 kg/km2)

The mean slope (5.95%) and mean permeability (0.56 in/hr) were similar to the mean slope and permeability throughout the Mud Hollow and Bingham Brook watersheds; the stream density was lower (0.000357), suggesting that runoff characteristics are roughly similar. The cultivated portion of the Lower LaPlatte-McCabe's Brook catchment (49%) was greater than that in the Lower Mud Hollow catchment, and the forest cover (32%) and wetland coverage (11.5%) were lower. But of particular importance using inputs employed in running the SPARROW model, was the discharge of treated sewage outfall to McCabe's Brook, explaining, along with a higher percentage of urban (2.3%) and suburban (3.46%) area, its higher P export level. When the loadings from the Shelburne waste treatment plant were adjusted to permitted and estimated current loadings, cultivated land increased in relative and absolute importance.

Overall, the SPARROW model predicted a total phosphorus loading of 16.4 metric tons per year from the LaPlatte watershed. This loading by itself far exceeds the total estimated phosphorus export of 11.8 metric tons to Shelburne Bay from all sources (Lake Champlain Basin Atlas, http://www.anr.state.vt.us/champ/Atlas/PDFmaps/is_pload.pdf). Changing the point source inputs to catchments 13562 and 13561 reduced the total loadings to 9.8 metric tons based on permitted discharges, and 9.17 metric tons based on rough estimates of current discharges from the Hinesburg and Shelburne sewage treatment plants. These reductions resulted in a dramatic change in the relative importance of phosphorus sources. Waste discharge loadings constituting 45% of the total loading employed during the application of the model, dropped to 8.6% and 2.2%, respectively, when permitted and estimated current discharge loadings were used. Under these scenarios, the present day role of "cultivated land," representing 81.5% and 87.2% of the total loadings, respectively.