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Loss of Nutrients and Soil from Sandy Pond Tributaries, Oswego County, N.Y.

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Executive Summary

1. North and South Sandy Ponds comprise one of the largest coastal bay ecosystems on Lake Ontario. Unlike South Sandy Pond, North Sandy Pond supports intensive recreational activities and intensive shorefront residential development including a commercial campground and several marinas. Both ponds have an over abundance of nutrients and are the likely cause of the over abundance of aquatic weeds in the water. The limnological literature is quite clear on the causes of this unwanted overabundance of aquatic weeds and microscopic plants – an excess amount of nutrients or fertilizers are entering the water. A short list of possible sources of nutrients and soil include point and non-point sources in the watershed of Sandy Pond, septic system losses in direct drainage areas adjacent to the Pond (e.g., from cottages and boats), and resuspension of nutrients from sediments in the Pond itself.

2. The purpose of this study was to determine the relative importance of losses of soil and nutrients from the five major tributaries draining sub-watersheds of North Sandy Pond hereafter referred to as Sandy Pond. Stream discharge and concentration of nitrate, total phosphorus, sodium, total suspended solids, and total Kjeldahl nitrogen were measured and converted into the amount of material lost from the watershed or loading into Sandy Pond during events and non-events.

3. In the past three years of tributary monitoring, we have established the importance of meteorological events to the loss of nutrients and material into Sandy Pond. We have also prioritized the sub-watersheds in terms of those losses.

4. For the 27 sampling dates, the average highest non-event (196,594 m^3/day) and event (658,359 m^3/day) flows were observed at Skinner and Little Sandy Creek, respectively.

5. Non-event losses of nutrients from the watersheds are generally low compared to event losses on a per day basis; that is losses from the watersheds are greatest during hydrometeorological events. Generally, daily losses from the watersheds during events are two to ten times the baseline losses for total suspended solids (soils), total phosphorus and total Kjeldahl nitrogen. The only exception to this is the Lindsey Creek watershed, where event and non-event losses are similar for total Kjeldahl nitrogen.

6. Considering daily areal loading, Little Sandy Creek at NYS Route 3 delivered more phosphorus (2.93 g P/ha/day) to downstream habitats than any other watershed during events. Two creeks, Skinner and Little Sandy Creek delivered 82% of the phosphorus entering Sandy Pond. Except for Lindsey Creek, total phosphorus loading (kg/ha/day) was highly correlated with discharge from Sandy Pond watersheds during events (r=0.79-0.89). This suggests that the phosphorus in the particulate form (soil) was being washed off the landscape or eroded from stream banks during periods of high water flow.

7. In general, soil erosion is one of the major sources of nutrient loss from watersheds and was positively correlated with total phosphorus and TKN loss in Sandy Pond. Several watersheds were losing suspended materials at roughly the same rate when normalized by watershed area. In descending order, they were: Lindsey Creek, Blind Creek, Skinner Creek, Little Sandy Creek and Mud Creek. However, Little Sandy Creek and Blind Creek are highlighted as the percentage increase in total suspended losses (soil) from non-events to events exceeded 1,000% (Little Sandy Creek =1162%, Blind Creek = 1,333%) compared to less than 500% in other subwatersheds. For Little Sandy Creek and Skinner Creek, over 11 tons of soil per storm event day were washed into the lake. In contrast, Mud Creek was delivering only 0.6 tons of soil per event per day.

8. The largest amount of nitrate loss to downstream habitats during events in descending order were: Skinner Creek (67.5 g/ha/day), Little Sandy Creek (40.0 g/ha/day), Lindsey Creek (31.5 g/ha/day), Blind Creek (28.0 g/ha/day) and Mud Creek (24.8 g/ha/ day). The same subwatersheds, Little Sandy and Skinner Creeks, also had a relatively high loss of total phosphorus from the upstream watershed. The high losses of nitrate from the Skinner Creek sub-watershed during non-events and events suggests a source within the watershed beyond those caused by elevated nitrate levels in the rain.

9. The higher loss of salt from Little Sandy Creek (1,040 g Na/ha/d) may be associated with deicing salt operations on NYS Route 3 where the sampling site is located.

10. In descending order, the greatest areal loss of total Kjeldahl nitrogen, a measure of organic nitrogen plus ammonia, from the watersheds to downstream systems occurred as follows in descending order: Mud Creek, Little Sandy Creek, Skinner Creek, Blind Creek and Lindsey Creek. Mud Creek was the only sub-watershed having a strong correlation between TKN loss and discharge ($r<0.91$) and suggests that organic nitrogen is being washed off the landscape. In the other four watersheds, total Kjeldahl nitrogen loading was not highly correlated with discharge from tributaries from Sandy Pond during events ($r<0.5$). In these watersheds, concentration of TKN was not significantly different between events and non-events. This suggests that major sources of organic nitrogen are not being swept off the landscape.

11. Comparison of the rate of nutrient loss from Sandy Pond sub-watersheds to watersheds with various land uses in western and central New York is instructive. Non-event phosphorus loss from Sandy Pond tributaries is similar to other watersheds in western and central New York irregardless of land use. However, during events, loss of phosphorus from Sandy Pond sub-watersheds are similar and comparable to the relatively unpolluted streams of Canandaigua Lake. Compared to selected tributaries draining watersheds known to deliver high losses of nutrients and materials because of land use, such as in Oneida Lake and Lake

Neatahwanta, losses of nutrients from the Sandy Pond sub-watersheds are low.

Recommendations

1. **Since the largest amount phosphorus delivered into Sandy Pond is from Little Sandy Creek, a stressed stream analysis/segment analysis should be considered.** Stressed stream analysis or segment analysis is a technique that identifies the sources of pollutants within a watershed by subdividing the impacted watershed into small distinct geographical units. Samples are taken at the beginning and end of each stream unit to determine if a nutrient (or other contaminant) source occurs within that reach. We have found this technique very useful in identifying point and non-point sources that are not always obvious. Identified sources can then be targeted for remediation and best management practices.

2. **The high loss of soil (TSS) from Blind Creek per unit area of watershed suggests that soil erosion is occurring from a relatively small watershed.** Similarly, the high loss of organic nitrogen per unit area of watershed in the Mud Creek watershed is suggestive of a source. As with phosphorus, a segment analysis could be used to identify locations of these losses.

3. Within the Sandy Pond watershed, the greatest loss of phosphorus and nitrate is from Little Sandy Creek and Skinner Creek during hydrometeorological events. However, it should be noted that these losses are not excessive when compared to losses from other watersheds known to be delivering large amounts of material because of land use practices**. Although reductions in nutrient loss can be accomplished by better management of the watershed, there may be other causes for the excessive macrophyte and algal development that occurs in Sandy Pond. A seasonal study of the Pond itself is warranted to determine if other sources of nutrients exist at or near the Pond's shoreline.** That is, seasonal levels of phosphorus and other nutrients, and algal abundance (i.e., chlorophyll) and coliform bacteria should be monitored to determine if sources exists within the Pond's shoreline. What is the thermal regime? Do lower layers of Sandy Pond become anoxic allowing phosphate to move in from the sediment? What role, if any, does wave action in resuspension of sediments and nutrient levels in the Pond. This study should have a geographic component to it. Also, the relationship between depth and phosphorus inputs should be established (Vollenweider analysis) to determine if the shallowness of the Pond may play a role in its excessive productivity.

Introduction

North and South Sandy Ponds comprise one of the largest coastal bay ecosystems on Lake Ontario (Fig. 1). North and South Sandy ponds are embayments formed by the eastern Lake Ontario sand dunes that form a ridge on the landward side of the beach, creating a barrier between the lake and inland areas. The extensive dune system and sheltered littoral areas found here are rare in New York's coastal waters. The barrier beaches at North Sandy Pond are unique and play an integral role sheltering the pond from prevailing winds, buffering water level fluctuations in nesting areas for birds and providing a refuge for concentrations of waterfowl during spring and fall. The abundance and diversity of birds occurring in this area are rarely equaled anywhere else on Lake Ontario. Unlike South Sandy Pond, North Sandy Pond supports intensive recreational activities and intensive shorefront residential development including a commercial campground and several marinas.

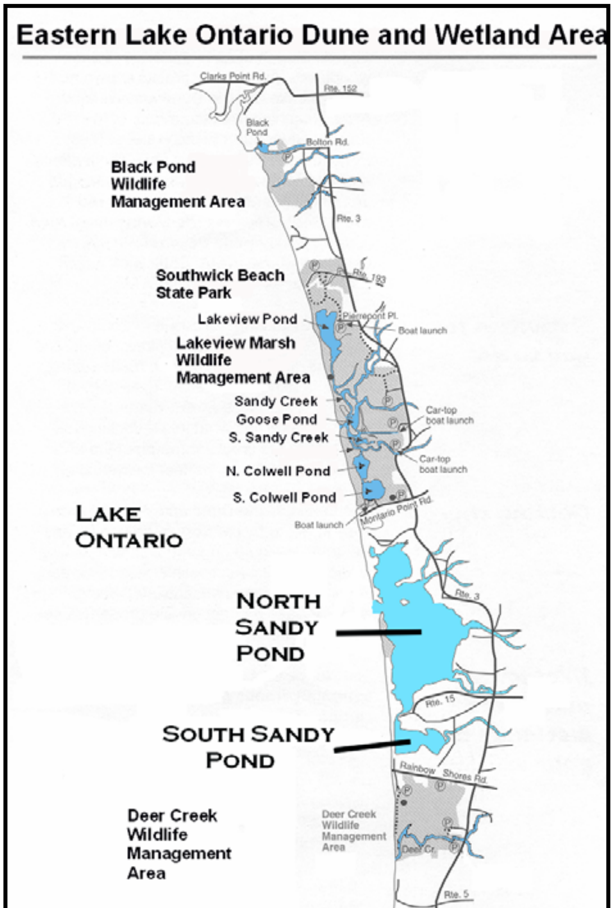

Figure 1. The east shore of Lake Ontario

Both ponds have an overabundance of nutrients and are the likely cause of the overabundance of aquatic weeds in the water (Makarewicz 2000). Aquatic vegetation forms large mats of weeds restricting recreational usage of the area. In places, the water milfoil (*Myriophyllum spicatum*) mats are so thick and dense that navigation is restricted and motor boat water intakes become clogged risking serious damage to engines. In addition, algae blooms, an overabundance of microscopic plants, become so prevalent that a thick green slime occurs on the surface water from June through October. As these algae die, bacteria decompose them and produce foul odors, a decrease in oxygen in the water and promote possible fish kills. Aesthetically this is not pleasing nor is this situation a positive force for economic development through recreation or for home owners on these bays.

The limnological literature is quite clear on the causes of this unwanted overabundance of aquatic weeds and microscopic plants – an excess amount of nutrients or fertilizers are entering the water. Cultural eutrophication has resulted in poor water quality including lack of clarity, high algal abundance and high weed abundance that ultimately decreases the aesthetic appeal of these waters to year-round residents and to the tourism industry

(Makarewicz 2000). Marinas and swimming areas become clogged with macrophytes or weeds inhibiting boat traffic, bathing and even fishing. At both North and South Sandy Ponds nutrients from agriculture run-off, septic system failures, “gray water” discharge, and lawn run-off are believed to be major sources of nutrients (Makarewicz 2000). The Oswego County Soil and Water Conservation District seeks to reduce non-point and point source loading of nutrients into Sandy Pond. The purpose of this study is to determine the relative importance of losses of soil and nutrients from the five major tributaries draining sub-watersheds of Sandy Pond. This was done by monitoring stream discharge and nutrient concentration over a three-year period during hydrometeorological events and non-events.

Definitions

Total Phosphorus- A measure of all forms of the element phosphorus. Phosphorus is an element required for plant growth on land or in water. In lakes, phosphorus is often the limiting factor of phytoplankton growth and is the cause of eutrophication, or overproduction, of lakes. Phosphorus may enter a watershed in soluble or organic form from several sources including sewage, heavy-duty detergents, fertilizer and agricultural waste. Some forms of phosphorus are more available to and cause more immediate activity in, plants.

Nitrate + Nitrite- A measure of the soluble forms of nitrogen used readily by plants for growth. Sources of nitrates in the environment are many and include barnyard waste and fertilizer.

Total Kjeldahl Nitrogen- The Kjeldahl method is a convenient method of analysis for nitrogen but cannot be used for all types of nitrogen compounds. It is, however, a good measure of organic nitrogen, including ammonia. Manure, for example, contains a large amount of organic nitrogen.

Sodium - A measure of the mineral, most commonly found as sodium chloride (NaCl), dissolved in water. NaCl naturally occurs in deep layers of local bedrock. Mined, it is stored and spread as a de-icing agent on roads and other pavements.

Total Suspended Solids - A measure of the loss of soil and other materials suspended in the water from a watershed. Water-borne sediments act as an indicator, facilitator and agent of pollution. As an indicator, they add color to the water. As a facilitator, sediments often carry other pollutants, such as nutrients and toxic substances. As an agent, sediments smother organisms and clog pore spaces used by some species for spawning.

Methods

Water samples and chemical and physical measurements were taken at five sites (Fig. 2, Appendix 2): Blind Creek, Lindsey Creek, Little Sandy Creek, Mud Creek and Skinner Creek. Temperature, dissolved oxygen, turbidity, and pH were measured in situ with a YSI Hydrolab Datasonde 4 by Oswego County Soil Water and Conservation District personnel. Over 130 water samples were taken during nine hydrometeorological events and 17 non-events from 7 January 2000 to 9 October 2002. Sample water for dissolved nutrient analysis (nitrate + nitrite) was filtered immediately with 0.45-μm MCI Magna Nylon 66 membrane filters and held at 4°C and transported to SUNY Brockport for water chemistry analysis.

All sampling bottles were pre-coded so as to ensure exact identification of the particular sample. All filtration units and other processing apparatus were cleaned routinely with phosphate-free RBS. Prior to sample collection, containers were rinsed with the water being collected. In general, all procedures followed EPA standard methods (EPA 1979) or Standard Methods for the Analysis of Water and Wastewater (APHA 1999). At the SUNY Brockport NELAC certified water laboratory, water was analyzed for total phosphorus (TP), nitrate + nitrite, total suspended solids (TSS),total Kjeldahl nitrogen (TKN) and sodium. Detailed methodology follows:

Figure 2. Sandy Pond tributaries showing sampling sites

Water Chemistry:

<u>Nitrate + Nitrite:</u> Dissolved nitrate + nitrite nitrogen analyses were performed by the automated (Technicon Autoanalyser) cadmium reduction method (EPA 1979, APHA 1999).

<u>Total Phosphorus:</u> Raw water was digested using the persulfate digestion procedure prior to analysis by the automated (Technicon autoanalyser) colorimetric ascorbic acid method (APHA 1999).

<u>Total Kjeldahl Nitrogen:</u> Analysis was performed using a modification of the Technicon Industrial Method 329-74W/B. The following modifications were performed:

1. In the sodium salicylate-sodium nitroprusside solution, sodium nitroferricyanide (0.4g) replaced the concentrated nitroprusside stock solution.
2. The reservoir of the autoanalyser was filled with 0.2M H_2SO_4 instead of distilled water.
3. Other reagents were made fresh prior to each analysis.

<u>Total Suspended Solids:</u> APHA (1999) Method 2540D was employed for this analysis.

<u>Sodium</u>: Sodium was determined by atomic absorption spectrophotometry (Perkin Elmer

Analyst 100) (APHA 1999) on filtered samples.

Stream Velocity: Stream velocity was measured at equally spaced locations in either a culvert or cement channel of a bridge under a road with a Global Water Flow Probe (Chow 1964) with the exception of 13 May 2002. On this date, a Weather-Measure water current meter was used. The number of velocity readings taken varied with the width of the stream. They varied from a low of three at Blind and Mud Creeks to a high of six at Skinner and Little Sandy Creeks.

Stream Height and Cross-Sectional Area: Stream depth was measured as the difference between the vertical height of the culvert/bridge opening and the distance between the stream surface and upper portion of the culvert/bridge. Stream cross-sectional area for various stream heights was calculated by planimetry after measuring the cross-sectional dimensions of each stream monitored at the culvert or bridge opening.

Discharge: Discharge was calculated using standard USGS protocol following Measurement and Computation of Streamflow by Rantz *et al*. (1982). In general, the area-velocity method was used where cross-sectional area and velocity are physically measured during each sampling trip across the width of the streambed.

Watershed Area: Subwatershed areas provided by the OCSWCD (Oswego County Soil and Water Conservation District) were estimated from USGS topographic maps.

Nutrient Loading: Daily nutrient and soil loss from the watershed were calculated by multiplying the discharge on the day of the sample by the concentration of the nutrient or solids from the appropriate water sample.

Statistics: Regression analysis and Student's T-test were performed on Microsoft Excel**.** The two-sample student's t-test assumed that the variances of both ranges of data are unequal (heteroscedastic t-test). A probability value of 0.05 was employed.

Problems with Data Sets: No discharge data were taken on 24 November 1999 and there were no estimates of stream flow in all streams on 5 February 2002 and 9 October 2002 due to thick surface ice or drought conditions, respectively. Loss of nutrients from the watershed were not calculated for those dates.

Quality Control

Quality Assurance Internal Quality Control:

Multiple sample control charts (APHA 1999) were constructed for each parameter analyzed, except total suspended solids. A prepared quality control solution was placed in the analysis stream for each sampling date. If the control solution was beyond the set limits of the control chart, corrective action was taken and the samples re-run.

External Quality Control:

The Water Chemistry Laboratory at SUNY Brockport is certified through the New York State Department of Health's Environmental Laboratory Approval Program (EPA Lab NY01449). This program includes biannual proficiency audits, annual inspections and good laboratory practices documentation of all samples, reagents and equipment (Appendix 1). SUNY Brockport is also certified through the National Environmental Laboratory Accreditation Conference.

Results and Discussion

Physical Measurements and Concentration of Analytes

Temperature:

Stream temperatures were not significantly different between the five streams sampled entering North Sandy Pond, hereafter referred to as Sandy Pond, during the study period. Average seasonal non-event temperatures measured by SWCD personnel ranged from 55.0 to 57.3 ^{o}F, while event average seasonal temperatures were slightly lower (range = 46.2 to 49.0^{o}F) (Table 2). Event temperatures are lower because hydrometeorlogical events tend to occur during the winter and spring.

pH:

pH is a measure of the hydrogen ion concentration or acidity of the water. Average seasonal pH at all sites were basic during events (range = 7.01 to 7.46) and non-events (range = 7.63 to 7.90) for all streams (Table 2). Event pH was more acidic reflecting the fact that precipitation in the region is acidic.

Specific Conductance:

Specific conductance is a measure of the ability of an aqueous solution to carry an electric current. The greater the amount of dissolved solids in the water, the greater the electrical current that can be carried by the water. Average seasonal non-event specific conductance ranged from 314 mS/cm at Mud Creek to a low of 170 mS/cm at Little Sandy Creek (Table 2). Average event seasonal specific conductance was significantly lower than non-event specific conductance (Table 2) ranging from a low of 121 mS/cm at Little Sandy Creek to a high of 232 mS/cm at Blind Creek. The significantly lower event values suggest dilution of baseline runoff by precipitation containing little or no inorganic dissolved substances.

Total Suspended Solids:

Total suspended solids (TSS) is a measure of materials suspended in the water column. The suspended materials could be soil, microscopic organisms called phytoplankton and zooplankton, and bacteria. Average seasonal event TSS was higher (range = 16.5 to 26.6 mg/L) in all streams except for Mud Creek (11.1 mg/L), although significantly higher ($P<0.05$) concentration was only observed at Lindsey Creek. At Mud Creek, TSS concentrations during non-events (23.5 mg/L) were significantly higher than during events (11.1 mg/L) (Table 2).

Dissolved Oxygen:

Dissolved oxygen is required by fish to live in water. Oxygen concentrations were typically high (> 9.0 mg/L) at all sites (Table 2) and support fish life. Event oxygen levels were higher than during non-events. Event water represents rain that is often near oxygen saturation for a given temperature.

Total Kjeldahl Nitrogen:
Total Kjeldhal nitrogen (TKN) is a measure of organic nitrogen plus ammonia. In all cases, average seasonal baseline TKN concentrations (range = 0.32 to 0.43 mg N/L) were higher, but not statistically significant, than event concentrations (range = 0.17 to 0.25 mg N/L) for each respective stream (Table 2). This was a surprising result and suggests that organic nitrogen is not being washed off the watershed (e.g., pasture land or land sprayed with manure) during events.

Nitrate +Nitrite:
Nitrate is a measure of the soluble forms of nitrogen used readily by plants for growth. Sources of nitrates in the environment are many and include barnyard waste and fertilizer. Mean event nitrate concentrations were significantly higher (range = 0.37 to 0.88 mg N/L) than non-events (range = 0.18 to 0.43 mg N/L) for each respective stream (Table 2). These higher concentrations observed during events are probably related to the elevated levels in rainfall known to occur in the Oswego area.

Total Phosphorus:
Phosphorus is considered the limiting nutrient to growth of microscopic plants (i.e., algae) and macrophytes (i.e., weeds). It is a fertilizer and excessive amounts will stimulate the growth of plants. Except for Mud Creek, average seasonal event (20 to 31µg P/L) total phosphorus concentrations were higher than non-events (range= 15 to 25 µg P/L) (Table 2). In Little Sandy Creek and Skinner Creek, event concentrations were significantly higher than non-events. Event and non-event average seasonal phosphorus concentrations were the same (25 µg P/L) for Mud Creek.

Sodium
Sodium is a measure of the mineral, most commonly found as sodium chloride (NaCl), dissolved in water. There were no significant differences in means of events and non-events.

LOSS OF MATERIALS AND NUTRIENTS FROM THE WATERSHED

Although concentration of pollutants are a useful piece of information in evaluating streams, these data are limited and may lead to an inaccurate conclusion. The total loss of a pollutant from a watershed or loading to downstream systems is a better measurement of a watershed's impact because it considers the volume of water in addition to the concentration of the nutrient in that water. A stream with a high concentration of a nutrient but a low discharge will have less of an impact on downstream systems than a stream with high discharge and a moderate concentration of a nutrient.

The current sampling scheme provides a “snapshot” for an instant in time. We have 27 snapshots (i.e. sample dates) or instances in time where samples were taken, which is a fairly good representation of likely conditions over a three-year period of time. Because flow or discharge was not monitored continuously, time trend analysis within the study period or into the future is not possible. However, prioritization of subwatersheds based on the amount of nutrients and materials lost from a subwatershed is possible and has been done below. It should be noted that these rankings may change as more sampling dates are added to the data base. However, this is unlikely with a relatively large number of sampling dates.

Direct comparisons of watersheds using areal losses (loss per watershed area) are used in this report (Table 3, Figs. 3 and 4), although non-weighted nutrient losses are also presented (Table 4, Figs. 5 and 6). By calculating the loss per unit area of watershed, we normalize the results so that subwatersheds of different areas can be effectively compared. A watershed with a high loss of nutrients per unit area compared to another would suggest that a non-point or point source of nutrients exists in this watershed. Also by considering areal loading, prioritization or ranking of watersheds for remedial action is possible. The data is separated into events and non-events reflecting the design of the sampling strategy whereby samples were taken during hydrometeorological events and non-events.

Average Daily Losses During Events and Baseline Conditions:

Each bar graph in this series of graphs (Figs. 3 and 4) represents the nutrient or material losses from a tributary and its associated watershed normalized by the size of the watershed to allow direct comparison of each tributary - sometimes termed areal loading. The blue bar (lighter bar) is average daily event loading; the red bar (darker bar) represents the average daily baseline or non-event loading to Sandy Pond from the five sub-watersheds.

Discharge (Tables 3 and 4, Figure 5a)

For the 27 sampling dates, the average highest non-event (196,594 m^3/day) and event (658,359 m^3/day) flows were observed at Skinner and Little Sandy Creek, respectively. The lowest flows were observed at Blind Creek (baseline: 7,088 m^3/day, event: 37,801 m^3/day) and Mud Creek (baseline: 11,104 m^3/day, event: 43,555 m^3/day). Except for Lindsey and Skinner Creeks, where flow increased by only 100% and 117%, respectively, from baseline conditions, all the other sampling locations experienced significantly higher event flows ranging as high as 397% (Little Sandy Creek) and 433 % (Blind Creek) over baseflow.

Phosphorus (Tables 3 and 4, Figure 3a):

The loss of total phosphorus during events from Sandy Ponds' subwatersheds was always higher than baseline losses. Baseline losses from each subwatershed were variable (0.13 to 0.50 g/ha/day), but much lower than event losses (1.30 to 2.93 g/ha/day). Considering daily areal loading, Little Sandy Creek at NYS Route 3 delivered more phosphorus (2.93 g P/ha/day) to downstream habitats than any other watershed during events (Fig. 3a). Skinner Creek at Weaver Road also had high event losses of total phosphorus relative to other Sandy Pond subwatersheds. Except for Lindsey Creek, total phosphorus loading (kg/day) was highly correlated with discharge from Sandy Pond watersheds during events (r=0.79-0.89)(Table 5). Also, loss of phosphorus was highly correlated with soil loss in Mud, Blind and Skinner Creeks (r^2= 0.67 to 0.96). This suggests that the phosphorus in the particulate form (soil) was being washed off the landscape or eroded from stream banks during periods of high water flow.

By considering the total loading of a subwatershed (not normalized by area of the subwatershed), a better sense of the amounts of phosphorus being delivered into Sandy Pond by a subwatershed is possible. For example, Little Sandy Creek, which had the highest areal loading to Sandy Pond, was delivering 45 lbs of phosphorus per storm event day. Since phosphorus is generally considered to be the limiting nutrient of phytoplankton growth in freshwater lakes, any remedial program to protect the water quality of Sandy Pond should develop a phosphorus reduction strategy with the various subwatersheds of Sandy Pond. Clearly, Little Sandy and Skinner Creeks are delivering the largest amounts of phosphorus on areal basis and non-areal basis during events and non-events (Tables 3 and 4).

Nitrate (Tables 3 and 4, Figure 3b)

Nitrate is a measure of the soluble forms of nitrogen that are used readily by plants for growth. The largest amount of nitrate loss to downstream habitats during events in descending order were: Skinner Creek (67.5 g/ha/day), Little Sandy Creek Creek (40.0 g/ha/day), Lindsey Creek (31.5 g/ha/day), Blind Creek (28.0 g/ha/day) and Mud Creek (24.8 g/ha/ day). Both Little Sandy and Skinner Creeks also had relatively high losses of total phosphorus from the upstream watershed. Compared to the other subwatersheds, Skinner Creek had a relatively high loss of nitrate from the watershed during non-events – as high as event losses from Blind and Mud Creeks. The high loss of nitrate during both events and non-events from Skinner Creek suggests a source in the watershed above elevated levels observed in rainfall in the Oswego area.

Total Suspended Solids (Tables 3 and 4, Figure 4a)

The loss of suspended solids is a measurement of the loss of soil and other materials suspended in the water from a watershed and can be used as a measure of soil erosion. In general, soil erosion is one of the major sources of nutrient loss from watersheds and is often positively correlated with total phosphorus and TKN loss as in the southern Oneida Lake tributaries (Makarewicz and Lewis 2000). Loss of phosphorus from Blind, Mud and Skinner Creeks was highly correlated with loss of soil (range of r = 0.82 to 0.98). Several watersheds were losing suspended materials at higher areal levels compared to other watersheds. In descending order, they were: Lindsey Creek, Blind Creek, Skinner Creek, Little Sandy Creek and Mud Creek. However, Little Sandy Creek and Blind Creek are highlighted as the percentage increase in total suspended losses (soil) from non-events to events exceeded 1,000% (Little Sandy Creek =1062%, Blind Creek = 1,234%) compared to less than 500% in other subwatersheds.

Another way of gauging the impact of a watershed is to consider the total loading from the watershed - that is not normalizing the data for area. For Little Sandy Creek and Skinner Creek, over 11 tons of soil per storm event day were washed into the lake. In contrast, Mud Creek was delivering only 0.6 tons of soil per event per day.

Total Kjeldahl Nitrogen (Tables 3 and 4, Figure 4b)

Total Kjeldahl nitrogen (TKN) is a measure of the organic nitrogen and ammonia loss from the watershed. For example, cow manure would contain a large amount of organic nitrogen. In descending order, the greatest event areal loss of total Kjeldahl nitrogen from the watershed to downstream systems was: Mud Creek, Little Sandy Creek, Skinner Creek, Blind Creek and Lindsey Creek. Total Kjeldahl nitrogen loading was not highly correlated with discharge from tributaries from Sandy Pond during events ($r<0.5$, Table 5). This suggests that nitrogen, in the particulate from, is not being washed off the landscape. Mud Creek was the only exception having a strong correlation between TKN loss and discharge (Table 5). Event (9.3 g N/ha/d) and non-event losses (7.8 g N/ha/d) from Lindsey Creek were similar suggesting that sources of nitrogen on the landscape were minimal.

Sodium (Tables 3 and 4, Figure 4c)

Sodium is a component of deicing salt. Unlike the other chemical analytes discussed where the highest concentration often occurred during hydrometeorologic events, concentrations of sodium were often similar between events and non-events. Because discharge was considered during the calculation of loading, loss of salt during events was greater than during baseline flows. Little Sandy Creek, followed by Lindsey Creek, Skinner Creek, Mud Creek and Blind Creek, delivered the highest amount of salt to downstream systems on an areal basis. The high loading of salt from Little Sandy Creek may be associated with deicing salt operations on NYS Route 3 where the sampling site is located.

Comparison to Other Watersheds

The various creeks of the Irondequoit Bay watershed (Monroe County, NY) have been identified as grossly polluted prior to remedial action (O'Brien and Gere 1983). Similarly, Northrup Creek (central Monroe County), which receives effluent from a sewage treatment plant, is known to be polluted and to possess a higher loading of phosphorus than creeks in the Irondequoit Bay watershed (Makarewicz 1988). A comparison of Sandy Pond tributaries to other creeks in western and central New York State has been made (Tables 6 and 7). Table 6 presents the loss of phosphorus from watersheds based on average "annual" daily loss from selected watersheds that consider both event and nonevent losses based on continuous discharge measurements. Sandy Pond "annual" daily average was not possible with the current data. Instead, we compared "daily" averages calculated separately for nonevents and events for Sandy Pond tributaries to the annual daily averages from several tributaries in Canandaigua and Oneida Lakes (Table 7). Although made, these comparisons should be interpreted carefully.

Comparison to watersheds with various land uses in western and central New York suggest phosphorus loss from tributaries in the Sandy Pond watershed are low and similar to losses experienced during non-events. However during events, losses from Sandy Pond tributaries are low compared to watersheds known to have high losses from the watershed due to land use practices (Table 7). For example, event losses of phosphorus from Limestone Creek (LS1, 24.6 g P/ha/d), Cowaselon Creek (CW1)(31.3 g P/ha/d), Canaseraga Creek (CN1) (24. 8 g P/ha/ d) and Oneida Creek (ON1) (14.4 g P/ha/d), all sub-watersheds of Oneida Lake, are substantially higher than event losses from Liitle Sandy Creek (2.9 g P/ha/d). Similarly, average annual daily losses from Sheldon Creek (27.4 g P/ha/d), a sub-watershed of Lake Neatahwanta, are substantially higher (Table 6) than any of the Sandy Pond tributaries. These Oneida Lake and Lake Neatahwanta tributaries are ether in agriculture or have sewage treatment plants located within the watershed. Event and non-event losses from Sandy Pond are more in line with tributaries from Canandaigua Lake (Table 7). Most of these tributaries are fairly forested. These comparisons between lakes suggest that losses of nutrients from Sandy Pond watersheds are not excessively high.

Acknowledgements

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Table 2. Average concentrations in selected Sandy Pond tributaries during events and nonevents. B+E refers to the average for hydrometerological events and baseline (non-events) conditions. Mean = average concentration, S.E. = standard error, TP = total phosphorus, TKN = total Kjeldahl nitrogen, TSS = total suspended solids, Temp. = water temperature, DO = dissolved oxygen, Turb. = Turbidity, SC = specific conductance.

		TP (mg/l)		Nitrate (mg/l)		TKN (mg/l)		Sodium (mg/l)		TSS (mg/l)		Temp (°F)		DO (mg/l)		pH		Turb (NTU)		SC mS/cm	
Creek		Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
Little Sandy Creek	Baseline	0.021	0.004	0.22	0.05	0.32	0.06	9.2	1.1	8.6	2.4	57.3	2.6	9.78	0.78	7.63	0.17	2.5	0.9	170.0	13.9
	Event	0.028	0.008	0.39	0.07	0.17	0.06	12.5	3.0	16.5	5.5	46.2	5.8	11.92	1.21	7.01	0.24	10.2	5.8	120.7	9.4
	B+E	0.023	0.003	0.28	0.04	0.27	0.04	10.4	1.2	10.4	2.3	55.1	5.5	10.50	0.62	7.23	0.49	5.0	1.8	153.6	10.2
Blind Creek	Baseline	0.016	0.003	0.18	0.04	0.43	0.08	14.6	1.0	18.4	2.5	55.0	2.7	9.39	0.78	7.75	0.16	4.4	1.5	289.5	13.2
	Event	0.027	0.010	0.38	0.09	0.25	0.09	16.4	2.8	26.6	12.0	48.7	5.9	11.18	1.47	7.39	0.17	19.1	9.7	232.3	25.4
	B+E	0.020	0.004	0.25	0.04	0.37	0.06	15.2	1.0	15.2	4.0	53.2	2.4	9.89	0.64	7.64	0.12	8.5	2.7	273.5	11.8
Mud Creek	Baseline	0.025	0.004	0.23	0.03	0.38	0.05	14.2	1.1	23.5	3.8	56.1	2.9	9.52	0.82	7.79	0.15	4.0	1.3	314.4	14.7
	Event	0.025	0.005	0.41	0.08	0.24	0.06	14.3	2.7	11.1	3.1	49.0	6.7	10.48	1.17	7.41	0.18	11.2	3.4	207.3	36.3
	B+E	0.025	0.003	0.29	0.03	0.33	0.04	14.2	1.1	14.2	2.7	54.1	2.5	9.79	0.62	7.68	0.12	6.0	1.3	284.4	16.1
Lindsey Creek	Baseline	0.015	0.001	0.20	0.04	0.38	0.08	16.1	1.4	12.8	1.7	56.6	3.0	9.97	0.75	7.90	0.16	6.9	2.6	255.1	19.5
	Event	0.020	0.005	0.37	0.09	0.20	0.06	13.9	3.1	19.8	5.8	48.8	6.4	12.05	1.56	7.46	0.15	6.6	3.1	139.0	12.5
	B+E	0.017	0.002	0.25	0.04	0.32	0.06	15.4	1.3	15.4	2.2	54.6	2.8	10.49	0.67	7.79	0.13	6.8	2.0	226.1	17.5
Skinner Creek	Baseline	0.019	0.002	0.43	0.09	0.37	0.07	15.2	1.3	19.3	3.4	57.1	3.0	9.50	0.80	7.80	0.16	4.5	1.6	294.0	17.6
	Event	0.031	0.006	0.88	0.14	0.24	0.06	15.4	2.8	22.5	5.4	48.8	6.4	10.87	1.37	7.28	0.24	9.1	5.0	184.5	25.2
	B+E	0.023	0.002	0.58	0.08	0.33	0.05	15.3	1.2	15.3	2.6	54.8	2.6	9.88	0.63	7.66	0.13	5.8	1.6	263.3	16.5

Table 3. Areal nutrient loss (g/ha/day) and discharge (m^3/day) from Sandy Pond watersheds during events (E) and non-events (NE). TP=total phosphorus, TSS=total suspended solids, Na= sodium, TKN=Total Kjeldahl nitrogen.

	Discharge (m^3/day)		TP (g P/ha/d)		Nitrate (g N/ha/d)		TSS (g/ha/d)		TKN (g N/ha/d)		Na (g/ha/d)	
	E	NE	E	NE	E	NE	E	NE	E	NE	E	NE
Little Sandy Creek	658,359	132,381	2.93	0.30	40.0	5.5	1,510	130	16.2	4.3	1,040	152
Blind Creek	37,801	7,088	1.92	0.13	28.0	3.2	1,707	128	10.4	3.4	713	131
Mud Creek	43,555	11,014	1.89	0.38	24.8	3.6	868	339	19.8	5.1	733	195
Lindsey Creek	244,434	122,414	1.30	0.47	31.5	12.1	1,915	382	9.3	7.8	921	423
Skinner Creek	426,044	196,594	2.08	0.50	67.5	26.3	1,534	331	13.6	3.1	915	307

Table 4. Nutrient loss (g and kg/day) and discharge from Sandy Pond watersheds during events (E) and non-events (NE). TP=total phosphorus, TSS=total suspended solids, Na= sodium, TKN=Total Kjeldahl nitrogen.

	Discharge (m^3/day)		TP (g P/d)		Nitrate (kg N/d)		TSS (kg/d)		TKN (kg N/d)		Na (kg/d)	
	E	NE	E	NE	E	NE	E	NE	E	NE	E	NE
Little Sandy Creek	658,359	132,381	20,507	2,097	280	39	10,552	911	113	30.2	7,266	1,065
Blind Creek	37,801	7,088	1,390	95	20	2	1,236	92	7	2.5	516	95
Mud Creek	43,555	11,104	1,267	255	17	2	582	227	13	3.5	492	131
Lindsey Creek	244,434	129,042	4,627	1,780	112	46	6,815	1,430	33	29.0	3,276	1,578
Skinner Creek	426,044	196,594	13,598	3,284	442	172	10,048	2,171	89	20.2	5,992	2,008

Table 5. Statistical correlation (r) between event discharge and nutrient loss (kg/day)from Sandy Creek tributaries. TSS=Total suspended solids, TKN=total Kjeldahl nitrogen, TP=Total phosphorus.

	TSS	TKN	TP
Little Sandy Creek	0.17	0.46	0.79
Blind Creek	0.82	0.14	0.89
Mud Creek	0.88	0.91	0.80
Lindsey Creek	0.85	0.32	0.57
Skinner Creek	0.89	0.50	0.79

Table 6. Comparison of phosphorus loading in subbasins of the Irondequoit Bay watershed, other Monroe County creeks, tributaries of Sodus and Port Bays, tributaries of Orleans and Niagara County and Lake Neatahwanta tributaries.

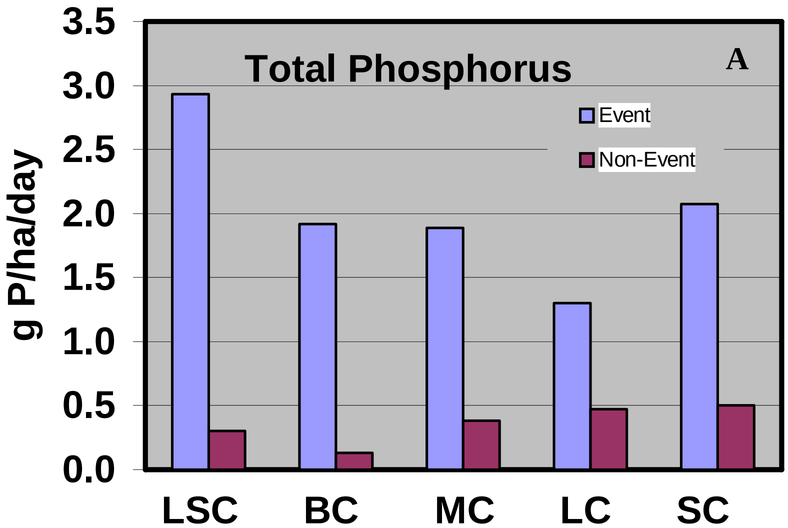
Subbasin or Creek	**Watershed**	**Land Use**	**Total Phosphorus Loading (g P/ha/d) Annual Daily Average**	
Sucker Brook	Canandaigua Lake	Agriculture/Urban	7.66	
Irondequoit Creek (pre-diversion)	Irondequoit Bay	Several Sewage Plants	5.60	
1978-79 (post-diversion)	Irondequoit Bay		2.00	
Larkin	Lake Ontario	Suburban	0.70	
Buttonwood	Lake Ontario	Suburban	1.58	
Lower Northrup	Long Pond	Sewage Plant	6.64	
Upper Northrup	Long Pond	Urban	3.23	
First	Sodus Bay	Forested	0.11	
Clark	Sodus Bay	Forested	0.22	
Sodus East	Sodus Bay	Agriculture	8.57	
Wolcott	Port Bay	Agriculture	5.01	
Bobolink	Port Bay	Forested	0.02	
Sheldon	Lake Neatahwanta	Muckland	27.41	
Summerville	Lake Neatahwanta	Suburban	5.47	
			Two-Year Range	
Oak Orchard	Lake Ontario		3.48	2.86
Johnson	Lake Ontario		1.81	1.17
Sandy	Lake Ontario		0.98	0.77
Twelvemile Creek East	Lake Ontario	Agriculture	0.5	0.26

Irondequoit basin data are from 1980-81 (O'Brien and Gere 1983). Data from other Monroe County creeks are from 1987-88 (Makarewicz 1988). Wayne County creek data from 1991-93 are from Makarewicz et al. 1991, 1992, and1993. Orleans and Oswego data are from Makarewicz and Lewis (1998a, 1998b, 1999).,

Table 7. Comparison of average daily event and non-event phosphorus loading of Sandy pond tributaries with tributaries of Oneida Lake, Lake Neatahwanta and Canandaigua Lake.

Subbasin or Creek	**Watershed**	**Land Use**	**Total Phosphorus Loading (g P/ha/d) Daily Non-event**	**Average Event**
			1999-2000	
Chittenango Creek (CH2)	Oneida Lake	Agriculture	0.6	9.0
Chittenango Creek(CH1)	Oneida Lake	Agriculture	0.8	4.8
Limestone Creek (LS2)	Oneida Lake		0.7	6.0
Limestone Creek (LS1)	Oneida Lake		0.1	24.6
Butternut Creek (BN1)	Oneida Lake	Urban?	0.1	3.8
Cowaselon Creek (CW1)	Oneida Lake	Agriculture, STP	0.3	31.3
Cowaselon Creek (CW2)	Oneida Lake	Agriculture, STP	0.5	18.8
Canastota Creek (CT1)	Oneida Lake		1.2	3.6
Canaseraga Creek (CN1)	Oneida Lake		1.8	24.8
Clockville Creek (CK1)	Oneida Lake		0.6	3.2
Oneida Creek (ON1)	Oneida Lake	Agriculture, STP	1.0	14.4
			1999-2002	
Little Sandy Creek	Sandy Pond		0.3	2.9
Blind Creek	Sandy Pond		0.1	1.9
Mud Creek	Sandy Pond		0.4	1.9
Lindsey Creek	Sandy Pond		0.5	1.3
Skinner Creek	Sandy Pond		0.5	2.1
			1997-1999	
T1 Fallbrook	Canandaigua Lake		0.79	2.58
T2 Deep Run	Canandaigua Lake		0.37	2.45
T3 Gauge Gully	Canandaigua Lake		0.10	0.86
T4 Fisher Gully	Canandaigua Lake		0.07	0.22
T6 Lower Vine Valley	Canandaigua Lake		0.37	2.00
T8 Lower West River	Canandaigua Lake		2.72	1.33
T9 Clark Gully	Canandaigua Lake		0.14	1.11
T10 Parish Gully	Canandaigua Lake		0.16	3.70
T11 Upper Naples Creek	Canandaigua Lake		0.16	3.48
T13 Cooks Point	Canandaigua Lake		0.50	24.54
T14 Hicks Point	Canandaigua Lake		0.15	5.44
T15 Seneca Point Gully	Canandaigua Lake		0.20	1.11
T16 Barnes Gully	Canandaigua Lake		0.08	2.06
T17 Menteth	Canandaigua Lake		0.03	1.15
T18 Tichenor Gully	Canandaigua Lake		0.30	3.58
TSB - Sucker Brook - grabs	Canandaigua Lake		0.09	1.95
T24 Tannery Creek	Canandaigua Lake		0.05	0.92
T25 Eelpot Creek	Canandaigua Lake		0.10	1.94
T26 Reservoir Creek	Canandaigua Lake		0.12	10.8
T27 Grimes Creek	Canandaigua Lake		0.22	1.06

Oneida Lake and Canandaigua Lake data are from Makarewicz and Lewis (2000a, 1998c)
Oneida and Canandaigua Lake data represents the daily average for events and nonevents.



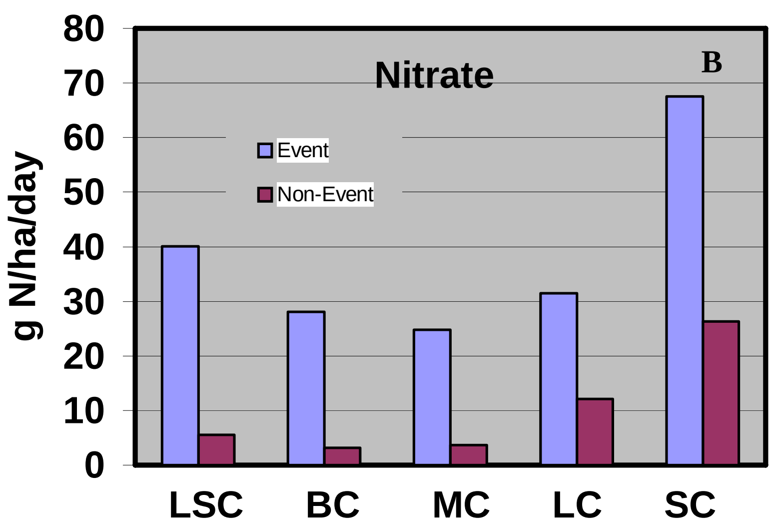


Figure 3. Average daily areal event and non-event loss of total phosphorus (A) and nitrate (B) from Little Sandy Creek (LSC), Blind Creek (BC), Mud Creek (MC), Lindsey Creek (LC) and Skinner Creek (SC).

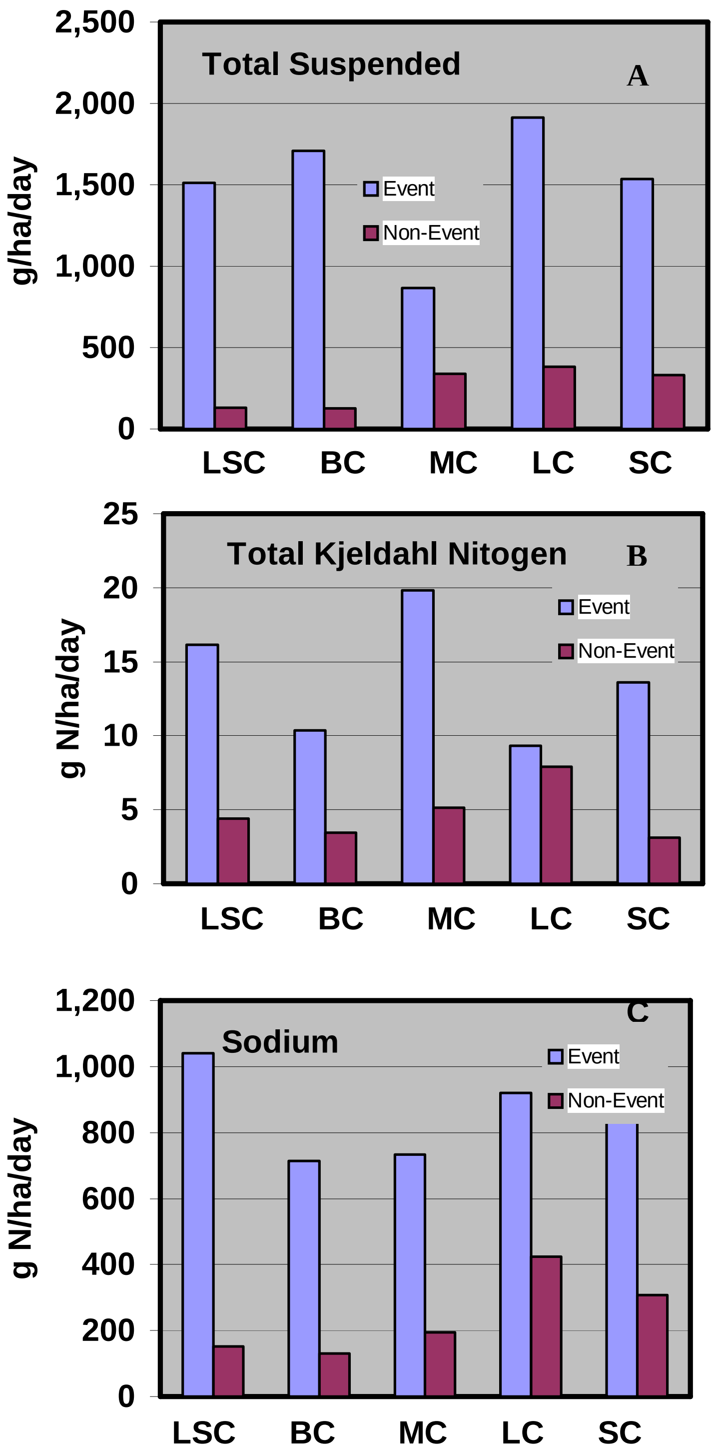


Figure 4. Average daily areal event and non-event loss of total suspended solids (A), total Kjeldahl nitrogen (B) and sodium (C) from Little Sandy Creek (LSC), Blind Creek (BC), Mud Creek (MC), Lindsey Creek (LC) and Skinner Creek (SC).

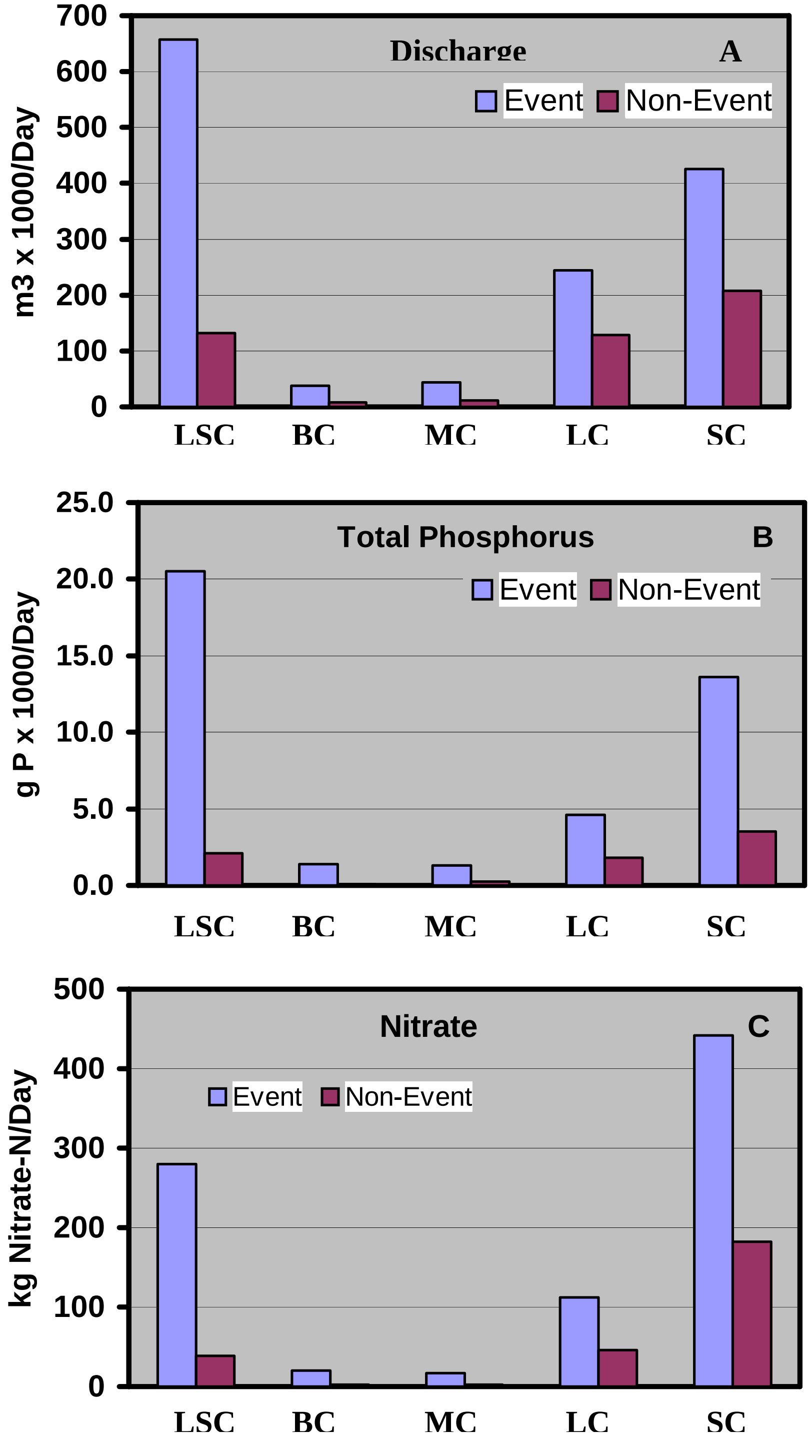


Figure 5. Average daily event and non-event discharge (A) and loss of total phosphorus (B) and nitrate-nitrogen (C) from Little Sandy Creek (LSC), Blind Creek (BC), Mud Creek (MC), Lindsey Creek (LC) and Skinner Creek (SC).

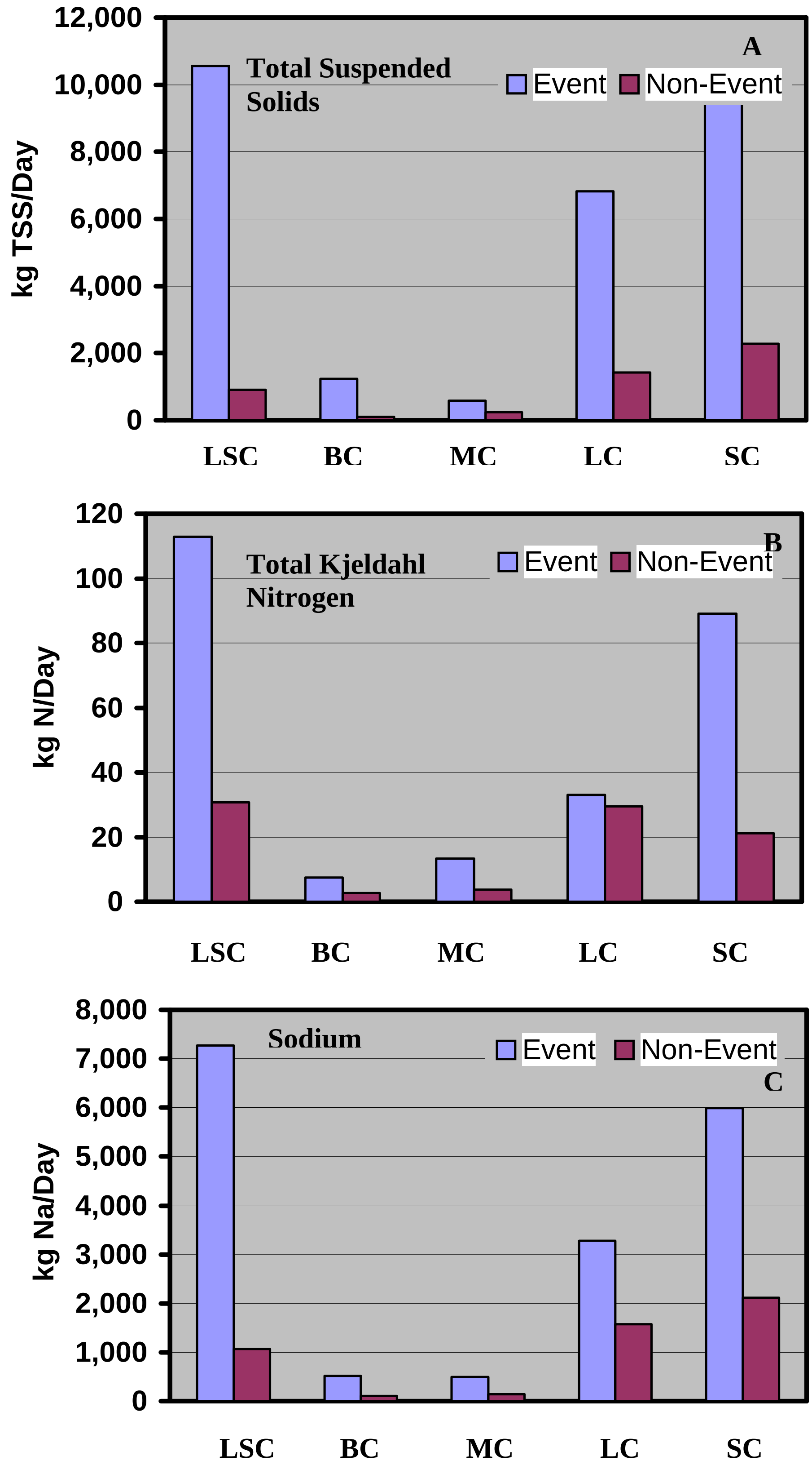


Figure 6. Average daily event and non-event loss of total suspended solids (A), total Kjeldahl nitrogen (B) and sodium (C) from Little Sandy Creek (LSC), Blind Creek (BC), Mud Creek (MC), Lindsey Creek (LC) and Skinner Creek (SC).

Appendix 1. WADSWORTH CENTER
NEW YORK STATE DEPARTMENT OF HEALTH
ENVIRONMENTAL LABORATORY APPROVAL PROGRAM

Proficiency Test Report

Lab 11439 SUNY BROCKPORT EPA Lab ID NY01449 Page 1 of 1
WATER LAB LENNON HALL
BROCKPORT, NY 14420
USA

Shipment 255 Non Potable Water Chemistry
Shipment Date: 22-July-2002

Analyte	Sample ID	Result	Mean/Target	Satisfactory Limits	Method	Score
Approval Category : **Non Potable Water**						
Sample: **Residue**						
Solids, Total Suspended 280 passed out of 302 reported results.	5502	54.0	51.4	45.5 – 57.2	SM18 2540D	Satisfactory
Sample: **Organic Nutrients**						
Kjeldahl Nitrogen, Total 120 passed out of 122 reported results.	5504	9.95	9.78	7.96 – 11.6	EPA 351.3	Satisfactory
Phosphorus, Total 132 passed out of 145 reported results.	5504	8.87	8.12	6.98 – 9.26	SM18 4500-PB,E	Satisfactory
Sample: **Inorganic Nutrients**						
Nitrate (as N) 113 passed out of 120 reported results.	5507	6.22	6.33	5.47 – 7.19	SM18 4500-NO3 F	Satisfactory
Orthophosphate (as P) 94 passed out of 106 reported results.	5507	0.735	0.717	0.636 – 0.799	SM18 4500-P F	Satisfactory
Sample: **Metals I and II**						
Sodium, Total 102 passed out of 120 reported results.	5511	69.0	69.6	65.1 – 74.1	ASTM D-1688-95 C	Satisfactory

Appendix 2. Locations of tributary sampling sites at Sandy Pond

Location	GPS	Culvert	Construction	Notes
Little Sandy Creek**:** Oswego County atNYS Route 3 Crossing	43" 38' 03N 76" 09' 10W	Approx. 50' Wide	Concrete	no restriction of flow, solid gravel stream bottom, good flow, meandering stream, potential pasture located to the East
Blind Creek North: at Hadley Road crossing	43" 39' 09N 76' 08' 16W		Corrugated metal	
Mud Creek South: Oswego County at Weaver Road crossing	43" 40' 03N 76"08"57W	6' diameter	Corrugated metal	pipe replaced in Spring of 2002, water is clear, no obstructions in pipe
Lindsey Creek: Jefferson County at Weaver Road crossing (gravel road, portion of road over bridge is paved)	43" 40' 44N 76" 09' 32W	approx. 33' Wide	Concrete	wooden bridge, fast flow, stony stream bottom, small rapids, minor loss of soil from road ditch, recent highway construction
Skinner Creek: Jefferson County, at Weaver Road crossing, (gravel road, portion of road over bridge is paved)	43" 41' 05N 76" 09' 30W	approx. 34' Wide	Wood	wooden bridge and side walls, gabion baskets along bank, DEC fishing access, flow partially restricted by woody debris caught up under bridge, moderate flow, gravel stream bottom

Appendix 3 . Event and non-event nutrient and suspended solids losses from subwatersheds of Sandy Pond. TP = Total Phosphorus; TKN = Total Kjeldahl Nitrogen; TSS = Total Suspended Solids; Avg. Vel. = Average Velocity.

LITTLE SANDY CREEK (43°38'03"N; 76°09'10"W)					Watershed Area: 6989 ha		
DATE	Avg. Vel (m/s)	Discharge (m3/d)	TP (g/d)	Nitrate (kg/d)	TSS (kg/d)	TKN (kg/d)	Sodium (kg/d)
EVENTS							
1/7/00	1.07	1,259,885	62,364	743	6,929	151	4,717
3/13/00	0.54	583,704	12,608	298	10,215	7.0	5,458
4/21/00	0.99	1,127,122	8,115	383	8,228	271	7,528
10/30/01	0.56	411,826	3,954	37	1,936	25	1,660
1/8/02	0.45	348,980	1,675	168	698	4.2	9,513
1/24/02	0.86	749,981	23,324	570	16,875	9.0	10,335
5/14/02	0.49	566,307	41,567	125	30,014	334	6,818
5/31/02	0.60	644,817	28,630	116	18,377	168	17,391
6/26/02	0.34	232,606	2,326	77	1,698	48	1,975
Average	0.65	658,359	20,507	280	10,552	113	7,266
S.E.	0.08	114,380	6,917	81	3,224	42	1,609
NON-EVENTS							
6/26/00	0.18	186,818	2,391	16	355	99	1,515
7/31/00	0.12	92,373	1,857	21	139	12	1,032
9/8/00	0.06	40,303	580	5.6	407	21	777
5/23/01	0.38	235,300	5,812	184	1,765	42	4,541
6/6/01	0.33	191,085	1,758	15	497	29	1,318
7/26/01	0.05	25,023	520	2.3	148	10	365
8/21/01	0.09	53,743	2,112	13	2,150	49	354
9/6/01	0.10	47,223	1,261	0.5	458	27	331
11/19/01	0.19	114,501	492	18	115	2.9	1,027
3/7/02	0.64	256,785	3,030	141	2,388	3.1	1,489
4/17/02	0.38	334,953	5,627	64	3,417	97	1,089
5/20/02	0.38	322,921	2,971	74	904	32	1,379
7/24/02	0.06	33,554	550	14	168	5.0	252
8/8/02	0.05	26,479	2,039	7.4	628	19	326
9/27/02	0.05	24,660	456	1.7	123	6	177
Average	0.20	132,381	2,097	39	911	30	1,065
S.E.	0.05	29,095	443	14	265	8.0	278

Appendix 3 (Continued). Event and non-event nutrient and suspended solids losses from subwatersheds of Sandy Pond.

BLIND CREEK (43°39'09"N; 76°08'16"W)					Watershed Area: 724 ha		
DATE	Avg. Vel (m/s)	Discharge (m3/d)	TP (g/d)	Nitrate (kg/d)	TSS (kg/d)	TKN (kg/d)	Sodium (kg/d)
EVENTS							
1/7/00	0.67	30,368	474	19	161	5.5	284
3/13/00	0.89	45,041	685	23	437	5.9	603
4/21/00	0.97	48,924	294	11	362	11	453
10/30/01	0.70	14,088	73	1.0	45	1.1	257
1/8/02	0.76	19,948	82	8.8	90	0.2	594
1/24/02	2.55	125,494	7,367	110	5835	6.3	1,303
5/13/02	0.72	30,334	2,818	5.8	3488	27	377
5/31/02	0.62	24,666	696	3.7	678	10	756
6/26/02	0.11	1,343	25	0.4	27	0.4	19
Average	0.89	37,801	1,390	20	1,236	7.5	516
S.E.	0.22	11,995	800	12	680	2.8	123
NON-EVENTS							
6/26/00	0.23	6,551	91	0.5	18	3.1	84
7/31/00	0.40	10,405	468	1.1	208	3.7	128
9/8/00	0.05	757	12	0.1	28	0.5	20
5/23/01	0.11	2,405	46	0.6	30	0.9	26
6/6/01	0.39	5,848	54	0.5	158	0.8	49
7/26/01	0.05	323	10	0.0	10	0.2	7.4
8/21/01	0.55	8,272	208	1.5	284	5.7	96
9/6/01	0.14	1,393	20	0.1	27	0.5	27
11/19/01	0.72	12,253	66	1.2	135	18	206
2/5/02	0.77	24,726	262	19	272	1.7	333
3/7/02	0.73	22,132	150	11	38	0.3	266
4/17/02	0.41	12,412	70	2.0	196	3.6	196
5/20/02	0.27	8,110	97	1.1	97	1.0	105
7/24/02	0.32	3,423	37	1.2	50	1.4	45
8/8/02	0.05	120	4.1	0.02	3.9	0.1	1.8
9/27/02	0.11	694	8.3	0.03	4.9	0.2	8.5
10/9/02	0.09	667	3.9	0.05	12.9	0.2	8.3
Average	0.32	7087.71	94.60	2.33	92.45	2.49	94.50
S.E.	0.06	1810.94	29.46	1.19	23.52	1.07	24.31

Appendix 3 (Continued). Event and non-event nutrient and suspended solids losses from subwatersheds of Sandy Pond.

MUD CREEK (43°40'03"N; 76°08'57"W)					Watershed Area: 671 ha		
DATE	Avg. Vel (m/s)	Discharge (m3/d)	TP (g/d)	Nitrate (kg/d)	TSS (kg/d)	TKN (kg/d)	Sodium (kg/d)
EVENTS							
1/7/00	1.62	32,860	1,351	22	171	11	328
3/13/00	1.42	55,040	870	30	517	10	571
4/21/00	1.81	96,148	1,500	20	1,298	31	737
10/30/01	0.86	13,313	133	3.5	63	0.8	248
1/8/02	1.04	15,957	164	8.1	29	0.2	428
1/24/02	0.82	43,325	1,243	36	4.3	3.0	331
5/13/02	0.79	102,034	5,326	24	2,653	50	892
5/31/02	1.04	30,626	747	5.5	438	13	865
6/26/02	0.36	2,696	72	0.8	66	0.8	27
Average	1.08	43,555	1,267	17	582	13	492
S.E.	0.15	11,753	539	4.2	293	5.6	98
NON-EVENTS							
6/26/00	1.11	26,879	833	2.6	22	18	348
7/31/00	1.12	23,250	1,441	6.0	923	12	299
9/8/00	0.29	3,393	108	0.7	172	2.7	96
5/23/01	0.22	6,493	60	0.9	31	1.0	88
6/6/01	0.69	13,863	202	3.9	557	2.9	150
7/26/01	0.05	396	19	0.2	11	0.2	7.3
8/21/01	0.87	8,683	214	2.4	256	3.5	134
9/6/01	0.32	2,631	139	0.5	147	1.4	57
11/19/01	0.71	9,009	73	3.3	157	1.4	142
2/5/02	0.76	20,054	405	0.2	140	0.2	187
3/7/02	0.78	21,956	88	11	270	0.3	206
4/17/02	1.64	30,397	456	4.3	869	11	308
5/20/02	0.75	17,800	235	4.6	262	2.8	177
7/24/02	0.41	1,754	50	0.8	38	0.6	18
8/8/02	0.05	49	1.5	0.01	1.5	0.03	0.6
9/27/02	0.29	230	4.0	0.03	0.4	0.10	3.1
10/9/02	0.40	403	7.1	0.04	7.0	0.13	5.3
Average	0.62	11013.99	255.06	2.41	227.29	3.45	130.95
S.E.	0.10	2528.21	90.56	0.69	70.34	1.27	27.35

Appendix 3 (Continued). Event and non-event nutrient and suspended solids losses from subwatersheds of Sandy Pond.

LINDSEY CREEK (43°40'44"N; 76°09'32"W)				Watershed Area: 3558 ha			
DATE	Avg. Vel (m/s)	Discharge (m3/d)	TP (g/d)	Nitrate (kg/d)	TSS (kg/d)	TKN (kg/d)	Sodium (kg/d)
EVENTS							
1/7/00	0.77	18,755	816	11	319	6.4	81
3/13/00	0.82	340,706	7,359	174	5,962	4.1	3,186
4/21/00	1.06	59,337	760	17	635	15	529
10/30/01	1.03	359,511	3,811	29	2,049	4.3	2,193
1/8/02	0.58	244,364	2,639	105	806	2.9	7,182
1/24/02	1.55	665,018	7,049	585	33,716	53	7,728
5/13/02	0.72	333,628	17,015	63	16,014	153	3,820
5/31/02	0.38	146,540	1,846	16	1,319	50	4,308
6/26/02	0.12	32,043	346	8.0	513	8.4	458
Average	0.78	244,434	4,627	112	6,815	33	3,276
S.E.	0.14	69,447	1,775	62	3,760	16	938
NON-EVENTS							
6/26/00	0.31	93,120	1,192	7.8	121	44	1,372
7/31/00	0.28	6,899	185	0.7	83	1.5	113
9/8/00	0.08	19,006	315	2.5	443	2.1	497
5/23/01	0.37	119,412	2,424	31	346	17	1,278
6/6/01	0.54	147,950	2,175	16	2,382	19	1,465
7/26/01	0.05	12,817	300	1.7	244	7.3	317
8/21/01	0.41	126,212	2,348	24	2,878	107	2,377
9/6/01	0.13	35,399	464	1.4	634	48	742
11/19/01	0.52	167,105	207	20	1,337	92	1,872
2/5/02	0.99	415,848	4,657	250	3,951	5.0	4,645
3/7/02	1.08	420,948	7,451	185	4,083	5.1	4,159
4/17/02	0.48	214,432	2,595	131	3,699	69	2,033
5/20/02	0.37	151,677	2,093	32	1,623	12	1,435
7/24/02	0.09	68,073	1,116	23	517	18	1,402
8/8/02	0.05	10,489	194	1.3	271	4.3	212
9/27/02	0.06	55,286	757	2.8	265	13	1,339
10/9/02	0.07	16,368	170	0.8	254	5.2	338
Average	0.36	129,042	1,780	46	1,430	29	1,578
S.E.	0.08	32,338	490	19	370	8.4	321

Appendix 3 (Continued). Event and non-event nutrient and suspended solids losses from subwatersheds of Sandy Pond.

SKINNER CREEK (43°41'05"N; 76°09'30"W)					**Watershed Area: 6551 ha**		
DATE	Avg. Vel (m/s)	Discharge (m3/d)	TP (g/d)	Nitrate (kg/d)	TSS (kg/d)	TKN (kg/d)	Sodium (kg/d)
EVENTS							
1/7/00	1.02	603,290	34,146	664	11,945	169	3,644
3/13/00	0.49	222,864	7,644	265	5,037	29	2,474
4/21/00	1.43	788,571	8,753	655	13,800	237	8,674
10/30/01	0.98	372,337	8,191	186	1,973	56	4,345
1/8/02	0.52	183,602	1,836	235	477	2.2	5,264
1/24/02	1.79	1,112,424	38,601	1,735	38,935	67	16,842
5/13/02	0.54	177,185	9,763	74	10,100	90	1,983
5/31/02	0.38	326,417	12,600	137	7,181	140	10,076
6/26/02	0.07	47,706	849	29	988	12	625
Average	0.80	426,044	13,598	442	10,048	89	5,992
S.E.	0.18	114,982	4,491	179	3,952	26	1,698
NON-EVENTS							
6/26/00	0.10	66,037	1,222	11	125	32	855
7/31/00	0.05	26,033	666	6.8	164	3.6	409
9/8/00	0.05	13,732	251	4.0	545	2.9	424
5/23/01	0.49	191,726	1,304	38	460	19	3,240
6/6/01	0.34	148,075	2,739	84	3,598	31	1,925
7/26/01	0.05	17,990	711	1.3	878	12	269
8/21/01	0.05	16,334	376	3.1	707	8.7	328
9/6/01	0.05	10,420	157	0.5	365	11	159
11/19/01	0.66	314,086	2,544	207	2,042	50	3,807
2/5/02	1.49	931,080	18,808	1,387	6,331	11	8,659
3/7/02	1.93	971,920	15,648	894	9,719	12	6,988
4/17/02	0.44	274,130	3,481	49	4,496	74	2,459
5/20/02	0.36	278,535	6,239	203	6,044	33	3,106
7/24/02	0.05	26,033	607	20	286	20	457
8/8/02	0.05	21,065	451	7.6	480	12	421
9/27/02	0.05	14,247	264	1.9	197	4.0	286
10/9/02	0.06	20,662	355	5.0	461	7.4	351
Average	0.37	196594.41	3283.70	172.11	2170.53	20.22	2008.37
S.E.	0.13	73570.73	1335.94	92.29	693.56	4.59	610.88