A Biological and Chemical Survey of Selected Surface Waters in the Lye Brook Wilderness Area, Vermont

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Lye Brook Wilderness Study of Surface Waters Executive Summary

Introduction

The Vermont Department of Environmental Conservation (VTDEC) has monitored water quality in and around the Lye Brook Wilderness Area (LBW) since 1980 in an effort to document the effects of acid deposition on sensitive lakes. In 1993, the Vermont Monitoring Cooperative (VMC), working with the Green Mountain National Forest (GMNF) and the VTDEC, established a southern Vermont monitoring site in the LBW. VTDEC and GMNF subsequently entered into three consecutive cooperative agreements to jointly conduct expanded surface water monitoring activities in response to mandates under the Clean Air Act to protect Air Quality Related Values (AQRV) in Class I Wilderness Areas such as the LBW. The following monitoring activities were conducted by the Vermont Department of Environmental Conservation under the conditions of these agreements from 1993 through 1995:

- Fish and aquatic macroinvertebrate communities were sampled at seven stream sites in and around the LBW.
- Quantitative and qualitative benthic macroinvertebrate samples were collected at four lakes and ponds in and around the LBW.
- Sediments were collected from two lakes and analyzed for selected organic and inorganic contaminants.
- Water chemistry was monitored at all stream and lake sites where biological sampling was conducted.
- Fish were collected from four lakes; edible portions of tissue were analyzed for selected organic and inorganic contaminants.

The study area is highly susceptible to surface water acidification primarily due to the fact that the waterbodies are situated in geologic areas resistant to chemical weathering. Much of the surface water in the study area is affected by organic acids and is tannic/brown in color. This region of Vermont has in addition, some of the highest levels of sulfate deposition and ozone in the state (R. Poirot - Personal Communication). Long distance transport of atmospheric pollutant is the suspected cause of these air quality related issues.

Results

Lake Water Chemistry: Water chemistry was sampled three times a year in all years at Branch and Bourn Pond. Both ponds are considered to be acidified, with average Calcite Saturation Indices (CSI) greater than 6. The pH of Branch Pond is consistently less than 5.00 standard units while Bourn Pond is in the 5.00-5.50 range on a consistent basis. Both lakes are relatively high in organic carbon and aluminum. It is likely that the organic carbon ameliorates the potential toxic effects of aluminum to aquatic biota in these lakes. Little Mud Pond was sampled twice in 1993, and Lye Brook Meadows was sampled once in 1995. Both waterbodies are acidic and highly colored and support significant sphagnum mats. Ionic concentrations were lower in Little Mud Pond than in the other lakes and ponds sampled in the study area. Both waterbodies are considered to be acidified. Branch and Bourn Ponds both exhibit thermal stratification. Although no dissolved oxygen samples were collected, biological analyses indicate severe oxygen depletion in the hypolimnion of these lakes. Long-term monitoring data collected from acid sensitive lakes and ponds by VTDEC since 1981 suggest a trend of decreasing calcium, magnesium, and sulfate in ponded surface waters statewide, with a lake-specific trend of decreasing sulfate described for Bourn Pond (Stoddard and Kellogg, 1993).

Lake Sediments: Sediments from Bourn and Branch Ponds were collected from deep areas of the lakes. No chlorinated pesticides or poly-chlorinated biphenyls (PCB's) were detected. Three polycyclic aromatic hydrocarbons (PAH) were detected. Flouranthene and pyrene were detected at very low levels in sediments from both lakes; phenanthrene was detected in sediment from Branch Pond. All PAH concentrations were well below concentrations known to threaten the well-being of aquatic life. Lead and mercury were detected at levels indicating potential low-level risk to aquatic biota. It is likely that the source of these contaminants is atmospheric deposition.

Lake Benthos: Benthic macroinvertebrates were sampled from different habitats in Branch, Bourn, and Little Mud Ponds in May, 1993, and Lye Brook Meadows in July, 1995. Ekman dredge samples were collected from both profundal and sub-littoral areas of Branch and Bourn Ponds and from sub-littoral only at Little Mud Pond. Qualitative littoral sampling was conducted at all four ponds. Total taxa richness from the Ekman dredge sampling ranged from six in the profundal zones of Branch and Bourn Ponds to 18 in Little Mud Pond. Sub-littoral samples were generally more diverse than profundal samples. Dipterans, primarily of the Chaoboridae and Chironomidae families, dominated the profundus of both lakes, with the profundal community of Bourn Pond made up of 96 percent Chaoboridae. Communities in both profundal zones were indicative of severe oxygen stress. No taxa of the acid-sensitive groups Mollusca/Crustacea/Ephemeroptera were observed in any of the profundal and sublittoral Ekman dredge samples. Qualitative shoreline sampling produced more taxa. Taxa richness in Little Mud, Bourn, and Branch Ponds averaged about 60 taxa, while Lye Brook Meadow produced 40 taxa. No Crustacea (eg. crayfish) were observed in any of the four waterbodies. No acid-sensitive mayflies or mollusca were observed in Lye Brook Meadows. Little Mud Pond contained one mayfly species but no mollusca. Branch and Bourn Ponds both contained three mayfly and two molluscan taxa.

Fish Tissue Contaminants: During 1994 and 1995, fish for contaminant analysis of edible tissue were collected from Branch, Bourn, Stratton, and Grout Pond by angling and gill nets. Only brook trout were collected from Branch, Bourn, and Stratton Ponds. Brown bullhead, chain pickerel, and smallmouth bass were collected from Grout Pond. Concentrations of PCBs and chlorinated pesticides were below detection limits in all brook trout samples. Metabolites of DDT, up to 0.12 ppm DDE in smallmouth bass, were detected in all samples from Grout Pond. Mercury was detected in all samples. Concentrations ranged from 0.08 ppm in brook trout from Stratton Pond to 1.45 ppm in one smallmouth bass from Grout Pond. Of five smallmouth bass tested from Grout Pond, four had concentrations of mercury in excess of 1.00 ppm, the FDA action level for mercury in fish. Additional metal fish tissue analysis was conducted at Grout Pond during the summer of 1996.

Stream Chemistry: Stream chemistry was sampled at two sites each on Bourn and Lye Brook, and one site each on Branch Pond Brook and Winhall River. Considerable spatial and temporal variability was observed in stream chemistry parameters. All streams sampled underwent a reduction in pH, alkalinity, and calcium in response to snowmelt and spring run-off. Lack of significant spring run-off followed by drought conditions in 1995 resulted in higher pHs throughout most of the 1995 sampling period than in the previous two years. Differences in stream chemistry were observed between upstream and downstream sites on Bourn and Lye Brooks. All stream sites are considered to be acidified, with the exception of the downstream site on Lye Brook. Stream chemistry at this site is influenced by dolomitic outcroppings which increase pH and alkalinity. A maximum alkalinity of 10.5 mg/l was observed at this site in the fall of 1995, compared with an alkalinity of less than one mg/l at the upstream site at the same time. Concentrations of aluminum were highest during periods of run-off. Aluminum was observed at concentrations that, depending on the duration of exposure, would be potentially toxic to aquatic biota.

Stream Fish Populations: Stream fish populations were sampled by electroshocking at six sites on four streams; two sites each on Lye and Bourn Brooks and one site each on Branch Pond Brook and the Winhall River. All four streams are characterized as small cold-water streams. No fish were observed at the most upstream site on Lye Brook. Only brook trout at relatively low densities were found at the upstream Bourn Brook site and the Branch Pond Brook site. Three and four species were found at the lower Lye and Bourn Brook sites respectively. A total of eight species, including three salmonids, were found at the Winhall River site. Salmonid species observed were brook and brown trout, and Atlantic salmon; non-salmonids included slimy sculpin, longnose and blacknose dace, white sucker, and creek chub.

Stream Macroinvertebrate Populations: Stream macroinvertebrates were sampled at seven sites on four streams. Substrate composition at all sites was dominated by boulder and cobble. Most sites were sampled annually for the three years of the project. Sampling was conducted in the fall using standardized kick-net sampling techniques consistent with VTDEC field protocols. In addition to an estimate of the abundance per unit sampling effort, a number of community-based metrics were calculated, including total number of taxa present (taxa richness), the total number of stonefly, mayfly, and caddisfly taxa present (EPT richness), a bio-index indicative of overall productivity (Bio-Index or BI), a diversity index, the relative dominance of an individual taxon (% Dom Tax), and the percent composition of various taxonomic and functional components of the macroinvertebrate community. The upstream Lye Brook sites exhibited poor biological integrity and were the most biologically depauperate and least diverse of the sites sampled. The uppermost site was dominated by dipterans and had no mayfly or stonefly taxa, which were abundant at all other sites. The upper Lye Brook site was unique among the sites sampled in that it was characterized as enriched and had a significant periphytic blue-green algal growth at the time of sampling.

The Branch Pond Brook and upper Bourn Brook sites exhibited some biological impairment in 1994, a year when stream pH's were generally lower than in 1993 or 1995. It is likely that the reduced biological integrity at these sites is at least in part a result of episodic exposures to high acidity and to high levels of aluminum. The Winhall River and lower Bourn Brook sites had the most diverse and well-balanced benthic communities of the sites sampled. These two sites, along with the lowest Lye Brook site, were all rated as having good to excellent biological integrity.

Recommendations: Recommendations are made in this report relative to maintaining a continued long-term monitoring presence in the Lye Brook Wilderness Area. It is recommended that stream and lake chemical monitoring should continue at the intensity conducted during these studies; and that biological monitoring should be repeated on a regular basis at five-year intervals.

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INTRODUCTION

The VTDEC has monitored water quality in and around the LBW since 1980 in an effort to document the effects of acid deposition on sensitive lakes. The VTDEC has established a biological (Fiske, 1987) and chemical (Burnham and Kellogg, 1989) data base for long-term trends in both Bourn and Branch Ponds. In addition, several other lakes within the GMNF have been intensively monitored. These include: Beebe, Big Mud, Griffith, Grout, Haystack, Little (Winhall), Little (Woodford), Little Rock, Moses, Somerset and Stratton. Between 1982 and 1984, fish and chemical surveys were conducted on several lakes and rivers which were within or adjacent to GMNF (Langdon, 1982; 1983; 1984; 1985).

In 1993, the Vermont Monitoring Cooperative (VMC), working in close cooperation with the Green Mountain National Forest (GMNF) and the State of Vermont, established a southern Vermont monitoring site in the Lye Brook Wilderness (LBW) area. The Vermont Department of Environmental Conservation (VTDEC) and the GMNF subsequently entered into three consecutive cooperative agreements that provided for an expansion of monitoring activities within the LBW. Funding for these monitoring activities has been provided by the GMNF in response to mandates under the Clean Air Act to protect Air Quality Related Values (AQRV) in LBW, a Class I Wilderness Area. Inventorying and monitoring hydro-geochemical and biological characteristics of lakes and streams within and adjacent to LBW were identified by GMNF through it's planning process as essential tasks contributing to the determination of current and future effects of air quality on AQRV's in LBW.

The field element of this project was carried out cooperatively by the GMNF and the VTDEC. The GMNF was responsible for:

1. The sampling of the fish community characteristics and water chemistry at one site on Branch Pond Brook and the Winhall River.

2. Fish collection using gill net sets in Grout and Stratton Ponds. Attempts to sample fish were made at Lye Brook Meadows but no fish were collected.

The VTDEC was responsible for:

1. The sampling of Bourn, Branch, and Little Mud Ponds and Lye Brook Meadows for littoral and profundal macroinvertebrates, with emphasis on documenting populations from groups known to be sensitive to acid precipitation (Crustacea, Mollusca, Ephemeroptera).

2. The sampling of Bourn, Branch and Little Mud Ponds and Lye Brook Meadows for water chemistry.

3. Analysis of one representative deep site surficial sediment from both Bourn and Branch Ponds for priority pollutant metals, polynuclear aromatic hydrocarbons (PAHs), PCBs and chlorinated pesticides.

4. The sampling of macroinvertebrate and fish community characteristics and water chemistry at two sites in both Bourn and Lye Brooks documenting the effects of elevation, drainage area and bedrock geology on stream biota and chemistry.

5. Fish collection in Bourn and Branch Ponds by hook and line (fly fishing) in 1994; analysis of fish tissue for some priority pollutant metals, PAHs, PCBs and chlorinated pesticides.

This report fulfills VTDEC's obligations to the GMNF by providing a summary and assessment of the biology and chemistry of the major waterbodies within or adjacent to LBW. A recommended long-term biological and chemical monitoring plan is also provided.

STUDY AREA AND METHODS

Study Area

Three of the lakes and most of the river sites were located within the boundaries of the LBW (**Figure 1**). Refer to **Tables 1 and 2** for a description of the physical characteristics of the study streams and lakes.

The LBW area is highly susceptible to surface water acidification primarily due to the fact that the waterbodies are situated in geologic areas resistant to chemical weathering that permits neutralization of acidic surface and ground waters. This susceptibility has been well documented by the ongoing Vermont Long-Term Lake Monitoring Program and past river studies conducted by the VTDEC. This region of Vermont has in addition, some of the highest levels of sulfate deposition and ozone in the state (R. Poirot - Personal Communication). Long distance transport of atmospheric pollutant is the suspected cause of these air quality related issues.

A classification of geologic terrain was conducted by Norton and was based on the acid neutralizing capacity (ANC) or buffering capacity of bedrock formations (Hendrey et al., 1979). The classification consisted of four bedrock types as outlined below:

Type I: Low to no buffering capacity -- Granite-Syenite or metamorphic equivalent; granitic gneisses; quartz sandstone or metamorphic equivalent.

Type II: Medium to low buffering capacity -- sandstone, shales, conglomerates or their metamorphic equivalent (no free carbonate phase present), high-grade

Table 1. Physical characteristics of Lye Brook Wilderness streams

Stream	Site ID	Station (Mile)	Town	Latitude	Longitude	Elev. (feet)	Drainage Area-km[2]	Topography[1]	Bedrock[2] Type	Location Description
Bourn Bk. (upper)	592600000041	4.1	Winhall	430825	725922	2161	11.1	SL-Mod	I	1/4 mile below confluence with Little Mud Pond and 1/4 mile above lean-to.
Bourn Bk. (lower)	592600000016	1.6	Winhall	430934	730135	900	18.3	High	II	1/4 mile above O.M. Pleisner Homestead.
Branch Pond Bk.	591410000001	0.1	Sunderland	430314	730316	2160	6.3	Mod	I	Immediately above confluence of Roaring Bk.
Lye Bk. (Highest)	592500000070	7.0	Sunderland	430531	730150	2595	1.2	SL-Mod	I	20m below Lye Brook Meadows.
Lye Bk. (Upper)	592500000034	3.4	Manchester	430758	730229	1300	14.8	High	I	20m below confluence of Lye Brook Falls Tributary.
Lye Bk. (Lower)	592500000018	1.8	Manchester	430912	730223	840	19.1	Mod	II	Immediately inside LBW boundary above first small tributary.
Winhall River	033500000081	8.1	Winhall	430818	725555	1470	46.6	SL-Mod	I	At site of IPCO bridge off Kendall Farm Road.

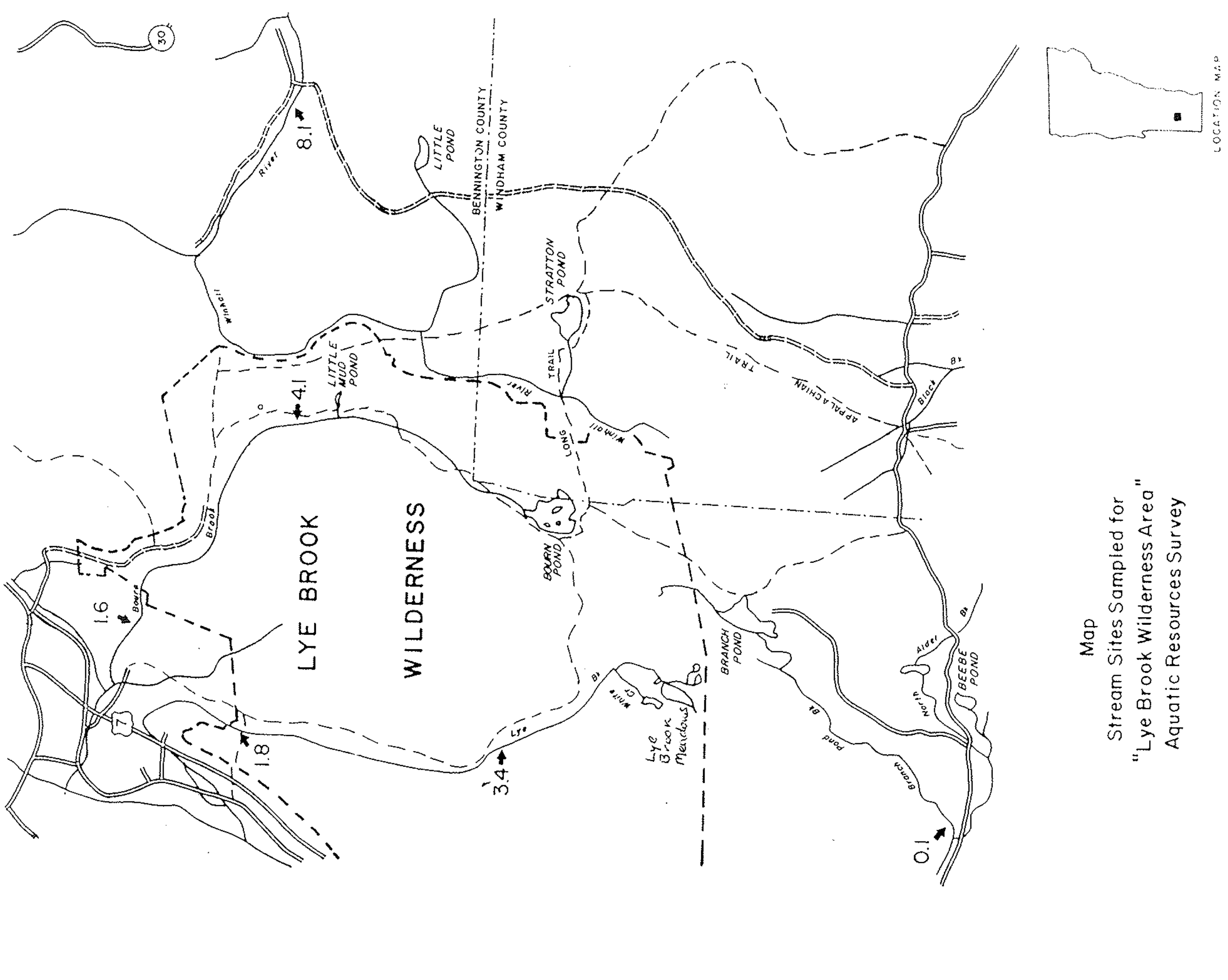
1 SL = slight relief. Mod = moderate relief. High = high relief.
2 Type I = low to no buffering capacity; granite/syenite/granitic gneisses, quartz sandstones or metamorphic equivalents. Impacts from acid precipitation expected.
Type II = medium to low buffering capacity; sandstones, shales, conglomerates, high-grade metamorphic site to intermediate igneous rock, calcsilicate gneisses (no free carbonates). Impacts from acid precipitation restricted to first and second order streams and small lakes.

Table 2. Physical characteristics of Lye Brook Wilderness lakes

Lake	Site ID	Station	Town	Latitude	Longitude	Elev. (feet)	Drainage Area(ha)	Surface Area(ha)	DA/SA (ha)	Maximum Depth (m)	Topography[1]	Bedrock[2] Type
Bourn Pond	592600000075	7.5	Sunderland	430625	730018	2552	166	19	9	9	Mod	I
Branch Pond	591410000033	3.2	Sunderland	430458	730105	2632	134	14	10	12	SL	I
Little Mud Pond	59L000500533	0.3	Winhall	430802	735901	2303	34	2	17	1.3	SL	I
Lye Brook Meadows	592500000071	7.1	Sunderland	430529	730151	2600	200	2	100	1	Mod	I

1 SL = slight relief, Mod = moderate relief.
2 Type I = all lakes have low to no buffering capacity and are expected to have been impacted from acid precipitation.

Figure 1.



Map
Stream Sites Sampled for
"Lye Brook Wilderness Area"
Aquatic Resources Survey

metamorphic felsic to intermediate volcanic rocks; intermediate igneous rocks; calc-silicate gneisses with no free carbonate phases.

Type III: Medium to high buffering capacity -- slightly calcareous rocks, low-grade intermediate mafic volcanic rocks; ultramafic rocks; glossy volcanic rocks.

Type IV: Infinite buffering capacity -- highly fossiliferious sediments or metamorphic equivalents, limestone or dolostones.

Much of the GMNF east of US Route 7 is described as Type I or II. All four study lakes are underlaid by Type I bedrock as are the streams with the exception of the lower two stations on Bourn and Lye Brooks. The lower stations on these streams have Type II bedrock. This is readily apparent by comparing the chemical sampling events results between the upper and lower stations of the brooks. Refer to **Table 5** for a comparison of these sites.

The soil associations for Bourn and Branch Pond have been determined (Kellogg, 1985). These ponds occur in soils that formed in glacial till on uplands and mountains. These soils can be shallow to deep, depending on the depth of bedrock or hardpan. Often, there is hardpan or bedrock within three feet of the surface. They tend to be loamy and low in lime. The three soil associations are:

BPT Berkshire-Peru-Tunbridge Association: Moderately deep to deep, dominantly well drained, loamy soils low in lime, and with a hardpan or bedrock within three feet. Located on steep slopes along the western edge of the LBW.

MHW Mundal-Houghtonville-Wilmington Association: Moderately well to well drained soils interspersed with smaller areas of poorly drained soils. Soils are loamy, high in surface organic matter, low in lime and have a hardpan within three feet. Located on the upland flats, depressions, and sideslopes in the eastern half of the LBW.

RMH Rawsonville-Mundal-Houghtonville Association: Moderately well to well drained loamy soils, high in surface organic matter, low in lime, and have a hardpan or bedrock within three feet. Located on the upland flats, sideslopes and ridgetops in areas with greater local relief than the MHW Association.

The USFS is in the process of conducting intensive Ecological Land Type classifications in the LBW and adjacent areas. These classifications will result in a much more detailed description of the geological and physical characteristics of the study area than is presented here.

The Calcite Saturation Index (CSI) is computed using pH, alkalinity and calcium measurements. This index is used to determine a waterbody's sensitivity to acid deposition (Conroy et al., 1974). The equation for CSI is:

$$CSI = -\log \frac{Ca\ (mg/l)}{40{,}000} - \log \frac{Alk\ (mg/l)}{50{,}000} - pH + 2$$

The CSI values cannot be accurately calculated for waterbodies with alkalinities below zero. For those lakes with alkalinity values below zero the alkalinity was assumed to be 0.01 mg/l and a greater than (>) value is assigned to the calculated CSI.

Appendix 2 and 3 present the CSI values and classifications, based on mean chemical values over the period of record, for the streams and lakes in the study area.

Table 3. LBW waterbodies found in each CSI classification.

CSI	Description of Values	Rivers and Lakes
≥ 6	acidified	Branch Pond Brook, Bourn Pond, Branch Pond, Little Mud, Lye Brook Meadow
≥ 4 <6	unstable to acid loading	Bourn Brook (Upper and Lower), Lye Brook (Upper and Lower), Winhall River
≥ 3 <4	susceptible to acid loading	
≥ 0 - <3	in equilibrium with $CaCO_3$	Lye Brook (Lowest)
≤ 0	saturated with $CaCO_3$	

Based on these CSI values, with the exception of the lowest Lye Brook site, all sites are at least considered unstable to acid loading. Clearly, the waterbodies of the southern Green Mountains have most likely been affected by both natural and antropogenic acidification processes.

Water Chemistry

Branch Pond was sampled three times on a seasonal basis in 1993, 1994, and 1995 and was found to be stratified during the spring and summer. The maximum depth is approproimately 12.0 meters. Samples were collected from a canoe (see map, **Appendix 6**).

Bourn Pond was sampled three times on a seasonal basis in 1993, 1994, and 1995 and was found to be stratified during the spring and summer. The maximum depth is approximately 9.0 meters. Samples were collected (see map, **Appendix 7**) during the spring and summer using an inflatable raft and in the fall of 1994 with a 15 foot aluminum canoe.

Little Mud Pond was sampled twice (May 18 and August 11) in 1993. The shallow maximum depth of approximately 1.3 meters does not allow for stratification. The pond was sampled at what was suspected to have been the "deep" hole (see map, **Appendix 8**) by using a small inflatable two-person raft.

Lye Brook Meadows was sampled on July 15, 1995. Like Little Mud Pond, the shallow maximum depth of 1.4 meters does not allow for stratification. It was sampled at the "deep" hole (see map; **Appendix 9**) using a small inflatable two person raft.

All lake samples were collected with a 1.2ℓ acrylic Kemmerer bottle at one meter and, if found to be stratified, approximately one to two meters from the bottom. Water was transferred into two one-liter Nalgene high density polyethylene (HDPE) bottles and, upon return to the vehicle, placed in coolers with ice for transport to the field laboratory or VTDEC Laboratory in Waterbury, Vermont. In-situ measurements include Secchi disk transparency and temperature profiles from surface to bottom at 1.0 meters intervals. A field sheet was filled out to record in-situ measurements, weather conditions, and other observations.

The lower stream stations were sampled between 17 and 24 times during the three years. More intensive weekly sampling was undertaken during spring runoff to track water chemistry changes during spring snowmelt. Because of their remote locations, the upper streams were sampled only once or twice yearly.

Bourn and Lye Brooks were sampled by the VTDEC, and Branch Pond Brook and the Winhall River were sampled by the GMNF. The samples were collected at, or near the centroid of flow directly into two one-liter Nalgene HDPE bottles. The samples collected by the GMNF were brought to the Manchester District office in coolers and refrigerated. These samples were picked up on a weekly basis by VTDEC staff for transport to the field laboratory or VTDEC Laboratory. In-situ pH (Beckman 21 meter) and conductivity (Hanna HI 8633) were measured only at Bourn and Lye Brooks, and temperature (mercury thermometer) was recorded from all streams. A field sheet was filled out to record snowmelt and runoff conditions, weather and additional observations.

The streams were also sampled once during the summer and the fall each year. Bourn and Lye Brooks were sampled at two sites each to determine the effects of elevational differences, drainage area and bedrock on water chemistry. Additional water chemistry sampling was proposed if warranted by extreme summer precipitation events. No events of a magnitude large enough to generate the extreme high-flow conditions were observed, and thus no additional samples were collected.

If an overnight sampling trip was planned, a field laboratory was set-up in a nearby motel so the samples could be processed as soon as possible following collection. One of the two liter bottles collected was filtered through a Gelman Supor-450 0.45μm filter into a one liter side-arm flask using a Doerr electric vacuum pump. Prior to filtration, all filtration apparatus, including the filters, were thoroughly rinsed with deionized water. Filters were soaked, then pre-rinsed with approximately 25ml of sample. Stringent rinsing protocols with both deionized water and filtered sample all but eliminate the possibility of contamination. The filtered liter was split into aliquots for dissolved organic carbon (DOC), base cations, aluminum, and anions. The remaining one liter bottle was used for pH, alkalinity, colors, and conductance. pH and alkalinity were determined in the field laboratory and colors and conductance are analyzed in the VTDEC Laboratory upon return.

All field and laboratory procedures are consistent with the "Vermont Field Methods Manual" (VT DEC, 1989) and the "Vermont Quality Assurance Plan" (VTDEC, 1992). The analytical procedures are presented in **Appendix 1** along with the reference source. These methods are also consistent with the U.S. EPA Quality Assurance Plan for the Long-Term Monitoring Project (Morrison, 1991). The VTDEC is a participant in this project, the objectives of which are to detect and measure trends in the chemistry of low-alkalinity surface waters over gradients of H^+ and SO_4^{2-} deposition in different geographic regions. Bourn and Branch Ponds have been examined under this project since 1982.

Sediments

Sediments were collected from Bourn and Branch Ponds on August 11 and 12, 1993 at or near the area of maximum depth. A six-inch Ekman dredge was used to collect one representative sample. The sediment sample was emptied into a plastic sieve bucket where the center portion ($\approx$ 1500mls) was placed in a new gallon size Ziploc brand plastic freezer bag. This bag was placed in a second bag to prevent accidental spillage while in the backpack. Upon returning to the laboratory the sediment was transferred to the appropriate containers: two 500ml Nalgene plastic bottles were used for the thirteen priority pollutant metals and a 500ml amber glass bottle was used for PAHs, PCBs and pesticides. The samples were kept on ice while in transit and refrigerated until analyzed.

For mercury analyses, a one or two gram dry weight subsample of well mixed sediment was digested in Aqua Regia (3:1 HCl/HNO_3), oxidized with potassium permanganate, and analyzed by cold vapor methods (Method 7471, VTDEC, 1992).

For other metals analyses, a one or two gram dry weight subsample of well-mixed sediment was digested in nitric acid and hydrogen peroxide, filtered, and analyzed by flame for cadmium, chromium, copper, lead, nickel, zinc (Perkin-Elmer Model 3030 Atomic Absorption Spectrophotometer) or graphite furnace for silver, arsenic, beryllium, antimony, selenium, thallium (Perkin-Elmer Model HGA-600 graphite furnace). Percent moisture was determined on separate subsamples (Method 3050, VTDEC, 1992).

For organic analyses, eight to ten gram wet weight subsamples of well mixed sediment were subject to Soxhlet extraction with 1:1 acetone/hexane (Method 8080, VTDEC, 1992). Both semi-volatiles and organochlorines were extracted using method 3540 (VTDEC, 1992). Samples for semi-volatile compounds were analyzed by GC/MS methodologies using a Finnegan Instrument Model INCOS 50 GC/MS (Method 8027, VTDEC, 1992). Organochlorine compounds were analyzed with a Hewlett-Packard 5890 GC/Electron Capture Detector using method 8080 (VTDEC, 1992). Separate subsamples were used for percent moisture determinations.

All sediment results are reported on a dry weight basis in ppm (mg/kg) for metals and ppb (μg/kg) for organic contaminants.

Macroinvertebrates - Lakes

The lake surveys were primarily designed to document targeted populations of "pH-sensitive" taxa from the macroinvertebrate groups Crustacea, Mollusca, and Ephemeroptera. Two collection methods were employed to cover all habitats within each pond with the exception of Lye Brook Meadows where only littoral zone sweeps were employed in part due to its very small shallow nature. Six inch Ekman dredge samples were collected from the profundal zone and sublittoral areas in early spring (VTDEC Field Method 4.4.5, 1989). Three replicate dredge samples were collected from each pond and depth zone. The littoral zones were qualitatively sampled twice, once in May and once in August. A large 12 x 18 inch kick net was used to sweep through vegetation and bottom muck, while forceps and small sieves were used to collect animals from the surfaces of rocks and snags. All sieves and nets used were equipped with 560 micron mesh netting or smaller. Qualitative sampling was done for two hours at each pond covering all habitat types offered along the shoreline. The sampling locations for both the Ekman dredge and the littoral shoreline sampling are shown on the lake maps in **Appendices 6-9**. The specific areas along the shoreline where populations of Mollusca (Bivalvia and Gastropoda), and Ephemeroptera are located were also marked on these maps.

All animals collected were preserved in the field using 75 percent ethyl alcohol (ETOH), brought back to the laboratory, picked and identified to the lowest possible taxonomic level, usually genus or species. While the targeted taxa were the Crustacea, Mollusca, and Ephemeroptera, an effort was made to collect all taxa encountered during each two-hour survey.

Macroinvertebrates - Streams

Stream macroinvertebrate communities were sampled at seven sites over three years. Two sites on Bourn Brook and two sites on Lye Brook were sampled all three years, and an additional site on Lye Brook was sampled in 1995 in its headwaters immediately below Lye Brook Meadows. Branch Pond Brook and the Winhall River were both sampled at one site during the last two years of the study (**Figure 1**). Branch Pond Brook and the Winhall River will be sampled again during September, 1996. The sites represent different elevations, drainage areas, and bedrock geology. The physical characteristics of each stream site are presented in **Table 1**. The samples were collected from riffle habitats using the two minute kick net technique (VTDEC Field Method 4.4.1, 1989). Samples were preserved in the field with 75 percent ETOH and returned to the laboratory for processing. Samples were processed following the VTDEC Field Method 4.6.1-4, 1989, using a gridded tray, 2X magnifier light and forceps. The protocol requires that the macroinvertebrates from at least one quarter of each sample be picked; picking then continues if necessary a grid at a time until a minimum of 300 animals have been removed or the entire sample is picked.

Fish

Six sections (sites) on four streams in the GMNF were surveyed during the months of August and September 1993-1995. The stream sections sampled were representative of the physical habitat in each of the overall stream reaches. General physical characteristics were recorded at each site. Water temperature and specific conductance were taken during each sampling event.

Fish populations were sampled using pulsed-DC backpack electroshockers. Fish were sampled in an upstream direction using block nets at some sites. At sites where no nets were used, the upper end of the section was located at the foot of a cascade which acted as a barrier to fish attempting to escape the electric field. Two to three electrofishing passes were completed at all but one site. When no fish were collected or observed at the Lye Brook 3.4 site after the first pass it was decided not to conduct any further efforts during 1994 or 1995.

All individuals were identified to species and salmonids measured for total length. For the Winhall site, all species were weighed individually or in groups, and total lengths were measured. The removal method of Carle and Strub (1978) was used to generate population estimates. A relative density measure based on raw numbers from run one/100m^2, was also used to facilitate comparison to the VTDEC state-wide database. The Vermont Index of Biotic Integrity (VTIBI) was applied to population data to characterize fish population health. Only the Winhall site, however, supported enough species to run the index.

RESULTS AND DISCUSSION

Lake Chemistry

Branch and Bourn Ponds have been monitored on a seasonal basis since 1981 and 1982 respectively as part of the Vermont Long-Term Monitoring Program (VLTMP). VLTMP data suggest a clear statewide trend of decreasing calcium, magnesium, and sulfate concentrations in surface waters in response to lower inputs of sulfate from atmospheric deposition. The decrease in calcium and magnesium (base cations) is due to declining base cation deposition and reduced cation leaching from the watershed soils. A lake-specific trend of decreasing sulfate concentrations has been described for Bourn Pond (Stoddard and Kellogg, 1993). Refer to **Appendix 4** for a presentation of the lake results from 1993 through 1995. The means and ranges are presented in **Table 4**.

Both lakes are dystrophic and highly "stained" a tea color due to dissolved organic matter. This organic "humic" matter originates from the breakdown of organic material of both terrestrial and aquatic origin. Dissolved organic carbonaceous matter readily binds with inorganic monomeric aluminum (IMAL), the form of aluminum most toxic to aquatic biota, to form organic monomeric aluminum (OMAL) complexes, a much less toxic form of aluminum. Recent *in situ* studies in the Adirondacks have shown that brook trout and blacknose dace mortality in low-pH streams is directly correlated with IMAL concentration and exposure duration with an inverse correlation to DOC (Simonen et al., 1993). IMAL concentrations greater than 150-200 μg/l have been shown to be toxic to some species of aquatic biota within the pH range 4.5-5.5 (Baker et al., 1982). The levels of IMAL in Bourn Pond epilimnion samples are not considered an immediate threat because the concentrations are quite low (18-57g/l) and the dissolved organic carbon (DOC) levels observed

(4.09-5.49mg/l) will likely mitigate toxicity. IMAL concentrations in Branch Pond (22-142μg/l) are generally in a range indicating potential toxicity at DOC concentrations similar to those found in Bourn Pond. Aluminum is most toxic in the pH level 5.2 to 5.4 range (Baker et al., 1982). Bourn Pond is often found in this pH range while Branch Pond has pH values consistently below 5 (except in the hypolimnion on July 17, 1995). It does appear that, in both ponds, the DOC component may be alleviating the symptoms of aluminum toxicity that are observed in clearwater systems. Dissolved aluminum concentrations in both ponds were at potentially toxic levels if the aluminum was to occur as IMAL. Acidification may remove DOC from a waterbody and can cause a conversion, over time, from a brown water acid pond to a clearwater acid pond (Bailey, 1987). If this were to happen, both fisheries would be potentially jeopardized by the conversion of aluminum to toxic (IMAL) forms.

It is recommended that these lakes, as part of the VLTMP, continue to be monitored on a regular basis to provide information regarding water quality trends in dystrophic waterbodies.

Little Mud Pond was surveyed for the first time during this study. Refer to **Table 2** for a description of its physical characteristics and **Appendix 4** for a presentation of the results from 1993. The means and ranges are presented in **Table 4**. It has many of the characteristics of a bog in that it is shallow, acidic, highly colored, and a sphagnum mat appears to be encroaching over much of the open water. This pond will, in time, become a sphagnum bog. The chemistry is different from the other study lakes in that although the pH, alkalinity and color are similar, the total ionic composition is lower in concentration for both anions and cations. It is recommended that this lake be re-evaluated every five years.

Lye Brook Meadows are the headwaters to Lye Brook and was also sampled for the first time during this study. Chemically, it is similar to Little Mud Pond, though considerably more colored and thus lower in IMAL.

Table 4. Means and ranges for Lye Brook Wilderness study lakes (1993-1995)

Ponds and Strata	pH Std. U.	Alk mg/l	Cond[0] µs/cm	DC_2[1] Pt-Co	DCL[2] mg/l	DNO_3[3] mg/l	DSO_4[4] mg/l	DCA[5] mg/l	DMG[6] mg/l	DNA[7] mg/l	DK[8] mg/l	DAL[9] µg/l	IMAL[10] µg/l	OMAL[11] µg/l	DOC[12] mg/l	DSI[13] mg/l
Bourn *Epilimnion*	5.40 5.07-5.76	0.39 .01-.79	14.7 13.1- 17.2	51 22-112	0.27 .23-.33	0.03 <.01- .11	3.37 3.03- 3.80	0.75 .70-.82	0.33 .29-.38	0.52 .44-.60	0.35 .31- .40	175 87-312	36 22-55	56 28-88	4.80 4.09- 5.49	0.13 .08-.18
Bourn *Hypolimnion*	5.51 5.19-5.83	1.88 .44- 3.89	14.5 13.0,1 7.2	94 67-128	0.35 .24-.55	0.03 .01-.07	2.94 1.90- 3.84	0.82 .78-.90	0.32 .31-.33	0.49 .44-.57	0.37 .33- .43	246 213-279	28 9-57	68 42-85	5.54 5.40- 5.71	1.04
Branch *Epilimnion*	4.82 4.67-5.32	-0.46 -.06- -.85	18.6 15.1- 21.3	62 46-88	0.32 .25-.34	0.05 <.01- .12	3.91 3.36- 4.16	0.73 .61-.91	0.25 .23-.27	0.50 .42-.56	0.36 .30- .41	248 156-315	89 22-142	66 45-104	4.77 3.87- 5.30	.39 .07-.71
Branch *Hypolimnion*	4.96 4.76-4.94	0.20 -.68- 1.97	18.2 15.7- 20.3	100 91-108	0.34 .30-.38	0.08 <.01- .12	3.58 3.00- 3.95	0.70 .65-.74	0.25 .24-.27	0.50 .45-.54	0.41 .39- .44	290 280-303	100 76-124	92 66-141	5.95 4.88- 7.70	2.00
Little Mud	4.95 4.85-5.04	-0.30 -.62- -.01	12.4 9.5- 15.2	79 78-80	0.06 .02-.10	<0.01 <.01- .01	2.38 1.93- 2.84	0.68 .65-.72	0.21 .18-.24	0.30 .19-.42	0.10 .03- .16	117 94-140	32	41	8.05	--
Lye Brook Meadows	4.93	0.00	15.4	355	0.10	0.01	1.80	0.56	0.19	0.75	0.17	215	4	214	--	--

* All DNO_3 <0.01 values were assumed to be 0.01 for statistical purposes.

[0] Cond = conductivity
[1] DC_2 = filtered color
[2] DCL = dissolved chloride
[3] DNO_3 = dissolved nitrate
[4] DSO_4 = dissolved sulfate
[5] DCA = dissolved calcium
[6] DMG = dissolved magnesium
[7] DNA = dissolved sodium
[8] DK = dissolved potassium
[9] DAL = dissolved aluminum
[10] IMAL = inorganic monomeric aluminum
[11] OMAL = organic monomeric aluminum
[12] DOC = dissolved organic carbon
[13] DSI = dissolved silica

Stream Chemistry

Refer to **Appendix 5** for a presentation of the stream results from 1993 through 1995. The means and ranges are presented in **Table 6**. All parameter results have been graphed and are available upon request.

Much of what was stated pertaining to color and aluminum in the lakes is true for the streams. The streams do have significant chemical differences from the lakes, most notably higher concentrations of aluminum, DOC, and base cations. Whereas no lakes had calcium levels exceeding one mg/l, calcium concentrations greater than one mg/l were often observed on Bourn and Lye Brooks and the Winhall River and occasionally noted on the most acidic stream, Branch Pond Brook.

All streams underwent a reduction of pH, alkalinity and calcium between mid-April to early May when spring run-off was at its highest stage. For example, Bourn Brook (Lower) experienced a typical decline in these parameters in the spring of 1994 with a 1.9 pH unit decrease from the fall of 1993, a 4.49mg/l alkalinity decrease (this resulted in a negative alkalinity) and a 1.15mg/l decrease in calcium. The fall was chosen to illustrate the spring acidification phenomena because the fall period generally has the lowest flows and often the highest pH, alkalinity and base cations. The spring periods of 1993 and 1994 had similar snowmelt/run-off/stream chemistry characteristics, but due to the lack of snowfall during the winter of 1994, the spring runoff of 1995 was much less dramatic than in the previous two years, as were the resulting fluctuations in stream chemistry. It is realistic to assume that our limited monitoring may not have observed the lowest pH, alkalinity and calcium conditions and thus, even greater decreases could be occurring.

The effects of the drought of 1995 highlights what happens to a stream when not significantly influenced by surface run-off resulting from snowmelt and precipitation. pH levels in 1995 at Branch Pond Brook remained above 5.00 during seven out of eight sampling events. This is in contrast to 1993, a relatively wet year, when seven out of eight sampling events recorded pH levels below 5.00. This pattern was observed for all streams, clearly showing the significance of surface run-off in influencing stream water quality. Branch Pond Brook is chemical similar to its headwaters, Branch Pond.

The mean DOC (Bourn and Lye upper stations not included) of the study streams ranged from 5.75 to 9.12 mg/l in the following gradient: Winhall < Bourn < Branch Pond Brook < Lye. These DOC levels have a positive biological effect by allowing the humic material to bind with the toxic IMAL. The mean IMAL (Bourn and Lye upper stations included) ranged from 31 to 90 μg/l in the following gradient: Bourn (lower) < Winhall < Bourn (upper) < Lye (lower) < Branch Pond Brook < Lye (upper). The highest levels of inorganic monomeric aluminum were observed during the spring run-off period and it is highly likely that potentially toxic thresholds for IMAL were exceeded in Lye Brook, and furthermore, that toxic thresholds were exceeded in both Bourn and Branch Pond Brooks. Actual in-stream impacts would be dependent upon the duration of elevated concentrations in the stream water. These observations may account for the absence of fish in the upper Lye Brook station. The pH of 4.96 observed on September 22, 1993 is near the reported 5.2-5.4 range when IMAL is most lethal.

One of the secondary objectives of this study was to document the effects of elevation, or location within the watershed gradient, on water chemistry. Bourn and Lye Brook had upper stations selected for this purpose. Although no statistical comparisons could be made, differences were

observed between the sites for a number of parameters, including both pH and alkalinity during several dates. **Table 5** shows the greatest differences in pH and alkalinity between stations. The difference is probably due to higher levels of chemical weathering products in the lower reaches (Bailey, 1987). The "drought" of 1995 especially highlighted the differences. Regardless of the sites, the limited spring runoff and lack of rainfall diminished the effects of anthropogenic acidification for 1995. The pH and alkalinities at both elevational sites were considerably higher than in previous years, with the buffering effects most pronounced at the lower sites. This observation of higher pH and alkalinities in 1995 was also observed on several of the Vermont Long-Term Monitoring Program lakes that were monitored during 1995.

Table 5. Comparison of pH and alkalinity from fall sampling at two sites on Bourn and Lye Brooks.

		BOURN BROOK			LYE BROOK		
pH/Alkalinity	**Year**	**Upper 4.1**	**Lower 1.6**	**Diff**	**Upper 3.4**	**Lower 1.8**	**Diff.**
pH (Std. U)	1993	5.69	6.78	1.09	4.96	6.69	1.73
Alkalinity (mg/l)	1993	0.62	3.94	3.32	-0.02	2.30	2.32
pH (Std. U)	1994	5.97	6.76	0.79	4.46	6.77	2.31
Alkalinity (mg/l)	1994	1.85	4.68	2.83	-1.99	5.56	7.55
pH (Std. U)	1995	6.64	7.21	0.57	5.67	7.19	1.52
Alkalinity (mg/l)	1995	2.88	7.28	4.40	0.77	10.46	9.69

Table 6. Means and ranges for Lye Brook Wilderness streams (1993-1995)

River and # of Samples	Yr	pH Std. U.	Alk mg/l	Cond[0] µs/cm	DC_1[1] Pt-Co	DCL[2] mg/l	DNO_3[3] mg/l	DSO_4[4] mg/l	DCA[5] mg/l	DMG[6] mg/l	DNA[7] mg/l	DK[8] mg/l	DAL[9] µg/l	IMAL[10] µg/l	OMAL[11] µg/l	DOC[12] mg/l
Bourn Bk. (1) (Upper-4.1)	93	5.69	0.62	21.9	85	0.27	0.02	3.83	1.40	0.59	0.92	0.39	299	58	147	9.69
Bourn Bk. (1) (Upper-4.1)	94	5.97	1.85	18.3	169	0.48	0.03	3.46	1.29	0.59	1.04	0.58	348	12	120	9.03
Bourn Bk. (1) (Upper-4.1)	95	6.64	2.88	20.8	92	0.47	0.10	3.80	1.28	0.61	1.22	0.73	162	--	--	--
Bourn Bk. (8) (Lower-1.6)	93	6.08 4.94-6.78	1.93 -0.28-3.94	19.7 17-22.9	99 73-135	0.33 0.24-0.48	0.09 <0.01-0.20	4.20 3.23-4.84	1.80 1.07-2.24	0.65 0.33-0.95	0.65 0.38-0.89	0.51 0.36-0.65	272 175-299	32 30-33	102 83-120	6.89 5.83-7.80
Bourn Bk. (5) (Lower-1.6)	94	5.69 4.80-6.76	1.81 -0.55-4.92	21.3 17.2-26.6	89 81-104	0.30 0.20-0.40	0.15 0.07-0.26	3.91 3.23-4.39	1.59 1.01-2.31	0.60 0.32-0.93	0.61 0.36-0.93	0.49 0.33-0.65	238 80-306	29 0-60	87 58-107	6.18 5.03-6.90
Bourn Bk. (4) (Lower-1.6)	95	6.48 5.94-7.21	3.47 1.18-7.28	25.0 20.7-32.5	120 46-195	0.43 0.34-0.56	0.20 0.10-0.28	4.62 4.38-4.82	2.00 1.57-2.70	0.83 0.58-1.22	0.80 0.62-0.95	0.61 0.48-0.69	189 82-281	--	--	
Branch Pd. Bk. (8) 0.1	93	4.78 4.61-5.06	-0.75 -1.34- -0.04	21.4 16.4-27.2	88 71-130	0.28 0.20-0.40	0.14 <0.01-0.38	3.80 3.06-4.53	0.94 0.67-1.17	0.30 0.24-0.36	0.58 0.45-0.86	0.42 0.33-0.54	305 224-382	76 70-83	121 90-152	7.83 5.60-10.0
Branch Pd. Bk. (9) 0.1	94	4.93 4.61-5.41	-0.42 -1.05-0.53	20.5 15.2-25.2	92 55-155	0.26 0.17-0.39	0.13 <0.01-0.32	3.69 2.73-4.45	0.89 0.73-1.02	0.30 0.24-0.36	0.61 0.39-0.88	0.39 0.31-0.47	306 279-315	60 25-89	99 78-127	6.40 4.30-8.75
Branch Pd.Bk. (8) 0.1	95	5.18 4.91-5.54	0.07 -0.42-0.69	21.0 19.0-22.7	74 43-168	0.36 0.31-0.42	0.19 <0.01-0.38	4.59 3.94-5.71	1.03 0.90-1.23	0.38 0.33-0.47	0.91 0.71-1.19	0.55 0.47-0.66	231 196-294	76	105	
Lye Bk. (1) (Upper-3.4)	93	4.96	-0.02	20.4	142	0.45	0.04	3.56	1.09	0.46	0.82	0.41	365	89	155	11.67
Lye Bk. (2) (Upper-3.4)	94	4.49 4.46,4.52	-1.78 -1.99- -1.56	25.9 22.4,29.4	178 162,194	0.33 0.18-0.47	0.05 0.02,0.09	3.83 3.07,4.59	0.82 0.58,1.06	0.31 0.20,0.41	0.48 0.35,0.62	0.42 0.36,0.47	423 342,504	90 89,98	116 98,134	11.61 9.31,13.9
Lye Bk. (1) (Upper-3.4)	95	5.67	0.77	22.9	--	0.54	0.26	5.12	1.29	0.62	0.88	0.68	198	--	--	--
Lye Bk. (8) (Lower-1.8)	93	5.78 4.67-6.69	1.48 -1.21-2.78	20.2 17.8-23.2	141 111-161	0.32 0.21-0.39	0.32 0.21-0.51	3.95 2.97-4.74	1.56 0.75-2.32	0.78 0.30-1.52	0.55 0.33-0.76	0.47 0.37-0.69	323 140-411	57 51-66	147 123-173	9.39 8.67-10.2

River and # of Samples	Yr	pH Std. U.	Alk mg/l	Cond[0] µs/cm	DC_1[1] Pt-Co	DCL[2] mg/l	DNO_3[3] mg/l	DSO_4[4] mg/l	DCA[5] mg/l	DMG[6] mg/l	DNA[7] mg/l	DK[8] mg/l	DAL[9] µg/l	IMAL[10] µg/l	OMAL[11] µg/l	DOC[12] mg/l
Bourn Bk. (1) (Upper-4.1)	93	5.69	0.62	21.9	85	0.27	0.02	3.83	1.40	0.59	0.92	0.39	299	58	147	9.69
Lye Bk. (5) (Lower-1.8)	94	5.51 4.54-6.77	1.24 -1.36-5.56	23.5 18.2-30.6	136 92-163	0.39 0.22-0.56	0.14 0.07-0.22	4.00 3.22-4.82	1.29 0.81-2.42	0.66 0.34-1.22	0.52 0.34-0.83	0.47 0.35-0.61	349 276-456	80 13-119	106 83-130	8.86 7.99-9.47
Lye Bk. (4) (Lower-1.8)	95	6.55 6.03-7.19	4.99 1.82- 10.46	25.5 18.9-33.6	107 53-185	0.42 0.36-0.42	0.21 0.14-0.26	4.94 4.51-5.41	2.22 1.69-3.34	1.16 0.79-1.88	0.68 0.62-0.79	0.60 0.56-0.67	228 134-290	--	--	--
Winhall R. (7) (8.1)	93	5.63 5.16-6.44	0.87 0.14-2.14	18.2 13.4-21.1	65 55-84	0.32 0.27-0.50	0.11 <0.01-0.22	3.89 3.37-4.68	1.54 1.14-2.26	0.43 0.31-0.66	0.67 0.45-0.89	0.50 0.42-0.59	208 154-246	26 24-27	91 73-109	6.45 5.21-7.68
Winhall R. (7) (8.1)	94	5.95 5.01-6.70	1.58 0.19-3.42	18.5 16.2-22.5	64 42-83	0.30 0.24-0.45	0.14 0.03-0.27	3.72 3.14-4.30	1.37 1.12-1.59	0.40 0.30-0.51	0.62 0.43-0.73	0.47 0.41-0.55	218 168-246	33 3-70	87 71-106	5.05 3.74-6.17
Winhall R. (7) (8.1)	95	6.29 5.89-6.82	1.83 0.51-3.79	21.6 19.3-28.4	133	0.43 0.40-0.49	0.17 <0.01-0.30	4.61 4.21-5.72	1.67 1.33-2.21	0.54 0.43-0.77	0.93 0.74-1.25	0.61 0.53-0.80	134 90-184	40	90	--

* All DNO_3 <0.01 values were assumed to be 0.01 for statistical purposes.

[0] Cond = conductivity
[1] DC_1 = filtered color
[2] DCL = dissolved chloride
[3] DNO_3 = dissolved nitrate
[4] DSO_4 = dissolved sulfate
[5] DCA = dissolved calcium
[6] DMG = dissolved magnesium
[7] DNA = dissolved sodium
[8] DK = dissolved potassium
[9] DAL = dissolved aluminum
[10] IMAL = inorganic monomeric aluminum
[11] OMAL = organic monomeric aluminum
[12] DOC = dissolved organic carbon

Sediments

A representative surficial sediment sample was collected from Bourn, Branch and Ponds in August, 1993 or 1994. These samples represent a continuation of a 1992 sediment characterization study of other VLTMP lakes. The VLTMP lakes were chosen for this study because their remote, high elevation locations tend to isolate atmospheric deposition as the primary source of toxic pollutants. Sediments from six lakes within the GMNF have now been examined for toxic substances.

Refer to **Tables 7 and 8** for the results of the PAHs, PCBs, pesticides and priority pollutant metals found in the three target lakes in or near LBW. Since this was the first time these lake sediments have been analyzed by the VTDEC there is no historical data on these waterbodies for trend analysis. Charles and Norton have analyzed sediment cores from Branch Pond for diatom remains and changes in inferred pH. Results suggest that the pH of Branch Pond has not changed significantly from background conditions, although minor increases in acidity since 1930 are indicated. It is not known if these cores were analyzed for atmospheric contaminants (Charles and Norton, 1986). Nine of the metals were found below the minimum detection level (MDL). Arsenic and zinc were found in levels comparable to the other VLTMP lakes and well below the low level environmental risk (ER-L) guidelines proposed by NOAA (NOAA, 1990). Lead was found in both lake sediments at levels slightly above twice the ER-L guidelines of 35 mg/kg dry weight (dw). The VLTMP lakes surveyed had lead values ranging from <25 to 83 mg/kg dw with a mean value of 44 mg/kg dw.

Sediment mercury was also found in both lakes to exceed the ER-L guidelines of 0.15 mg/kg dw. Bourn, Grout, and Branch Pond each had levels of more than twice the ER-L with average concentrations of 0.32, 0.54 and 0.46 mg/kg dw, respectively. The VLTMP lakes surveyed had mercury values ranging from <0.10 to 0.24 mg/kg dw with a mean of 0.14 mg/kg dw. Two other GMNF lakes, Big Mud and Little Rock Ponds, had values of 0.24 mg/kg dw. Though our sediment database is limited, it clearly suggests that of the lakes sampled, the GMNF region in southern Vermont has the highest levels of sediment mercury compared to other remote undisturbed Vermont lakes. Both lead and mercury have been implicated as metals subject to atmospheric transport. Lead sources are predominantly automotive emissions, while mercury, like the major precursors to acid deposition (sulfur and nitrogen oxides), originates from coal burning utilities and smelters.

Table 8 presents the organic results for Bourn and Branch Ponds where some levels did exceed the practical quantitation limits (PQL). The PAHs fluoranthene and pyrene were found in both ponds and phenanthrene was found in Branch. The values did not greatly exceed the PQLs, if at all, and do not pose a threat to the aquatic biota. PCBs and pesticides were not detected in these ponds. The survey of 16 VLTMP lakes reported no lakes with PAHs, PCBs, or pesticides found in levels above the PQLs (Kellogg, 1992)

Table 7. Sediment metals analysis from three Lye Brook Wilderness area lakes. All metals reported in mg/kg dry weight (ppm). **Bold** values indicate a value in exceedance of the low level environmental risk guidelines proposed by NOAA (NOAA, 1990). < values indicate results are below VTDEC's minimum detection level.

Pond	**Date**	**Arsenic**	**Beryllium**	**Cadmium**	**Chromium**	**Copper**	**Lead**	**Mercury**	**Nickel**	**Selenium**	**Silver**	**Zinc**
Bourn	08/12/93	5.20	0.51	<5	<25	<25	**79**	**0.34**	<25	<2.5	<0.50	102
Bourn	07/20/94	3.70	1.00	<5	<25	<25	**90**	**0.30**	<25	<2.5	<0.50	126
Branch	08/12/93	3.70	<0.50	<5	<25	<25	**80**	**0.51**	<25	<2.5	<0.50	96
Branch	07/20/94	5.90	<0.50	<5	<25	<25	**86**	**0.40**	<25	3.4	0.51	116
Grout	08/03/93	2.50	0.90	<5	27	27	**98**	**0.34**	<25	<2.5	<0.50	150

Table 8. PAHs, PCBs and chlorinated pesticides from two Lye Brook Wilderness lakes sediments. All organics reported in µg/kg Dry Weight (ppb). The Practical Quantitative Limits (PQL) varies with percent moisture of the sample.

BOURN			BRANCH		
Parameter	**PQL**	**Result**	**Parameter**	**PQL**	**Result**
PAHs					
Napththalene	10	N.D.	Naphthalene	50	N.D.
2-Methylnaphthalene	10	N.D.	2-Methylnaphthalene	50	N.D.
1-Methylnaphthalene	10	N.D.	1-Methylnaphthalene	50	N.D.
Acenaphthylene	10	N.D.	Acenaphthylene	50	N.D.
Acenaphthene	10	N.D.	Acenaphthene	50	N.D.
Dibenzofuran	10	N.D.	Dibenzofuran	50	N.D.
Fluorene	10	N.D.	Fluorene	50	N.D.
Phenanthrene	10	N.D.	Phenanthrene	50	46
Anthracene	10	N.D.	Anthracene	50	N.D.
Fluoranthene	10	17	Fluoranthene	50	79
Pyrene	10	< 14	Pyrene	50	58
Benzo[a]anthracene	20	N.D.	Benzo[a]anthracene	90	N.D.
Chrysene	20	N.D.	Chrysene	90	N.D.
Benzo[b]fluoranthene	20	N.D.	Benzo[b]fluoranthene	90	N.D.
Benzo[k]fluoranthene	20	N.D.	Benzo[k]fluoranthene	90	N.D.
Benzo[a]pyrene	20	N.D.	Benzo[a]pyrene	90	N.D.
Indeno[1,2,3,cd]pyrene	40	N.D.	Indeno[1,2,3,cd]pyrene	200	N.D.
Dibenz[a,h]anthracene	40	N.D.	Dibenz[a,h]anthracene	200	N.D.
Benzo[g,h,i]perylene	40	N.D.	Benzo[g,h,i]perylene	200	N.D.
PCBs					
Dichlorobiphenyl congeners	30	N.D.	Dichlorobiphenyl congeners	90	N.D.

BOURN			BRANCH		
Parameter	**PQL**	**Result**	**Parameter**	**PQL**	**Result**
Trichlorobiphenyl congeners	30	N.D.	Trichlorobiphenyl congeners	90	N.D.
Tetrachlorobiphenyl congeners	30	N.D.	Tetrachlorobiphenyl congeners	90	N.D.
Pentachlorobiphenyl congeners	30	N.D.	Pentachlorobiphenyl congeners	90	N.D.
Hexachlorobiphenyl congeners	30	N.D.	Hexachlorobiphenyl congeners	90	N.D.
Heptachlorobiphenyl congeners	60	N.D.	Heptachlorobiphenyl congeners	200	N.D.
Total PCBs (done with ECD)	300	N.D.	Total PCBs (done with ECD)	900	N.D.
Pesticides					
Aldrin	30	N.D.	Aldrin	90	N.D.
Heptachlor epoxide	30	N.D.	Heptachlor epoxide	90	N.D.
Chlordane	100	N.D.	Chlordane	400	N.D.
4,4'-DDE	30	N.D.	4,4'-DDE	90	N.D.
Dieldrin	30	N.D.	Dieldrin	90	N.D.
Endrin	30	N.D.	Endrin	90	N.D.
4,4'-DDD	30	N.D.	4,4'-DDD	90	N.D.
4,4'-DDT	30	N.D.	4,4'-DDT	90	N.D.
Methoxychlor	30	N.D.	Methoxychlor	90	N.D.

ND = not detected

Macroinvertebrates

Lakes

The biometrics of density/m^2, mean richness, total richness, diversity, and the number of dominant taxa (≥3.5 percent) for the Ekman dredge data from Bourn, Branch, and Little Mud Ponds are reported in **Table 9**. The data represent the mean of three Ekman dredge samples taken within each depth zone (sublittoral and profundal).

Density ranged from a low of 367 organisms/m^2 in the profundal zone of Branch Pond to a high of 6967/m^2 at one meter depth in Little Mud Pond. The density in Branch Pond within the sublittoral zone (three to four meters) is very close to that collected by the VTDEC in 1983. In Bourn Pond, the density within the sublittoral zone is seven times higher than found in 1983.

Taxa richness (mean and total) ranged from a low in the Branch Pond profundal zone (2.7 and 6.0 taxa respectively) to a high in Little Mud Pond (12.3 and 18.0 taxa respectively). Since Little Mud Pond was only one meter in depth, the dredge samples cannot be directly compared to the sublittoral samples from Bourn and Branch Ponds. Both Bourn and Branch Ponds had very similar numbers of taxa from both sublittoral and profundal zones. Taxa richness decreased significantly from the sublittoral to the profundal zone areas of both ponds, from about seven taxa in the sublittoral to three or four taxa in the profundal. The sublittoral zone taxa richness values collected here are very similar to those reported in 1983 by the VTDEC. The diversity of the macroinvertebrate community and the number of dominant taxa also decreased in the profundal zones of both Branch and Bourn Ponds.

The percent composition by major taxonomic groups is presented in **Table 10** and by species in **Table 11**. Little Mud Pond is dominated by the Chironomidae (84 percent) and Tubificidae (9 percent). Branch Pond is dominated by the Chironomidae (69 percent), Chaoboridae (13 percent) and Trichoptera (7 percent) in the sublittoral zone. In the profundal zone the Chironomidae (50 percent) and Chaoboridae (45 percent) are co-dominant, with the Ceratopogonidae at 5 percent as the only other group present. Bourn Pond is dominated by the Tubificidae (44 percent), Chaoboridae (37 percent), and the Chironomidae (18 percent) in the sublittoral zone. The profundal zone is dominated by the Chaoboridae (96 percent).

Both Bourn and Branch Ponds exhibit strong thermal stratification during the summer months (**Appendix 4).** The dominance of Chaoboridae in the profundal zone of Bourn Pond indicates it is a severely dissolved oxygen (D.O.) stressed environment. The macroinvertebrate community composition within the sublittoral zone of Bourn Pond also indicates that D.O. is becoming a significant environmental stress within that zone of the pond. Compared to the 1983 VTDEC data, there has been a compositional shift in the sublittoral zone community composition toward more D.O. tolerant taxa; the Trichoptera have disappeared, and the D.O. tolerant Chironomidae Chironomus sp. has moved in and become the dominant Chironomid. At the same time the D.O. tolerant taxa Chaoboridae and Tubificidae have increased in their dominance.

Table 9. Macroinvertebrate community biometrics from sublittoral and profundal zones of Little Mud, Branch, and Bourn Ponds. Samples were collected with a six inch Ekman dredge in May, 1993. The values represent the mean from three samples.

Pond	Little Mud	Branch Pond		Bourn Pond	
Depth (m)	2	3 (sublittoral)	9 (profundal)	4 (sublittoral)	8 (profundal)
Density/m^2	6967	1117	367	6500	7217
Mean Richness	12.3	7.3	2.7	7	3.7
Total Richness	18	12	6	9	6
Diversity	3.10	2.34	1.09	1.70	.29
# Dominant Taxa (≥3.5%)	9	9	4	4	1

Table 10. Percent composition of major taxa groups from sublittoral and profundal zones of Little Mud, Branch, and Bourn Ponds. Samples were collected with a six inch Ekman dredge in May, 1993. The values represent the mean from three samples.

Pond	Little Mud	Branch Pond		Bourn Pond	
Depth (m)	2	3 (sub-littoral)	9 (profundal)	4 (sublittoral)	8 (profundal)
Chironomidae	84	69	50	18	3
Ceratopogonidae	2	4	5	1	0
Chaoboridae	3	13	45	37	96
Trichoptera	0	7	0	0	<1
Odonata	0	1	0	0	0
Megaloptera	0	4	0	0	0
Oligocheata	9	0	0	44	1
Other	2	0	0	<1	0

Table 11. Percent composition of the taxa from sublittoral and profundal zones of Little Mud, Branch, and Bourn Ponds. Chironomidae taxa in **bold** print. The dominant taxa (≥3.5 percent) for each pond are marked with an asterisk *.

Pond	Little Mud Pond	Branch Pond		Bourn Pond	
Depth (m)	2	3 (sublittoral)	9 (profundal)	4 (sublittoral)	8 (profundal)
Taxa					
Bezzia	2	0	5*	1	0
Ceratopogonidae	0	4*	0	0	0
Chaoborus	3	13*	45*	37*	96*
Ablabesmyia	4*	0	0	0	0
Chironomus	18*	0	27*	13*	1
Cladotanytarsus	1	0	0	0	0
Cladopelma	13*	0	5*	0	0
Cryptochironomus	0	0	0	0	<1
Dicrotendipes	11*	7*	0	0	0
Heterotrissocladius	0	3	0	<1	0
Orthocladius	0	17*	0	0	0
Paratanytarsus	1	0	0	0	0
Pagastiella	<1	7*	0	1	0
Polypedilum	4*	0	0	0	0
Procladius	9*	30*	0	4*	0
Psectrocladius	12*	0	14*	0	0
Telopelopia	<1	0	0	0	0
Tanytarsus	10*	1	0	1	0
Zalutschia	0	18*	0	0	0
Nematocera	2	0	0	0	0
Oxyethira	0	0	0	0	<1
Phylocentropus	0	7*	0	0	0
Libellula	0	1	0	0	0
Sialis	0	4*	0	0	0
Hydracarina	0	0	0	<1	0
Tubificidae	8*	0	0	44*	1
Naididae	1	0	0	0	0

The profundal zone community of Branch Pond is also dominated by the taxa Chaoboridae and Chironomus sp., indicating that low D.O. also exists in the Branch Pond deep water habitat. The sublittoral zone community in Branch Pond has a more diverse community than that of the Bourn Pond sublittoral zone, with nine species among the dominant taxa (≥3.5 percent). Of these the species Zalutschia sp. is one of the more dominant taxa at 18 percent. It is typically found in very dystrophic lakes. The order Trichoptera is represented by the taxa Phylocentropus sp. and the order Megaloptera by Sialis sp. The presence of these taxa as well as the diversity present indicates that D.O. is not limiting in the sublittoral zone of Branch Pond.

The bottom community of Little Mud Pond contains a diverse number of Diptera and Oligocheata. The species diversity indicates that D.O. stress is not a problem in Little Mud Pond. The lack of Trichoptera, Megaloptera, and Ephemeroptera in the lake may be attributable to the bottom substrate being made up of mostly peat and to the low pH.

Finally, no "pH sensitive" Crustacea, Mollusca, or Ephemeroptera species were found in Ekman dredge samples from the three ponds. The VTDEC samples collected in the winter of 1983 also did not contain any of these taxa. The probable limiting environmental factors to these taxa are the low pH (pH 4.67-5.83) and dissolved calcium levels (0.56-0.91 mg/l) recorded from these ponds (**Appendix 4**). A complete list of lake macroinvertebrates collected by Ekman dredge is available upon request.

A list of the taxa recorded from the qualitative shoreline surveys is presented in **Appendix 11** for all four ponds. The pH sensitive Mollusca and Ephemeroptera taxa have been listed first and highlighted in bold print. No Crustacea taxa were found in any of the ponds, and the Mollusca, and Ephemeroptera taxa groups were also absent from Lye Brook Meadows.

Three Ephemeroptera (mayfly) species were found in the study lakes. The mayfly Arthroplea bipunctata was found in Little Mud, Branch, and Bourn Ponds. Two additional mayfly species, Eurylophella temporalis and Leptophlebia sp., were found in both Branch and Bourn Ponds. Arthroplea bipunctata was not previously listed in the 1983 VTDEC biosurvey of Branch and Bourn Ponds. In fact, in the 1983 biosurvey of 26 acid sensitive lakes, it was only found in two lakes, both with pHs over 6.0. The present study indicates that it is a more pH tolerant mayfly than supposed from the results of the 1983 study. Leptophlebia sp. was reported as present in 1983 but was identified as Paraleptophlebia sp. These are closely related taxa that are difficult to tell apart as immature larvae. Eurylophella temporalis was not reported in 1983 in Bourn Pond but was found in Branch Pond.

Three Mollusca taxa were also found in the study lakes. The fingernail clam Pisidium casertanum was found in both Branch and Bourn Ponds. Bourn Pond contained an additional species, Musculium securis. These same taxa were reported in the ponds in 1983.

Branch Pond contained the only Gastropod species found in any of the ponds; the species Ferrissia fragilis was found in two lakes of similar water quality (pH and alkalinity) in 1983 (Beebe and Forester Ponds) both nearby in southern Vermont. It was not, however, found in Branch Pond in 1983 and represents a new listing for Branch Pond.

Taxa from the Chironomidae, Odonata, Coleoptera, Trichoptera and Hemiptera groups were often represented by six or more species in each pond. These taxa are generally considered as being tolerant toward low pHs. The Coleoptera family Dytiscidae (the predacious diving beetles) was most prevalent, representing 12 species of the 19 Coleoptera taxa found in the study lakes. The order Trichoptera was mostly represented by taxa from the families Limniphilidae and Phryganidae.

The list of taxa presented here is by no means complete for each lake, but it does show that the lakes are dominated by acid tolerant macroinvertebrate groups. No Crustacea (Decapoda, Isopoda and Amphipoda) species were found in the four ponds; and no Mollusca, Ephemeroptera, or Trichoptera taxa were found in Lye Brook Meadows, the least buffered of the study ponds. It is important to note that a few taxa from the typically more "acid sensitive" groups (Ephemeroptera and Mollusca) still manage to exist in three of these lakes. The populations of these "acid sensitive" species are the species most at risk from continued acid atmospheric deposition on these lakes.

Macroinvertebrate

Streams

The mean values of the macroinvertebrate biometrics, the percent composition of the major groups, and the percent composition of the functional feeding groups over the three year period of this study for each site are presented in **Table 12-14**. The data for each year of the above are presented in **Appendices 12-14**. The individual taxa - count, and percent composition data for all sampling events and replicates are available from the VTDEC Biomonitoring Section.

A successful monitoring program needs to be able to determine when both statistically and biologically significant changes have occurred. In general, it is possible to determine statistically significant differences between years or sites when those changes exceed the sampling or mean value precision estimate by at least twice the percent standard error of the sample mean, assuming sampling precision remains constant. Biological significance is a more judgmental determination. The VTDEC Biomonitoring Section generally would like to be able to determine a 50 percent change in density, and a 25 percent change in richness, EPT index and Bio Index value as being biologically significant changes. For the most part, it would appear that this three year baseline data set will provide the precision required to make future evaluations of biologically significant change.

The three years of baseline data summarized in **Table 12** show the degree of variability between years at the same site in the biometrics in terms of percent standard error (%SE) of the mean. As anticipated, density was the most variable biometric, with most sites ranging between 11 percent and 29 percent in this study. The exception to this was Bourn Brook 1.6 where the density was surprisingly consistent between years, with a SE of the mean of only 1 percent over three years. The species richness, EPT index, and Bio Index values mostly ranged between 6 and 15 percent. Again, several sites showed remarkable consistency between years. The Winhall River species richness and EPT index only varied by 2 percent , and the Bio Index value only varied by 3 percent at Lye Brook 3.4 and <1 percent at Branch Pond Brook 0.1.

The Student-Newman-Keuls non-parametric multiple comparison statistic at a probability level of $p<.05$ was used to evaluate statistically significant differences between sites in the three-year mean biometric values. Statistically significant differences were observed in the biometrics of density, richness, EPT, and Bio Index value between the study streams. **Table 12** shows which sites are significantly different from each other. Sites with a different letter in italics next to the mean biometric value are significantly different at $p<.05$.

The Winhall River 8.1 and Bourn Brook 1.6 had the highest average density, richness, EPT index, and Bio Index values and were statistically similar for those metrics. The Winhall River biometrics were significantly higher then those of the other sites except Bourn Brook site 1.6 for all the biometrics, and Bourn Brook site 3.4 for density and Bio Index value. On the other hand, Lye Brook 3.4 was significantly lower then all the other sites in density, richness, EPT index, and Bio Index value with the exception of lower Lye Brook 1.8 for density and Branch Pond Brook 0.1 for the EPT index. Only one year's data were available for Lye Brook 7.0, so statistical differences from other sites could not be determined.

The biometrics presented in **Table 12** and **Appendix 12** show that the two uppermost Lye Brook sites, 7.0 and 3.4, have poor overall biological integrity compared to the other sites in this study as well as the VTDEC biocriteria (see **Appendix 10**). Lye Brook 7.0 was poor to fair in species richness, the EPT index, EPT/Richness ratio, EPT/EPT&Chiro ratio, Bio Index, Diversity index, %Dom Taxa, and also contained no Ephemeroptera, or Plecoptera species. The site was also very high in density. A high density and Bio Index value and a low EPT/EPT&Chiro ratio is indicative of an enriched stream. This site was also characterized as having significant blue-green periphytic algal growth at the time of sampling, a unique characteristic among the sites sampled. The very low species richness, EPT Index, and absence of Ephemeroptera and Plecoptera indicate the community is additionally under stress from environmental factors that are limiting to sensitive species. Environmental limitations to these species at Lye Brook 7.0 probably include temperature, and toxic levels of pH and aluminum.

Lye Brook 3.4 rated as poor to fair for the biometrics of species richness, EPT index, Diversity index (1994 & 1995), and % Dom Taxa (1995). This site was also very low in density. The low density, species richness , EPT index, and diversity index all point toward a toxic stress on the community at this site. This site was recorded as having the lowest mean pH (4.49) and highest levels of aluminum (**Table 6**) of any of the stream sites. The biological integrity at Branch Pond Brook site 0.1 and the upper Bourn Brook site 4.1 in 1994 was lower then would be expected due to a reduced number of species and a low EPT index value. During other years, these two sites showed good biological integrity. In 1994, the pH's of the streams were generally lower then in 1993 and especially so in 1995. These two sites may be showing the effects of periodic low pH's during some years. The remaining three sites, the Winhall River site 8.1, Bourn Brook site 1.6, and Lye Brook site 1.8, all rated as having good to excellent overall biological integrity.

upper Lye Brook sites, 7.0 and 3.4. Lye Brook 7.0 is located immediately below the outlet of Lye Brook Meadows and is highly dominated by collector filterer invertebrate animals taking advantage of the pond seston as it flows by. Predacious invertebrates were the only other significant component of the community, taking advantage of the high density of filter feeders in the stream.

Lye Brook 3.4 is located about 3.5 miles downstream and is dominated by predators (54 percent), and detritus (leaf) shredders (30 percent). Other sites with a high percentage of leaf shredders are Bourn Brook 4.1, and Branch Pond Brook 0.1. These three sites have a closed canopy of trees, and therefore not only receive large amounts of leaf litter, but are also completely shaded, limiting the amount of instream algae growth. They also have relatively smaller drainage areas and therefore the amount of finer particles from processed leaf material above them is limited. At the sites located lower in the drainage, Bourn Brook 1.6, Lye Brook 1.8, and the Winhall River, the leaf shredders are less dominant and the collector gatherers/filterers become more prevalent for the same reason as mentioned above. The scraper functional group, which consume nonfilamentous algae like diatoms, are best represented in the Bourn Brook sites and Branch Pond Brook. The scraper feeding group is noticeably depressed in Lye Brook compared to the other streams. This may be in part due to the highly acidic nature of this stream and the toxic effects of pH and aluminum on diatoms and the scraper invertebrate species. The scraper invertebrate species found at the other sites are primarily from the orders Ephemeroptera and Coleoptera, both of which are also noticeably under-represented in Lye Brook.

Table 14. Mean percent composition of macroinvertebrate functional groups in the Lye Brook Wilderness Streams (1993-1995). Most sites were sampled three times (annually in the late summer). Branch Pond Brook was sampled only twice (1994 &1995). Lye Brook 7.0 was sampled once during the summer of 1995. All values are based on a kick net sample unit, subsampled in the laboratory to 1/4 of sample or a minimum 300 macroinvertabrates.

River (mi)	Collector Gatherer	Collector Filterer	Predator	Shredder Detritus	Shredder Herbivore	Scraper
Bourn Brook (4.1)	7	13	16	35	9	18
Bourn Brook (1.6)	17	23	12	13	6	20
Branch Pond Brook (0.1)	12	10	21	34	6	18
Lye Brook (7.0)	9	62	23	3	2	2
Lye Brook (3.4)	7	8	54	30	<1	1
Lye Brook (1.8)	19	35	27	15	2	2
Winhall River (8.1)	27	28	21	6	3	8

The mean percent composition of the dominant taxa (genera) > 3 percent of the community at each site over the three years of monitoring is presented in **Table 15**. Similarity in community composition between sites was evaluated using the Pinkham Pearson Coefficient of Similarity. The similarity between the sites based on the presence/absence of these dominant taxa is shown in **Table 16**. The Pinkham Pearson Coefficient of Similarity ranges from 0 to 1, with 0 indicating total dissimilarity and 1 total similarity. The index points out that the Lye Brook uppermost site 7.0 is highly dissimilar in dominant taxa to all the other stream sites. The site is highly dominated by the filter feeding midges *Tanytarsus sp.* and *Micropsectra sp.* and the predacious midge *Thiennemanymia spp*. The only other site with any of these species among their dominant taxa was the Winhall River, where *Micropsectra sp.* represented 7 percent of the community. The link between these two sites may be the fact that the Winhall River drains a large wetland beaver pond complex that probably also produces substantial amounts of filterable seston.

Table 15. Mean percent composition of the dominant taxa in the Lye Brook Wilderness Streams (1993-1995).
+ = present but less than one percent.
bold = equal to or > three percent.

	Bourn Brook 4.1	Bourn Brook 1.6	Branch Pond Brook 0.1	Lye Brook 7.0	Lye Brook 3.4	Lye Brook 1.8	Winhall River 8.1
Ferrissia rivularis	0	**3**	0	0	0	0	0
Optioservus sp	+	2	0	0	0	+	+
Oulimnius sp	**5**	**5**	0	0	+	+	**3**
Promoresia sp	**13**	2	**7**	0	+	+	+
Atherix sp	**3**	2	**4**	0	+	2	+
Antocha sp	0	+	0	0	+	+	**3**
Cricotopus spp	0	**4**	+	2	0	+	**3**
Eukiefferella spp	**6**	**3**	**6**	0	+	**4**	+
Orthocladius spp	0	+	+	0	0	0	**3**
Tvetenia spp	+	+	+	0	0	+	2
Polypedilum spp	+	1	1	0	0	+	**3**
Micropsectra spp	+	+	1	**5**	0	1	**7**
Tanytarsus spp	+	0	0	**51**	0	0	+
Thiennemanymia spp	+	+	1	**23**	+	+	1
Ameletus sp	0	0	0	0	**4**	0	0
Baetidae	1	**6**	0	0	0	**10**	2

	Bourn Brook 4.1	Bourn Brook 1.6	Branch Pond Brook 0.1	Lye Brook 7.0	Lye Brook 3.4	Lye Brook 1.8	Winhall River 8.1
Ephemerellidae	+	**9**	1	0	0	+	**6**
Eurylophella sp	2	+	**4**	0	0	+	+
Parapsyche sp	0	0	0	0	**6**	+	0
Symphitopsyche spp	**12**	**14**	**7**	0	+	**10**	**15**
Cheumatopsyche spp	+	0	0	**5**	0	0	2
Arctopsyche sp	0	+	1	0	+	2	0
Brachycentrus sp	0	+	0	0	0	0	**4**
Glossosoma sp	0	**6**	0	0	0	+	+
Lepidostoma sp	+	**6**	2	0	0	**8**	**5**
Dolophilodes sp	+	**7**	+	0	+	**22**	**6**
Apatania sp	+	1	**11**	0	0	+	+
Rhychophila sp	2	2	**7**	0	**6**	**7**	2
Chloroperlidae	**6**	**4**	**6**	0	**34**	**12**	**8**
Leuctra spp	**13**	**5**	**12**	0	**8**	+	1
Peltoperla sp	**5**	1	2	0	0	**3**	+
Taeniopteryx sp	**7**	0	1	0	0	+	+
Capniidae	**15**	+	**17**	0	**21**	2	+
Isoperla sp	+	1	+	0	2	2	**7**
Malirekus sp	0	0	0	0	**7**	+	+

One other site, Lye Brook 3.4, was less then 50 percent similar to the other streams. The primary reason is the hyper-dominance of several stonefly taxa, Chloroperlidae, *Leuctra sp.*, and *Malerikus sp.*, and the only site with the mayfly *Ameletus sp.* and caddisfly *Parapsyche sp.* These taxa, as well as the caddisfly *Rhycophila spp.*, also dominant at this site, are considered tolerant of low pH and have been found at other high-elevation, low pH streams around the state. The other four sites were about 70 to 80 percent similar, indicating that major ecological differences are less likely between the other sites.

Table 16. The similarity in dominant macroinvertebrate taxa (presence/absence), between the Lye Brook Wilderness Streams using the Pinkham-Pearson Coefficient of Similarity (PPCS).

	Bourn Brook (4.1)	Bourn Brook (1.6)	Branch Pond Brook (0.1)	Lye Brook (7.0)	Lye Brook (3.4)	Lye Brook (1.8)
Bourn Brook (1.6)	0.69					
Branch Pond Brook (0.1)	0.71	0.73				
Lye Brook (7.0)	**0.15**	**0.10**	**0.12**			
Lye Brook (3.4)	*0.40*	*0.44*	*0.43*	**0.50**		
Lye Brook (1.8)	0.74	0.81	0.73	**0.10**	*0.53*	
Winhall River (8.1)	0.81	0.82	0.69	**0.16**	*0.41*	0.82

Table 17 shows the habitat characteristics between the sites, and **Table 18** presents the percent periphyton cover. The substrate composition at all sites was dominated by boulder and cobble. Bourn Brook 4.1 and Branch Pond Brook 0.1 were the only two sites with measurable amounts of sand, causing some increase in the embeddedness rating at these two sites. The canopy cover was more than 75 percent at all sites with the exception of Bourn Brook 1.6 where it was rated at 50 percent cover. The periphyton was dominated by diatoms and mosses at most sites. Mosses were especially dominant (80 percent cover) at the two upper sites on Bourn and Lye Brooks. The only site not dominated by diatoms and mosses was the uppermost site on Lye Brook 7.0, which was the only site with significant cover of blue green algae (50 percent).

Table 17. The percent composition of the physical habitat characteristics in the Lye Brook Wilderness Streams.

Location	Bedrock	Boulder > 10"	Cobble 2.5-10"	Coarse Gravel .5-2.5"	Gravel .05-.15"	Sand <.05"	Embeddedness	Canopy Cover
Bourn Brook (4.1)	0	30	30	20	15	5	25-35	90
Bourn Brook (1.6)	0	60	30	10	0	0	0-5	50
Branch Pond Brook (0.1)	0	30	30	20	10	10	25-35	80
Lye Brook (7.0)	0	20	50	20	10	0	0-5	90
Lye Brook (3.4)	0	55	25	10	10	0	0-5	100
Lye Brook (1.8)	0	45	30	15	10	0	0-5	80
Winhall River (8.1)	0	30	40	20	10	0	0-5	75

Table 18. Percent periphyton cover in the Lye Brook Wilderness Streams.

	Diatoms	Filamentous Green	Blue Green	Mosses
Bourn Brook (4.1)	100	0	0	80
Bourn Brook (1.6)	100	0	2	20
Branch Pond Brook (0.1)	100	10	0	40
Lye Brook (7.0)	0	10	50	20
Lye Brook (3.4)	100	0	0	80
Lye Brook (1.8)	100	0	2	40
Winhall River (8.1)	100	10	0	0

In summary, the Lye Brook study streams sites ranged widely in their biological integrity, and functional feeding attributes as reflected in the macroinvertebrate biometrics, order composition, functional group composition, and the dominant taxa found at the sites. The two upper Lye Brook sites were the most dissimilar from all the other sites, and also showed the most impaired level of biological integrity. Bourn Brook 1.6 and the Winhall River both exhibited the highest level of biological integrity, rating as excellent.

The ecological stresses at the uppermost Lye Brook site 7.0 as indicated by the macroinvertebrate community appears to be a combination of enrichment and temperature stress (due to Lye Brook Meadows), pH, and possibly toxic levels of aluminum. The Lye Brook 3.4 macroinvertebrate community on the other hand is not at all enriched but does appear to be impaired from pH, and aluminum toxicity. Branch Pond Brook is in better condition, but does appear to be limited by pH and aluminum toxicity, as well as substrate embeddedness from sand. The upper Bourn Brook macroinvertebrate community presently is in good condition; however, its taxa richness and EPT index are borderline and significantly lower then the other lower sites. This may be do in part to several factors, including pH stress, toxic aluminum, and substrate embeddedness.

The lowest Lye Brook site (1.8) macroinvertebrate community is presently in good condition but is slightly lower in density and species richness, compared to Bourn Brook 1.6 and the Winhall River. The site is also weak in the scraper functional group category. These community attributes indicate a possible limitation or toxic stress at the site from low pH, and aluminum. The lower Bourn Brook site 1.6 and the Winhall River both exhibited the highest level of biological integrity, and functional feeding group diversity.

Fish

All four of the study streams can be classified as cold water and moderately acidic **(Table 6)**. They drain poorly buffered watersheds which originate at elevations of greater than 2,500 feet. Bourn, Lye, and Branch Pond Brook sites are of moderate to high gradient, contain a mix of riffles and pools, a substrate composed primarily of gravel, cobble and boulder, and have extensively canopied riparian habitats. Drainage area at the sampling sites in these streams ranges from 6-19km^2 **(Table 1)**. The Winhall River site exhibits similar conditions as the other sites but drains an area of 47km^2.

Small, cold water streams in Vermont generally support relatively few fish species. Branch Pond, Lye and Bourn Brooks are typical examples. As a rule, the number of species increases with stream size, with the smallest cold headwater area supporting only brook trout. Fish species that are commonly added in a downstream direction include slimy sculpin, black and longnose dace, white sucker, creek chub, and brown trout.

In geographic areas characterized by acidic waters, small streams, in addition to having few species, also support relatively low total population densities. Populations from reference-level (least impacted) streams in Vermont with site drainages less than 25km^2 (as are Bourn, Branch Pond, and Lye Brooks) average three species (n=33). Stream sites in this range which support one or two species can still be considered unimpacted if those species include trout and/or slimy sculpin. Larger reference streams in Vermont with site drainages from 25-75km^2 (Winhall site) support an average of six species (n=20). In order of increasing drainage size, the number of species recorded from the present study sites were: one in Branch Pond Brook and Bourn Brook 4.1, none in Lye Brook 3.4, three in Lye Brook 1.8, four in Bourn Brook 4.1, and eight in Winhall River. Refer to **Table 19** for general fish population parameters for the four study streams. **Appendix 15** contains length data for salmonids.

The sampling conducted during 1995 indicated high over-winter survival for most species, with the highest densities recorded of the three years sampled. This may have been due to the relatively dry spring and slow, consistent snowmelt which provided more even discharges. Normally, run-off from snowmelt combined with spring rains creates high stream discharges which may displace and kill some stream fish.

Bourn Brook - Site 4.1

This site was populated by only brook trout at low densities. All three size/age classes (young of the year (yoy), four to six inches and more than six inches) were collected during 1993 and 1995. The 1994 sample yielded only fish greater than six inches.

Table 19. Fish population parameters for the Lye Brook Wilderness streams (1993-1995).

Location	VT IBI			Species	One Run Density			% Composition		
	1993	1994	1995		1993	1994	1995	1993	1994	1995
Bourn Brook 4.1	-	-	-	Brook Trout	0.8	0.7	4.7	100	100	100
Bourn Brook 1.6	-	-	-	Slimy Sculpin	14.4	15.9	10.7	85	84	69
				Brook Trout	1.9	2.5	3.8	11	11	16
				Brown Trout	0.2	1.1	2.4	1	4	10
				Blacknose Dace	0.4	0.1	0.7	2	1	5
				Total	**16.8**	**19.6**	**17.7**	**100**	**100**	**100**
Branch Pd. Bk. 0.1	-	-	-	Brook Trout	1.9	2.2	4.0	100	100	100
Lye Brook 3.4	-	-	-	No Fish	-	-	-	-	-	-
Lye Brook 1.8	-	-	-	Brook Trout	2.4	5.3	7.9	65	55	45
				Slimy Sculpin	0.9	3.2	5.4	24	38	45
				Brown Trout	0.3	0.6	1.5	11	7	11
				Total	**3.5**	**9.0**	**12.8**	**100**	**100**	**100**
Winhall River 8.1	43[1]	41[1]	41[1]	Blacknose Dace	4.2	15.1	80.6	16	30	47
				Longnose Dace	6.6	16.2	26.0	31	33	20
				Slimy Sculpin	7.3	14.1	42.1	27	25	26
				Atlantic Salmon	6.7	5.2	9.7	19	9	5
				Brook Trout	2.2	2.1	3.6	7	4	2
				White Sucker	0.1	0.1	0.1	<1	<1	<1
				Creek Chub	0	0.1	0.3	0	<1	<1
				Brown Trout	0	0	0.1	0	0	<1
				Total	**26.9**	**52.7**	**162.4**	**100**	**100**	**100**

1 Value is out of a possible 45. The range of values here indicate "excellent" community health.

Bourn Brook - Site 1.6

The community at this site was dominated by slimy sculpin for all three years sampled. The remaining species: brook and brown trout and blacknose dace, comprised as a group, from 14 to 31 percent of the population. With the exception of 1994, all three age/size classes of brook trout were represented in the collections. Numbers of brown trout were low in all age/size classes.

Branch Pond Brook - Site 0.1

This site supported only brook trout at low densities. All three age/size classes were present during all three years sampled.

Lye Brook - Site 3.4

No fish were captured or observed at this site. It is suspected that low pH and/or high aluminum concentrations precluded fish life for this reach of Lye Brook.

Lye Brook - Site 1.8

Brook trout accounted for 45 to 65 percent of the fish community at this site. Slimy sculpin and brown trout rounded out the remainder of the population. All three age/size classes were present in the sample for brook trout for all three years. YOY brown trout were not observed in the 1993 sample and no four to six inch or six inch plus class individuals were collected during 1995.

Winhall River - Site 8.1

This site drained the most land area and was the largest of the four streams. As a result, eight species were recorded during the three years of sampling. The community was dominated by blacknose dace, longnose dace and slimy sculpin, which collectively accounted for 74 to 93 percent of total species numbers. Following at low to moderate abundance were Atlantic salmon and brook trout. All three age/size classes of brook trout were present during all three years. Both YOY and one year and older salmon were present during the three years. Brown trout were collected in low numbers only during 1995, when all three age/size classes were sparsely represented **(Tables 19 and 20)**.

Table 20. Fish population parameters for the Winhall River (1993-1995).

	1993	1994	1995	Mean
VT IBI	43 (excellent)	41 (excellent)	41 (excellent)	41.3 (excellent)
Richness	6	7	8	7
Run 1 Density[1]	32.6	52.7	162.4	82.6
Species[2]	Slimy Sculpin Longnose Dace Atlantic Salmon Blacknose Dace Brook Trout White Sucker	Longnose Dace Blacknose Dace Slimy Sculpin Atlantic Salmon Brook Trout Creek Chub	Blacknose Dace Slimy Sculpin Longnose Dace Atlantic Salmon Brook Trout Creek Chub White Sucker Brown Trout	Blacknose Dace Longnose Dace Slimy Sculpin Atlantic Salmon Brook Trout White Sucker Creek Chub Brown Trout

[1] Numbers of fish captured on first electrofishing pass/100m^2

2 Species listed in order of dominance in catch

Fish Contaminants

Fish contaminant data was collected during 1993-95 from Bourn, Branch, Grout, and Stratton Ponds. Both composite and individual samples were taken from edible tissue. Total mercury was analyzed for in all samples, while lead, PCBs and pesticides were analyzed for in seven samples and arsenic in one sample. All concentrations were reported in mg/kg (ppm), wet weight. This data is presented in **Table 21.**

Total mercury concentrations in fish fillets ranged from 0.08 ppm in brook trout from Bourn Pond to 1.45 ppm in a smallmouth bass from Grout Pond. Levels of mercury have been generally the highest in the state in smallmouth bass from lakes in the Deerfield drainage. Follow-up sampling from other lakes in the drainage was conducted by the VTDEC in 1996 and will be analyzed during the fall of 1996. A consumption advisory issued by the Vermont Department of Health placed smallmouth bass with lake trout in the category of: women of child-bearing age eat no more than one meal per month and all others eat no more than three meals per month.

Arsenic and lead were not found at levels above the detection limit of 0.25 ppm. Very low and trace concentrations of DDE and DDD (DDT metabolites) were found in bullhead, smallmouth bass and chain pickerel from Grout Pond.

Table 21. Fish contaminant data from the Lye Brook Wilderness lakes (1993-95). Values are in ppm.

Location	Species	No. of Fish	Mercury	Arsenic	Lead	DDT	DDD	DDE
Branch Pd.	Brook Trout	2	0.34	<0.25		<.01	<.01	<.01
	Brook Trout	3	0.35			<.01	<.01	<.01
Bourn Pd.	Brook Trout	3	0.18			<.01	<.01	<.01
	Brook Trout	2	0.17				<.01	<.01
Stratton Pd.	Brook Trout	3	0.08		<0.25			
Grout Pd.	Brown Bullhead	3	0.15			<.01	<.01	Trace
	Chain Pickerel	1	0.69		<0.25	<.01	<.01	Trace
	Smallmouth Bass	1	1.13		<0.25			
		1	1.29		<0.25			
		1	0.73		<0.25			
		1	1.45		<0.25			
		1	1.16		<0.25			
		5				<.01	Trace	0.12

Other contaminants analyzed for, but not detected above practical quantitation limits were: total PCB's, DDT, Aldrin, Heptachlor epoxide, Chlordane, Dieldrin, Endrin, Methoxychlor, and Dursban.

RECOMMENDATIONS

This study provided a good opportunity for the State of Vermont to survey remote surface waters to documen their present biological and chemical status. The Lye Brook Wilderness is an important resource that needs ongoing monitoring to assure that its integrity remains undisturbed. Changes to Air Quality Related Values (AQRVs) can be documented by a regularly scheduled monitoring program. Waterbodies within the LBW, because of their sensitivity to atmospheric deposition are well suited as long-term indicators of environmental change (eg. acidification, global warming, loss of biodiversity, etc.) A program based on the following recommendations would satisfy the USFS mandate to protect AQRVs by monitoring water quality. Lakes and rivers can highlight subtle changes like the recen decreases in sulfate resulting from improved air quality. Conversely, new sources of emissions built down wind of LBW can potentially impair these waterbodies causing detectable changes to water quality.

The State has been fortunate to have been part of the U.S. EPA/VTDEC Long-Term Monitoring Program. I would be beneficial to the GMNF, the State and its citizenry if this study continues along with the VTDEC's stream Ambient Biomonitoring Network.

The following recommendations direct a continued monitoring effort for the surface waters of LBW:

Lakes:

1. The chemical monitoring of Branch and Bourn Ponds should continue indefinitely as part of the ongoing U.S. EPA/VTDEC's Long-Term Monitoring Program. Sampling should occur three times per year during the spring, summer (both epilimnion and hypolimnion) and fall.

2. Little Mud Pond and Lye Brook Meadow should be sampled for water chemistry every five years. The next sampling should occur in the summers of 1998 and 2000.

3. Surficial sediments of Branch and Bourn Ponds should be examined every five years for priority pollutant metals, PCBs, PAHs and chlorinated pesticides. The next sampling would be in the summer of 1999.

4. Fish tissue analysis on brook trout in Branch and Bourn Ponds for metals and organics should be undertaken every five years. Fish should be collected by rod and reel. The next sampling would be in the summer of 1999.

5. Macroinvertebrate monitoring of Branch and Bourn Ponds should be conducted every five years unless a change in the water chemistry would warrant more frequent analysis. The sensitive mayflies and crustacean communities can be examined on a qualitative informal basis as part of the present VT DEC Long-Term Monitoring Program by using non-destructive sampling techniques. No benthic samples need to be collected until the summer of 1998.

Rivers:

1. A subset of these rivers should be part of the VTDEC's Ambient Biomonitoring Network and sampled on a regularly scheduled basis

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APPENDICES

Appendix 1. Analytical methods for the Lye Brook Wilderness study.

Parameter	Method/Equipment	Method Reference	Reference #
pH, field	Beckman 21 meter with temperature compensation. Sample placed in 30ml plastic beaker and analyzed.	U.S. EPA, 1983 Method 150.1	1
pH, lab (stirred)	Cole Palmer DigipHase meter, Ross combination electrode model 81-02.	U.S. EPA, 1983 Method 150.1	1
Gran Alkalinity	Titration with 0.020 N H_2SO_4 to pH 3.5, with a minimum of 17 points used for Gran plot calculation.	Pfeiffer and Festa, 1980	3
Conductivity	YSI model 32 with two cells, one for samples <20 μmhos, another for samples >20 μmhos.	U.S. EPA, 1983 Method 120.1	1
Cl^-, SO_4^{2-}, NO_3^-	Dionex Ion Chromatograph 2000 with integrator; manual injection, 3 to 6 calibration standards with an independent check sample run after every 10 samples.	Pfaff, Brockhoff and O'Dell U.S. EPA, 1989 Method 300.0	4
Ca, Mg, Na, K	Perkin Elmer 3030B; 5 calibration standards; acetylene flame for Mg, Na and K, nitrous oxide flame for Ca, 1 out of every 10 samples is a duplicate or spike. Lanthanum added to base cations.	U.S. EPA 1983 Method 215.1 (Ca) Method 242.1 (Mg) Method 273.1 (Na) Method 258.1 (K)	1
Si	Colorimetric, automated, molybdate blue method using Technicon Autoanalyzer Unit.	APHA, 1992 Section 4500-SiF	6
Al, total dissolved	Perkin Elmer 3030B, Perkin Elmer 5100 PC and OHGA 600 furnace with autosampler.	U.S. EPA, 1983 Method 202.1	1
*Total Monomeric and Organic Al	Pyrocatechol violet - manual injection with 5cm flow cell Milton-Roy Spectronic 601.	U.S. EPA, 1987 Section 8.0	2
*Dissolved Organic Carbon	Oceanographic Institutes Model 700 Spectrophotometer. Persulfate oxidation, Infra-red dispersion 2 point calibration.	U.S. EPA, 1987 Section 14.0	2
Color	True color is filtered through 0.45-μm filter and measured at 420 nm on a spectrophotometer. Bauch and Lomb Spectronic 100	Black & Christman, 1963.	5
	Apparent color is unfiltered and measured on a Taylor color comparator.	U.S. EPA, 1983 Method 110.2	1

Temperature	Cole-Parmer thermistor (Model 8402-00) with weighted cable.	APHA, 1992 Section 2550B	6
Secchi Disk Transparency	Secchi Disk with calibrated line.	U.S. EPA, 1989 Section 11.0	7

* These parameters are analyzed by the Environmental Chemistry Laboratory at the University of Maine in Orono.

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Appendix 2. Lye Brook Wilderness CSI index for streams

Date	Bourn Bk. (Upper)	Bourn Bk. (Lower)	Branch Pond Bk.	Lye Bk. (Upper)	Lye Bk. (Lower)	Winhall R.
Mar-30-93			>8.60			
Apr-05-93			>8.43			5.86
Apr-08-93		3.99			5.13	
Apr-13-93			>8.67			6.49
Apr-14-93		4.49			6.30	
Apr-20-93			>8.82			6.89
Apr-22-93		>8.33			>8.76	
Apr-26-93			>8.76			6.84
Apr-28-93		6.91			7.05	
May-04-93			>8.60			5.52
May-06-93					4.94	
Aug-04-93			>8.36			4.61
Aug-05-93		3.74			3.62	
Sep-21-93	5.70	3.63		>8.55	4.20	
Oct-06-93		6.46				
Oct-19-93			>8.25			
Oct-21-93		4.11			4.42	4.35
Mar-16-94						4.94
Apr-06-94			>8.56			5.63
Apr-13-94			>8.68			6.26
Apr-14-94		>8.40			>8.82	
Apr-28-94		>8.50	>8.83	>9.08	>8.69	6.96
May-11-94			>8.60			5.00
May-18-94			>8.77			5.93
May-19-94		6.22			5.75	
Aug-01-94			6.55			4.05
Aug-02-94		3.55				
Aug-03-94					1.70*	
Sep-14-94		8.40			>8.82	
Sep-20-94	4.95	3.53			3.40	
Oct-02-94				>8.76		
Oct-03-94			>8.09			4.99
Apr-07-95		5.09			4.78	
Apr-11-95			>8.29			5.09
Apr-25-95			>8.39			5.26
May-04-95		4.40	>8.22		3.72	4.63
May-09-95			6.72			4.38
Jul-17-95					4.17	
Jul-18-95		4.06	5.99			4.13
Sep-19-95	4.09			5.63		
Sep-20-95		2.80			2.57	
Oct-03-95			>8.09			3.56
MEAN	4.91	>5.36	>8.20	>8.00	5.60	5.30

* This sample taken at the lowest Lye Brook station, but excluded from the mean calculation.

Appendix 3. Lye Brook Wilderness CSI index for lakes

Month	Year	Bourn (Epi)	Bourn (Hypo)	Branch (Epi)	Branch (Hypo)	Little Mud	Lye Brook Meadows
May	1993	6.84	6.58	>8.60	>8.59	>8.64	
August	1993	6.34	5.38	>8.69	>8.52	>8.40	
October	1993	6.46		>8.48			
May	1994	>8.32		>8.76			
July\Aug	1994	6.76	6.03	>8.76	>8.70		
September	1994	6.16		>8.77			
May	1995	6.18		>8.54			
July\Aug	1995	4.91	4.93	>8.47	5.87		>7.62
October	1995	5.87		>8.49			
MEAN		>6.43	5.73	>8.62	>7.92	>8.52	>7.62

Epi = Epilimnion
Hypo = Hypolimnion

Appendix 4. Chemistry of Lye Brook Wilderness lakes (1993-1995)

Lake	Depth (m)	Date	TEMP °C	pH STD. U	ALK mg/l	COND[0] µs/cm	DC2[1] Pt-Co	TC[2] Pt-Co	DCL[3] mg/l	DNO3[4] mg/l	DSO4[5] mg/l	DCA[6] mg/l	DMG[7] mg/l	DNA[8] mg/l	DK[9] mg/l	DAL[10] µg/l	IMAL[11] µg/l	OMAL[12] µg/l	DOC[13] mg/l	DSi[14] mg/l
Bourn	1	27-May-93	14.3	5.34	0.18	14.1	55	40	0.25	0.02	3.12	0.74	0.31	0.46	0.34	173	--	--	--	--
Bourn	6	27-May-93	6.2	5.19	0.44	16.1	67	65	0.28	0.07	2.95	0.78	0.31	0.44	0.33	235	--	--	--	--
Bourn	1	12-Aug-93	21.2	5.43	0.49	13.1	--	45	0.26	<0.0	3.80	0.70	0.34	0.51	0.31	97	55	28	4.09	--
Bourn	6.5	12-Aug-93	9.6	5.68	2.14	13.0	86	>70	0.55	0.04	3.84	0.81	0.31	0.49	0.37	213	57	42	5.40	--
Bourn	1	07-Oct-93	9.8	5.39	0.35	17.2	--	45	0.28	0.03	3.74	0.81	0.38	0.55	0.36	129	37	37	4.35	--
Bourn	1	10-May-94	11.2	5.07	0.01	14.8	64	60	0.25	0.11	3.03	0.82	0.29	0.44	0.33	252	42	69	4.52	--
Bourn	1	20-Jul-94	22.6	5.28	0.26	14.0	112	>70	0.23	<0.0	3.29	0.70	0.30	0.48	0.32	312	27	63	5.43	--
Bourn	8	20-Jul-94	8.0	5.34	1.07	14.9	128	>70	0.24	<0.0	3.09	0.79	0.31	0.47	0.36	279	9	77	5.52	--
Bourn	1	29-Sep-94	13.0	5.36	0.79	15.6	67	>70	0.26	<0.0	3.22	0.76	0.33	0.49	0.34	195	24	49	5.43	--
Bourn	1	10-May-95	11.3	5.54	0.51	14.7	--	45	0.33	0.08	3.42	0.74	0.34	0.58	0.40	188	49	50	4.27	--
Bourn	1	01-Aug-95	25.0	5.44	0.34	14.3	--	65	0.28	<0.0	3.21	0.72	0.34	0.60	0.36	144	35	88	5.49	0.08
Bourn	7	01-Aug-95	14.0	5.83	3.89	14.2	97	>70	0.33	<0.0	1.90	0.90	0.33	0.57	0.43	255	18	85	5.71	1.04
Bourn	1	04-Oct-95	13.5	5.76	0.61	14.7	--	45	0.32	<0.0	3.53	0.77	0.36	0.60	0.38	87	22	67	4.82	0.18
Branch	1	19-May-93	14.1	4.87	-0.63	19.0	83	>70	0.32	0.06	3.56	0.67	0.23	0.45	0.39	250	--	--	--	--
Branch	9	19-May-93	5.2	4.87	-0.45	19.3	94	>70	0.34	0.08	3.58	0.70	0.25	0.45	0.40	280	--	--	--	--
Branch	1	12-Aug-93	20.2	4.78	-0.35	15.1	46	55	0.25	<0.0	4.09	0.67	0.23	0.49	0.30	300	121	46	4.94	--
Branch	7.5	12-Aug-93	5.3	4.91	-0.06	15.7	105	>70	0.30	<0.0	3.00	0.74	0.24	0.48	0.39	303	124	66	5.27	--

Appendix 5. Chemistry of Lye Brook Wilderness streams (1993-1995)

River	Date	TEMP °C	pH Std. U.	ALK mg/l	COND[0] µs/cm	DC2[1] Pt-Co	TC[2] Pt-Co	DCL[3] mg/l	DNO3[4] mg/l	DSO4[5] mg/l	DCA[6] mg/l	DMG[7] mg/l	DNA[8] mg/l	DK[9] mg/l	DAL[10] µg/l	IMAL[11] µg/l	OMAL[12] µg/l	DOC[13] mg/l
Bourn (Upper)	21-Sep-93	7.0	5.69	0.62	21.9	85	65	0.27	0.02	3.83	1.40	0.59	0.92	0.39	299	58	147	9.69
Bourn (Upper)	20-Sep-94	9.0	5.97	1.85	18.3	169	>70	0.48	0.03	3.46	1.29	0.59	1.04	0.58	348	12	120	9.03
Bourn (Upper)	19-Sep-95	8.5	6.64	2.88	20.8	92	60	0.47	0.10	3.80	1.28	0.61	1.22	0.73	162	--	--	--
Bourn (Lower)	08-Apr-93	1.5	6.51	3.08	22.9	56	45	0.29	0.20	4.40	2.05	0.80	0.61	0.56	210	--	--	--
Bourn (Lower)	14-Apr-93	3.0	6.25	1.94	21.4	72	55	0.27	.0.16	4.18	1.86	0.66	0.54	0.49	237	--	--	--
Bourn (Lower)	22-Apr-93	3.0	4.94	-0.28	18.0	86	60	0.22	0.12	3.23	1.07	0.33	0.38	0.36	297	--	--	--
Bourn (Lower)	28-Apr-93	5.5	5.21	0.12	16.7	77	55	0.24	0.08	3.66	1.25	0.39	0.49	0.41	261	--	--	--
Bourn (Lower)	06-May-93	11.0	5.67	0.82	17.0	110	>70	0.24	0.08	3.26	2.15	0.57	0.78	0.46	286	--	--	--
Bourn (Lower)	05-Aug-93	15.5	6.67	3.49	22.2	96	70	0.35	0.14	4.89	2.24	0.95	0.82	0.62	213	--	120	7.80
Bourn (Lower)	21-Sep-93	8.5	6.78	3.94	17.8	135	65	0.27	0.04	4.36	2.16	0.86	0.89	0.50	197	--	104	7.04
Bourn (Lower)	21-Oct-93	7.0	6.62	2.31	21.9	73	65	0.48	<0.01	4.84	1.62	0.64	0.74	0.65	175	--	83	5.83
Bourn (Lower)	14-Apr-94	1.5	4.85	-0.41	20.1	84	65	0.23	0.26	3.58	1.13	0.38	0.41	0.46	306	60	91	6.54
Bourn (Lower)	28-Apr-94	4.0	4.80	-0.55	17.7	104	>70	0.20	0.13	3.23	1.01	0.32	0.36	0.33	303	26	107	6.90
Bourn (Lower)	19-May-94	6.5	5.33	0.43	17.2	81	60	0.24	0.07	4.14	1.32	0.44	0.49	0.41	299	55	101	5.91
Bourn (Lower)	08-Aug-94	17.5	6.70	4.92	26.6	97	70	0.40	0.19	4.23	2.31	0.93	0.86	0.65	204	0	80	6.50
Bourn (Lower)	20-Sep-94	10.5	6.76	4.68	24.9	81	55	0.42	0.08	4.39	2.20	0.91	0.93	0.61	80	5	58	5.03
Bourn (Lower)	07-Apr-95	0.5	5.94	1.18	20.7	46	40	0.34	0.28	4.53	1.60	0.58	0.62	0.48	180	--	--	--
Bourn (Lower)	04-May-95	5.0	6.41	1.97	21.4	--	>70	0.37	0.20	4.75	1.57	0.63	0.78	0.60	212	--	--	3.97
Bourn (Lower)	18-Jul-95	15.5	6.37	3.44	25.5	195	>70	0.56	0.10	4.38	2.15	0.88	0.86	0.67	281	--	--	--

Lake	Depth (m)	Date	TEMP °C	pH STD. U	ALK mg/l	COND[0] µs/cm	DC2[1] Pt-Co	TC[2] Pt-Co	DCL[3] mg/l	DNO3[4] mg/l	DSO4[5] mg/l	DCA[6] mg/l	DMG[7] mg/l	DNA[8] mg/l	DK[9] mg/l	DAL[10] µg/l	IMAL[11] µg/l	OMAL[12] µg/l	DOC[13] mg/l	DSi[14] mg/l
Branch	1	06-Oct-93	9.7	4.95	-0.15	19.3	69	>70	0.34	0.02	4.01	0.74	0.26	0.49	0.36	248	114	45	5.08	--
Branch	1	10-May-94	9.8	4.67	-0.85	19.0	88	>70	0.28	0.12	3.36	0.74	0.24	0.42	0.34	315	95	68	5.30	--
Branch	1	20-Jul-94	21.7	4.76	-0.67	19.7	71	55	0.36	0.03	4.02	0.61	0.24	0.53	0.35	252	79	57	4.85	--
Branch	9	20-Jul-94	4.3	4.76	-0.68	20.3	91	65	0.32	0.12	3.81	0.70	0.24	0.53	0.44	292	99	69	4.88	--
Branch	1	29-Sep-94	12.4	4.68	-0.74	21.3	77	>70	0.33	0.04	3.97	0.71	0.24	0.50	0.41	270	69	51	5.12	--
Branch	1	10-May-95	10.0	4.88	-0.18	19.2	68	>70	0.33	0.17	3.86	0.76	0.27	0.53	0.41	280	142	63	4.96	--
Branch	1	18-Jul-95	21.3	4.88	-0.33	17.0	--	45	0.30	0.01	4.16	0.91	0.26	0.56	0.35	156	68	95	4.07	0.07
Branch	9	18-Jul-95	5.4	5.32	1.97	17.6	108	>70	0.38	0.11	3.95	0.65	0.27	0.54	0.41	284	76	141	7.70	2.00
Branch	1	04-Oct-95	13.2	4.94	-0.26	17.5	--	45	0.34	0.01	4.16	0.75	0.27	0.53	0.38	157	22	104	3.87	0.71
L.Mud	1	05-May-93	16.0	4.85	-0.62	15.2	80	>70	0.10	<0.0	2.84	0.65	0.24	0.42	0.16	140	--	--	--	--
L.Mud	1	11-Aug-93	21.0	5.04	0.01	9.5	78	55	0.02	0.01	1.93	0.72	0.18	0.19	0.03	94	--	--	--	--
LBM[15]	0.2	17-Jul-95	20.0	4.93	0.00	15.4	355	>70	0.10	0.02	1.80	0.56	0.19	0.75	0.17	215	40	214	--	--

Parameter:
[0]Cond = Conductivity
[1]DC2 = Filtered Color
[2]TC = Unfiltered Color
[3]DCL = Dissolved Chloride
[15]LBM = Lye Brook Meadows
[4]DNO3 = Dissolved Nitrate
[5]DSO_4 = Dissolved Sulfate
[6]DCA = Dissolved Calcium
[7]DMG = Dissolved Magnesium
[8]DNA = Dissolved Sodium
[9]DK = Dissolved Potassium
[10]DAL = Dissolved Aluminum
[11]IMAL = Inorganic Monomeric Aluminum (most toxic form to aquatic biota
[12]OMAL = Organic Monomeric Aluminum
[13]DOC = Dissolved Organic Carbon
[14]DSi = Dissolved Silica

River	Date	TEMP °C	pH Std. U.	ALK mg/l	COND[0] µs/cm	DC2[1] Pt-Co	TC[2] Pt-Co	DCL[3] mg/l	DNO3[4] mg/l	DSO4[5] mg/l	DCA[6] mg/l	DMG[7] mg/l	DNA[8] mg/l	DK[9] mg/l	DAL[10] µg/l	IMAL[11] µg/l	OMAL[12] µg/l	DOC[13] mg/l
Branch Pond Brook	14-Sep-94	11.5	5.22	0.45	21.6	--	70	--	--	--	--	--	--	--	--	--	--	--
Branch Pond Brook	19-Sep-94	10.5	5.41	0.53	--	117	>70	--	--	--	--	--	--	--	--	--	--	--
Branch Pond Brook	03-Oct-94	5.5	5.22	-0.29	20.8	86	65	0.39	<0.01	4.45	0.98	0.34	0.72	0.44	309	56	108	7.79
Branch Pond Brook	03-Apr-95	0.5	5.10	-0.10	22.2	--	45	--	--	--	--	--	--	--	--	--	--	--
Branch Pond Brook	11-Apr-95	1.5	5.00	-0.23	21.2	43	40	0.37	0.38	4.64	1.03	0.36	0.73	0.49	227	--	--	--
Branch Pond Brook	25-Apr-95	5.0	4.91	-0.42	21.1	56	60	0.32	0.24	3.94	1.00	0.33	0.71	0.47	239	76	105	4.84
Branch Pond Brook	04-May-95	10.5	5.13	0.01	19.4	45	70	0.31	0.17	3.98	0.90	0.33	0.80	0.51	206	--	--	4.71
Branch Pond Brook	09-May-95	4.5	5.52	0.23	19.0	59	50	0.34	0.17	4.39	0.95	0.34	0.89	0.53	216	--	--	--
Branch Pond Brook	18-Jul-95	14.5	5.25	0.69	22.7	168	>70	0.42	0.16	5.02	1.23	0.47	1.19	0.65	294	--	--	--
Branch Pond Brook	03-Oct-95	8.5	5.38	0.31	21.5	76	70	0.40	<0.01	5.57	1.09	0.43	1.15	0.64	202	--	--	--
Branch Pond Brook	03-Oct-95	8.5	5.54	0.33	21.7	75	70	0.42	<0.01	5.71	1.18	0.45	1.14	0.66	196	--	--	--
Lye (Upper)	22-Sep-93	9.0	4.96	-0.02	20.4	142	>70	0.45	0.04	3.56	1.09	0.46	0.82	0.41	365	--	155	11.67
Lye (Upper)	28-Apr-94	4.0	4.46	-1.99	22.4	162	>70	0.18	0.09	3.07	0.58	0.20	0.35	0.36	342	89	134	9.31
Lye (Upper)	02-Oct-94	5.5	4.52	-1.56	29.4	194	>70	0.47	0.02	4.59	1.06	0.41	0.62	0.47	504	98	98	13.90
Lye (Upper)	19-Sep-95	10.5	5.67	0.77	22.9	--	60	0.54	0.26	5.12	1.29	0.62	0.88	0.68	198	--	--	--
Lye (Lower)	08-Apr-93	1.0	5.74	1.37	21.4	111	>70	0.37	0.15	4.66	1.56	0.68	0.55	0.60	411	--	--	--
Lye (Lower)	14-Apr-93	2.5	5.25	0.45	19.5	135	>70	0.28	0.10	4.02	1.26	0.55	0.46	0.48	140	--	--	--

River	Date	TEMP °C	pH Std. U.	ALK mg/l	COND[0] µs/cm	DC2[1] Pt-Co	TC[2] Pt-Co	DCL[3] mg/l	DNO3[4] mg/l	DSO4[5] mg/l	DCA[6] mg/l	DMG[7] mg/l	DNA[8] mg/l	DK[9] mg/l	DAL[10] µg/l	IMAL[11] µg/l	OMAL[12] µg/l	DOC[13] mg/l
Bourn (Lower)	20-Sep-95	10.0	7.21	7.28	32.5	--	40	0.44	0.21	4.82	2.70	1.22	0.95	0.69	82	--	--	--
Branch Pond Brook	30-Mar-93	1.0	4.69	-0.81	27.2	68	55	0.32	0.38	3.84	1.02	0.33	0.55	0.50	382	--	--	--
Branch Pond Brook	05-Apr-93	1.0	4.86	-0.73	23.9	72	55	0.33	0.26	4.39	1.12	0.34	0.54	0.54	279	--	--	--
Branch Pond Brook	13-Apr-93	2.0	4.64	-1.07	22.8	82	65	0.26	0.21	3.84	0.97	0.30	0.54	0.47	315	--	--	--
Branch Pond Brook	20-Apr-93	2.0	4.61	-1.34	22.1	86	60	0.25	0.14	3.42	0.75	0.25	0.45	0.34	328	--	--	--
Branch Pond Brook	26-Apr-93	4.0	4.62	-1.16	20.3	98	70	0.20	0.10	3.06	0.84	0.24	0.45	0.34	288	--	--	--
Branch Pond Brook	04-May-93	10.0	4.87	-0.58	19.2	97	70	0.23	0.03	3.22	0.67	0.24	0.50	0.37	313	--	--	--
Branch Pond Brook	04-Aug-93	16.0	4.87	-0.24	16.4	130	>70	0.23	0.02	4.13	1.17	0.35	0.77	0.33	312	--	152	10.00
Branch Pond Brook	19-Oct-93	8.5	5.06	-0.04	19.1	71	70	0.40	<0.01	4.53	0.98	0.36	0.86	0.45	224	--	90	5.66
Branch Pond Brook	06-Apr-94	1.0	4.73	-0.65	22.9	55	--	0.29	0.28	4.24	1.02	0.36	0.68	0.47	279	79	79	4.30
Branch Pond Brook	13-Apr-94	1.0	4.66	-1.28	25.2	58	50	0.24	0.32	3.87	0.91	0.31	0.53	0.41	303	82	78	5.07
Branch Pond Brook	28-Apr-94	--	4.61	-1.26	19.8	93	>70	0.17	0.20	3.01	0.73	0.24	0.39	0.31	314	61	90	6.56
Branch Pond Brook	11-May-94	8.5	4.76	-0.72	18.7	84	65	0.23	0.06	3.71	0.87	0.27	0.54	0.38	309	26	127	5.84
Branch Pond Brook	18-May-94	9.0	4.58	-1.05	20.1	88	70	0.22	0.06	3.84	0.89	0.27	0.52	0.34	315	89	100	6.46
Branch Pond Brook	01-Aug-94	14.5	5.17	0.47	15.2	155	>70	0.26	0.01	2.73	0.82	0.30	0.88	0.41	312	25	114	8.75

River	Date	TEMP °C	pH Std. U.	ALK mg/l	COND[0] µs/cm	DC2[1] Pt-Co	TC[2] Pt-Co	DCL[3] mg/l	DNO3[4] mg/l	DSO4[5] mg/l	DCA[6] mg/l	DMG[7] mg/l	DNA[8] mg/l	DK[9] mg/l	DAL[10] µg/l	IMAL[11] µg/l	OMAL[12] µg/l	DOC[13] mg/l
Lye (Lower)	22-Apr-93	2.0	4.67	-1.21	20.5	170	>70	0.22	0.08	2.97	0.75	0.30	0.33	0.37	396	--	--	--
Lye (Lower)	28-Apr-93	4.5	5.08	0.14	18.0	140	>70	0.21	0.05	3.53	1.05	0.46	0.35	0.39	387	--	--	--
Lye (Lower)	06-May-93	11.5	5.92	1.76	17.8	161	>70	0.22	0.08	3.12	1.56	0.61	0.50	0.42	391	--	--	--
Lye (Lower)	05-Aug-93	16.0	6.68	4.31	23.2	140	>70	0.39	0.10	4.56	2.32	1.52	0.69	0.44	291	--	173	10.20
Lye (Lower)	22-Sep-93	10.0	6.69	2.30	18.3	157	>70	0.39	0.06	3.97	2.16	1.14	0.76	0.40	289	--	144	9.30
Lye (Lower)	21-Oct-93	7.0	6.19	2.78	22.8	116	70	0.51	<0.01	4.74	1.78	0.96	0.76	0.69	276	--	123	8.67
Lye (Lower)	16-Mar-94	1.0	6.10	1.92	24.2	92	65	0.42	0.20	4.82	0.95	0.77	0.63	0.61	276	--	--	--
Lye (Lower)	14-Apr-94	2.0	4.54	-1.36	25.8	139	>70	0.26	0.22	3.65	0.87	0.36	0.37	0.48	456	119	101	9.09
Lye (Lower)	28-Apr-94	5.0	4.70	-0.82	18.8	163	>70	0.56	0.08	3.22	0.81	0.34	0.34	0.35	348	103	109	9.47
Lye (Lower)	19-May-94	6.5	5.46	0.88	18.2	148	>70	0.22	0.07	4.06	1.40	0.64	0.43	0.39	390	84	130	8.88
Lye (Lower)	20-Sep-94	10.5	6.77	5.56	30.6	137	>70	0.50	0.11	4.27	2.42	1.22	0.83	0.54	276	13	83	7.99
Lye (Lower)	07-Apr-95	0.5	6.03	1.82	18.9	82	60	0.42	0.20	5.02	1.69	0.79	0.63	0.57	268	--	--	--
Lye (Lower)	04-May-95	6.0	6.69	4.11	25.0	--	>70	0.36	0.14	4.82	1.90	1.02	0.62	0.56	220	--	--	--
Lye (Lower)	17-Jul-95	15.5	6.29	3.58	24.5	185	>70	0.38	0.26	4.51	1.93	0.95	0.69	0.67	290	--	--	--
Lye (Lower)	20-Sep-95	10.0	7.19	10.46	33.6	53	50	0.52	0.25	5.41	3.34	1.88	0.79	0.61	134	--	--	--
Lye[14] (Lowest)	03-Aug-94	17.5	7.43	24.10	58.8	114	>70	0.46	0.21	4.14	6.22	3.28	0.65	0.53	192	15	92	6.77
Winhall	05-Apr-93	4.5	5.61	0.50	19.2	56	50	0.35	0.22	4.19	1.35	0.40	0.61	0.57	223	--	--	--
Winhall	13-Apr-93	4	5.32	0.25	18.0	57	50	0.27	0.17	3.80	1.24	0.34	0.52	0.46	225	--	--	--
Winhall	20-Apr-93	5	5.21	0.14	17.3	58	35	0.27	0.14	3.37	1.14	0.31	0.45	0.42	212	--	--	--
Winhall	26-Apr-93	7	5.16	0.14	13.4	71	70	0.23	0.09	3.37	1.42	0.36	0.58	0.43	246	--	--	--
Winhall	04-May-93	9	5.67	0.74	19.2	72	40	0.32	0.06	3.43	1.75	0.42	0.77	0.47	204	--	--	--
Winhall	04-Aug-93	17.5	6.00	2.15	19.3	84	70	0.27	0.06	4.37	2.26	0.66	0.88	0.54	189	24	109	7.68

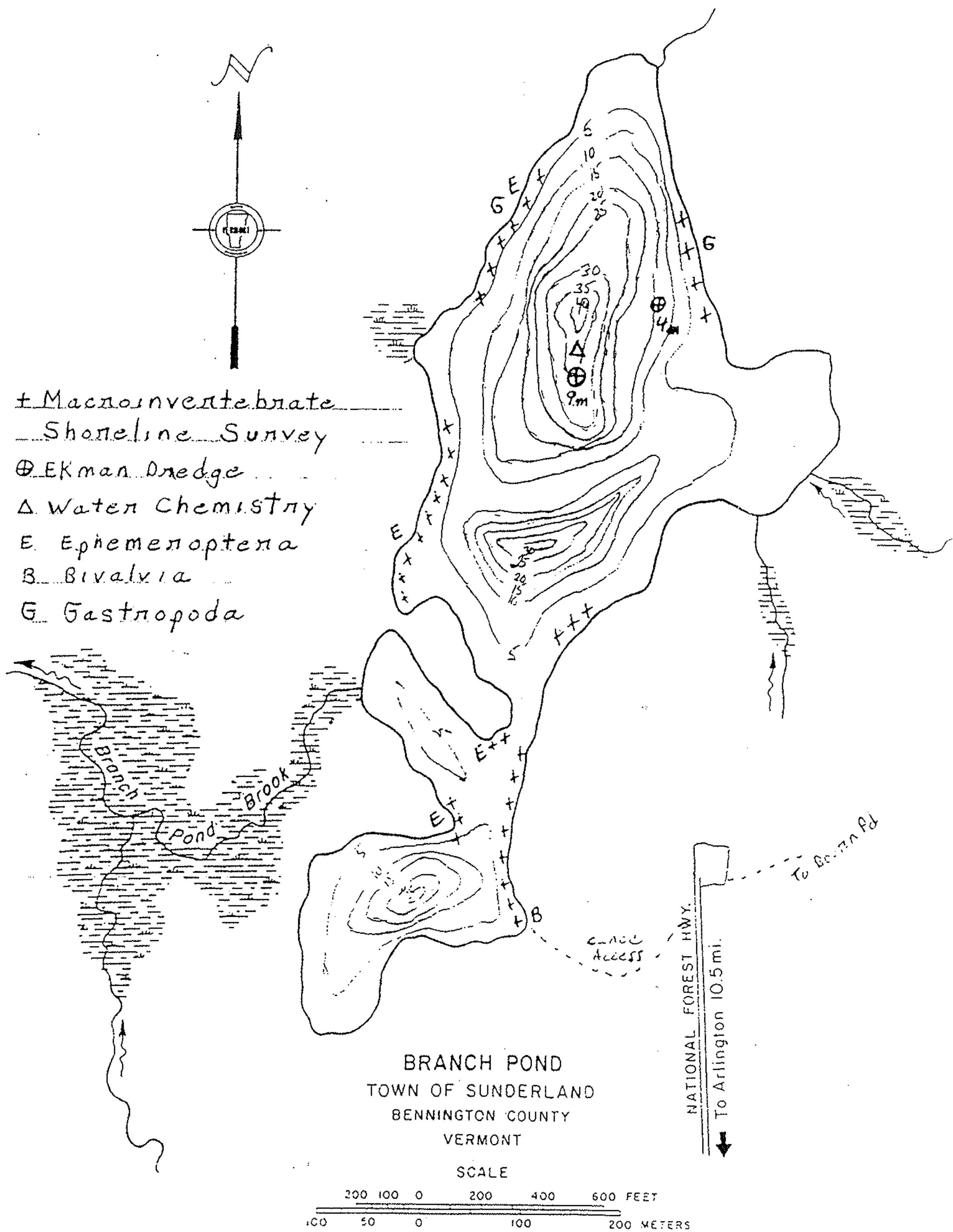
River	Date	TEMP °C	pH Std. U.	ALK mg/l	COND[0] µs/cm	DC2[1] Pt-Co	TC[2] Pt-Co	DCL[3] mg/l	DNO3[4] mg/l	DSO4[5] mg/l	DCA[6] mg/l	DMG[7] mg/l	DNA[8] mg/l	DK[9] mg/l	DAL[10] µg/l	IMAL[11] µg/l	OMAL[12] µg/l	DOC[13] mg/l
Winhall	19-Oct-93	8.5	6.44	2.15	21.1	55	50	0.50	<0.01	4.68	1.62	0.55	0.90	0.59	154	27	73	5.21
Winhall	06-Apr-94	1.0	5.68	0.71	18.3	45	--	0.30	0.26	3.88	1.37	0.42	0.63	0.47	190	35	71	3.74
Winhall	13-Apr-94	1.0	5.40	0.34	18.6	42	45	0.24	0.27	3.52	1.28	0.37	0.55	0.44	214	41	72	4.14
Winhall	28-Apr-94	--	5.01	0.19	17.3	67	55	0.25	0.17	3.43	1.12	0.30	0.43	0.41	246	63	93	5.41
Winhall	11-May-94	10.0	6.14	1.10	16.2	59	50	0.27	0.07	3.83	1.33	0.35	0.58	0.45	230	10	100	4.56
Winhall	18-May-94	9.0	5.44	0.64	16.5	64	50	0.25	0.06	3.97	1.32	0.35	0.56	0.41	246	70	82	5.27
Winhall	01-Aug-94	18.5	6.56	3.06	18.9	83	60	0.31	0.08	3.14	1.59	0.51	0.95	0.55	168	3	82	6.17
Winhall	14-Sep-94	12.5	6.66	3.42	22.5	--	--	--	--	--	--	--	--	--	--	--	--	--
Winhall	19-Sep-94	10.5	6.70	3.39	--	80	--	--	--	--	--	--	--	--	--	--	--	--
Winhall	03-Oct-94	4.5	5.98	1.37	19.5	71	50	0.45	0.03	4.30	1.58	0.49	0.73	0.54	231	10	106	6.05
Winhall	03-Apr-95	0.5	6.08	0.51	20.6	--	35	--	--	--	--	--	--	--	--	--	--	--
Winhall	11-Apr-95	2.0	6.00	1.04	19.5	--	35	0.41	0.30	4.50	1.56	0.45	0.77	0.53	138	--	--	--
Winhall	25-Apr-95	6.0	5.89	0.96	19.5	--	55	0.43	0.22	4.21	1.48	0.43	0.74	0.54	156	--	--	--
Winhall	04-May-95	12.0	6.36	1.54	19.3	--	65	0.40	0.15	4.32	1.33	0.44	0.82	0.55	119	40	90	--
Winhall	09-May-95	6.5	6.43	2.05	20.4	--	40	0.40	0.15	4.34	1.51	0.48	0.89	0.58	120	--	--	--
Winhall	18-Jul-95	14.0	6.42	2.92	23.7	133	>70	0.45	0.20	4.55	1.92	0.64	1.12	0.65	184	--	--	--
Winhall	03-Oct-95	10.0	6.82	3.79	28.4	--	45	0.49	<0.01	5.72	2.21	0.77	1.25	0.80	90	--	--	--

Parameter:

[0]Cond = Conductivity
[1]DC2 = Filtered Color
[2]TC = Unfiltered Color
[3]DCL = Dissolved Chloride
[12]OMAL = Organic Monomeric Aluminum
[4]DNO_3 = Dissolved Nitrate
[5]DSO_4 = Dissolved Sulfate
[6]DCA = Dissolved Calcium
[13]DOC = Dissolved Organic Carbon
[7]DMG = Dissolved Magnesium
[8]DNA = Dissolved Sodium
[9]DK = Dissolved Potassium
[10]DAL = Dissolved Aluminum
[11]IMAL = Inorganic Monomeric Aluminum (most toxic form to aquatic biota)

[14] This Lye Brook sample was collected further downstream near the campsite just upstream from the parking area. The bedrock type is Dunham dolomite and imparts a considerable source of buffering. Lye Brook headwaters are located in an area of profound unconformity dominated by gneiss, quartzite and calc-silicate granulite. The lower site is located in Cheshire quartzite and between the upper and lower sites is the Dalton formation (a conglomerate found at the base of the southern Green Mountains).

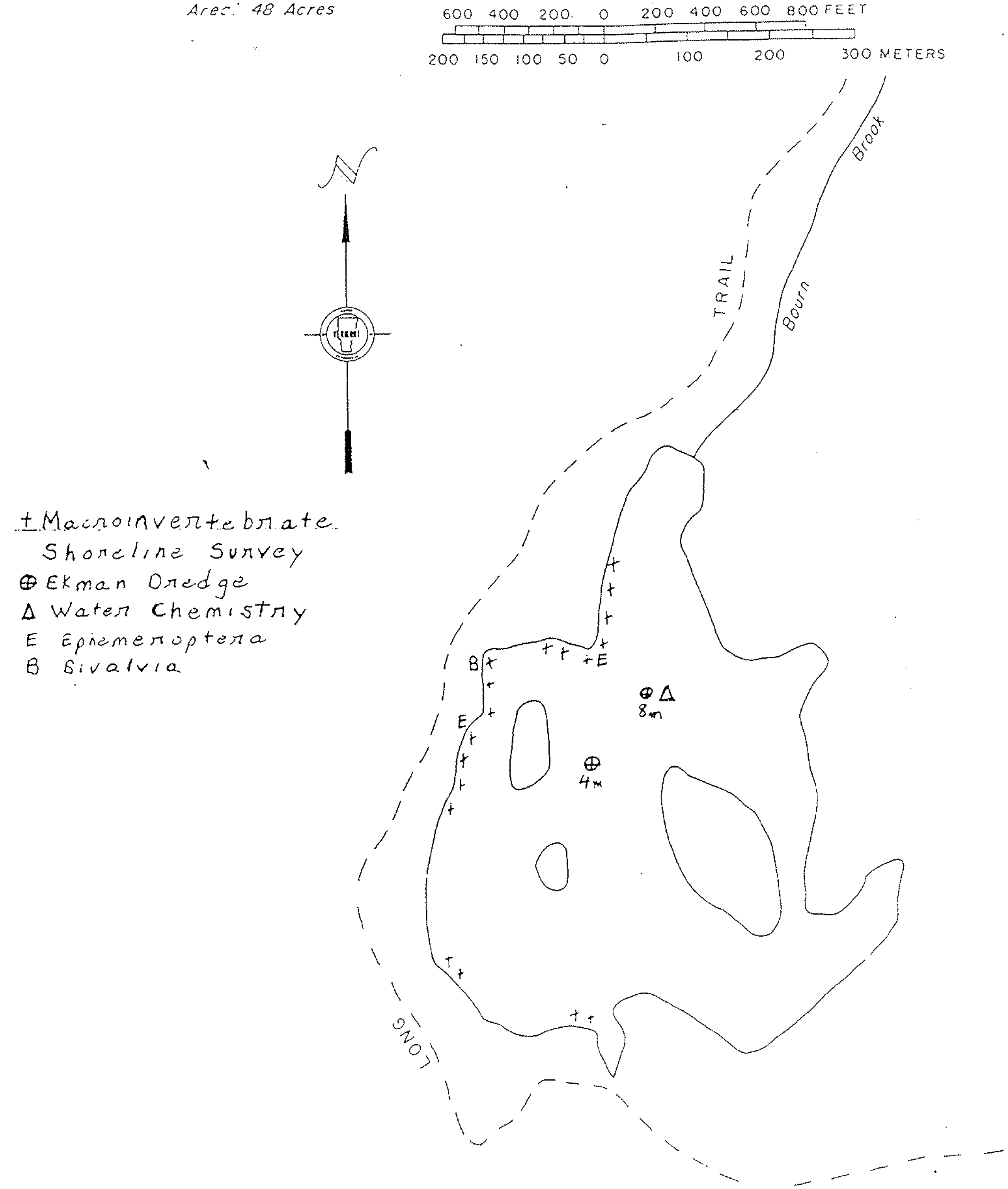
Appendix 6 Map of Branch Pond.



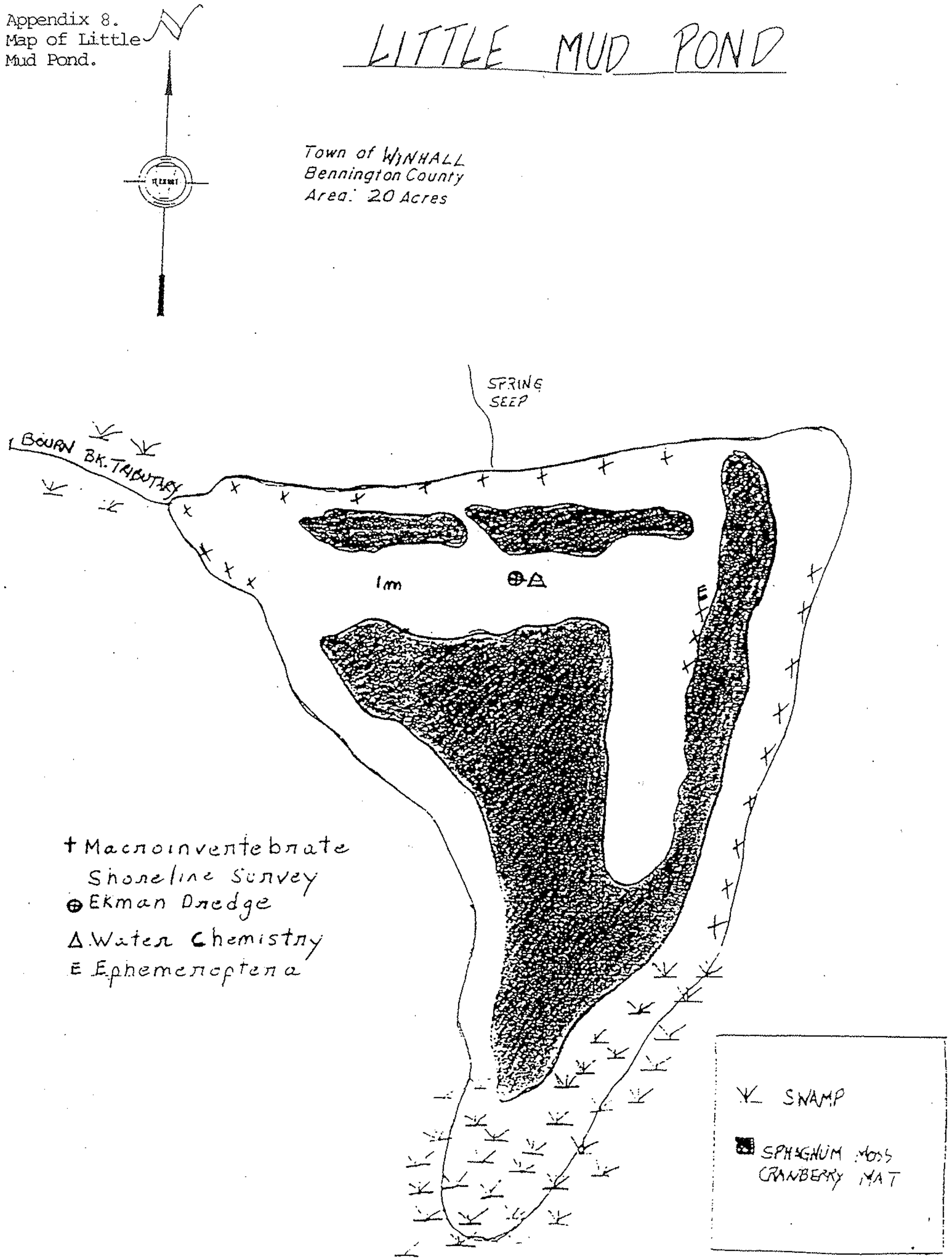
Appendix 7 Map of Bourn Pond.

BOURN POND

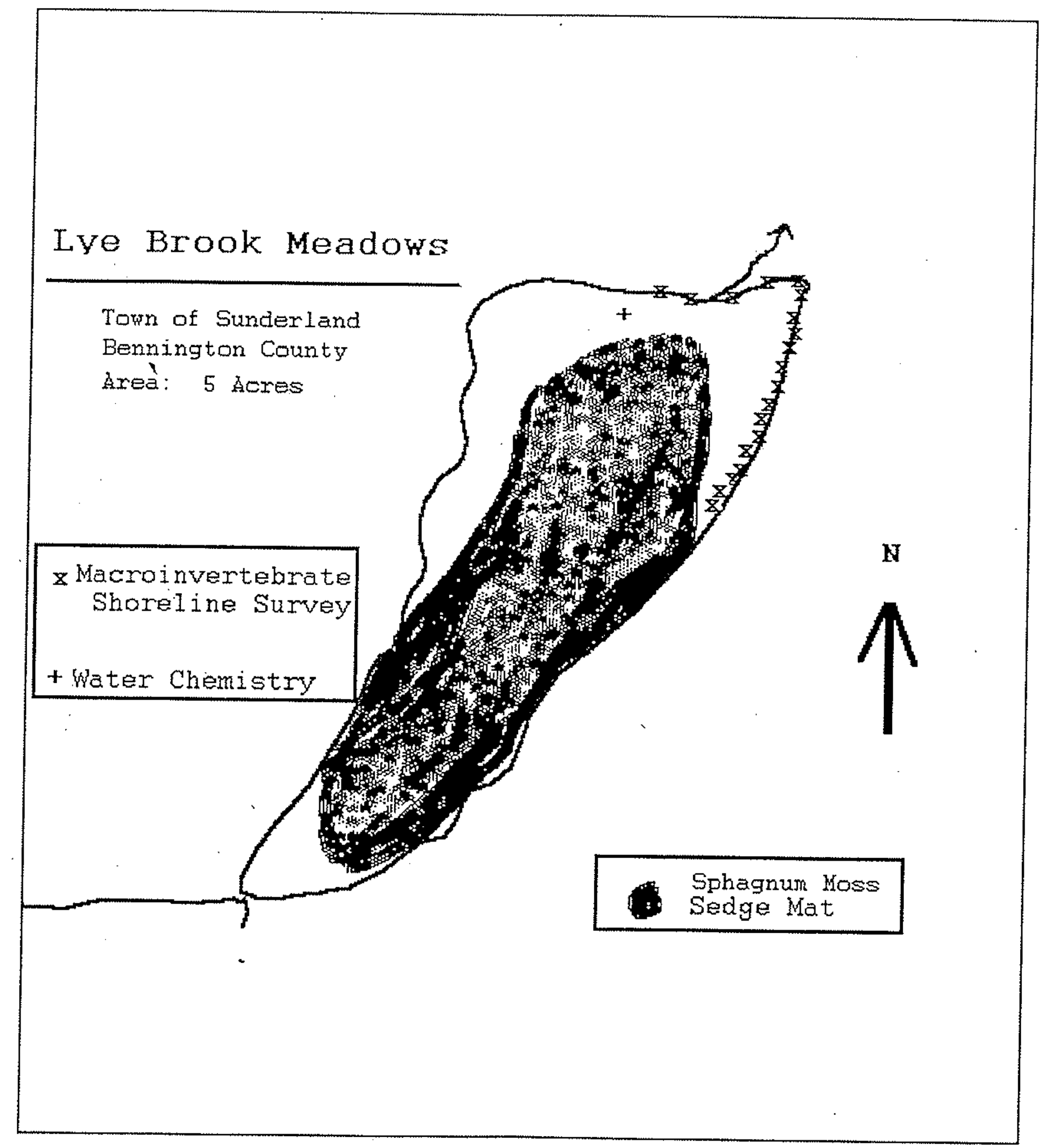
Town of Sunderland
Bennington County
Area: 48 Acres



Appendix 8.
Map of Little
Mud Pond.



Appendix 9. Map of Lye Brook Meadows.



Appendix 10: Macroinvertebrate Biocriteria

Biocriteria used for determining the biological integrity of the aquatic biota for wadeable streams and rivers in Vermont. Method used is a two minute kick net sample subsampled in laboratory by picking one quarter of sample, if subsample is less than 300 macroinvertabrates then additional subsample is picked until a minimum of 300 macroinvertabrates are in the subsample. The proportion of sample picked is then recorded. Identifications are done in the laboratory to the genus - species level. The overall biological integrity of a stream is determined by evaluating the rating and degree of each metric and the number of metrics which are found to be in an acceptable or unacceptable range.

Metric Rating	Mean Richness	Mean EPT	Bio Index	Diversity
Very Poor	<15	<8	≥3.50	<1.50
Poor	15-19	8-12	3.01-3.49	1.51 - 2.24
Fair	20-29	13-17	2.75-3.00	2.25 - 2.99
		Unacceptable		
		Acceptable		
Good	30-39	18-22	2.01-2.74	3.00-3.99
Very Good	40-49	23-25	1.51-2.00	4.00-4.49
Excellent	≥50	>25	≤1.50	>4.50

	% Dominant Genera	#EPT/#EPT&CHIRO	# EPT/# Chiro	EPT/R
Poor	≥55	<.25	≤.50	≤.30
Fair	≥40 <55	>.25<.45	>.5 <1.00	>.30 ≤.45
	Unacceptable			
	Acceptable			
Good	≥25 <40	>.45<.75	>1 <2	>.45 ≤.60
Excellent	<25	>.75	>2	>.60

*Generated using ABN Data 1987-1992
SF\125-0900.93

Appendix 11. The presence (x) of macroinvertebrate taxa collected from shoreline qualitative sampling for Little Mud, Branch and Bourn Ponds and Lye Brook Meadows. Taxa (species) sensitive to decreases in pH are in **bold** print. The number of taxa within an order is listed for each lake.

		Little Mud	Branch	Bourn	Lye Brook Meadows
Bivalvia		0	1	2	0
	Pisidium casertanum		x	x	
	Musculium securis			x	
Gastropoda		0	1	0	0
	Ferrissia fragilis		x		
Ephemeroptera		1	3	3	0
	Eurylophella temporalis		x	x	
	Arthroplea bipunctata	x	x	x	
	Leptophlebia sp.		x	x	
Coleoptera		9	6	2	10
	Haliplus sp.			x	x
	Illybius sp	x			x
	Peltodytes sp.		x		
	Donacia sp.		x		
	Hydroporus sp.	x	x	x	x
	Coptotomus sp.		x		
	Dytiscus sp.	x	x		
	Graphoderus sp.	x	x		
	Acilius sp.				x
	Agabetes acuductus				x
	Laccophilus sp.				x
	Rhantus sp.				x
	Carrhydrus crassipes				x
	Dineutes sp.	x			
	Enochrus sp.	x			
	Tripostemus sp				x
	Desmopachria sp.	x			
	Scirtidae imm.				x
	Cyphon sp.	x			
Trichoptera		6	6	6	0
	Glyphopsyche sp.			x	
	Limnephilus sp.	x	x	x	
	Molanna uniophila		x	x	
	Triaenodes sp.	x			
	Banksiola smithi	x	x	x	
	Ptilostomis ocellifera	x	x	x	
	Nyctiophylax sp.		x		
	Polycentropus sp.	x	x	x	

	Little Mud	Branch	Bourn	Lye Brook Meadows
Oxyethira sp.	x			
Megaloptera	1	2	1	0
Chauliodes sp.	x	x		
Sialis sp.		x	x	
Lepidoptera	1	0	0	0
Pyralidae sp.	x			
Neuroptera	0	1	0	0
Climacia sp.		x		
Diptera	12	14	16	8
Chironomidae	10	13	15	8
Orthocladiinae uid	x			
Ablabesmyia sp.	x	x	x	x
Corynoneura sp.		x	x	
Chironomus sp.		x		x
Cricotopus sp.		x	x	
Cryptochironomus sp.			x	
Dicrotendipes sp.	x		x	
Dorocricotopus sp.	x			
Endochironomus sp.	x	x	x	x
Heterotanytarsus sp.		x		
Lapposmittia sp.			x	
Maeropelopia sp.		x		
Microtendipes sp.			x	
Polypedilum illionoense	x	x	x	x
Procladius sp.	x	x	x	x
Psectrocladius sp.	x	x	x	x
Tarytarsus sp.	x	x	x	x
Telopelopia sp.	x			
Thienemanniella sp.			x	
Tribelos sp.		x	x	x
Tvetenia discoloripes			x	
Xenochironomus sp.		x		
Ceratopogonidae	1	1	1	0
Bezzia sp.	x	x	x	
Tipulidae	1	0	0	0
Rhabdomastix sp.	x			
Odonata	12	8	5	8
Aeshna sp.	x	x	x	x
Boyeria uinosa	x	x	x	x
Coenagrion sp.	x			
Arigomphus sp.	x			

	Little Mud	Branch	Bourn	Lye Brook Meadows
Sympetrum sp.	x			
Erythemis sp.	x	x		
Leucorrhinia sp.	x	x	x	
Leucorrhinia glacilus				x
Leucorrhinia proxima				x
Leucorrminia hudsonica				x
Libellula sp.	x	x		x
Ladona sp.	x	x	x	
Lestes sp.	x			x
Neurocordulia sp.			x	
Tetraogeneuria sp.			x	
Enallagma sp.	x	x		
Anomalagrion sp.			x	
Chromagrion sp.		x		
Coenagrion sp.	x			
Hemiptera	6	5	4	5
Corixidae	x	x	x	x
Belostomatidae	x			x
Notonecta sp.	x	x	x	
Buenoa sp.				x
Gerris sp.	x			x
Hesperocorixa sp.	x	x	x	x
Trichorixa sp.	x	x		
Microvelia sp.		x		
Mesovelia sp.			x	
Hydracarina	0	0	1	0
Hirudinea	1	0	1	
Oligobdella biannulata	x		x	
Oligocheata	2	3	1	1
Lumbriculidae	x	x	x	x
Naididae	x	x		
Tubificidae		x		

Appendix 12. The macroinvertebrate community metrics of Lye Brook Wilderness streams (1993-1995).

River (mi)	Date	Density	Richness	EPT Index	EPT/Rich	Bio Index (0-5)	Diversity	#E/P/T	EPT/EPT&C	% Hydrop	% Dom Taxa
Bourn (4.1)	9/21/93	756	27.5	19.0	.69	1.03	3.79	4/6/12	.99	10	22 *Capniidae*
Bourn (4.1)	9/21/94	1754	31.5	16.5	.53	1.35	3.86	3/7/9	.82	9	14 *Promoresia*
Bourn (4.1)	9/19/95	2268	39.0	23.0	.59	1.54	4.22	4/10/13	.89	16	19 *Promoresia*
Bourn (1.6)	9/21/93	1704	46.5	25.5	.55	1.41	4.60	8/7/14	.92	16	16 *Symphitopsyche*
Bourn (1.6)	9/21/94	1760	46.5	24.0	.52	1.43	4.77	5/9/12	.85	10	10 *Symphitopsyche*
Bourn (1.6)	9/19/95	1682	55	29.5	.54	1.81	4.75	8/9/14	.82	15	15 *Symphitopsyche*
Branch Pd Brook (0.1)	9/19/94	912	27.5	14.5	.53	1.12	3.81	1/6/9	.85	7	21 *Capniidae*
Branch Pd Brook (0.1)	9/20/95	1534	37.0	20.0	.54	1.11	4.08	1/9/13	.88	8	15 *Apatania*
Lye Brook (7.0)	7/17/95	2740	23.0	8	.30	2.97	2.43	0/0/8	.12	8	51 *Tanytarsus*
Lye Brook (3.4)	9/22/93	166	21.5	14.5	.67	.65	3.44	1/5/13	.97	<1	28 *Chloroperlidae*
Lye Brook (3.4)	9/19/94	246	18.5	12	.65	.55	2.77	2/8/6	.99	0	35 *Chloroperlidae*
Lye Brook (3.4)	9/19/95	216	22.5	14.5	.64	.39	2.87	2/6/10	.99	0	46 *Chloroperlidae*
Lye Brook (1.8)	9/22/93	460	34.0	21.0	.58	1.08	4.08	5/9/12	.95	11	24 *Dolophilodes*
Lye Brook (1.8)	9/19/94	682	42.5	23.5	.55	1.08	4.49	5/8/13	.93	13	18 *Chloroperlidae*
Lye Brook (1.8)	9/20/95	1224	43.5	26.0	.59	0.99	3.97	6/9/13	.84	6	33 *Dolophilodes*
Winhall River (8.1)	10/14/92	2212	51.0	28.5	.56	1.86	4.53	13/8/12	.61	14	14 *Symphitopsyche*
Winhall River (8.1)	9/19/94	2344	53.5	30.5	.57	1.52	4.92	8/13/16	.82	16	14 *Symphitopsyche*
Winhall River (8.1)	9/19/95	3200	55.5	29.0	.59	1.66	4.77	8/12/15	.84	22	18 *Symphitopsyche*

Appendix 13. The macroinvertebrate community major group (orders) percent composition of the Lye Brook Wilderness streams (1993-1995).

River (mi)	Date	% Coleoptera	% Diptera	% Ephemeroptera	% Trichoptera	% Plecoptera	% Oligocheata	% Other
Bourn (4.1)	9/21/93	13	5	4	16	60	0	1
Bourn (4.1	9/21/94	17	19	3	13	48	0	<1
Bourn (4.1)	9/19/95	24	14	4	23	34	0	<1
Bourn (1.6)	9/21/93	4	12	22	53	8	1	0
Bourn (1.6)	9/21/94	14	18	17	34	17	<1	<1
Bourn (1.6)	9/19/95	11	17	18	33	13	1	6
Branch Pd Brook (0.1)	9/19/94	6	20	2	26	46	0	<1
Branch Pd Brook (0.1)	9/20/95	8	15	7	36	34	0	<1
Lye Brook (7.0)	7/17/95	0	88	0	11	0	<1	<1
Lye Brook (3.4)	9/22/93	1	6	11	17	62	1	2
Lye Brook (3.4)	9/19/94	1	4	<1	12	83	0	<1
Lye Brook (3.4)	9/19/95	<1	4	1	17	75	<1	2
Lye Brook (1.8)	9/22/93	1	10	21	50	18	0	0
Lye Brook (1.8)	9/19/94	2	15	7	46	30	<1	<1
Lye Brook (1.8)	9/20/95	1	19	7	58	15	0	<1
Winhall River (8.1)	10/14/92	7	40	9	25	18	<1	<1
Winhall River (8.1)	9/19/94	3	22	17	34	22	1	<1
Winhall River (8.1)	9/19/95	1	20	22	46	11	0	<1

Appendix 14. The macroinvertebrate community functional group percent composition of the Lye Brook Wilderness streams (1993-1995).

River (mi)	Date	% Collector-Filterer	% Collector-Gatherer	% Predator	% Shredder-Detritus	% Shredder-Herbivore	% Scraper
Bourn (4.1)	9/21/93	2	12	22	43	7	14
Bourn (4.1	9/21/94	13	10	12	34	12	17
Bourn (4.1)	9/19/95	6	18	13	27	7	24
Bourn (1.6)	9/21/93	21	29	11	12	3	17
Bourn (1.6)	9/21/94	18	20	14	16	4	19
Bourn (1.6)	9/19/95	12	19	12	10	10	24
Branch Pd Brook (0.1)	9/19/94	15	7	24	38	3	13
Branch Pd Brook (0.1)	9/20/95	8	12	18	31	8	23
Lye Brook (7.0)	7/17/95	9	62	23	3	2	2
Lye Brook (3.4)	9/22/93	16	6	47	29	<1	2
Lye Brook (3.4)	9/19/94	2	6	45	46	<1	1
Lye Brook (3.4)	9/19/95	3	11	69	15	0	<1
Lye Brook (1.8)	9/22/93	24	36	25	12	1	1
Lye Brook (1.8)	9/19/94	11	28	36	17	2	4
Lye Brook (1.8)	9/20/95	21	41	20	15	2	2
Winhall River (8.1)	10/14/92	40	19	23	6	3	9
Winhall River (8.1)	9/19/94	24	28	25	6	5	10
Winhall River (8.1)	9/19/95	18	38	15	7	2	4

Appendix 15. Total length (mm) data of salmonid species for the Lye Brook Wilderness streams (1993-1995).

Species	1993	1994	1995		
Bourn Brook - Station 4.1					
Brook Trout	71	155	56	90	160
	97	185 (2)	60	92	163
	116	186	61	95 (2)	164 (2)
	122	190 (2)	70	97	165
	123	196	71	100	180
	126 (2)	213	72	106	190
	129	218	72	110	203
	139	280	73	123	
	145		75	125	
	149		76	128	
	150		81	137	
	156		84 (4)	139	
	176		86	150	
			88	152	
Brown Trout	192				
Bourn Brook Station 1.6					
Brook Trout	66	70	65	147	
	82	72	67	148	
	86	75	71	149	
	89	78	74	154 (2)	
	112	80 (2)	77 (2)	162	
	120	82 (2)	78 (2)	170	
	122	85 (2)	80		
	134 (2)	132	83		
	136	135	85		
	137	145	125		
	139	144	127		
	141		129		
	144		137		
	145		140		
	150		146		

Species	1993			1994			1995			
Brown Trout	225			68			59	84	240	
				150			60	127		
				152			68	139 (2)		
				175			72	136		
				182			74	140		
				230			79	142		
							80	181		
Branch Pond Brook										
Brook Trout	61	140	173	54	63	141	No Lengths Taken			
	69	153		57	68	144				
	75	153		57	125	146				
	76	155		59	129	153				
	98	157		59	136	160				
	107	161		62	140	168				
Lye Brook 1.8*										
Brook Trout	87	122	195	70	91	146	54	75 (3)	121	156
	91	128	196	75 (2)	92	148	55 (2)	76	122	177
	93	129		76 (2)	94 (2)	150	59	78	125 (4)	188
	96	130		80 (8)	95	154	60 (4)	80 (3)	126 (2)	
	97	138		81	97 (2)	158	61	81	132 (2)	
	98	145		82	130	170	62	82	134	
	100 (2)	146		83	132	176	65 (3)	83	135 (2)	
	106	147		84	135	182	66	84	136 (2)	
	108	188		88	136	185	70 (4)	85	137	
	112	191		90 (2)	145	195	71	86 (2)	144	
						198	72	90	145 (3)	
						199	74	110	146	
Winhall River										
Brook Trout	65	116 (2)	145 (2)	54	65 (2)	177	56	74 (2)	133	150
	69	120 (2)	154	55 (2)	70	179	58	75	134	154
	97	121	156	58	131	183	61	80	135	187
	101	123	182	59 (2)	134	198	62	91	136	222
	104	125	250	60	139	205	63	108	137	

Species	1993		1994			1995		
	110	127	61 (5)	140	233	65 (3)	110	138
	111	128	62	149		69 (2)	119 (2)	139
	112 (4)	130	63	163 (20)		70 (2)	124	140
	114	135	64 (3)	170		71 (2)	125	144
	115 (2)	140		171		72 (2)	126	149
							130	
Atlantic Salmon	65 (2)	85 (7)	70	115	136 (2)	70	90 (1)	136 (4)
	66 (2)	86 (5)	71 (2)	117	137	74	92 (2)	138
	67	87 (2)	72	118	138	75 (4)	114	142
	68	88 (3)	73 (3)	119	139 (3)	77 (3)	117 (2)	210
	69	90 (4)	74 (3)	120 (2)	140	78 (2)	122	
	71 (3)	91 (2)	75 (3)	121	141 (3)	79 (7)	133	
	73 (2)	92 (3)	76 (6)	122 (3)	143 (3)	80 (3)	124	
	74 (4)	94	77 (2)	123 (2)	144	81 (6)	125	
	75 (4)	95 (2)	78 (4)	124	145	82 (3)	126	
	76 (2)	130 (2)	79	125	148	83 (8)	127	
	78 (3)	136	80 (2)	126 (2)		84 (9)	128 (2)	
	79	137 (2)	81 (2)	127 (2)		85 (4)	130	
	80 (5)	146 (2)	82 (2)	130 (4)		86 (4)	131 (2)	
	81 (5)	152	84	131 (3)		87 (7)	132 (2)	
	82 (8)	155 (2)	89	132 (2)		88 (3)	134	
	83 (4)	165	107	135		89 (6)	135	

* No fish were captured at Lye Brook Station 3.

Appendix 16: Fish collections data by electrofishing pass

Species	Size	1993 Pass 1	1993 Pass 2	1993 Pass 3	1994 Pass 1	1994 Pass 2	1994 Pass 3	1995 Pass 1	1995 Pass 2	1995 Pass 3
Bourn Brook 4.1										
Brook Trout	YOY	1	0	1	0	0	0	21	3	–
	4-6 in.	*5	3	3	0	0	0	4	5	–
	>6 in.	*1	1	0	5	4	1	8	1	–
Bourn Brook 1.6										
Brook Trout	YOY	2	2		9	2		9	2	
	4-6 in.	9	3		3	1		9	1	
	>6 in.	0	0		0	0		4	0	
Brown Trout	YOY	0	0		1	0		8	0	
	4-6 in.	0	0		1	0		5	1	
	>6 in.	1	1		4	0		1	1	
Branch Pond Brook										
Brook Trout	YOY	4	0	–	6	2	–	12	2	0
	4-6 in.	4	0	–	6	1	–	17	0	0
	>6 in.	5	1	–	3	0	–	8	0	0
Lye Brook 1.8										
Brook Trout	YOY	5	1		23	4		28	10	
	4-6 in.	10	3		7	1		17	5	
	>6 in.	4	0		9	1		2	1	
Brown Trout	YOY	0	0		1	2		12	2	
	4-6 in.	0	1		1	0		0	0	
	>6 in.	2	1		2	0		0	0	
Winhall River										
Brook Trout	YOY	3	0	0	14	2	4	13	3	5
	4-6 in.	15	8	0	2	1	2	12	7	1
	>6 in.	4	0	0	7	3	0	1	1	1
Atlantic Salmon	YOY	63	11	3	40	5	8	50	16	10
	<1 in.	11	2	1	18	8	8	20	3	0
Brown Trout	YOY							0	2	0
	4-6 in.							1	0	0
	>6 in.							0	0	0