PROCESSES AFFECTING THE ACID-BASE STATUS OF SURFACE WATERS IN THE LYE BROOK WILDERNESS, VERMONT

BY

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TABLE OF CONTENTS

LIST OF TABLES

TABLE PAGE

LIST OF FIGURES

FIGURE PAGE

ABSTRACT

PROCESSES AFFECTING THE ACID-BASE STATUS OF SURFACE WATERS IN THE LYE BROOK WILDERNESS, VERMONT

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Factors controlling the acid-base status of streams were investigated in the Lye Brook Wilderness in southwestern Vermont. Streamwater samples were collected biweekly at nine sampling locations from May 1994 to August 1995. Acid neutralizing capacity (ANC) was used to determine the susceptibility of sites to acidification. Seven of nine sites sampled had ANC values less than zero, indicating that many of the streams are acidic. Acid neutralizing capacity values change in accordance with the balance between cations and anions. Therefore, processes that influence solute concentrations affect the ANC of surface waters. The presence of dolomitic bedrock in some areas appeared to be the overriding factor contributing to local increases in ANC. Reductions in ANC were caused primarily by SO_4^{2-}; however, at some sites NO_3^- and natural, weak organic acids were seasonally important. Sharp reductions in pH occurred during high discharge events which coincided with increases in inorganic Al concentrations. Inorganic Al was lower at sites with high total organic carbon (TOC) due to chelation by organic compounds. Many of the streams at high elevations were influenced by headwater wetlands which are prevalent in this wilderness area. Sulfate reduction in wetlands decreased SO_4^{2-} concentrations during the summer months; however, this was offset to some degree by increases in organic acidity. TOC concentrations were highest at sites in close proximity to wetlands and decreased as the distance between wetlands and the sampling site increased. Dissolved organic nitrogen (DON) was significantly correlated with TOC, indicating similarities in the production and export of organic matter. Although the role of DON in N cycling is poorly understood, organic N is an important mechanism of N loss because it comprises the majority of total dissolved nitrogen (TDN) in streamwater.

INTRODUCTION

The Lye Brook Wilderness is a Class I Wilderness Area located in the Green Mountain National Forest in southern Vermont. Under the Clean Air Act Amendments of 1977, a Class I designation safeguards wilderness areas from the negative effects of anthropogenic sources of air pollution. In these areas, only small, incremental increases in new pollution are permitted above baseline levels. Additional pollution is allowed only if national ambient air quality standards are not exceeded and the Air Quality Related Values (AQRV's) are not adversely affected. These values consist of features or properties that contribute to the wilderness characteristic of the area such as, scenic beauty, vegetation, wildlife and water.

The Prevention of Significant Deterioration (PSD) program is a permitting process that was enacted to protect the AQRV's. PSD permits are required prior to the construction of new emission sources within a designated radius of wilderness areas. If the projected emission levels of a proposed source of pollution are determined to cause adverse effects on the AQRV's, a PSD permit can be denied. It is the U. S. Forest Service's responsibility to determine the potential effects of increased levels of pollution and to develop screening criteria to evaluate PSD permits. Currently, there is little information on existing levels of pollution at the Lye Brook Wilderness Area, which makes it difficult to predict the effects of increased levels of pollution.

The Vermont Department of Environmental Conservation (VT DEC) has monitored lake water in the Lye Brook Wilderness and adjacent areas since 1980. As part of their study, data was collected at Bourn Pond, which is a high-elevation pond within the wilderness. Based on the data collected, researchers found that the pond was relatively acidic with a pH range of 4.8 to 5.5 (Adams et al. 1991). In addition, the ANC, defined as the ability of a lake or stream to buffer incoming acids, was close to zero and dissolved Al was relatively high.

In 1992, the Vermont Monitoring Cooperative (VMC), the Green Mountain National Forest (GMNF) and the VT DEC established additional monitoring sites in and around the Lye Brook Wilderness, including several stream locations. During 1993, the VT DEC monitored stream chemistry at these sites several times during the year, primarily at lower elevations during spring snowmelt. Spring samples were not analyzed for inorganic monomeric Al. However, the possibility of potentially toxic levels of inorganic Al were recognized in both streams (Kellogg et al. 1994).

In addition to sampling stream chemistry, fish population surveys were conducted using electroshockers at single high and low-elevation sites in Lye Brook. The results of this study revealed that brook trout and brown trout populations were found in the lower reaches of Lye Brook; however, no fish were found in the upper reaches. An analysis of macroinvertebrates indicated that some acid-sensitive species were absent from the upper site, and that populations were poor in density and species richness compared to the low-elevation site.

These data suggest that the aquatic systems of the Lye Brook Wilderness may already be impacted by acid deposition to some extent, and that acidity and Al toxicity appear to pose the greatest threat to the integrity of streams. However, in order to make strong conclusions regarding the effect of acid deposition in the Lye Brook Wilderness, a more thorough analysis was required.

OBJECTIVES

The objectives of this study were to:

1) Identify major site characteristics of the Lye Brook Wilderness including vegetation, land use, geology, soils and wetlands.
2) Characterize the chemistry of streams of the Lye Brook Wilderness.
3) Determine the spatial and seasonal variability in streamwater chemistry as a function of known soil, geological, vegetative and land use drivers.
4) Locate areas in the Lye Brook Wilderness that may be susceptible to acid deposition.

I. LITERATURE REVIEW

Acid deposition caused by atmospheric pollution is the major threat to aquatic systems in the Lye Brook Wilderness. The northeastern United States is vulnerable to acid inputs because the region receives relatively large amounts of acid deposition and the streams generally have a low ANC.

Acid Neutralizing Capacity

The ANC, or alkalinity, describes the ability of a system to buffer acids. Ruess and Johnson (1985) define alkalinity, in simplest terms, as the sum of carbonate, bicarbonate and hydroxyl ion concentrations minus the hydrogen ion concentration, represented by the following equation:

$$\mathrm{ANC} = [\mathrm{CO_3^-}] + [\mathrm{HCO_3^-}] + [\mathrm{OH^-}] - [\mathrm{H^+}] \qquad (1)$$

In acid waters, carbonate and hydroxyl ion concentrations are stoichiometrically negligible; therefore, these constituents are typically ignored.

Acid neutralizing capacity can also be defined as the sum of base cations minus the sum of strong acid ions because the charge balance requirements of natural waters mandate an equilibrium between anions and cations on a μeq/L basis. Therefore, (1) can be modified to include major cations and anions:

$$\mathrm{ANC} = \{[\mathrm{Cl^-}] + [\mathrm{NO_3^-}] + [\mathrm{SO_4^{2-}}]\} - \{[\mathrm{Ca^{2+}}] + [\mathrm{Mg^{2+}}] + [\mathrm{Na^+}] + [\mathrm{K^+}]\} \qquad (2)$$

In addition to these ions, other influential ions are commonly added to the equation depending on the concentration detected in the waters of interest. Aluminum can occur in high concentrations, and in some areas Fe and Mn are important. Organic acids should also be considered because these acids can contribute to reductions in ANC. The effect of organic acids is frequently included in charge balance studies by assigning a constant charge density value to organic C (Oliver and Thurman 1983). The resultant equation was used in this report to calculate ANC:

$$\mathrm{ANC} = [\mathrm{Cb}] + [\mathrm{Ali}^{2\text{-}3+}] + [\mathrm{Fe}^{3+}] + [\mathrm{Mn}^{2+}] - [\mathrm{Ca}] - [\mathrm{Oa}] \qquad (3)$$

Where Cb is the sum of base cations, Ali is inorganic monomeric Al, Ca is the sum of strong acid anions and Oa is an organic acid term. This equation, or a number of similar equations, have also been used in other research to determine ANC values (Kahl et al. 1989). Based on this definition, the alkalinity of streamwater is controlled by processes that influence the concentration of anions or cations. An increase in Ca or Oa, or a decrease in Cb, $\mathrm{Ali}^{2\text{-}3+}$ Fe^{3+} or Mn^{2+} would cause a reduction in the ANC of streamwater.

Strong Acid Anions

There are a variety of factors that can influence the acid-base status of streamwater. In the northeastern United States, an abundance of evidence indicates that acid deposition plays a major role in the acid-base status of surface water, specifically through the chronic addition of NO_3^- and SO_4^{2-}.

Sulfate - Research on the effects of atmospheric deposition in the United States has focused primarily on S and its contribution to the acidification of lake and streamwater. Brakke et al. (1989) determined that in the Northeastern United States, SO_4^{2-} in lakewater can be seven to ten times higher than background levels. Lake SO_4^{2-} concentrations correlate highly with SO_4^{2-} deposition at lake sites and lakes have been shown to receive large amounts of SO_4^{2-} from adjacent watersheds (Sullivan et al. 1988). During the last fifteen years, sulfur dioxide emissions have declined in the northeast as a result of better technology and more restrictive emission regulations. At the Hubbard Brook Experimental Forest in New Hampshire, the decrease in sulfur dioxide emissions has been correlated with a decrease in streamwater SO_4^{2-} and has also coincided with an increase in precipitation pH (Driscoll et al. 1989).

A similar trend is evident in Vermont where lakes have been monitored since 1980 as part of the Environmental Protection Agency's long-term monitoring program. In this region, decreasing SO_4^{2-} concentrations have been observed in lakewater throughout the state. However, despite these findings, the pH and ANC in lakewater did not increase significantly over the sampling period, and only small, statistically insignificant increases were observed in some lakes (Stoddard and Kellogg 1993). This poor response may be attributed in part to a decrease in base cations which accompanied decreases in SO_4^{2-}.

In addition to long-term trends, SO_4^{2-} often exhibits seasonal patterns that are commonly associated with streamflow. DeWalle and Swistock (1994) determined that increased concentrations of SO_4^{2-} during high discharge events were the primary cause of ANC declines in three of five streams sampled in Pennsylvania. Other streams in their study were affected by base cation dilution, and to a lesser extent, by weak organic acids. During periods of high discharge, SO_4^{2-} can also be diluted, although Stoddard and Murdoch (1991) determined that SO_4^{2-} is not affected to the extent that ANC or base cations are.

In addition to discharge-related trends, there are several biological processes that affect the concentration of SO_4^{2-} in streamwater. Driscoll and Newton (1985) determined that in the Adirondacks, the most important alkalinity-producing reaction is SO_4^{2-} reduction. An analysis of the water in Moose Pond revealed that the lake was fairly alkaline, which was inconsistent with what they had predicted. At this site there is little opportunity for weathering reactions to occur because the soils are thin and the bedrock does not contain acid-neutralizing carbonate. Further research indicated that the alkaline condition of the surface water was caused by deposits of thick peat that surrounded the pond. These deposits neutralized the water through SO_4^{2-} reduction reactions.

Similar neutralization processes can occur in reactions with the bottom sediments of lakes (Kelley 1994) . In sediments rich in organic matter, SO_4^{2-} can be reduced through ion exchange. In wet areas, SO_4^{2-} can be retained through reduction processes, which reduces the concentration of SO_4^{2-} in streamwater. However, this S may be oxidized during dry periods, and can accumulate in soil, ultimately resulting in the pulsed release of SO_4^{2-} into streamwater (Bayley et al. 1986).

Streamwater SO_4^{2-} may also be affected by watershed characteristics such as forest cover type. Several studies have hypothesized that coniferous vegetation may be linked to higher concentrations of SO_4^{2-} as a result of higher dry deposition capture (Lovett et al. 1982; Cronan 1985). The leaf area index (LAI) of coniferous vegetation is generally greater than deciduous vegetation; therefore, concentrations of SO_4^{2-} in streams draining coniferous forests may be higher. More recently, Cronan et al. (1987) determined that differences in surface water chemistry were independent of differences in vegetation among watersheds.

Nitrate - Historically, NO_3^- has been considered a small contributor to the acidity of surface waters, primarily because anthropogenic inputs of NO_3^- in the northeast are half that of S inputs. Future research efforts may focus on NO_3^- because from the mid 1800's to the 1970's, nitrogen oxide emissions in the northeast have increased dramatically. Since 1980, nitrogen oxide emissions have leveled off in most areas of the northeast, primarily in response to the enactment of the Clean Air Act (Husar et al. 1991). Despite this current trend, future emission levels are predicted to increase as a result of increased automobile use (NAPAP 1992).

Stoddard and Murdoch (1991) suggest that decreased SO_4^{2-} concentrations in streamwater are balanced by an increasing trend in NO_3^-. Research in the Catskill

Mountains of New York indicates that nitric acid is a major contributor to the acidity of streams in that region, primarily during periods of high discharge and reduced vegetative uptake (Murdoch and Stoddard 1992). Acidification due to NO_3^- inputs has also caused ANC declines in Adirondack lakewater (Schaefer et al. 1990).

Unlike SO_4^{2-}, NO_3^- exhibits strong seasonal patterns that are related to the biological uptake of NO_3^-. Nitrate concentrations are generally higher during high discharge and lower during base flow and there is often an inverse relationship between concentrations of streamwater NO_3^- and SO_4^{2-} (Likens et al. 1970). This can be attributed to the absorption of NO_3^- by vegetation during the growing season, which subsequently reduces streamwater NO_3^- during the summer months. Nitrate concentrations are generally higher over winter and peak at the start of spring snow melt (Likens and Bormann 1995). This peak is caused by the release of NO_3^- that has accumulated in the snowpack, in addition to NO_3^- generated through the process of nitrification (Galloway et al. 1987; Rascher et al. 1987).

The supply of NO_3^- to surface waters can also be affected indirectly by concentrations of NH_4^+ in watershed soils. Typically, NH_4^+ is deposited in the watershed as dry deposition or is released by decaying organic matter. Much of this is oxidized to form NO_3^- or is directly taken up by plants during the growing season. Therefore, NO_3^- and NH_4^+ exhibit similar seasonal patterns that are linked to surface water acidification.

<u>DON</u> - Much of the research on N has focused on biologically available inorganic forms of N (NO_3^- and NH_4^+). However, in recent years there has been growing interest in the loss of organic forms of N (DON). In an unpolluted region of southern Chile, Hedin et al. (1995) determined that DON accounted for 95% of N lost in streamwater. N losses in Puerto Rico were also dominated by DON (McDowell and Asbury 1994). In contrast, Newbold et al. (1995) found that NO_3^-, rather than DON, contributed to the majority of N in streamwater in Costa Rica. Despite a lack of data on streamwater DON in temperate areas, it is possible that DON may significantly contribute to N losses in this region.

Chloride - In addition to NO_3^- and SO_4^{2-}, Cl^- can also contribute to the acidity of surface waters. Chloride can be released through mineral weathering reactions but this contribution is generally small in comparison to atmospheric sources. A portion of Cl^- in the atmosphere is the result of seasalt spray which is dispersed as an aerosol and is later redeposited. Therefore, Cl^- concentrations are generally higher in coastal areas. Road salt is one of the few anthropogenic sources of Cl^- and impacts are generally minimal especially in roadless areas. Chloride concentrations in surface waters exhibit little spatial variation because Cl^- is refractory and few watershed processes affect its concentration.

Organic Acids

In addition to strong acid anions, there are other naturally occurring acids associated with organic C that can reduce the ANC of streamwater. DOC compounds contain organic acids, such as fulvic and humic, that are produced during plant decomposition (McDowell and Likens 1988). Concentrations of these acids are high in productive areas such as wetlands where slow rates of decomposition cause organic matter to accumulate.

DOC concentrations in streamwater may also be influenced by forest cover. In the Adirondacks, the concentration of DOC in soil water draining coniferous stands was 40% greater than concentrations draining hardwood stands (David and Driscoll 1984). Lawrence et al. (1986) studied streamwater chemistry along an elevational gradient at the Hubbard Brook Experimental Forest and found that concentrations of DOC were greater at higher elevations. This was partially attributed to the forest cover which was dominated by red spruce and balsam fir at higher elevations and deciduous species at lower elevations.

Although organic acids reduce the pH of natural waters, they can also act as a buffer against drastic pH changes. In waters that consist solely of strong acids and strong bases, a slight increase in strong acids can cause a drastic reduction in pH. However, when weak organic acids are present the reduction in pH is less severe. Therefore, the presence of weak organic acids may reduce the impact of strong acid inputs (Munson and Gherini 1991).

The contribution of weak organic acids, versus strong mineral acids, to the acidity of surface waters has long been debated. Kahl et al. (1989) investigated 225 lakes in Maine and found that both organic acids and anthropogenic acids contribute to the acidity of surface waters in that region. In acidic (ANC < 0) lakes with low DOC (DOC < 5 mg/L), acidity is caused by anthropogenic sources. However, in lakes with high DOC concentrations (DOC > 30 mg/L), organic acids are the primary cause of acidity. At intermediate DOC concentrations (5 to 30 mg/L), a combination of both sources contribute to acidity. Much of the information on organic acidity focuses on lakewater and few studies have investigated the contribution of organic acidity to steamwater. However, in the U. S., a National Acid Precipitation Assessment Program (NAPAP) study determined that organic acids dominated 22% of acidic lakes and 27% of streams surveyed (NAPAP 1990).

Base Cations

Although both weak and strong acids reduce ANC, ecosystems are capable of buffering incoming acids to some degree. One way that these acids are neutralized is through terrestrial soil and rock weathering reactions. These reactions release base cations (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}) into solution with an equivalent concentration of anions. The potential supply of base cations is large; however, weathering rates are slow in response to changes in H^{+} concentrations (Bailey et al. 1996). Therefore, in acidic areas, base cations are not released fast enough to buffer acids and H^{+} and Al^{+} are mobilized.

Johnson et al. (1981) observed an increase in pH and a decrease in Al concentrations with greater stream order and drainage area. They concluded that acid neutralization is a two step process. Initially, incoming acid is partially neutralized by Al in soils, which results in high concentrations of Al and H^{+} ions in streamwater. Both hydrogen and Al are then neutralized through chemical weathering reactions. This neutralization rate increases when the residence time of the soil water increases, allowing sufficient opportunity for ion exchange to occur. Water at downstream locations has a longer residence time in the soil-channel system; therefore, the water tends to be less acidic.

Other studies have investigated the effect of seasonality and streamwater discharge patterns on the cation/anion balance. Stoddard and Murdoch (1991) determined that 16% of streams sampled in the Catskills of New York were acidic during high discharge and only ~8% were acidic during base flow. These low discharge conditions enable streamwater to have more contact time with the soil, creating a more favorable medium for cation exchange. This causes a subsequent increase in the concentration of base cations during low discharge, coupled with a decrease in strong acid anions.

Peters and Driscoll (1987) found that flow paths and residence times have a major impact on the chemistry of water in the Adirondacks. During periods of base flow, water infiltrates the soil and moves slowly through deep flow paths. This allows ample opportunity for the soil water to react with base cations and increases the capacity to neutralize acids. Conversely, during periods of high discharge, water moves rapidly through surface soils and enters streams via runoff. This reduces the residence time and can lead to highly acidic waters.

In addition to the thickness of till, the bedrock itself may influence the chemistry of water. Newton et al. (1987) found that some alkaline surface waters were located in areas that lacked thick till. The bedrock underlying these surface waters contained calcareous rocks and water had enough contact with the rock to neutralize acids in the river basin.

Johnson and Reynolds (1977) analyzed the effect of various bedrock types on streamwater chemistry in Vermont and New Hampshire and found that streams draining plutonic rock in this region had higher concentrations of strong acids than streams draining metamorphic rock. This finding was attributed to carbonate which is commonly found in metamorphic rock and is absent in plutonic rock.

Disturbance Effects

In addition to the factors previously listed, the acid-base status of surface waters may also be related to both anthropogenic and natural disturbances. In undisturbed ecosystems, concentrations of solutes in streamwater are highly predictable (Johnson et al. 1969, Johnson and Swank 1973). However, human disturbances, such as deforestation and harvest, can drastically alter ion concentrations (Likens et al. 1970, Hornbeck et al. 1987). Similarly, natural disturbances, such as wildfire, have also been shown to impact ion concentrations in streamwater (Tiedemann et al. 1978, Chorover et al. 1994).

The common pattern following disturbance typically consists of a short-term increase in streamwater nutrients after the disturbance, followed by a long-term decrease in concentrations during forest regrowth. Biologically important nutrients, such as NO_3^- and K^+ tend to show the greatest fluctuations. The effects of disturbance may be short-term or may last for many years (Vitousek and Reiners 1975). At the Cone Pond watershed in New Hampshire, Fox (1995) hypothesized that low concentrations of NO_3^- in the streamwater could be the result of an intense fire that occurred in 1820.

Acidification Effects

Elevated N and S deposition often leads to anion leaching which causes the subsequent mobilization of H^+ and Al. Below a pH level of 5.5, concentrations of monomeric Al increase exponentially (Driscoll, 1989). The effect of streamwater pH on Al is generally greatest during spring snowmelt when pH values decrease. This is a major concern in areas that are sensitive to acid deposition because elevated levels of Al can be toxic to vegetation and aquatic biota.

Severely acidic soils are characterized by high concentrations of H^+ and Al and low concentrations of Ca^{2+} and Mg^{2+}. Cronan and Grigal (1995) used Ca/Al ratios to determine toxic thresholds for forest damage from Al stress. In the soil solution, low ratios are indicitive of systems that are likely to have reduced tree growth and nutrient deficiences.

Research on the effect of Al in surfacewaters has primarily focused on fish. Driscoll et al. (1980) determined that inorganic Al species (Al^{3+}, Al fluoride, hydroxide and sulfide complexes) are the most toxic to fish. However, it is difficult to establish lethal thresholds because mortality varies considerably according to the genetic background of fish, the acclimation history and the ionic strength of the water (Schofield 1976). Baker and Schofield (1981) found that the response of brook trout to Al concentrations varied considerably according to pH and to the developmental stage of the fish; however, Al concentrations greater than 2.0 mg/L caused a reduction in survival and growth of larvae and postlarvae at pH levels between 4.2 and 5.6.

Despite low pH levels, inorganic Al concentrations are generally lower in surface waters that contain high concentrations of organic C. Driscoll et al. (1980) determined that organic, monomeric Al was strongly correlated with concentrations of TOC in the Adirondacks. Although total Al concentrations tend to be higher in these waters, the organically complexed Al is generally less lethal to aquatic biota; therefore, organic matter may mitigate the effect of Al toxicity.

II. SITE DESCRIPTION

The 6,280 hectare Lye Brook Wilderness is located in the Green Mountain National Forest in southwestern Vermont (Figure 1). The area is 3 kilometers east of the town of Manchester and is approximately 50 kilometers north of Bennington. The majority of the Lye Brook Wilderness is in Bennington County; however, an area in the southeast section is located in Windham County. The western side of the wilderness area is adjacent to the Battenkill River and is bounded by Highway 7. The Appalachian and Long Trails transect the northeastern portion of the wilderness and most of the eastern boundary follows the Winhall River. Altitudes in the wilderness range from 240 meters, in the lower valley near Highway 7, to over 880 meters in the southern portion of the property (Figure 2). Most of the slopes are moderate; however, there are some steep areas along deeply cut stream valleys.

The wilderness area is named after Lye Brook, which is a perennial tributary to the Battenkill River (Figure 3). Other stream systems include Bourn Brook, Branch Pond Brook and several unnamed tributaries. The headwaters of many streams in the wilderness originate in a mosaic of wetlands and beaver ponds, collectively referred to as Lye Brook Meadows. These wetlands are located in southeast portion of the wilderness and generally occur at elevations greater than 790 meters. Other open water areas include Bourn Pond, Little Mud Pond and several other small ponds, many of which were created through beaver activity.

Figure 1.

Study Site

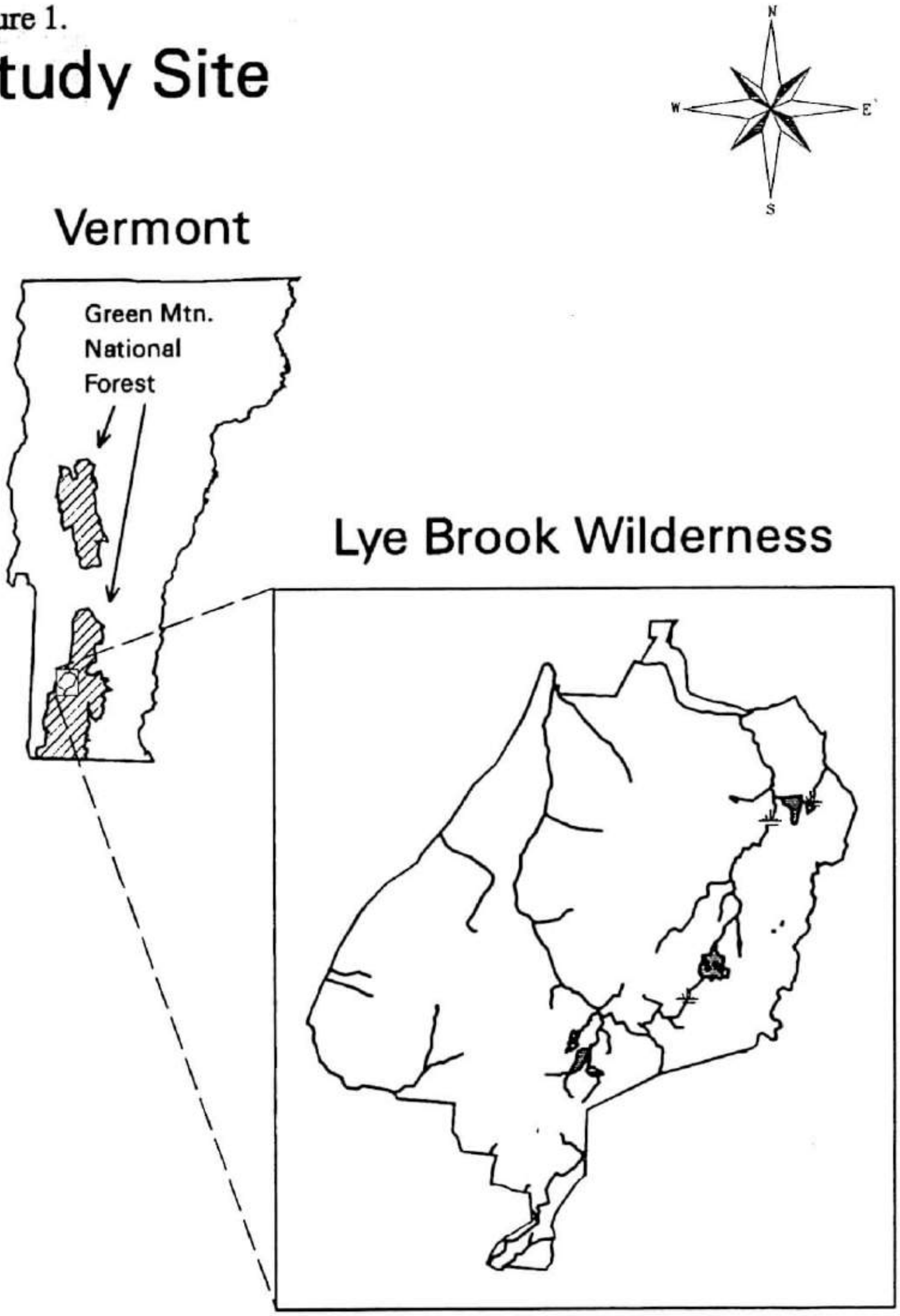


Figure 2.

Lye Brook Wilderness
Elevation

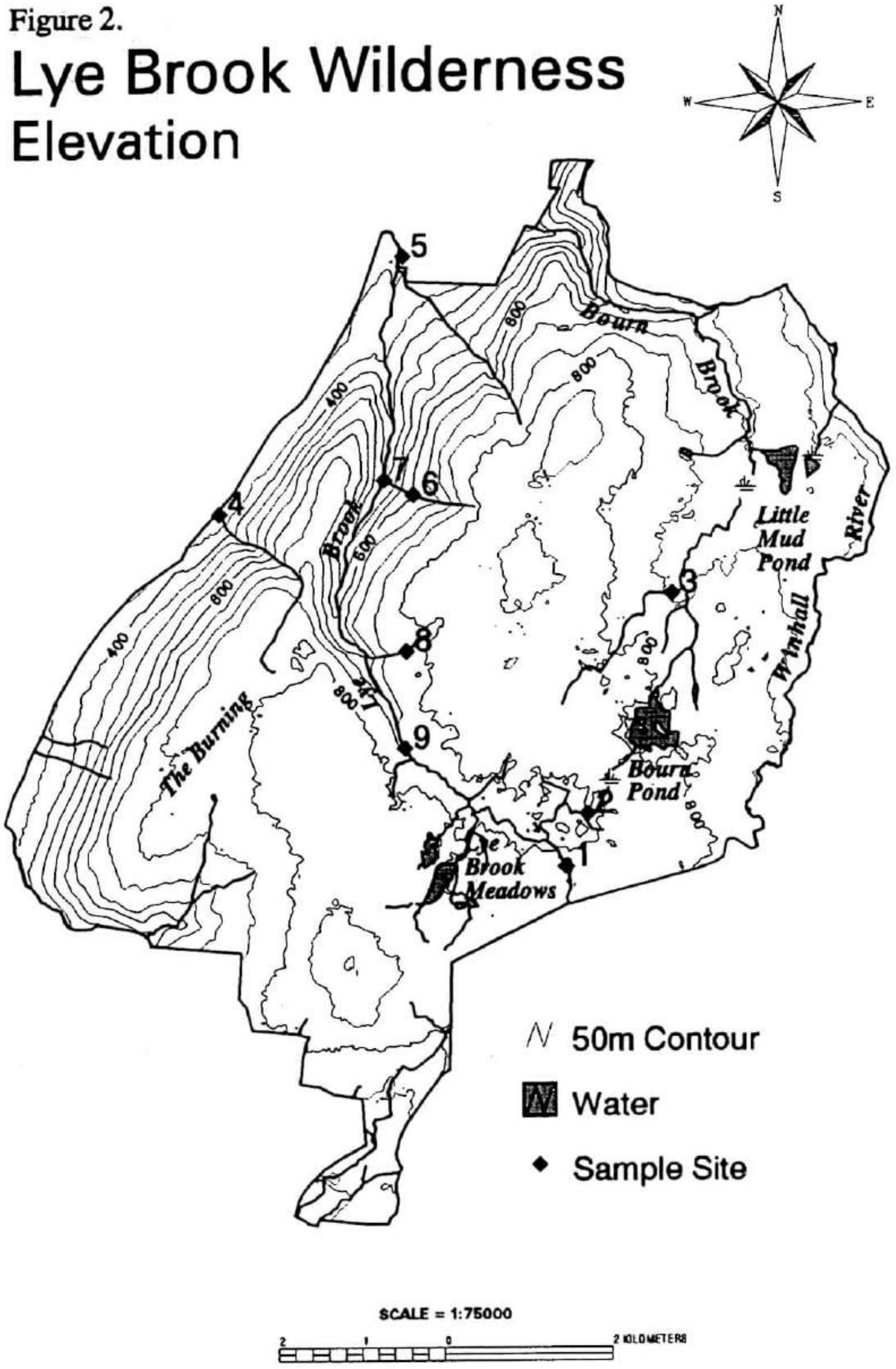
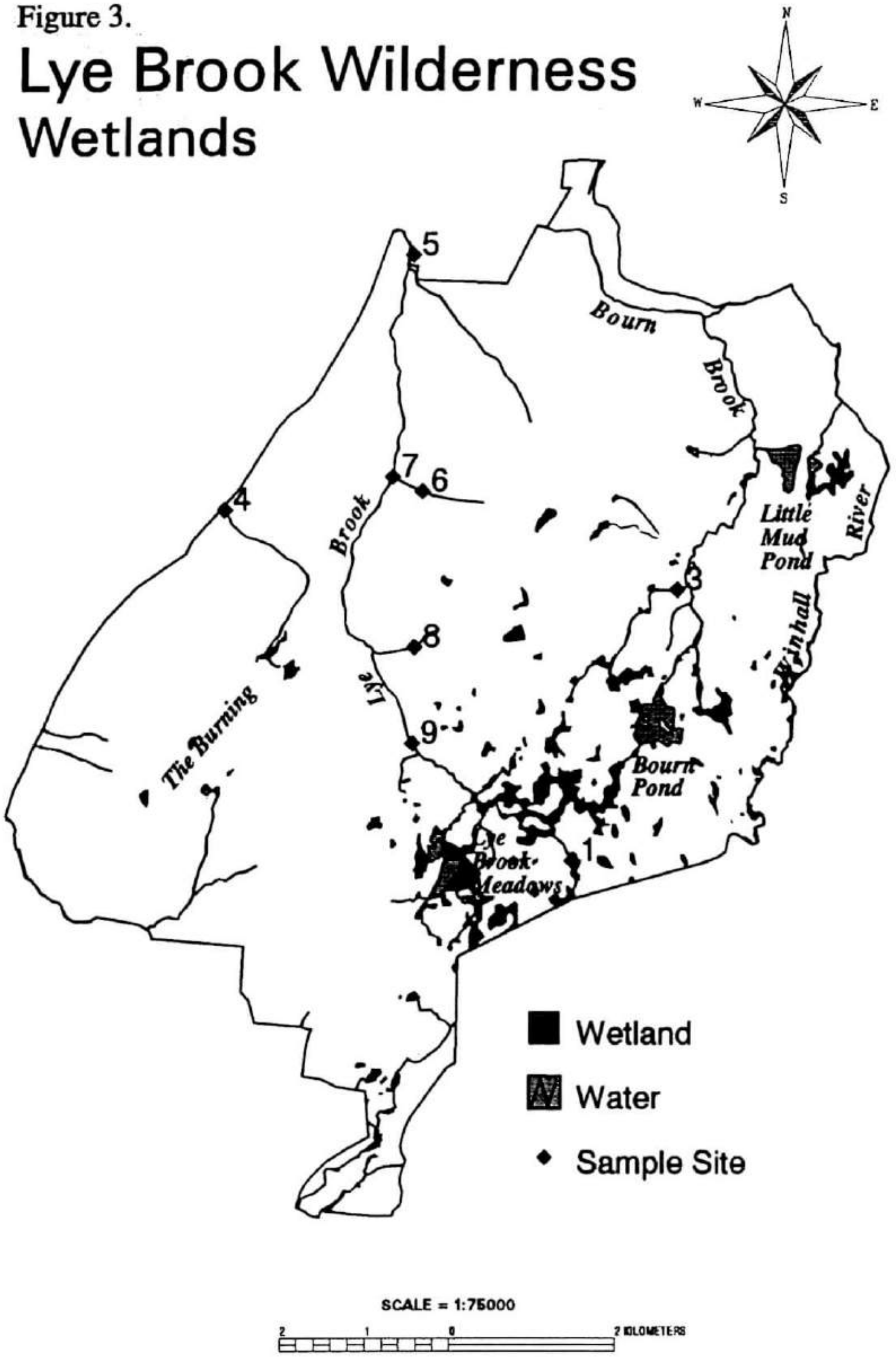


Figure 3.

Lye Brook Wilderness Wetlands



Soils

The parent material in the Lye Brook Wilderness consists of till that was deposited when the last glaciers receded. This gave rise to the current soils which are characteristically loamy and acidic. The soils are of the Houghtonville-Rawsonville-Mundal and Worden-Wilmington complexes. The Houghton-Rawsonville Mundal complex consists of moderately deep to very deep glacial till soils that are commonly found on hills and mountains. The Worden-Wilmington complex is found on hills and in depressional areas on uplands. These are very deep soils that are somewhat poorly drained to poorly drained (Sheehan 1987).

Land Use

The Lye Brook Wilderness was heavily logged at the turn of the century and most of the timber was carried by rail to Manchester. The remains of railroad embankments and logging roads are still visible throughout much of the wilderness. In 1916 an extensive fire swept through an area in the southwestern portion of the property. This has created a clearing known as "The Burning" which is still evident today.

Some mineral deposits are located throughout the wilderness; however, there is no evidence of past mining operations. The Wilderness Act of 1964 required the United States Geological Survey and the Bureau of Mines to survey the mineral resource potential of wilderness areas. The results of this survey are described more thoroughly in a report by Ayuso and Day (1981).

Vegetation

Prior to the onset of logging, the vegetation in Lye Brook Wilderness was dominated by pure stands of red spruce and balsam fir. Currently, approximately 80% of the land area consists of northern hardwood stands composed primarily of white ash, American beech, red maple, sugar maple, paper birch and yellow birch (Figure 4). For softwood species, stands of hemlock can be found on slopes at lower elevations. At higher elevations and in areas that were inaccessible to loggers, spruce and fir remain the dominant trees. The area known as "The Burning" consists of early successional species including lowbush blueberry, raspberry, and white pine. There are also several extensive wetland areas that contain a variety of hydrophytic vegetation.

Geology

The geology of the Lye Brook Wilderness consists of formations of the Mount Holly Complex, Mendon Formation, Cheshire Quartzite and Dunham Dolomite (Figure 5). These formations appear in a west-facing escarpment towards the Battenkill Valley. The Mount Holly complex underlies the other formations and is of unknown thickness. It is composed of an array of rock types including quartzites, schists, amphibolites and gneisses. The most important rocks of the Mendon Formation are conglomeratic quartzites, phyllitic conglomeratic quartzites, phylitic quartzites and quartz-mica-schists. Cheshire Quartzite overlays the Mendon Formation and consists of gray to tan, recrystallized orthoquartzite. The Dunham Dolomite is exposed in the northwest boundary of the wilderness near Lye Brook and is found throughout the lower Battenkill Valley. Dolomite is usually whitish-blue to dark gray and cream; however, in exposed, weathered outcrops it appears yellowish-orange (Ayuso and Robinson 1984).

Figure 4.

Lye Brook Wilderness
Forest Cover

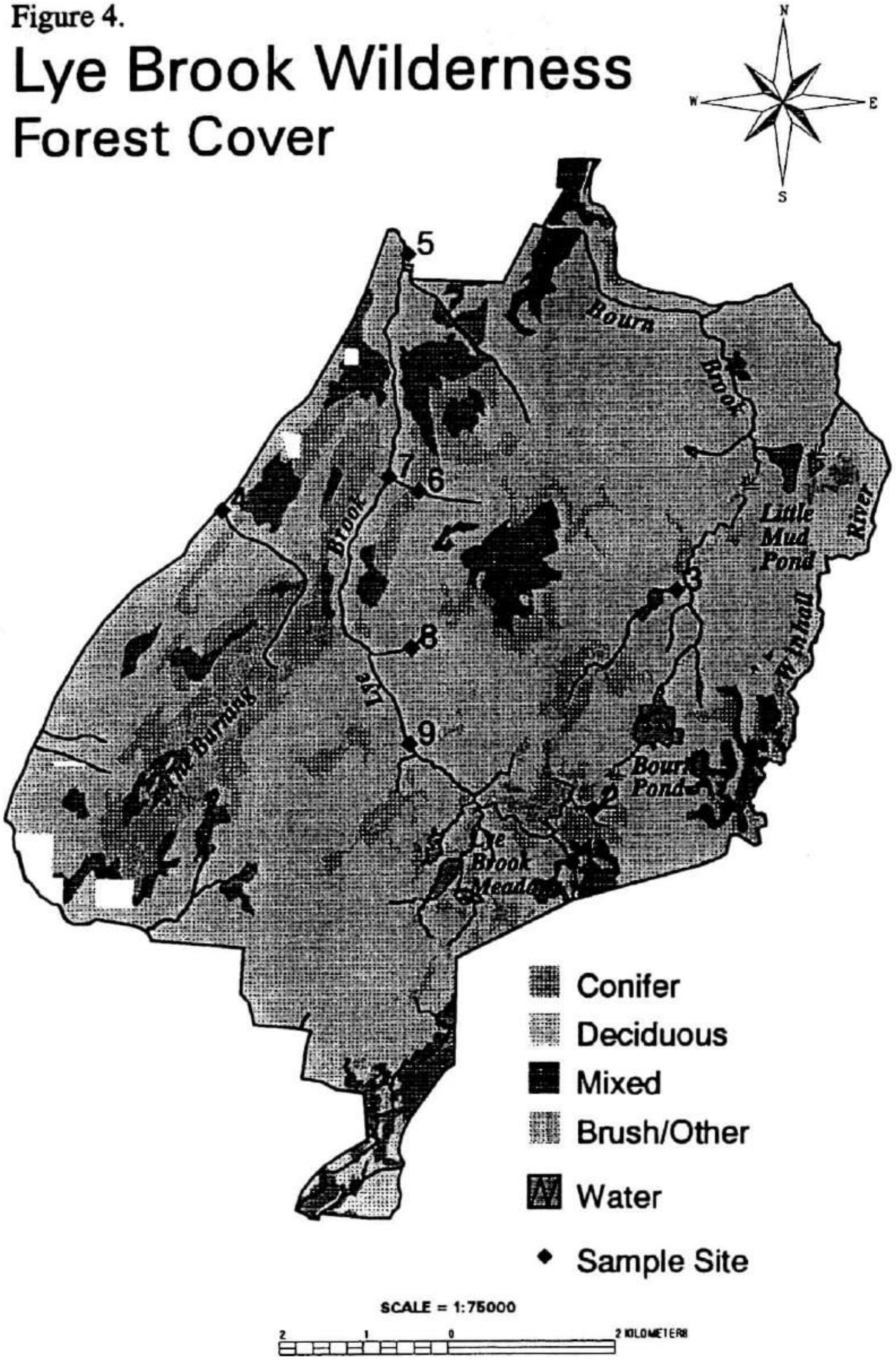
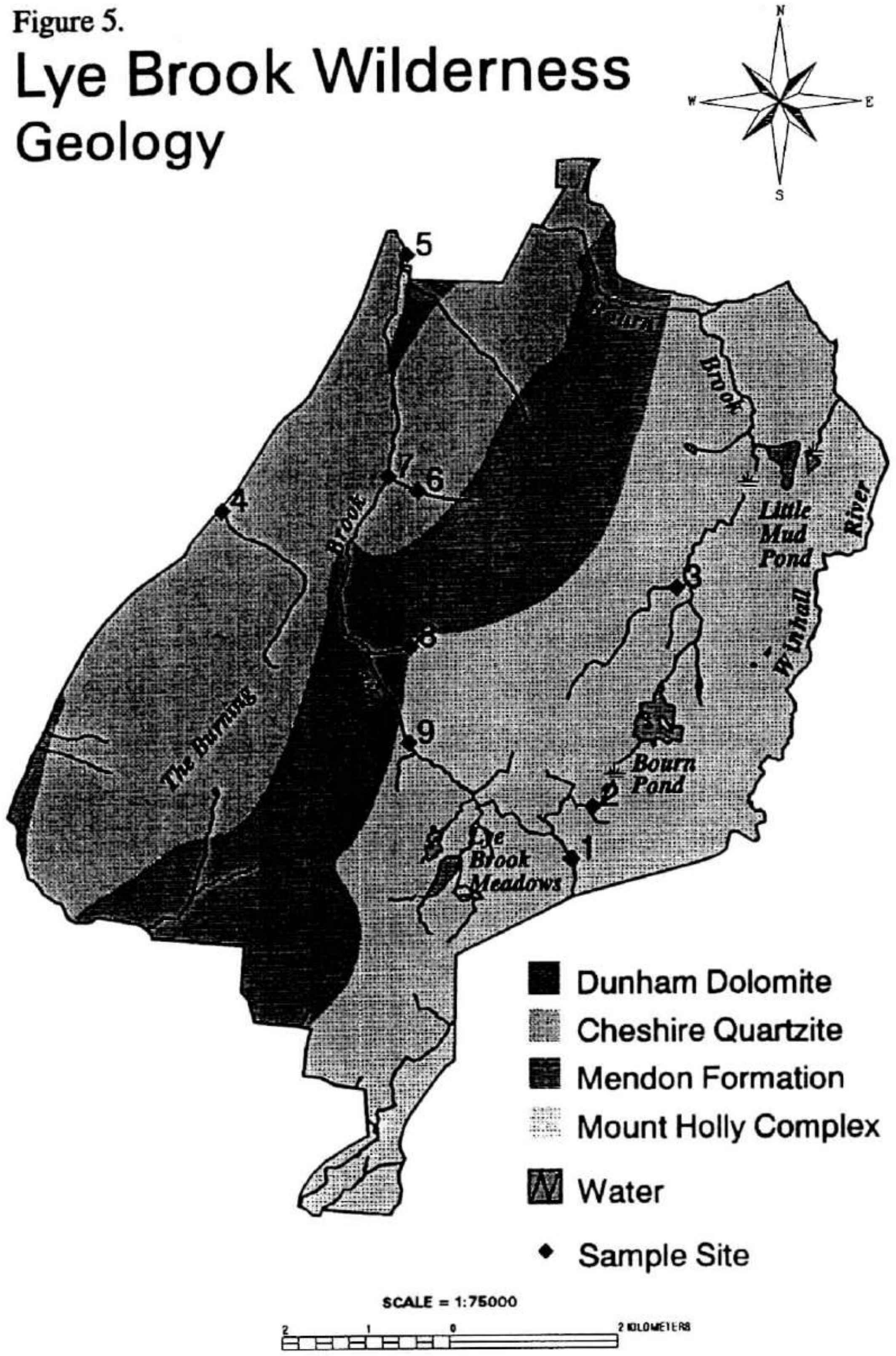


Figure 5.


Lye Brook Wilderness
Geology
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W
E
S
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7
6
4
3
8
9
2
1
Brook
Little Mud Pond
River
Winhall
Bourn Pond
Lye Brook Meadows
Brook
The Burning
Dunham Dolomite
Cheshire Quartzite
Mendon Formation
Mount Holly Complex
Water
Sample Site
SCALE = 1:75000
2
1
0
2 KILOMETERS

III. METHODS

Sample Collection

Nine streamwater sampling sites were established throughout the wilderness, to represent the major site characteristics of interest, such as geology, wetlands and elevation (Figures 1-5). Sites 1, 2 and 3 are high-elevation sites that are in close proximity to headwater wetlands. Site 4 is located at a low elevation in a watershed adjacent to the Lye Brook basin. This site drains an area that was burned in the early 1900's. Sites 5, 7 and 9 are all located in the main branch of the Lye Brook. Site 5 is underlain by dolomite and site 7 and 9 do not have a dolomite influence. Site 9 is at a relatively high elevation and has a slight wetland influence. Site 7 is farther downstream and did not appear to be affected by wetlands. Sites 6 and 8 are located on first order streams that are tributaries to Lye Brook. Both sites have similar characteristics in terms of size and discharge; however site 8 is located on an exposed ridge at a higher elevation and site 6 is a more protected, low-elevation site. Table 1 lists the characteristics at each site.

Table 1. - Description of major site features.

Site	Distance from Wetland (m)	Bedrock Type	Forest Cover Type	Elevation (m)
1	280	Mount Holly Complex	Mixed	838
2	55	Mount Holly Complex	Conifer	827
3	0	Mount Holly Complex	Deciduous	770
4	2291	Cheshire Quartzite	Deciduous	344
5	7123	Cheshire Quartzite (Dunham Dolomite)	Deciduous	302
6	----	Cheshire Quartzite	Deciduous	613
7	4441	Cheshire Quartzite	Deciduous	459
8	----	Mendon Formation (Mount Holly Complex)	Deciduous	800
9	749	Mount Holly Complex	Deciduous	764

Samples were collected biweekly from May 1994 through August 1995. Additional samples were taken at 5 of the 9 sites during March 1995 to characterize spring snowmelt. The water samples were stored in 250 ml and 50 ml high density Polyetheylene bottles. The bottles were acid washed and rinsed with distilled, deionized water and sample site streamwater prior to collection. General weather and discharge patterns were recorded at each site and stream temperature was measured with a digital thermometer.

After the samples were collected, they were stored in a cooler containing ice, for less than two days until they were brought to the laboratory. Aliquots from the 250 ml bottles were then filtered through a 0.2μm filter into a sample vial for anion analyses. The vials and the 250 ml bottles were refrigerated, and the 50 ml bottles were frozen. The 50 ml bottles were thawed for TOC and NH_4^+ analyses and sample water from the 250ml bottles was used for all other analyses.

Specific conductivity and pH were measured within one day of sampling and usually on the day the samples were collected. Both measurements were obtained with a Corning portable pH/conductivity meter. Acid neutralizing capacity was determined by potentiometric titration within a maximum of 6 months from the time of collection. The relatively long period of time between the collection and analysis date may have resulted in a change in the ANC value over time. This is probably minimal for sites with low pH values; however at site 5, where there are high concentrations of HCO_3^-, the difference may have been greater.

TOC was measured using a Shimadzu TOC 5000 Total Organic Carbon Analyzer. Samples were acidified with HCl and sparged with purified oxygen to remove inorganic C. A high-temperature combustion method was used to measure non-purgeable organic carbon (NPOC) which is identical to TOC described in standard methods (APHA 1989).

DON measurements were obtained using a chemiluminescent N detector and the Shimadzu TOC Analyzer combustion furnace (Merriam et al., *in press*). In this method, the sample is combusted at 680° which converts all forms of N to nitric oxide. The nitric oxide reacts with ozone to form nitrogen dioxide which is measured using the chemiluminescent detector. This method measures Total Dissolved N (TDN) which was used to calculate DON by subtracting inorganic forms of N (NO_3^- and NH_4^+) from total N.

Anion (NO_3^-, SO_4^{2-} and Cl^-) measurements were obtained using high performance liquid chromatography methods (Waters, Inc.). Ammonium was measured using flow injection, indophenol blue colorimetry (Lachat Instruments). Silica was also measured using flow injection analysis (molybdenum blue colorimetry). Speciated Al was determined on an autoanalyzer using pyrochatechol violet colorimetry (McAvoy et al. 1992). Cation (Ca^{2+}, Mg^{2+}, Na^+, K^+, Fe, Mn) concentrations were obtained using direct current plasma (DCP) spectroscopy.

Data Analysis

Stream sample ion concentrations were converted from mg/L to µeq/L for the purpose of establishing a charge balance. The concentration of H^+ was calculated from the pH value measured at the time of collection. The concentration of inorganic Al was determined using a variable charge based on pH, because the speciation of inorganic Al is pH-dependent (Driscoll 1989). At low pH values dissolved Al is generally in an aquo form (Al^{3+}). As pH increases, hydrolysis occurs, which results in a change in the form of inorganic Al. The Al concentrations in µeq/L were calculated using a charge of 3 if $pH \leq 4.5$, 2.5 if pH is 4.6 to 5.5, and 2 if $pH \geq 5.5$.

To convert TOC from mg/L to µeq/L, a charge density was established for TOC by using the following equation:

$$Oa = [Cb] - [Ca] + [Ali] \tag{4}$$

Where Cb is the sum of base cations, Ca is the sum of strong acid anions and Ali is inorganic monomeric Al. Fe and Mn were not included in the charge balance because speciated forms of these elements were not measured. Therefore, the values include colloidal and organic complexes as well as inorganic forms. The contribution of Mn was probably quite low; however, concentrations of Fe may have been high enough to alter the balance, specifically at sites that had high concentrations, such as site 8 (Table 1). By omitting these cations, this charge balance technique may have resulted in an overestimate of the charge density for TOC.

Mapping

The latitude, longitude and elevation of sampling locations were determined using a Global Positioning System (Trimble Navigation). Real-time measurements were differentially corrected to calculate sample locations within 3 to 5 meters of the exact location (Hurn 1993). The corrected site locations were then entered into a geographic information system (ARC/INFO).

A variety of geographic coverages were also incorporated into a database to determine the relationship between watershed characteristics and streamwater chemistry. All digital data were obtained from the Vermont Center for Geographic Information, Burlington Vermont, with the exception of the geologic map which was digitized at Complex Systems Research Center at the University of New Hampshire.

Hydrography data were digitized from United States Geological Survey 1:24000 topographic maps. Interval contours of 50 meters were generated from a 1:24000 digital elevation model. A geologic map of the Lye Brook Wilderness was digitized from a 1:48000 United States Geological Survey map created by Ayuso and Robinson (1984). Forest cover types were mapped by the United States Forest Service and included mapping units greater than one acre. Forest types were then aggregated into four categories (conifer, deciduous, mixed, brush/other).

The wetland coverage was created from National Wetland Inventory (NWI) maps prepared by the United States Fish and Wildlife Service. The maps were derived primarily from aerial photographs; therefore, the exact wetland boundaries may differ from the mapped boundaries to some extent. The wetland boundaries of interest were field checked and, despite minor discrepancies, are adequate for the purposes of this report.

IV. RESULTS

Charge Balance

The summed charges of measured cations nearly balanced the summed charges of measured anions at all sites with the exception of site 5 (Figure 6 and Table 2). The large imbalance at site 5 is thought to be mostly due to the presence of HCO_3^-, which was not measured. A HCO_3^- value of 182 μeq/L was calculated as the difference between anions and cations.

Calculated ANC values were compared with titrated ANC values as a quality control measure. To calculate ANC, a constant charge density was determined using an approach similar to the one developed by Oliver et al. (1983). Titrated ANC values were subtracted from calculated ANC values and the difference was divided by the concentration of TOC. The calculation yielded an average charge density of 4.6 μeq/mg TOC which is similar to values calculated for DOC in other studies (Kahl et al. 1989). Sites 1 and 5 (Table 3) were omitted from this calculation because both these sites contained HCO_3^- which was not measured.

Figure 7 shows that the titrated ANC values are strongly correlated with the calculated ANC values ($r^2 = 0.99$, $p<0.0001$). This relationship indicates that the TOC charge calculation appears to be appropriate and that the Al charge (based on pH) and other measured values are also acceptable.

Table 2. - Percent difference between cations and anions.

	Sample Site								
	1	2	3	4	5	6	7	8	9
Total Cations (μeq/L)	177	159	176	158	343	154	166	187	149
Total Anions (μeq/L)	160	153	181	176	161	168	174	198	144
Difference	17	5	-4	-19	182	-14	-8	-10	5
% Difference	10	3	2	11	53	8	5	5	4

Table 3. - Calculation of TOC charge density.

		Sample Site								
		1	2	3	4	5	6	7	8	9
Mg^{2+}	(μeq/L)	49	28	22	37	138	21	28	18	26
Ca^{2+}	(μeq/L)	61	41	40	57	152	39	45	27	42
K^{+}	(μeq/L)	14	13	14	14	20	22	19	19	14
Na^{+}	(μeq/L)	38	35	35	20	28	22	26	30	36
Al^{2-3+}	(μeq/L)	4	6	7	8	2	17	18	12	5
Total	(μeq/L)	166	123	118	136	340	120	136	106	123
SO_4^{2-}	(μeq/L)	77	67	87	117	98	105	102	102	66
NO_3^-	(μeq/L)	11	5	6	11	15	19	22	7	8
Cl^-	(μeq/L)	17	17	17	20	15	17	19	20	15
Total	(μeq/L)	105	89	110	148	128	141	143	129	89
Calculated ANC	(μeq/L)	60	34	7	-12	212	-20	-7	-23	34
Titrated ANC	(μeq/L)	0	-47	-69	-25	182	-42	-39	-104	-34
Difference	(μeq/L)	60	81	76	13	30	21	32	81	68
TOC	(mg/L)	12	14	15	6	7	6	7	15	12
TOC	(μeq/mg)	NA	5.8	5.0	2.1	NA	3.6	4.7	5.4	5.7
Average TOC	(μeq/mg)	4.6								
~TOC	(μeq/L)	55	65	70	27	33	28	31	69	54

Figure 6. - Average balance between anions and cations.

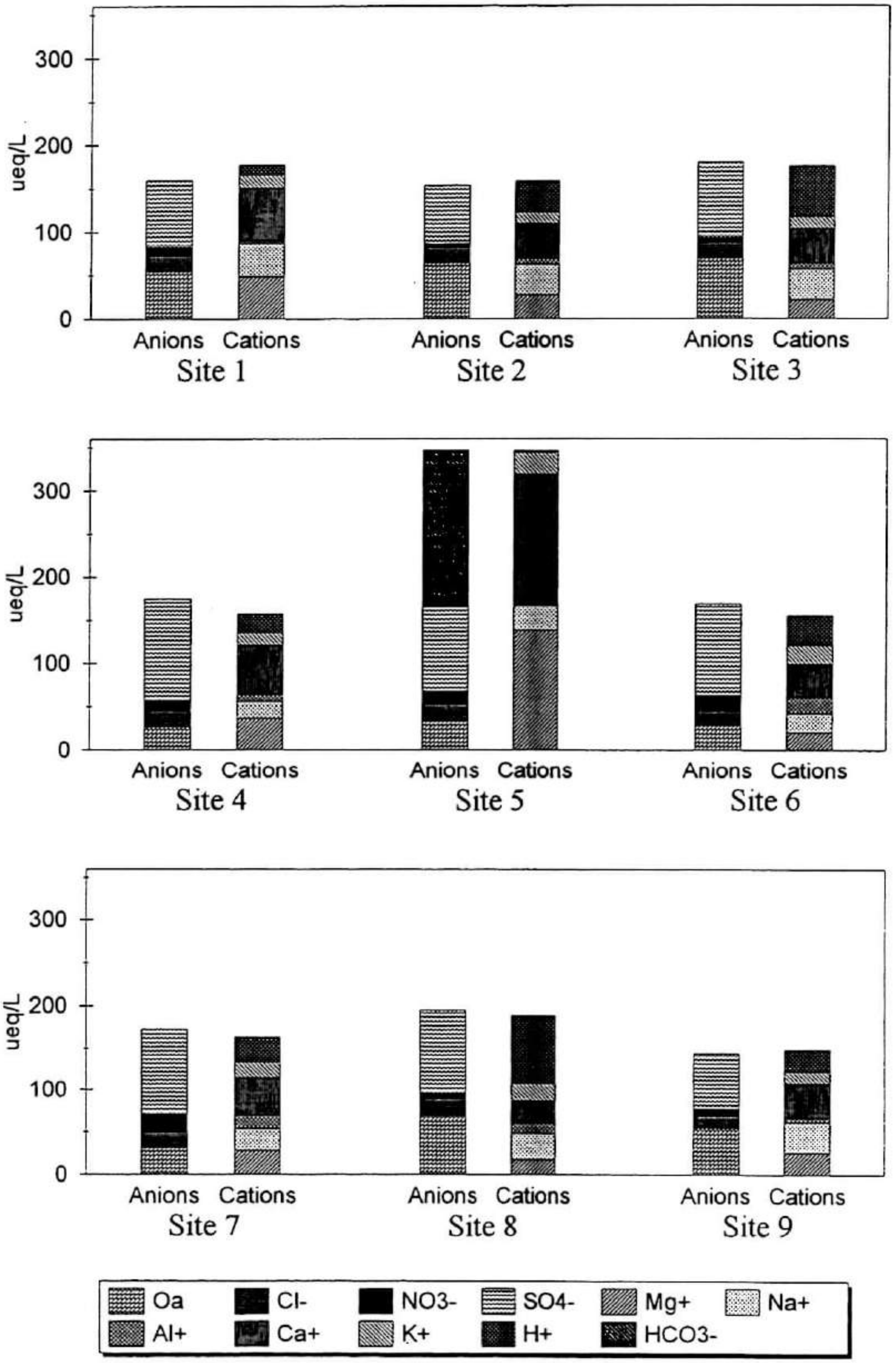
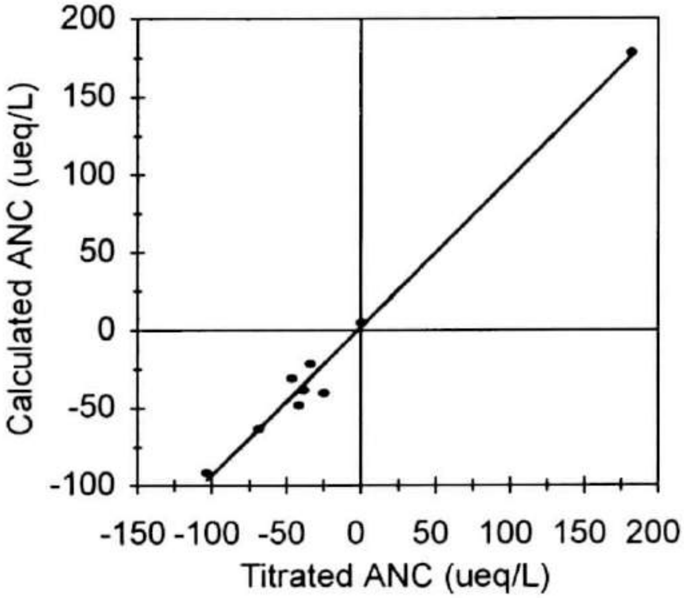


Figure 7. - Regression of titrated and calculated ANC. The line equation is $Y = 3.92 + 0.99x$ and $r^2 = 0.99$.



Chemical Characterization

Over the course of the sampling period, the mean chemical concentrations in streamwater varied considerably as a consequence of a number of factors. In general, the discharge-related events described in this report consist of abrupt changes in discharge associated with heavy rains and snowmelt runoff. The dates of these events are listed in Table 4. Seasonal trends can be closely linked to discharge-related events, but here they refer to gradual changes that occured over the course of the sampling period, assumed to be driven primarily by biological factors and variations in temperature.

Table 4. - Description of high discharge events.

Date	Event
08/17/94	Rain storm
09/27/94	Rain storm
12/06/94	Rain storm / Snow melt
1/16/95	Snow melt
07/19/95	Rain storm

Table 5 shows mean concentrations of the major constituents in streamwater for all sample dates at each site in addition to the average concentration for all sites. In general, stream chemistry concentrations are presented in mg/L; however, μeq/L are used in some instances for comparisons of ionic strength.

For strong acid anions, total concentrations ranged from 89 μeq/L to 150 μeq/L. Sites 2 and 9 had equally low concentrations and site 4 had the highest concentration. The average abundance of strong acid anions occurred in the following order: $SO_4^{2-} > Cl^- > NO_3^-$. At all sites SO_4^{2-} was the dominant anion and mean SO_4^{2-} concentrations were approximately 5 times that of Cl^-. In general, Cl^- was the second most abundant strong acid anion with an average concentration of 18 μeq/L. On a site-by-site basis there were some exceptions, specifically at sites 6 and 7 which had higher concentrations of NO_3^- (19, 21 μeq/L respectively) than Cl^- (17, 18 μeq/L respectively). In comparison, other sites had relatively low NO_3^- concentrations (5 - 15 μeq/L).

Weak organic acids associated with TOC contributed substantially to the acidity of streamwater. The average organic acid contribution was 52 μeq/L and was second only to SO_4^{2-}. At site 2, the organic acid contribution (69 μeq/L) slightly exceeded that of SO_4^{2}

Table 5. - Average stream chemistry (n = 35) at sample sites from May 1994 through August 1995. Standard deviations are shown in parentheses.

		Site									
		1	2	3	4	5	6	7	8	9	Mean
ANC	(ueq/l)	0	-47	-69	-25	182	-42	-39	-104	-34	-20
		(25)	(15)	(29)	(17)	(113)	(29)	(25)	(56)	(18)	(76)
SO4	(ueq/l)	77	67	87	117	98	105	102	102	66	91
		(17)	(38)	(26)	(13)	(9)	(11)	(12)	(18)	(24)	(17)
NO3	(ueq/l)	11	5	6	11	15	19	22	7	8	12
		(6)	(7)	(5)	(6)	(7)	(14)	(11)	(7)	(5)	(6)
Cl	(ueq/l)	17	17	17	20	15	17	19	20	15	17
		(8)	(9)	(8)	(7)	(4)	(5)	(12)	(8)	(7)	(2)
Ca	(ueq/l)	61	41	40	57	152	39	45	27	42	56
		(10)	(6)	(10)	(10)	(55)	(6)	(11)	(4)	(6)	(35)
Mg	(ueq/l)	49	28	22	37	138	21	28	18	26	41
		(8)	(5)	(4)	(9)	(55)	(4)	(10)	(2)	(4)	(35)
Na	(ueq/l)	38	35	35	20	28	22	26	30	36	30
		(8)	(7)	(11)	(5)	(5)	(4)	(6)	(8)	(5)	(6)
K	(ueq/l)	14	13	14	14	20	22	19	19	14	17
		(9)	(7)	(9)	(5)	(22)	(5)	(4)	(5)	(4)	(3)
H	(ueq/l)	12	36	58	22	3	34	30	81	26	34
		(12)	(11)	(22)	(14)	(6)	(22)	(18)	(38)	(12)	(22)
Ali	(ueq/l)	4	6	7	8	2	17	18	12	5	9
		(3)	(2)	(2)	(8)	(3)	(15)	(12)	(5)	(3)	(5)
Alo	(mg/L)	0.17	0.19	0.21	0.09	0.09	0.12	0.14	0.21	0.16	0.15
		(0.05)	(0.05)	(0.05)	(0.03)	(0.05)	(0.07)	(0.05)	(0.07)	(0.04)	(0.04)
NH4-N	(mg/L)	0.012	0.019	0.025	0.01	0.008	0.007	0.008	0.016	0.016	0.013
		(0.004)	(0.014)	(0.015)	(0.010)	(0.003)	(0.004)	(0.004)	(0.004)	(0.009)	(0.006)
Mn	(mg/L)	0.027	0.015	0.017	0.122	0.017	0.154	0.086	0.077	0.026	0.060
		(0.016)	(0.005)	(0.005)	(0.04)	(0.016)	(0.042)	(0.035)	(0.014)	(0.005)	(0.049)
Fe	(mg/L)	0.43	0.48	0.39	0.53	0.17	0.34	0.26	1.33	0.41	0.48
		(0.20)	(0.31)	(0.20)	(0.41)	(0.11)	(0.03)	(0.18)	(0.56)	(0.19)	(0.32)
TOC	(mg/L)	11.9	14	15.2	5.9	7.2	6	6.7	14.8	11.8	10.4
		(3.5)	(3.9)	(5.1)	(2.1)	(3.0)	(4.0)	(3.5)	(7.3)	(3.3)	(3.7)
DON	(mg/L)	0.37	0.41	0.41	0.17	0.24	0.2	0.23	0.33	0.37	0.30
		(0.11)	(0.13)	(0.14)	(0.08)	(0.08)	(0.09)	(0.09)	(0.15)	(0.13)	(0.09)
SiO2	(mg/L)	5.9	5.5	6.8	5	5.5	6.9	6.1	8.2	4.6	6.1
		(1.7)	(2.1)	(1.8)	(0.07)	(1.1)	(1.1)	(1.0)	(2.4)	(2.1)	(1.0)
Cond.	(uS/L)	25.2	27.5	37.3	26.5	35.6	28.1	28.9	46.3	24.1	31.1
		(6.4)	(6.2)	(9.8)	(6.7)	(10.6)	(9.8)	(8.2)	(15.9)	(6.3)	(6.8)
Temp.	(C)	10.3	10.7	9.9	10.1	10.4	8.9	10.1	8.5	10.7	10.0
		(6.4)	(7.3)	(7.0)	(5.9)	6.1	(5.6)	(5.8)	(5.4)	(6.8)	(0.7)
pH		5.1	4.5	4.3	4.7	6.4	4.5	4.6	4.1	4.6	4.8

(67 μeq/L). At all sites, organic acid concentrations were greater than NO_3^- and Cl^-, indicating the important contribution of natural weak acids

Total base cation concentrations were highest at site 5 (347 μeq/L) followed by site 1 (162 μeq/L). The range of base cations at the remaining sites was fairly narrow (95 - 127 μeq/L) with the lowest concentration occurring at site 8. The mean concentrations of individual base cations followed a general trend of $Ca^{2+} > Mg^{2+} > Na^+ > K^+$. However, this trend is substantially influenced by site 5, and to a lesser extent by site 1. Four sites (1, 4, 5, 7) followed this cation order and other sites had several different variations. The dominant base cation at all sites was Ca^{2+}, except for site 8, which had a slightly higher concentration of Na^+. Concentrations of K^+ were lower than other cations at all sites except 6 and 8.

Average titrated ANC values ranged from 182 μeq/L to -104μeq/L (Figure 8). Sites 1 and 5 were the only sites that had positive ANC values and site 1 was only slightly positive (0.4 μeq/L). Based on these data, sites 5 and 1 are the only locations that have HCO_3^- in the water and site 1 has minimal amounts indicated by the comparatively low ANC value.

Figure 9 illustrates fluctuations in ANC over the sampling period. A seasonal trend was evident at site 5, and to a lesser extent at site 1, with lower ANC values occurring during the winter and during spring runoff and higher values during the summer. At most sites, ANC values were lowest during high discharge events such as rain storms and snowmelt runoff.

Figure 8. - Average acid neutralizing capacity values determined by titration.

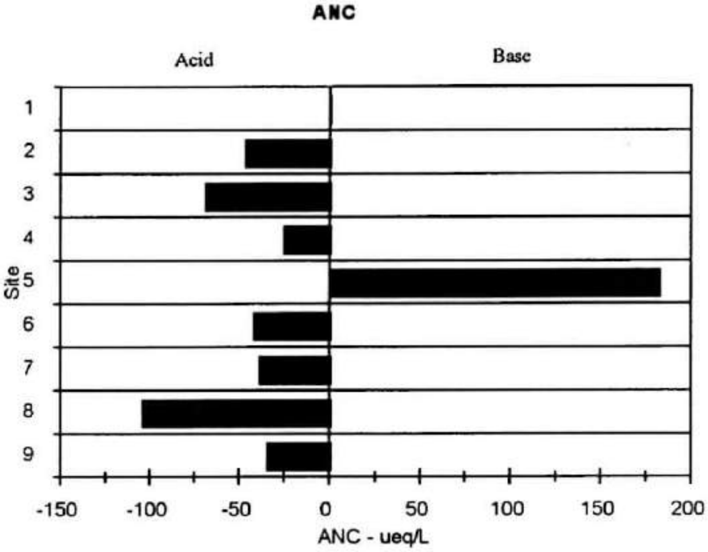
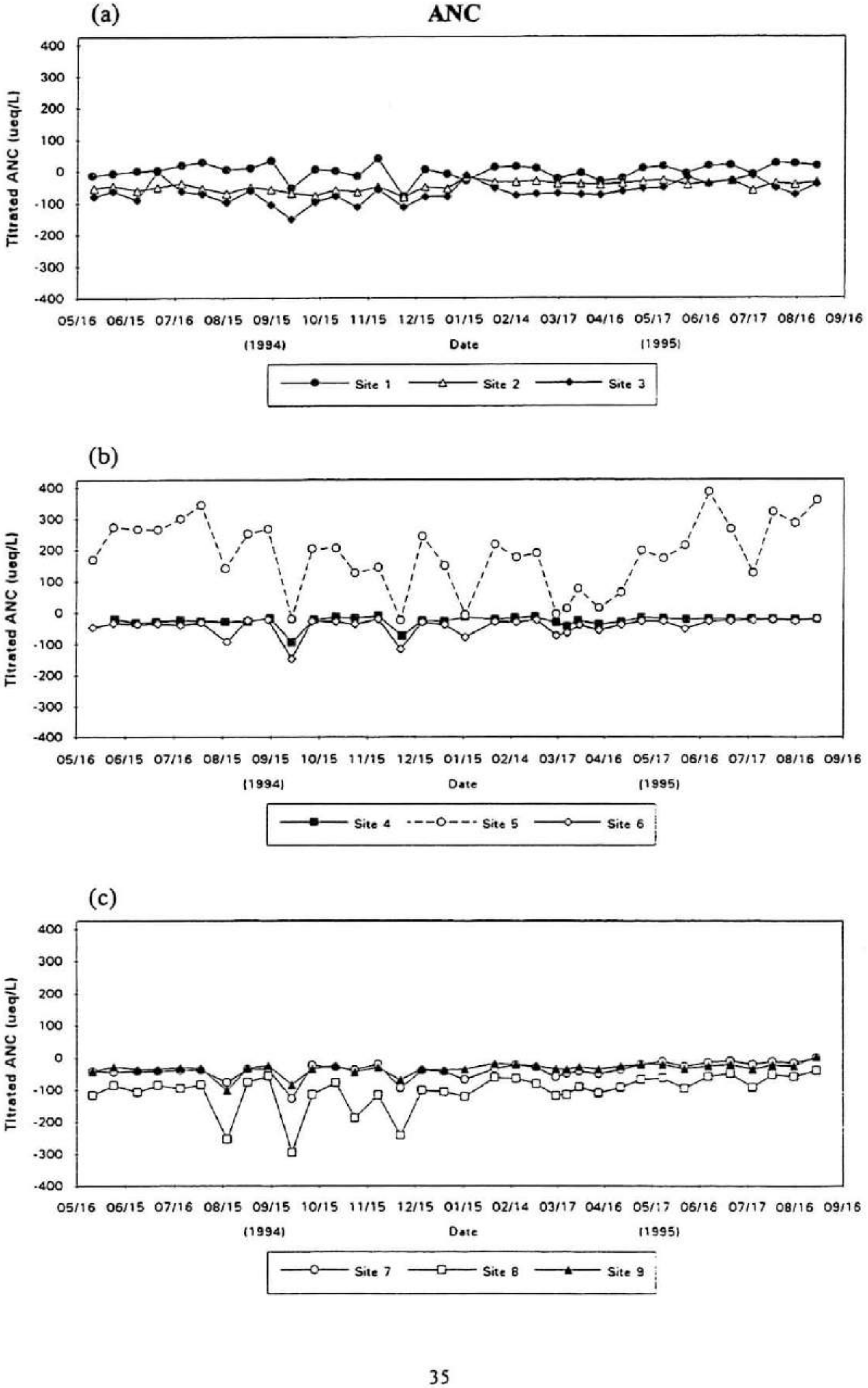


Figure 9. - The acid neutralizing capacity at sample sites from May 1994 through August 1995.



SO_4^{2-}-S concentrations varied among sites and were higher at some sites during the winter compared to summer (Figure 10). Concentrations also appeared to peak during high discharge events over the summer months, although they generally decreased during high discharge events in the winter. Large differences in SO_4^{2-}-S concentrations were evident among some sites. For example, site 2 had extremely low concentrations during the summer and higher concentrations during the winter. In comparison, sites 4 and 6 had concentrations that were consistently higher than site 2 during the summer and similar concentrations during the winter. At all three sites, an increase occurred during spring runoff.

Figure 11 indicates that NO_3^--N concentrations peaked during spring runoff at most sites, preceded by a gradual increase over winter. During the summer, NO_3^--N concentrations were generally lower and concentrations were close to 0 at some sites. Nitrate-N did not appear to be influenced by heavy rain in the summer; however, during the winter, peaks were obvious during high discharge.

There was no clear seasonal or discharge-related trends in Cl^- concentrations (Figure 12). Although some peaks did occur during spring, they were not consistently high during this period. In addition, there were no major differences in Cl^- concentrations among sampling sites.

The pattern for Ca^{2+} during the sampling period was similar to that of ANC (Figure 13). This was particularly true for site 5 which exhibited similar seasonal and discharge-related trends. At this site, concentrations also appeared to be greatest during the summer months. At other sites there was no apparent dilution of Ca^{2+} during high discharge and no seasonal trends are evident. Furthermore, concentrations were consistently low. Site 1 had slightly higher concentrations and some peaks are evident; however, it is difficult to determine if these peaks were associated with discharge.

There was a highly significant correlation between Mg^{2+} and Ca^{2+} ($r^2 = 0.98$, $p<0.0001$) and the pattern for both these cations was similar at all sites (Figure 13 and

Figure 10. - Sulfate-S concentrations at sample sites from May 1994 through August 1995.

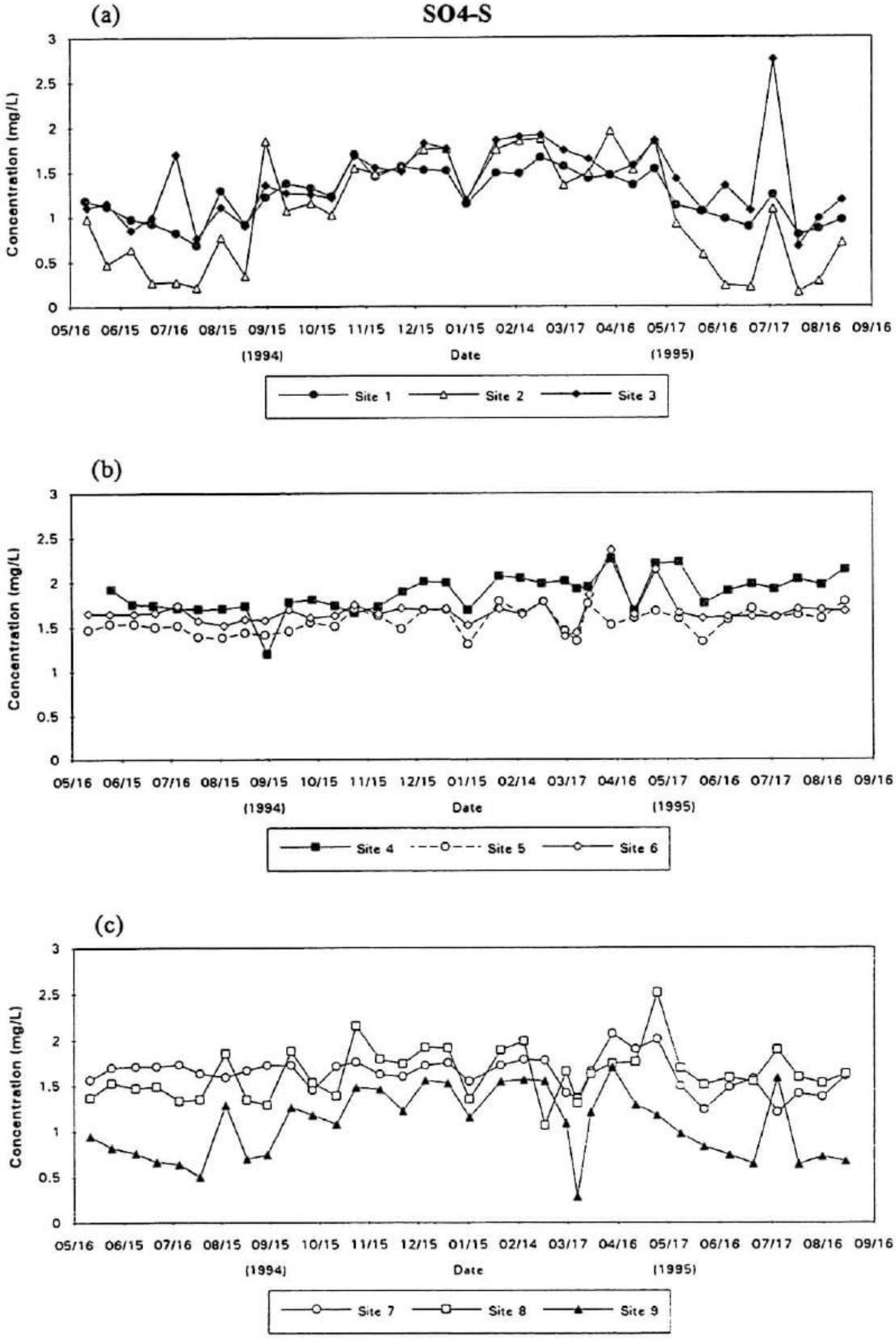


Figure 11. - Nitrate-N concentrations at sample sites from May 1994 through August 1995.

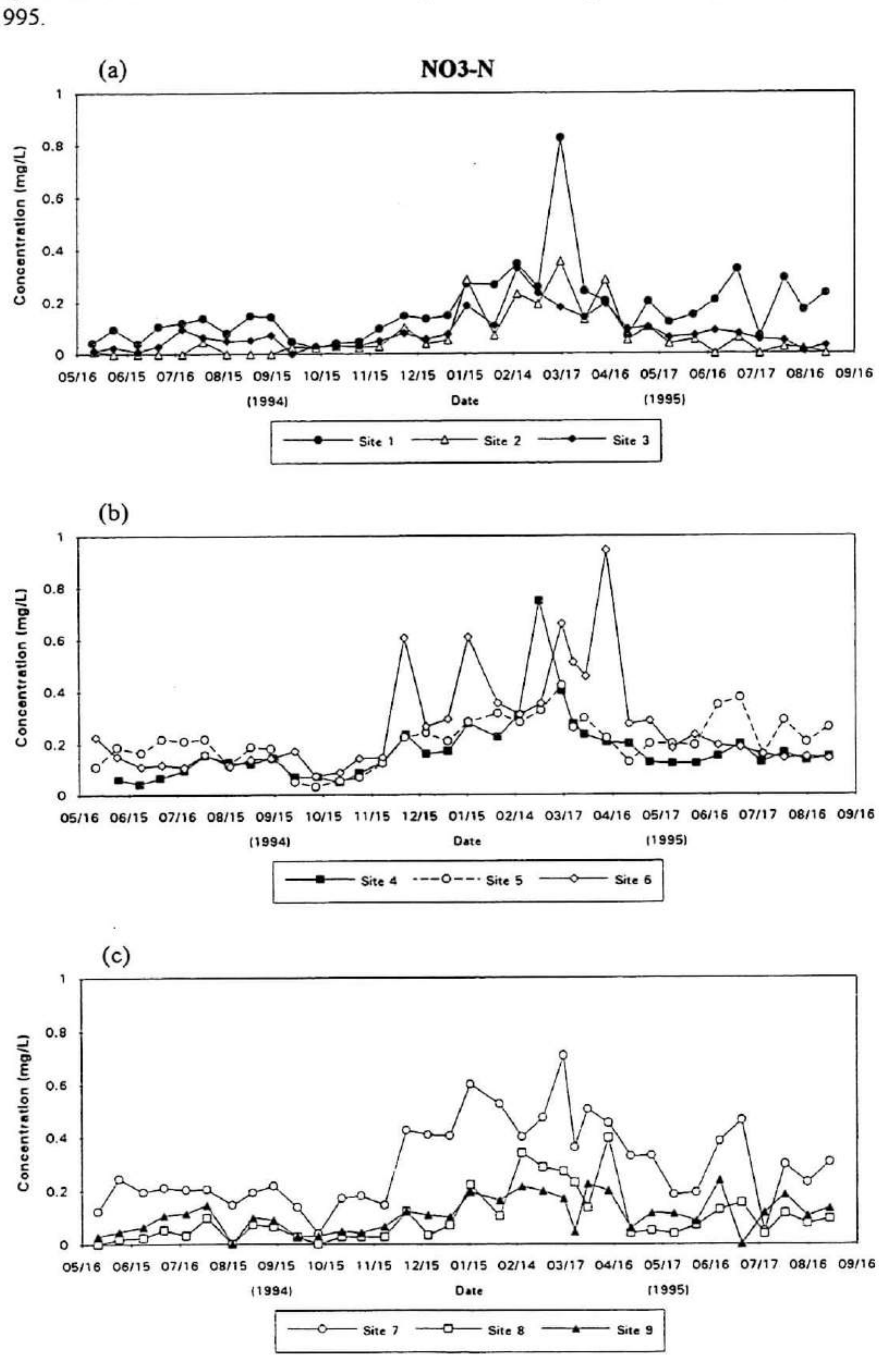


Figure 12. - Chloride concentrations at sample sites from May 1994 through August 1995.

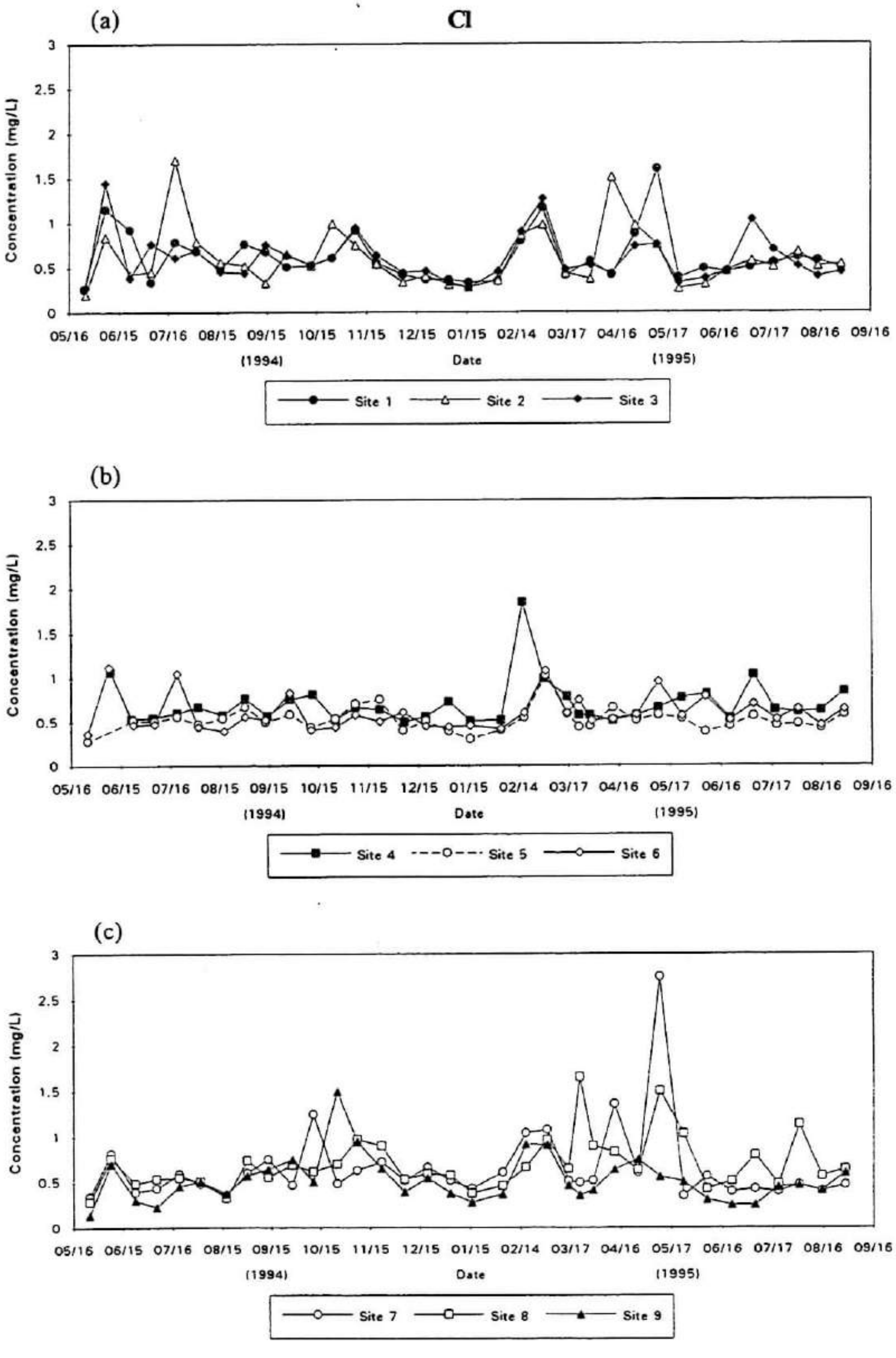


Figure 13. - Calcium concentrations at sample sites from May 1994 through August 1995.

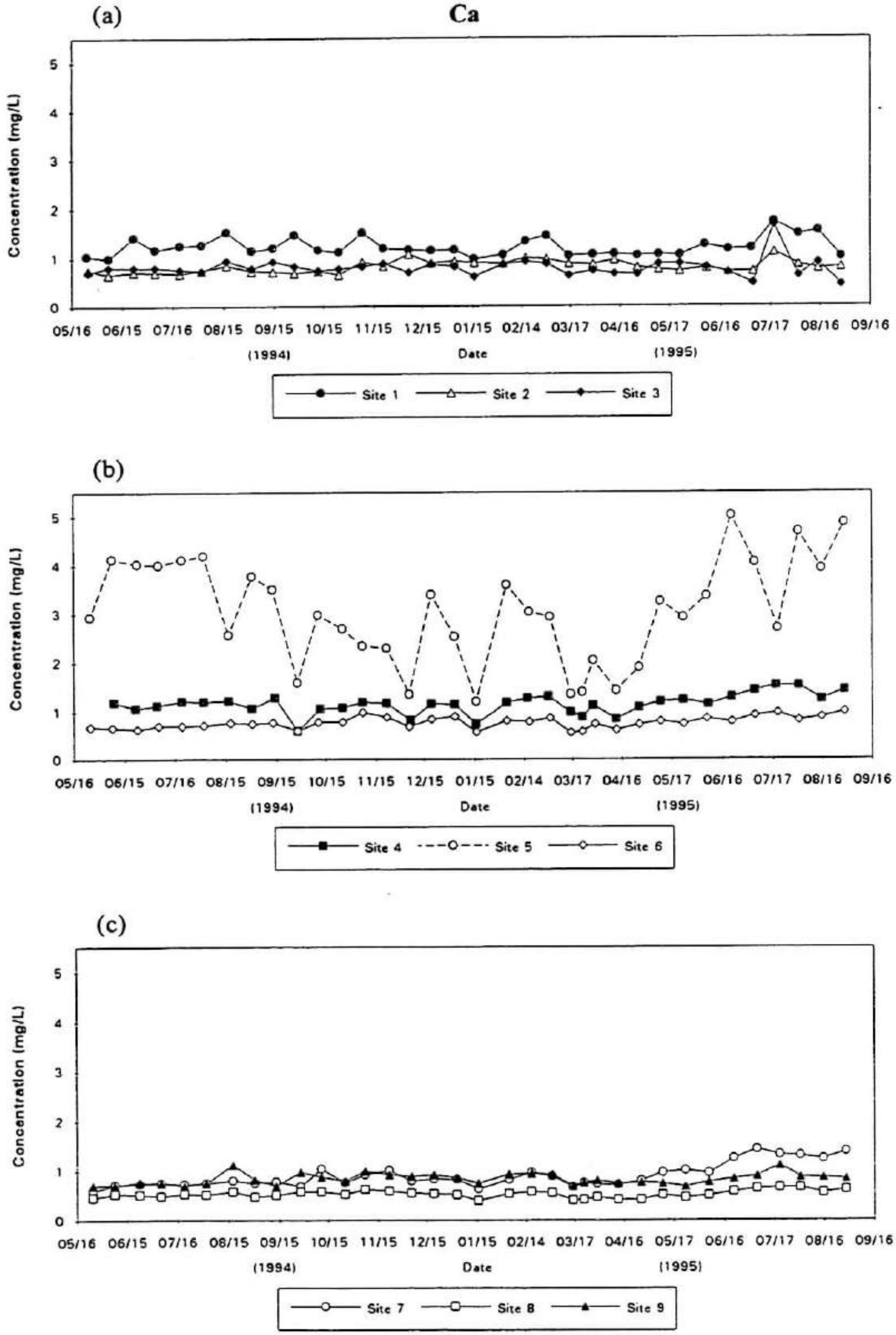


Figure 14. - Magnesium concentrations at sample sites from May 1994 through August 1995.

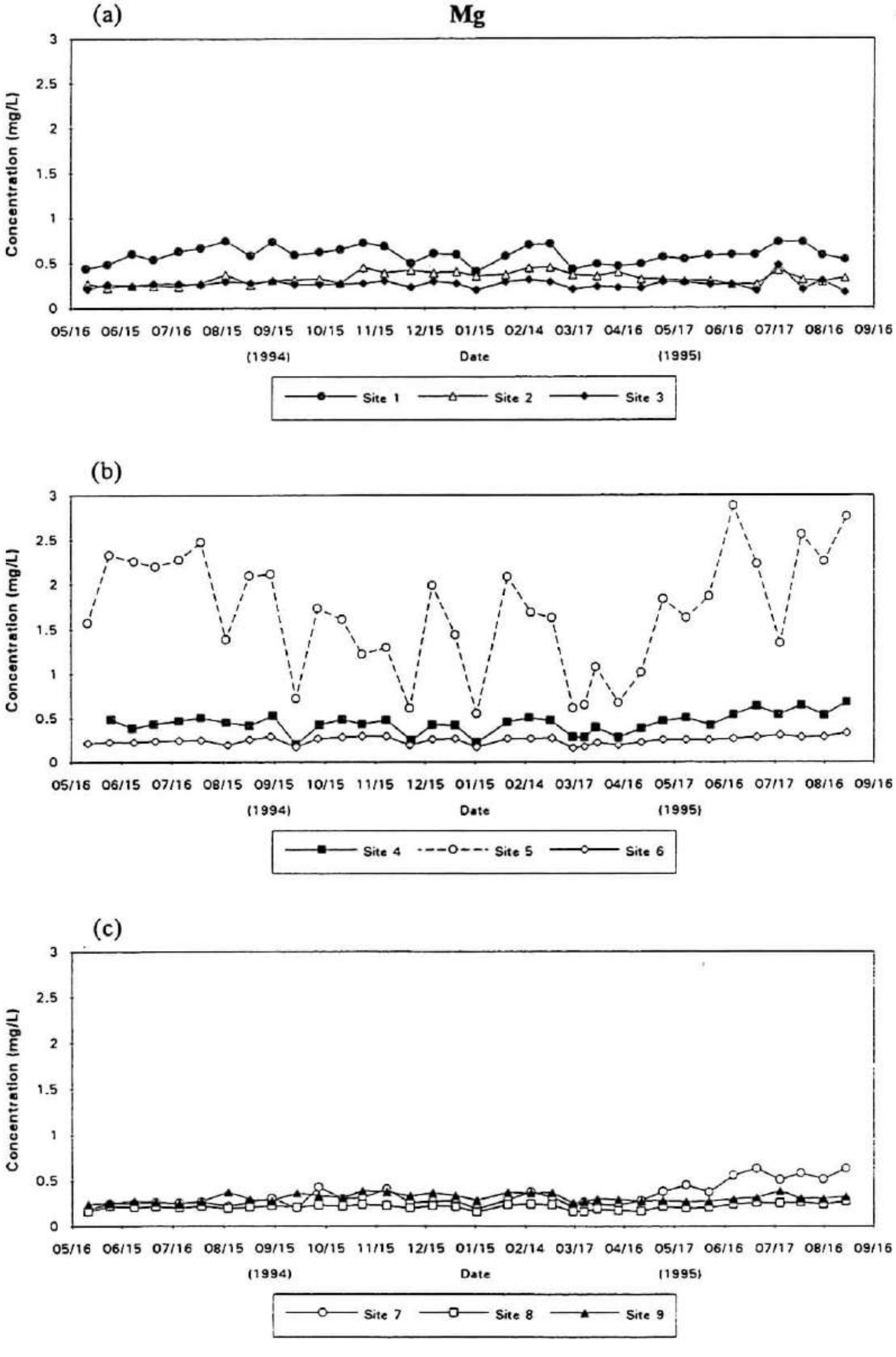


Figure 14). However, the concentrations of Mg^{2+} were lower than Ca^{2+} concentrations and, Mg^{2+} is less important than Ca^{2+} in terms of charge balance.

Figure 15 indicates that Na^{+} concentrations appeared to be diluted during high discharge, similar to the discharge-related dilution that occurred with Ca^{2+} and Mg^{2+}. Despite this similarity, there was no obvious seasonal pattern associated with Na^{+}. Concentrations of Na^{+} over time, were similar at all sampling sites; however, the concentrations varied among sites to some extent.

The general trend for K^{+} is shown in Figure 16. There were no apparent seasonal or discharge-related patterns for K^{+} and K^{+} did not vary considerably between sites.

In addition to base cations, other cations exhibited some general patterns, particularly Fe and Mn. Average Fe concentrations at all sites were less than 0.5 mg/L, except for site 8 which had comparably high concentrations (1.3 mg/L). The mean trend for Fe consisted of high concentrations during late summer, followed by low concentrations that occurred during the winter and spring (Figure 17).

At site 8, there was a strong seasonal pattern, with Fe concentrations being highest during summer 1994, and to a lesser extent, during summer 1995. Streamwater Fe at site 8 appeared to be diluted during one rainstorm that occurred on 17 August 1994; however, no other storm-related dilution was evident at this site during any other sampling date. Several other sites had seasonal patterns that were similar to site 8; however, no discharge-related patterns were obvious. Sites 5, 6 and 7 were different from the other sites, primarily because Fe appeared to increase during high discharge events and no seasonal trends were evident.

The general trend for Mn was similar to Fe (Figure 18); however, despite a general commonality between mean Fe and Mn trends, concentrations at individual sites differed. Unlike Fe, at site 6 Mn was diluted during periods of high discharge. In addition, at this site, and at several other sites, there was an overall seasonal trend with highest

Figure 15. - Sodium concentrations at sample sites from May 1994 through August 1995.

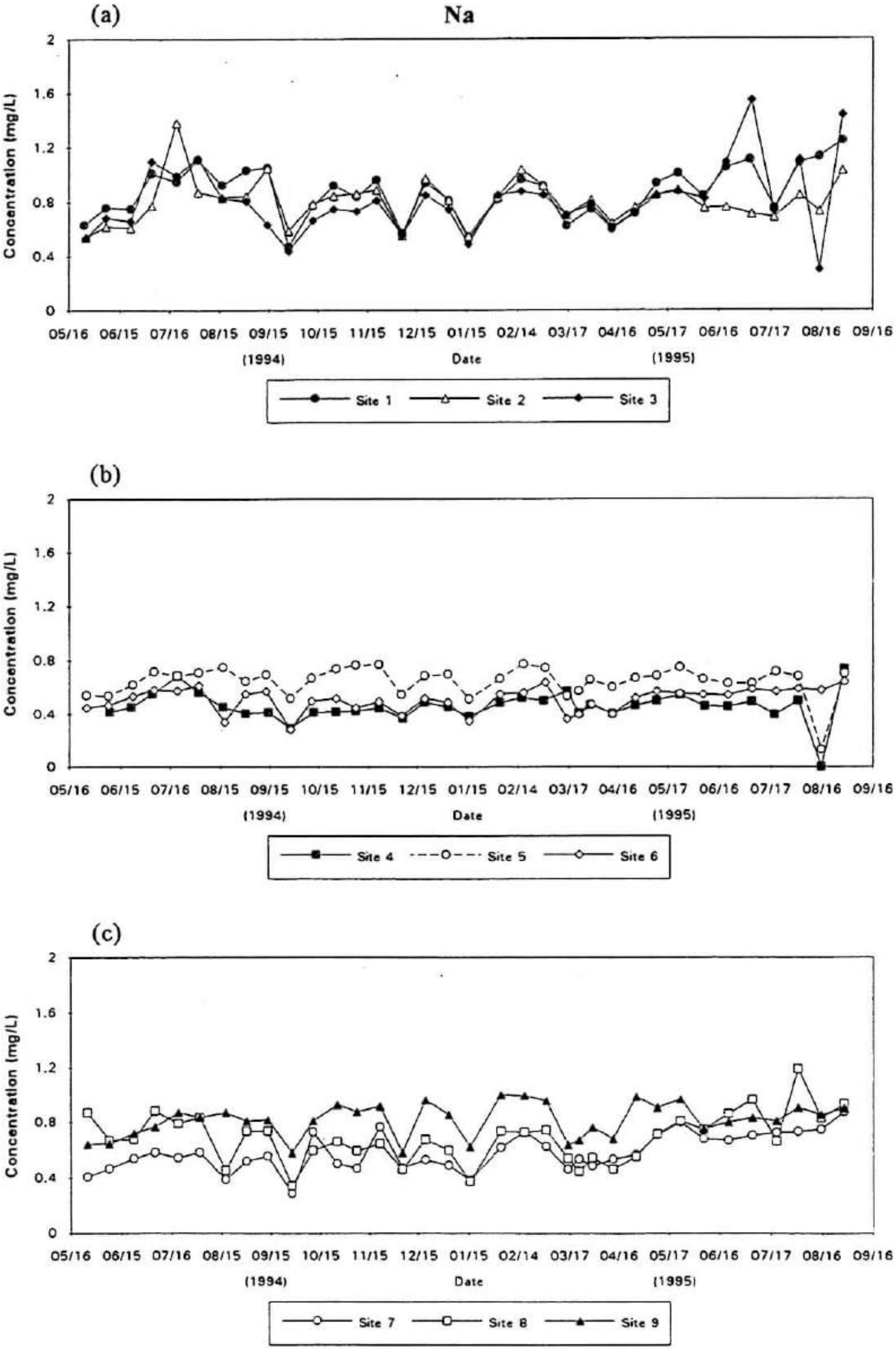


Figure 16. - Potassium concentrations at sample sites from May 1994 through August 1995.

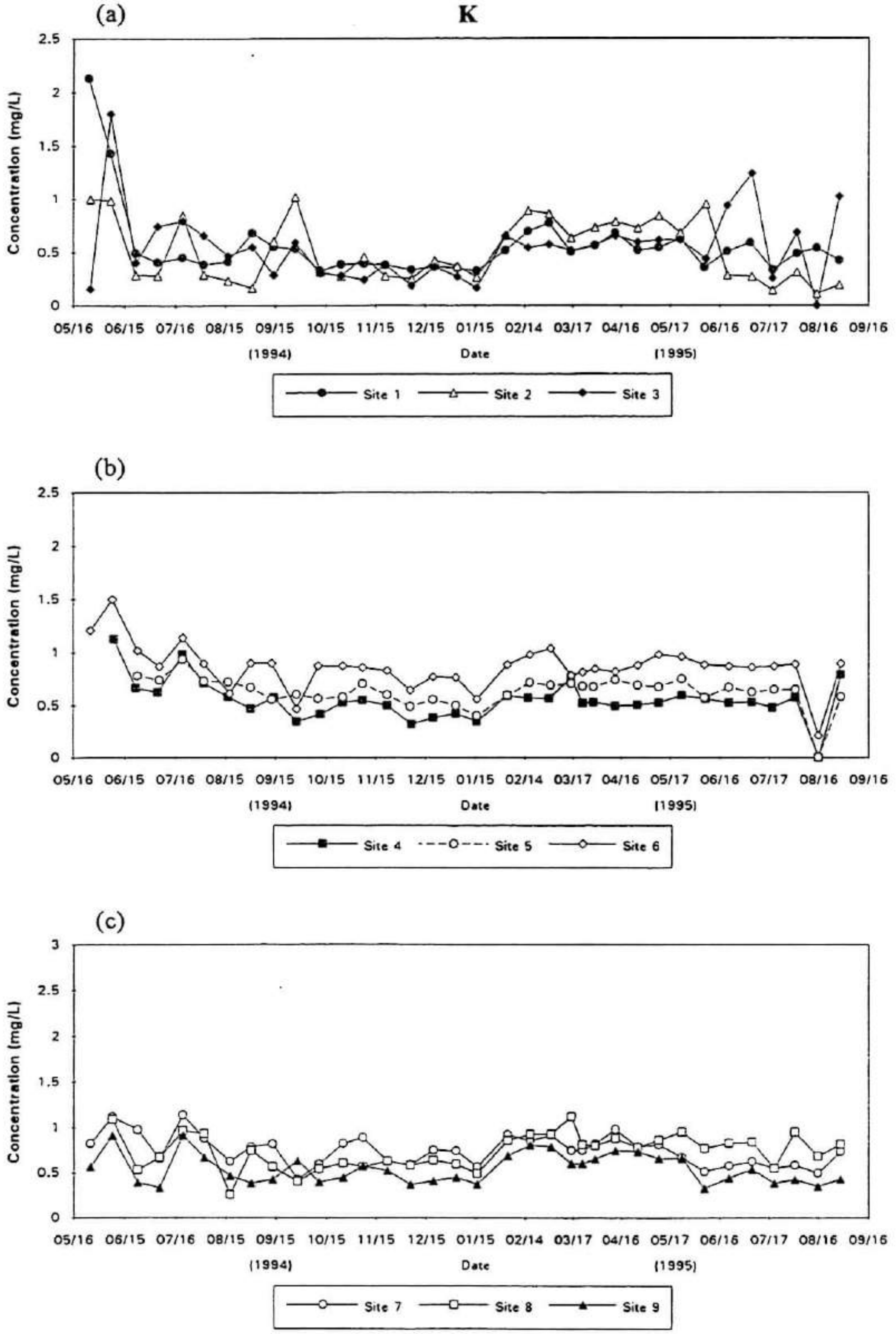


Figure 17. - Iron concentrations at sample sites from May 1994 through August 1995.

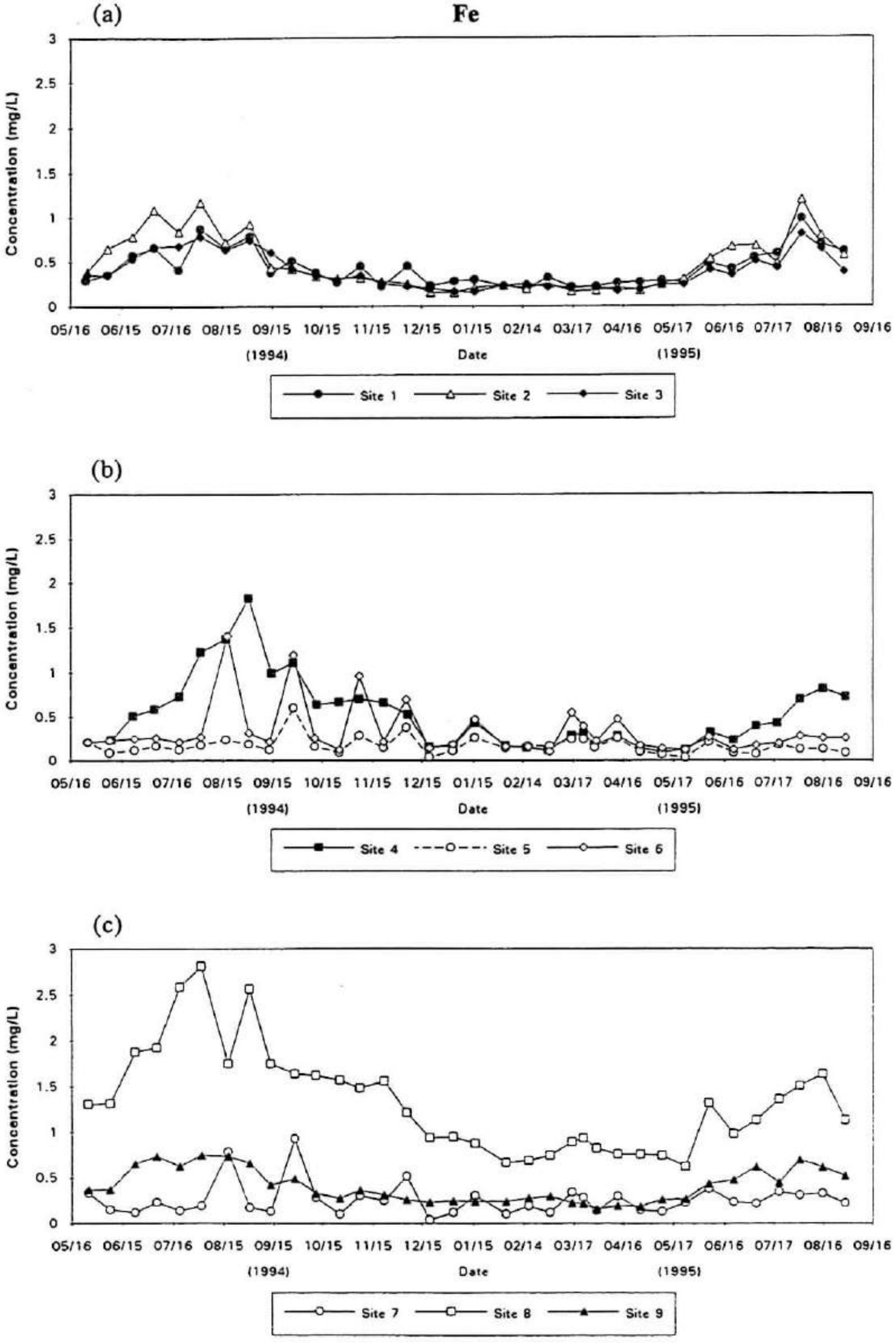
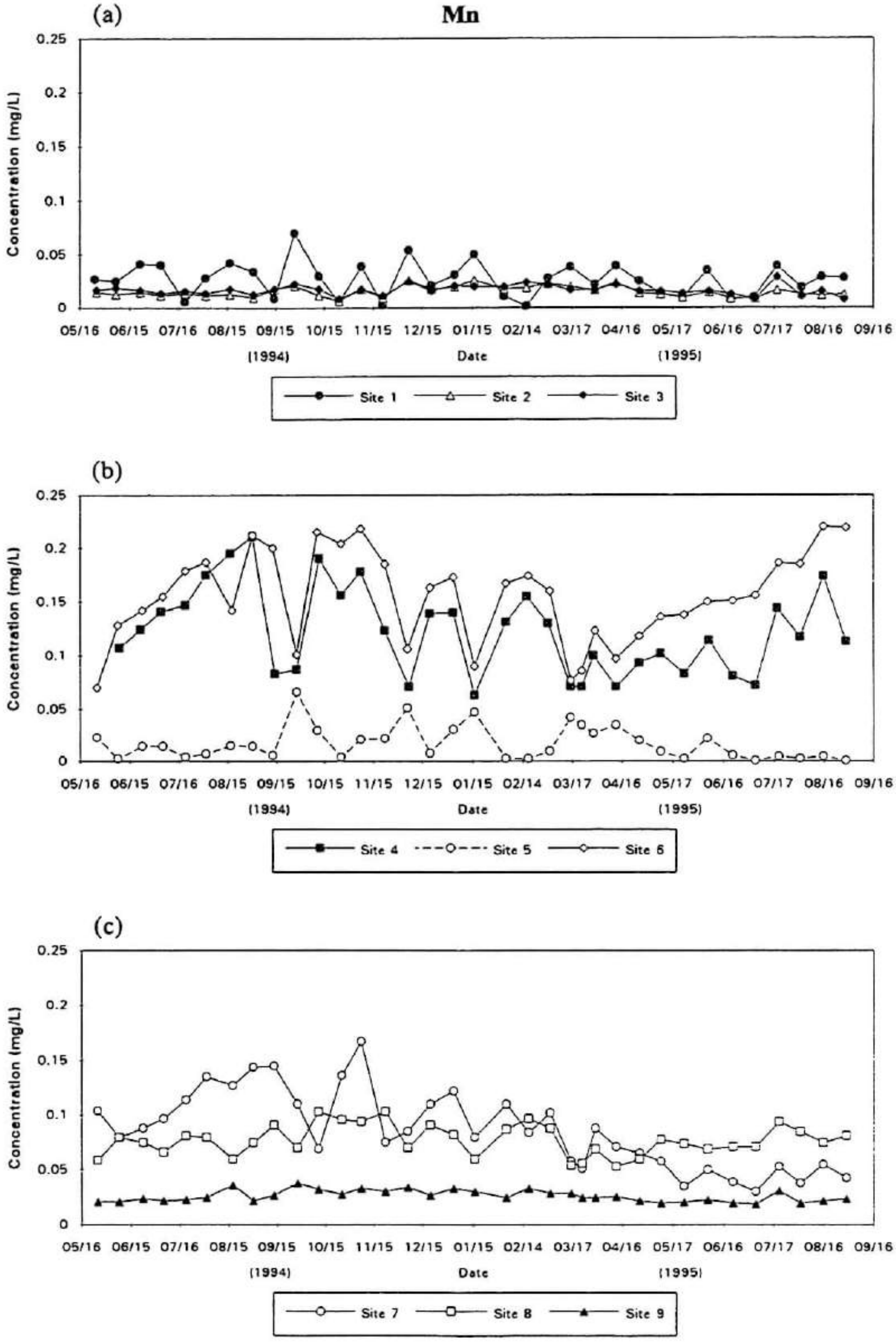


Figure 18. - Manganese concentrations at sample sites from May 1994 through August 1995.



concentrations peaking during the fall. Some sites, such as 2, 3 and 9, had consistently low and stable concentrations of Mn.

The average concentration of Mn for the sampling period was less than all other cations except for NH_4^+. Concentrations of NH_4^+ were low with average values below 0.02 mg/L; therefore, NH_4^+ had a negligible impact on the charge balance. In addition, NH_4^+ did not appear to exhibit any seasonal or discharge-related trends and there was little variability among sites.

Concentrations of inorganic Al were also fairly low with highest concentrations occurring at sites 6 and 7 (both had average concentrations of 0.17 mg/L). There were no obvious seasonal trends, although inorganic Al appeared to be highest during high discharge events such as rainstorms or snowmelt runoff (Figure 19). At some sites, such as sites 1, 2 and 3, concentrations were consistently low with no apparent peaks. At most sites, inorganic Al concentrations were highest during periods when the pH was lowest. Figure 20 indicates that there is a relationship between pH and inorganic Al. This figure shows that below a pH level of approximately 5, concentrations of inorganic Al increase sharply.

Figure 19. - Inorganic aluminum concentrations at sample sites from May 1994 through August 1995.

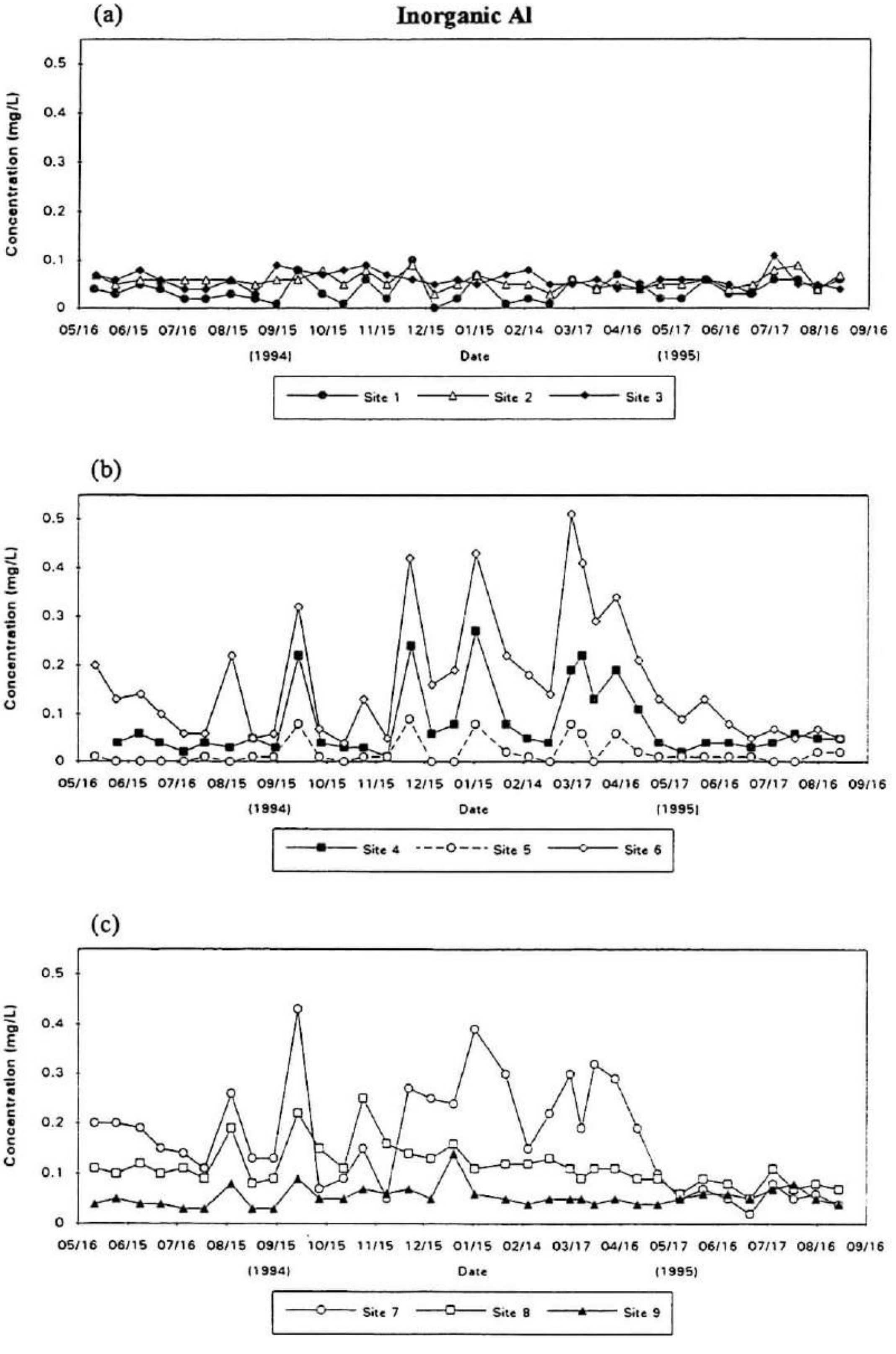
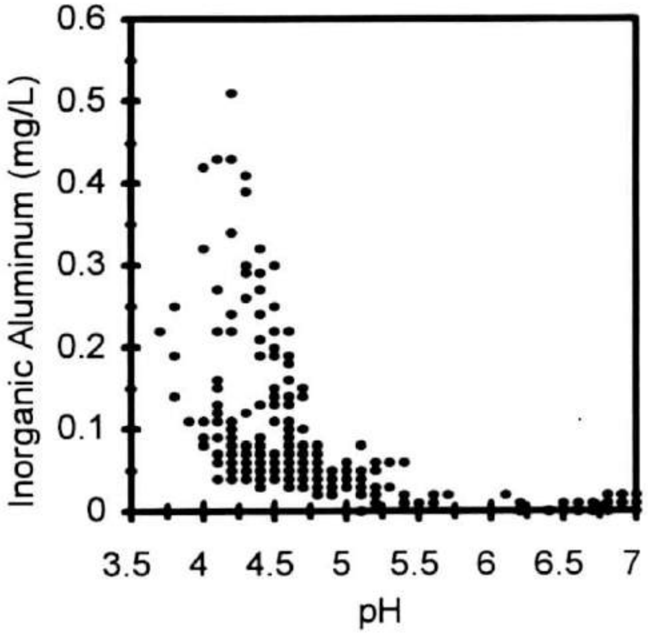


Figure 20. - Relationship between pH and inorganic Al.



The pH values in figure 21 were lowest at high discharge, particularly during snowmelt runoff and periods of heavy rain (Table 4). Despite a slight reduction in pH during storms, pH values during the summer were generally less affected by high discharge events. The pH at site 5 exhibited the most variability, with sharp decreases occurring during storms. Site 1 was similar to site 5 in this respect, although the pH was lower at site 1 and the reductions in pH were not as sharp. The pH at other sites was relatively stable and no seasonal or discharge-related trends were obvious. At site 8, pH values were consistently low (< 4.5) and they appeared to decrease even lower during high discharge. The average specific conductance of streamwater was closely linked to the pH with highest values occurring when pH was lowest (Figure 22). Maximum conductivities occurred during high discharge, indicating the high ionic strength of water during these periods.

Figure 21. - pH at sample sites from May 1994 through August 1995.

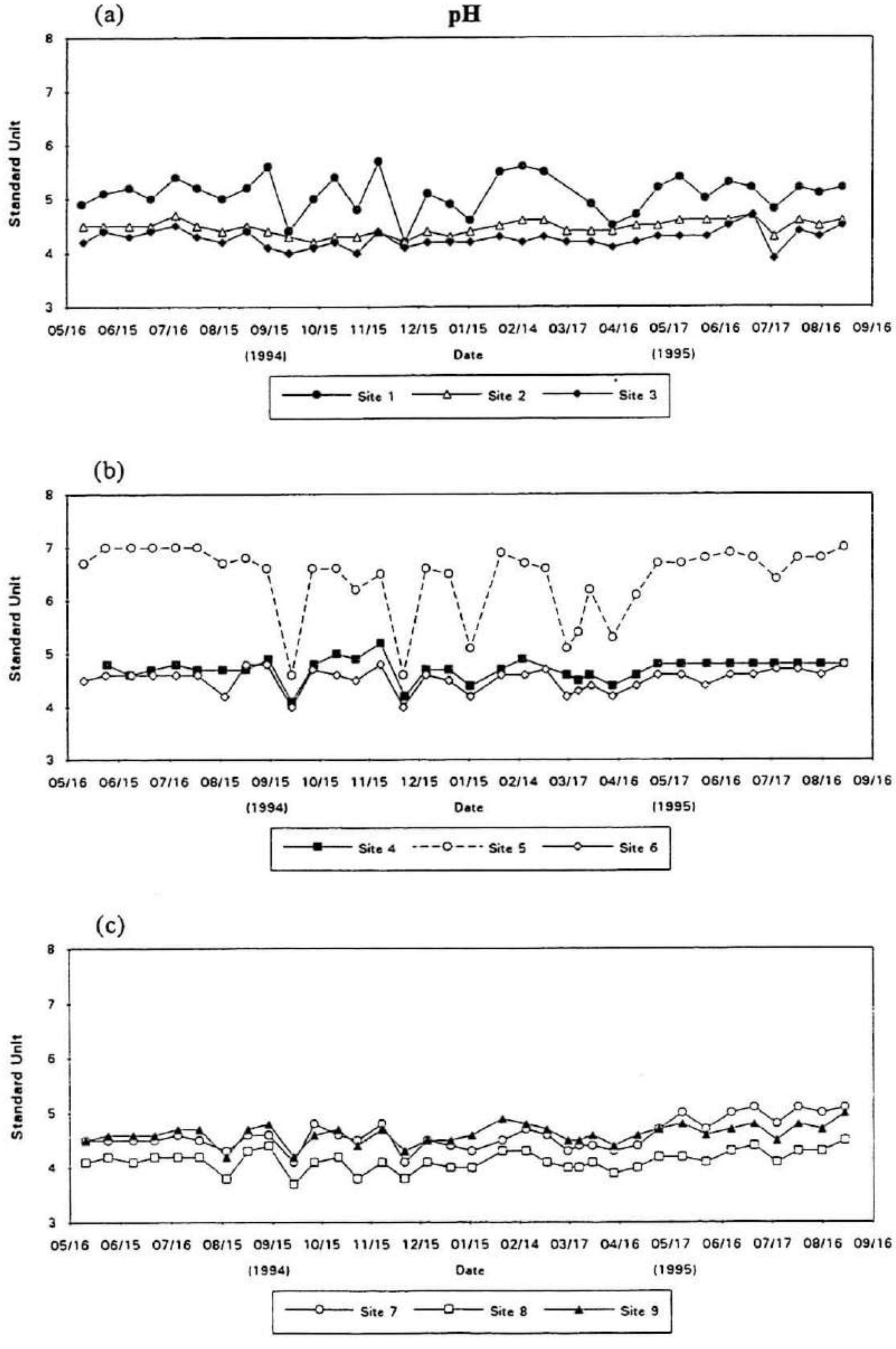
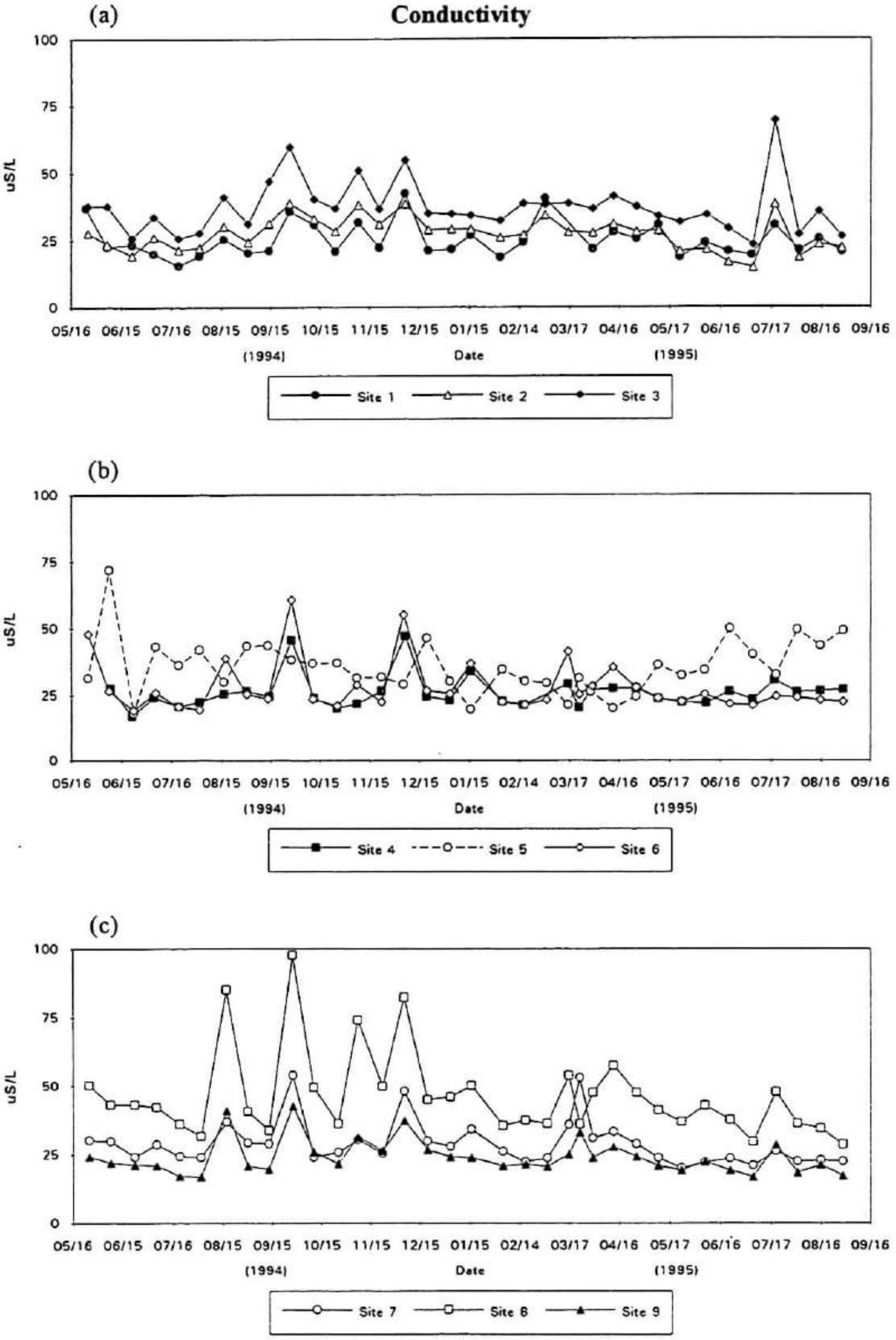


Figure 22. - Conductivity at sample sites from May 1994 through August 1995.



Organic Al concentrations were also higher during high discharge and mean concentrations were highest during the summer months (Figure 23). Both organic Al and inorganic Al concentrations were somewhat similar; however, organic Al concentrations were higher during the summer months and did not exhibit a characteristically high peak during spring runoff.

The general pattern for TOC was almost identical to organic Al. Concentrations of TOC had seasonal and discharge-related trends with higher concentrations occurring during summer and during high discharge events (Figure 24). A comparison of sites 2, 6 and 8 revealed some general differences among sites. Site 2 had higher concentrations during the summer months; however, there were no obvious increases in TOC during high discharge. In contrast, site 6 showed increases during high discharge, but not during summer. Site 8 was similar to both sites, with concentrations that were higher during the summer and during periods of high discharge.

Figure 25 shows that the trend for DON was far less apparent. However, there was a seasonal pattern at wetland sites such as 1, 2 and 3. These sites had higher concentrations of DON during the summer months and lower concentrations during the winter. In contrast, non-wetland sites, such as site 6, did not have a seasonal pattern but did have high DON concentrations during high discharge. Both wetland sites and non-wetland sites had DON trends that were similar to TOC trends. This relationship is indicated by the significant correlation ($r^2 = 0.52$, $p<0.0001$) between TOC and DON.

Dissolved organic nitrogen is important because it made up the majority of TDN. In the study streams, 62% of TDN consisted of DON with the rest being composed of dissolved inorganic N (DIN = $NO_3^- + NH_4^+$). The ratio of DON to DIN over the sampling period indicates how production and loss of both forms of N change seasonally (Figure 26). The ratio appeared to be higher during the summer months particularly at site 2. In addition, at most sites the ratio increased slightly during leaf senescence.

Figure 23. - Organic aluminum concentrations at sample sites from May 1994 through August 1995.

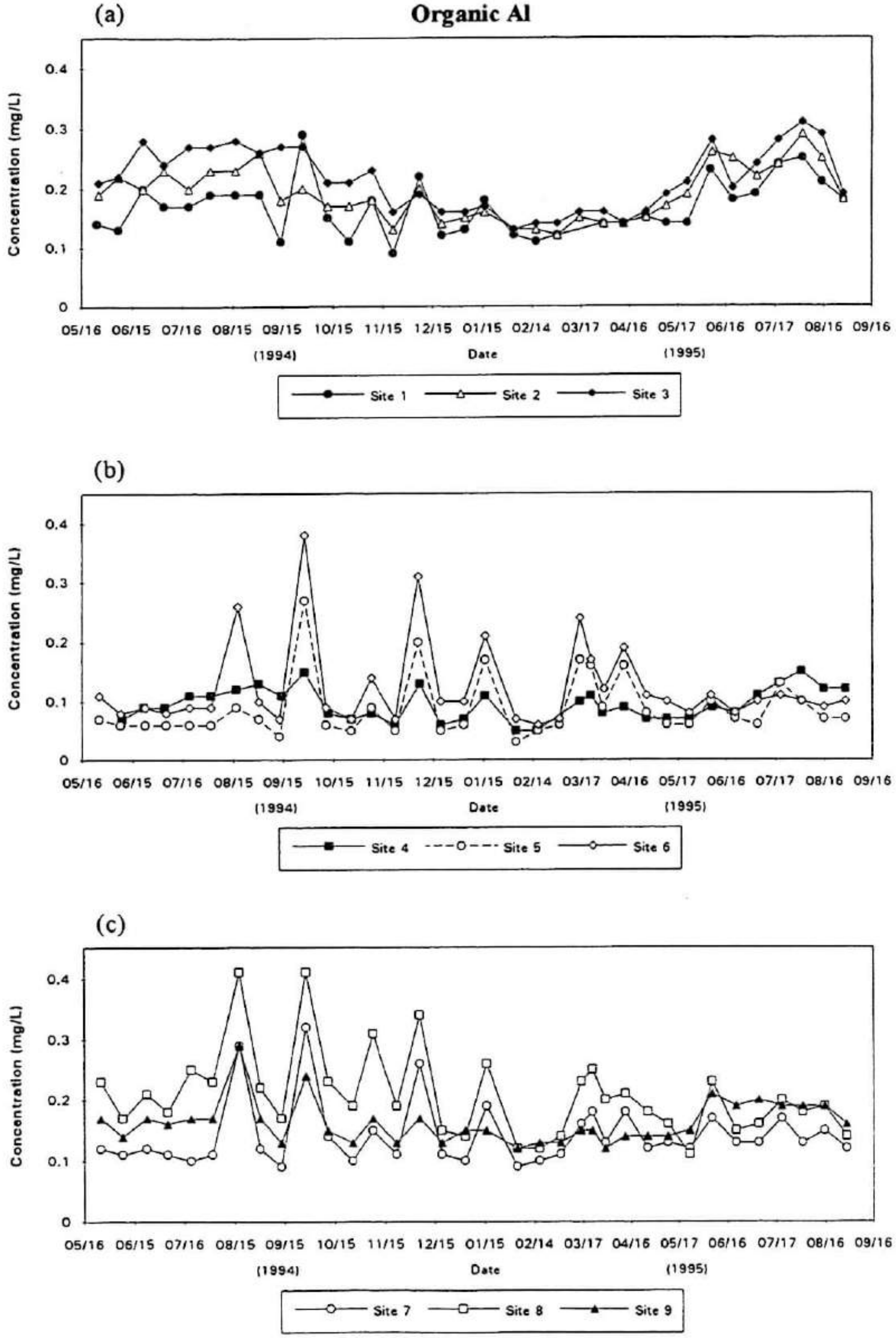


Figure 24. - Total organic carbon concentrations at sample sites from May 1994 through August 1995.

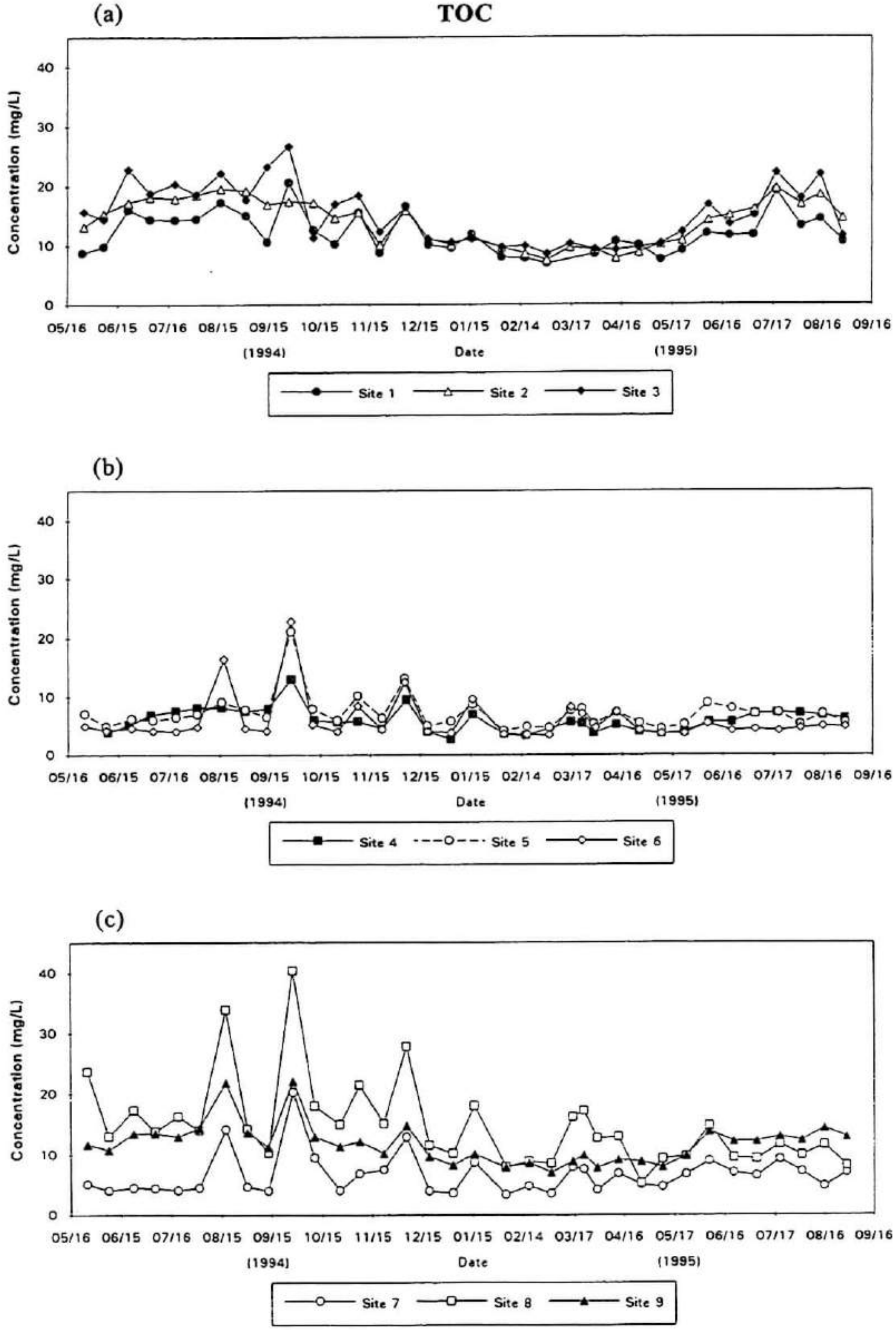


Figure 25. - Dissolved organic nitrogen concentrations at sample sites from May 1994 through August 1995.

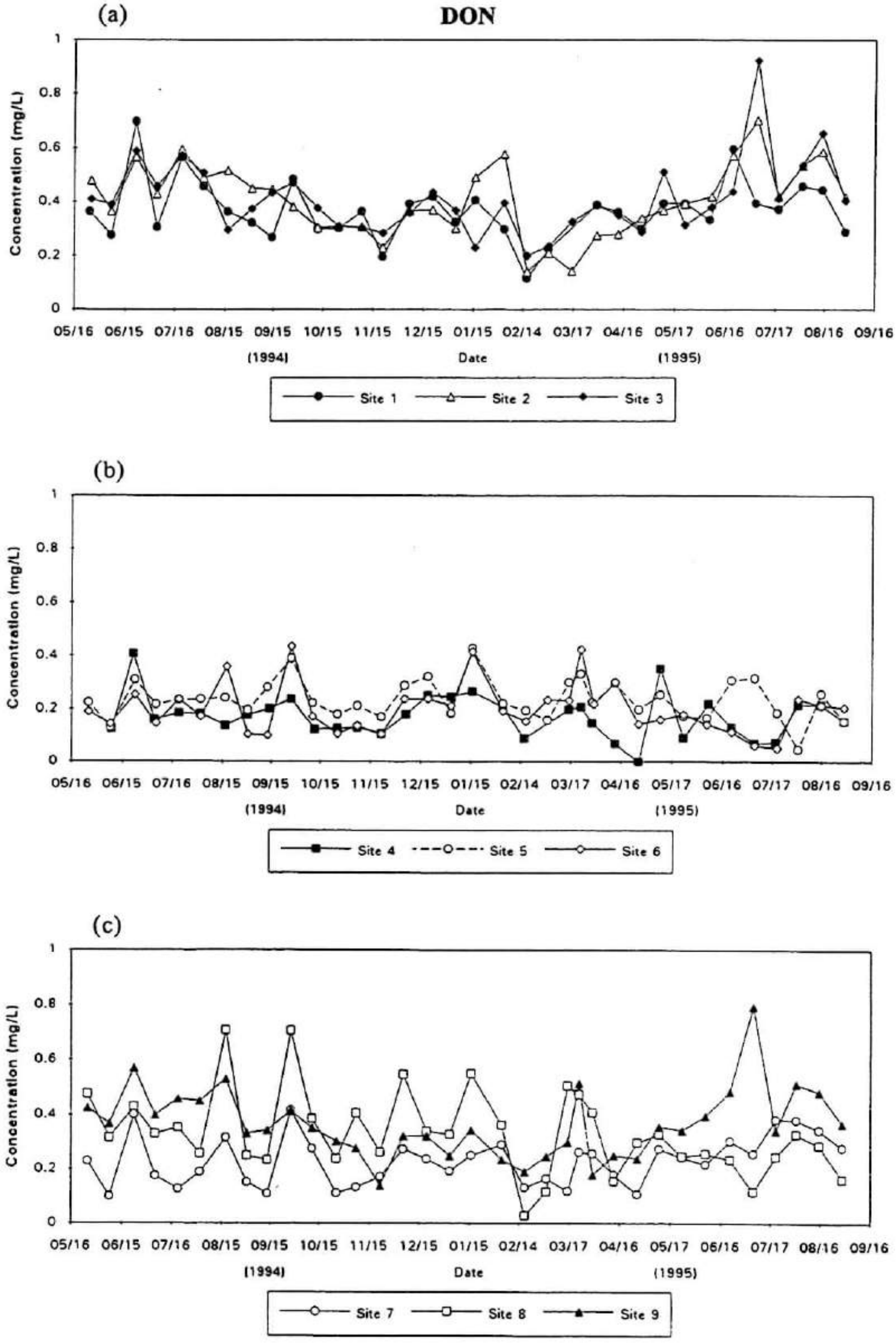
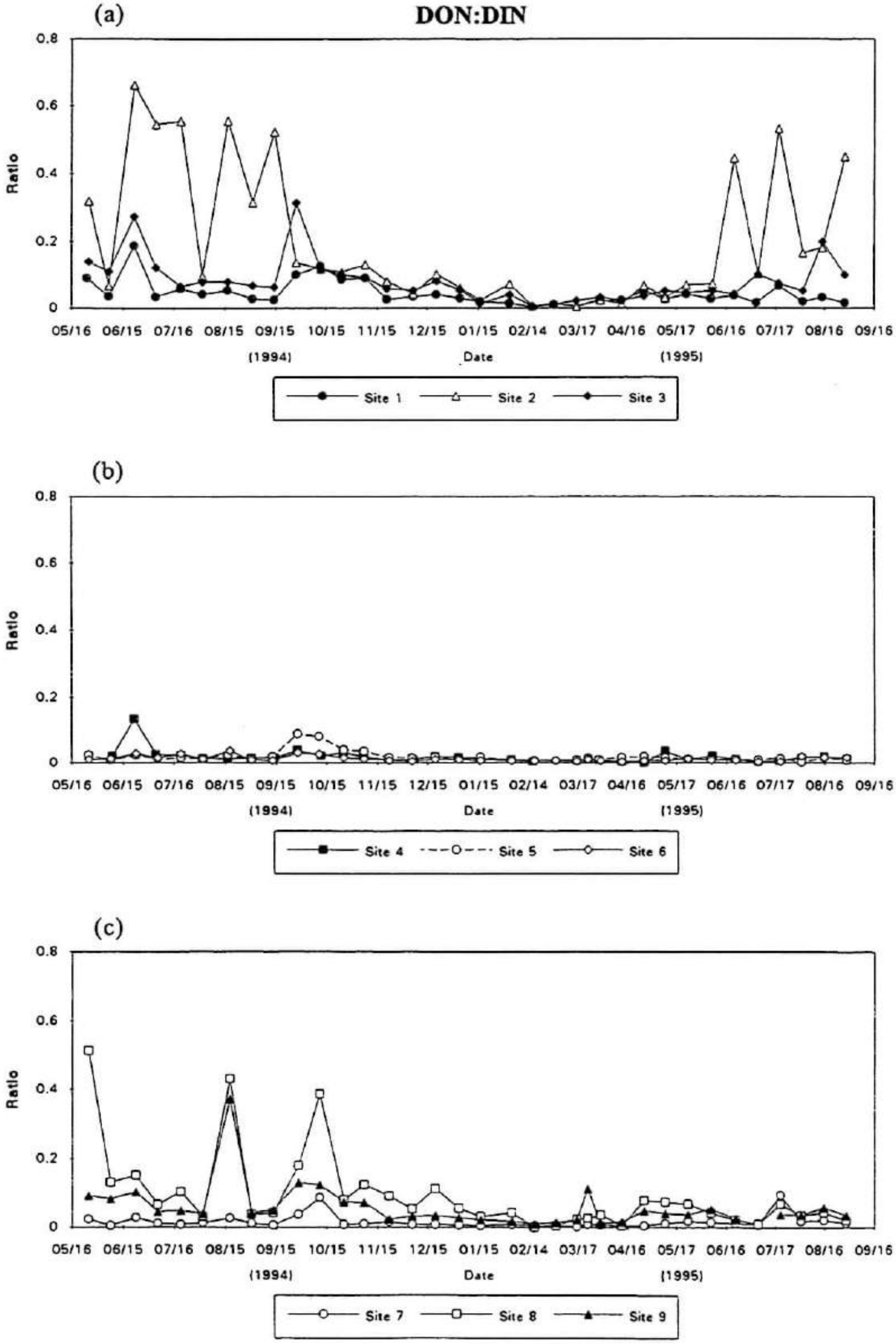


Figure 26. - The ratio of DON:DIN at sample sites from May 1994 through August 1995.



Silica was diluted during periods of high discharge and concentrations were highest during late summer and fall (Figure 27). Average SiO_2^+ concentrations did not vary much between sites (5 - 8 mg/L), but some sites did have seasonal differences. A comparison of sites 8 and 9 shows that there were similar seasonal and discharge-related patterns at both sites. However, at site 9, the concentrations were lowest during late spring and summer and highest during winter. In addition, at site 9 no dilution effect was evident when concentrations were low.

Streamwater temperature data are presented in Figure 28. These data are important because temperatures influence weathering rates and also affect species habitat. In the sampled streams, average temperatures were approximately 18° at the peak during the summer, dropping close to 0° from mid December through February.

Seasonal and Discharge-related Trends

The preceding descriptions illustrate the importance of discharge-related events in relation to streamwater chemistry. In an effort to determine a more general influence of discharge on concentrations, three categories (Low, Medium, High) were established. The discharge category for each sampling date was determined empirically, based on a fixed point located at site 9. Figure 29 shows the results of this analysis for all sites during the sampling period.

On average, base cations decreased with discharge except for K^+ which appeared to increase with discharge. Concentrations of strong acid anions did not exhibit any strong trends, although SO_4^{2-}-S concentrations increased slightly during high discharge. TOC concentrations were also higher during periods of high discharge, whereas SiO_2^+ was diluted. Conductivity, H^+ and both forms of Al were highest during high discharge and were lower during low discharge.

Figure 27. - Silica concentrations at sample sites from May 1994 through August 1995.

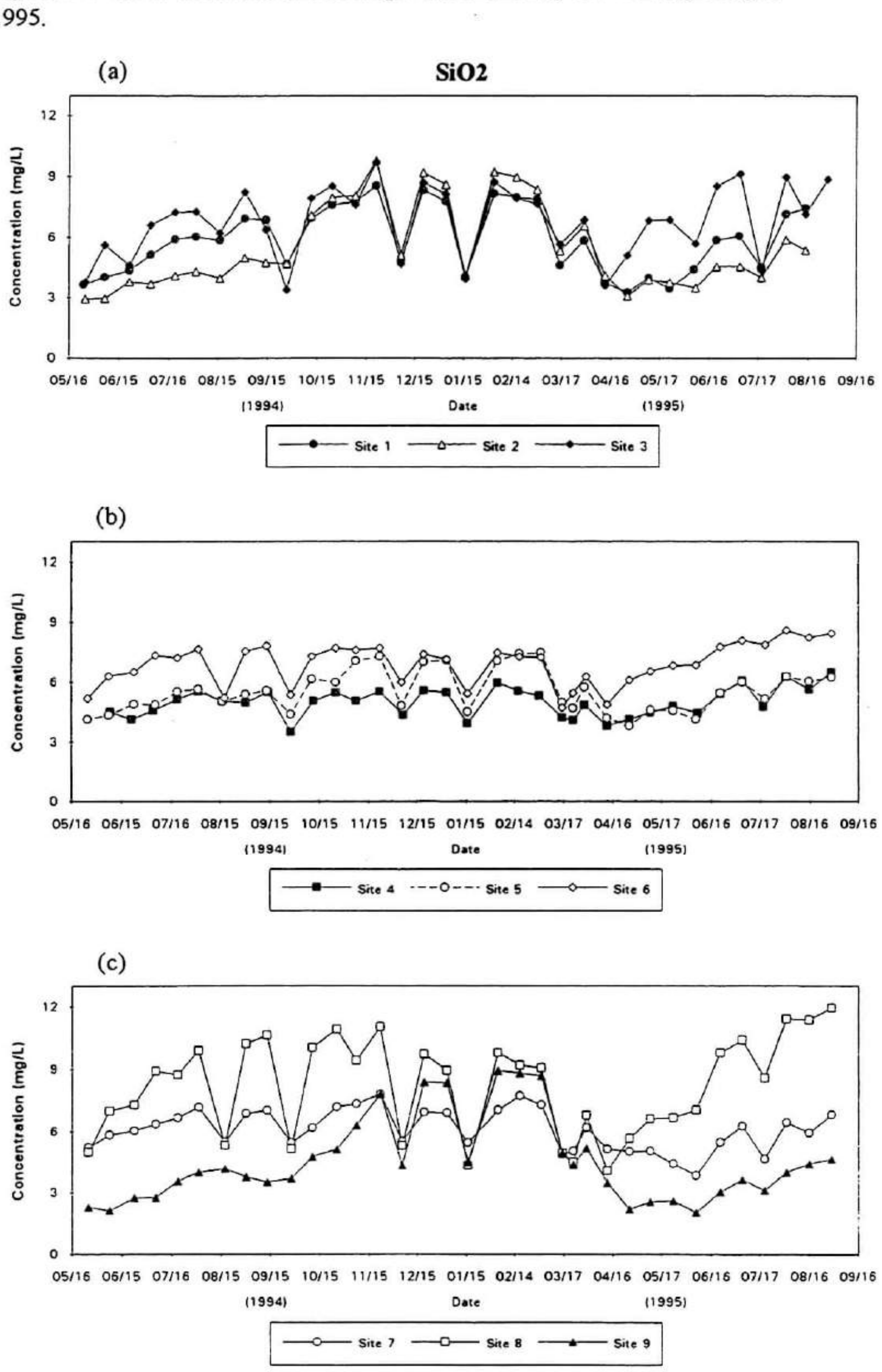


Figure 28. - Temperature of streamwater at sample sites from May 1994 through August 1995.

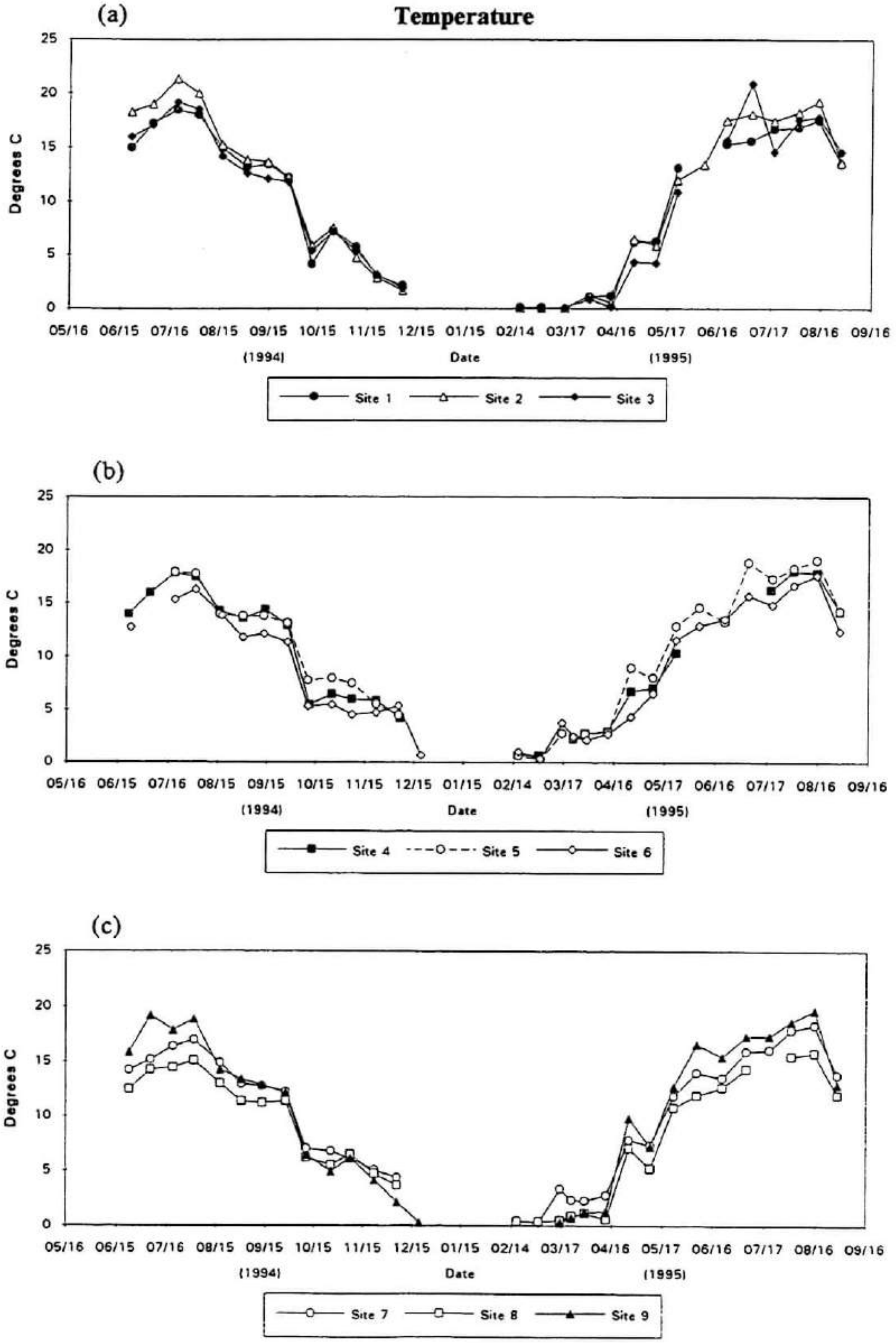
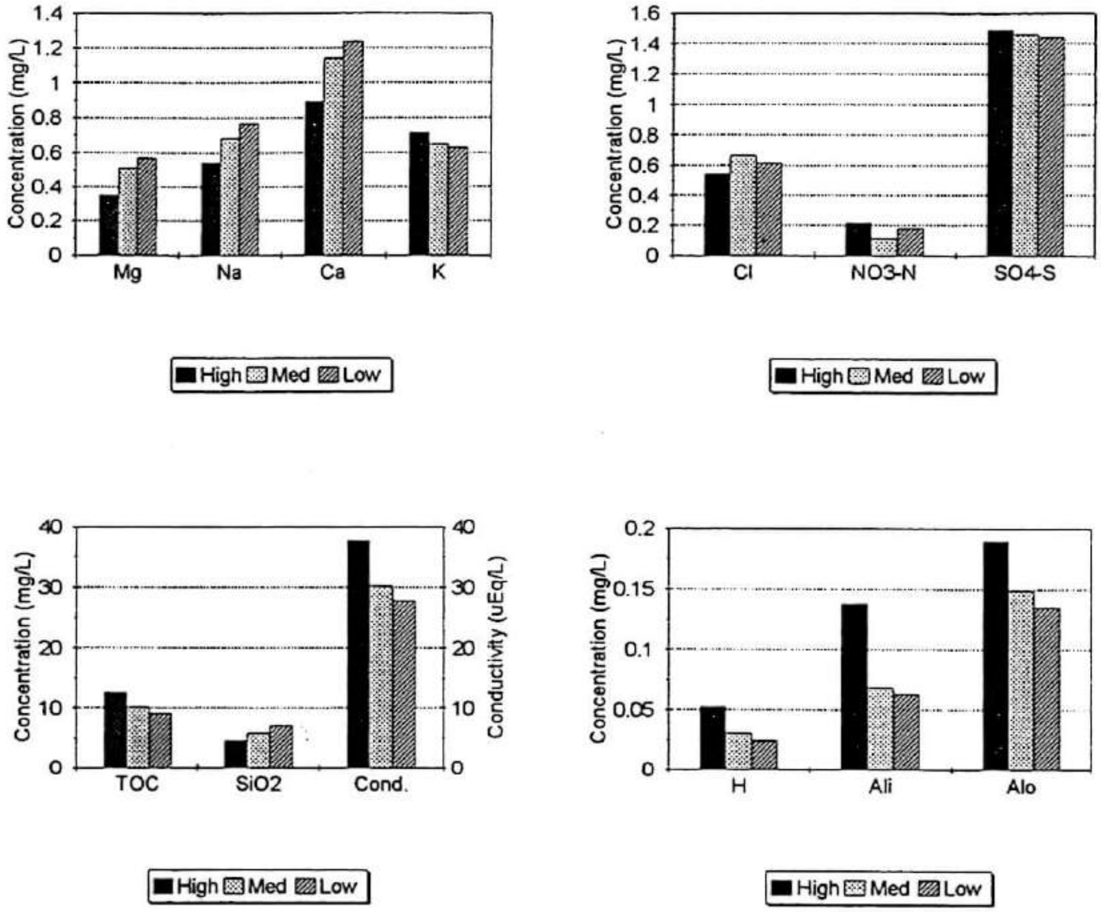


Figure 29. - Relationship between discharge and chemical concentrations in streamwater. Values represent the mean of all the sampling sites during the study period.



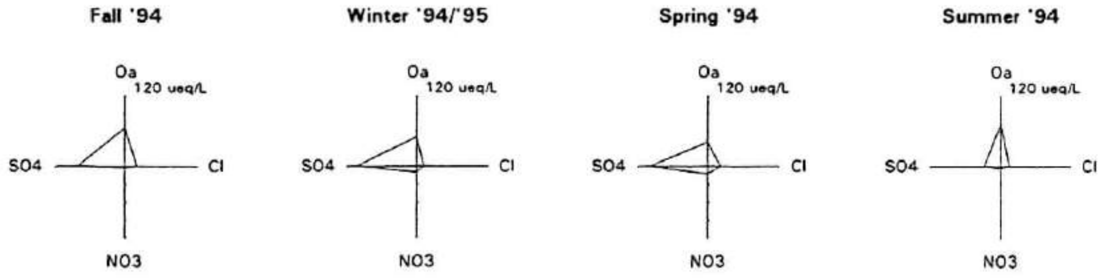
Seasonal patterns were also analyzed by grouping the results of the stream chemistry into four distinct seasons (summer, fall, winter, spring) to show seasonal variations. The sampling period spanned five seasons: summer 1994 (June - Sept. 1994), fall 1994 (Oct. - Nov. 1994), winter (Dec. - Feb 1994/1995), spring 1995 (March - May 1995) and summer 1995 (June - Sept. 1995). Figures 30 and 31 illustrate seasonal shifts in sources of acids and bases over the sampling period at sites 2, 5 and 6. Sulfate was the dominant acid in most streams throughout the year. However, at sites draining wetlands (site 2), the contribution of SO_4^{2-} was diminished during the summer because of SO_4^{2-} reduction reactions. This was coupled with a decrease in NO_3^- through the process of denitrification and uptake of N by vegetation. Conversely, organic acid concentrations increased because organic matter was released from wetlands during warmer periods and groundwater inputs were reduced.

Although organic acidity increased during the summer, the effect of weak acids was less than the effect of SO_4^{2-} during other times of the year. At non-wetland sites, such as site 6, SO_4^{2-} remained the dominant acid during all seasons. During winter and spring, the contribution of NO_3^- acidity augmented SO_4^{2-} acidity, particularly in first order streams.

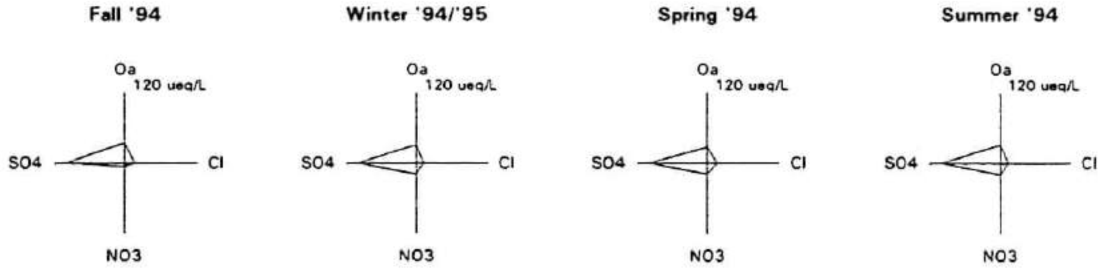
At most sites, base cations did not exhibit strong seasonal differences (Figure 31). However, site 5 did have an increase in Ca^{2+} and Mg^{2+} during the summer because water in the stream channel was more exposed to dolomite during base flow. Cation dilution, associated with single storms, was evident at other sites. Decreases in concentrations of base cations typically occurred during periods when acids were highest, resulting in sharp decreases in stream pH and increases in inorganic Al.

Figure 30. - Seasonal concentrations of acids at sites 2, 5 and 6.

Site 2



Site 5



Site 6

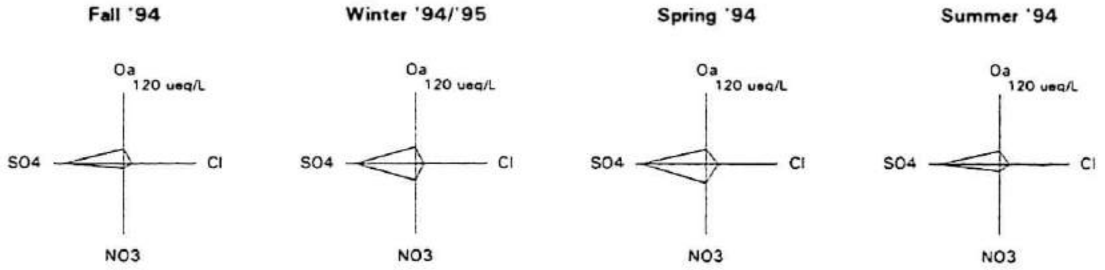
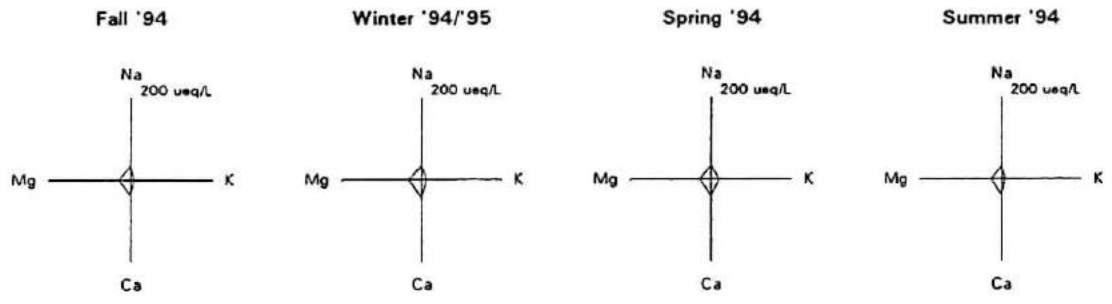
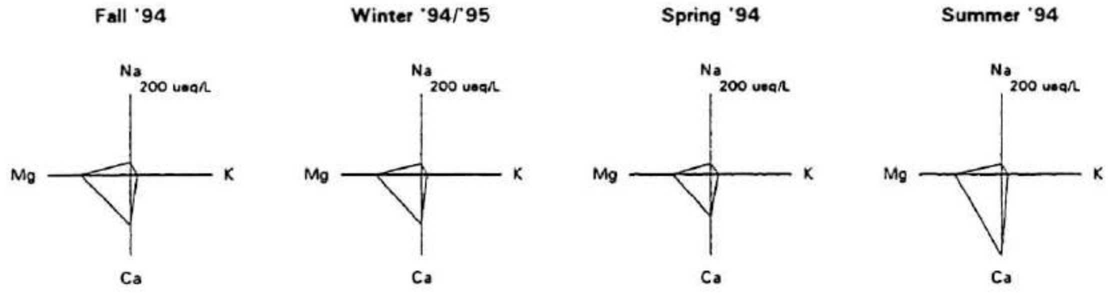


Figure 31. - Seasonal concentrations of base cations at sites 2, 5 and 6.

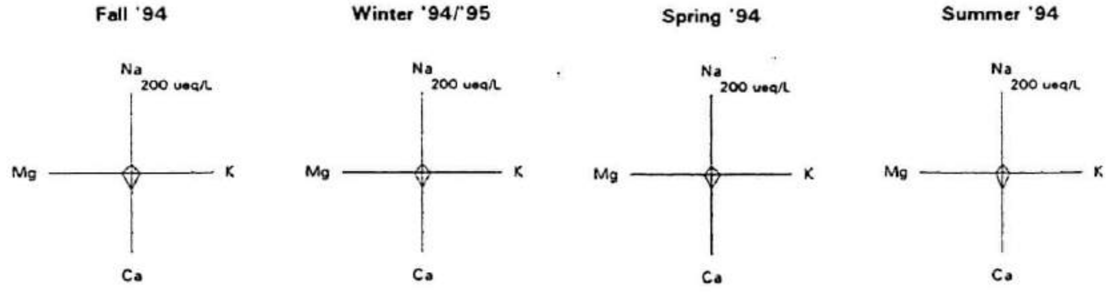
Site 2



Site 5



Site 6



Wetland Influence on Water Chemistry

Figure 3 shows the location of wetland areas within the wilderness boundary. Many of the study streams have headwaters that originate in a high-elevation, wet meadow plateau located in the southeast region of the wilderness. Table 1 summarizes the distance between the sampling location and the closest wetland upstream from the site, generated from the GIS database. Most of these are palustrine, emergent wetlands; however, the size and wetland type were not evaluated in this research.

In general, sites draining wetlands had relatively stable chemical concentrations that responded slowly to changes in discharge. Sites that did not have a wetland influence, had more pronounced responses to discharge. To analyze the effect of wetlands on streamwater chemistry more thoroughly, two representative sites (sites 2 and 6) were chosen for comparative purposes. Site 2 is located on a stream draining an emergent wetland and site 6 is located on a first order stream that does not drain a wetland.

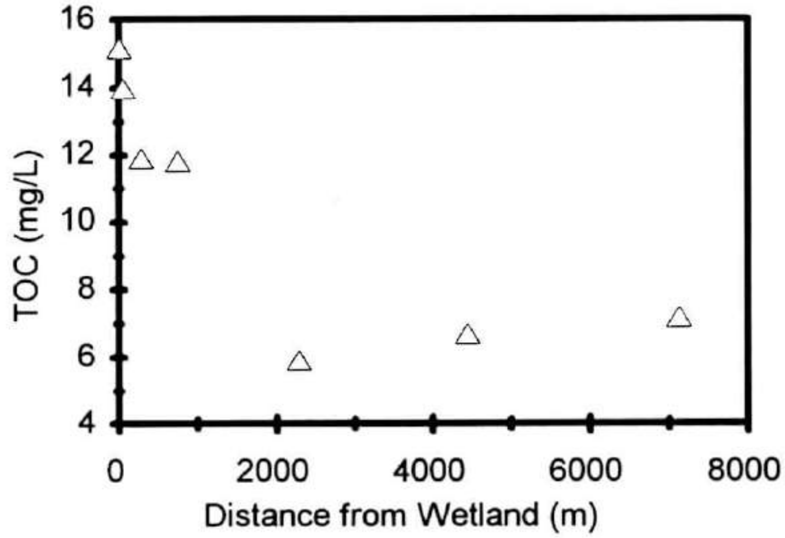
Despite similarities in stream size, there were several major differences between the chemistry of streamwater at sites 2 and 6. Concentrations of NO_3^-, SO_4^{2-}, TOC and Al were all less at the wetland site (2) compared to the non-wetland site (6). Concentrations of NO_3^--N and SO_4^{2-}-S were 0.07 mg/L and 1.07 mg/L at the wetland site and 0.26 mg/L and 1.68 mg/L at the non-wetland site. However, both sites were characterized by the occurrence of high concentrations during snowmelt runoff and low concentrations during the growing season.

At the non-wetland site, SO_4^{2-}-S concentrations were relatively stable with a slight increase during spring (Figure 30). This pattern differed distinctly from the wetland site which had much lower concentrations during the summer and higher concentrations during winter. Although the average SO_4^{2-}-S concentration at the wetland site were lower than the non-wetland site, the concentrations at both sites were similar during winter.

Figure 24 shows that concentrations of TOC were higher at the wetland site (14 mg/L) than the non-wetland site (6 mg/L) and there appears to be a relationship between

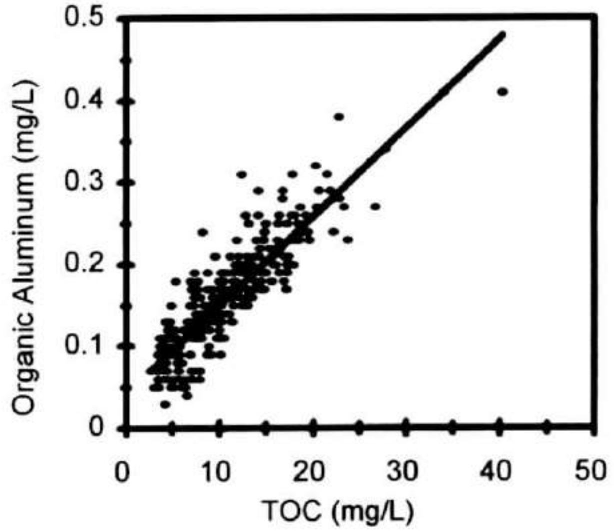
TOC and the proximity of the sampling site to the source wetland. Figure 32 shows that the concentrations of TOC are related to the distance between wetlands and sampling sites. As the distance increased up to 2000 meters, concentrations of TOC decreased. Site 8 was an exception to this relationship because this site had the second highest mean TOC concentration (15 mg/L) and the headwaters do not originate in a wetland.

Figure 32. - Relationship between TOC and distance from wetlands.



In addition to this relationship, TOC was also correlated with organic Al (Figure 33). Consequently, organic Al concentrations followed a trend that was similar to TOC concentrations (Figures 23 and 24). Although, average concentrations of organic Al were higher at the wetland site (0.19 mg/L) than the non-wetland site (0.12 mg/L), concentrations of inorganic Al were lower at the wetland site (0.06 mg/L) than the non-wetland site (0.17 mg/L). Moreover, inorganic Al concentrations at the wetland site were relatively stable compared to the non-wetland site. Inorganic Al was particularly high at the non-wetland site during thaws and snowmelt runoff.

Figure 33. - Relationship between organic Al and TOC.

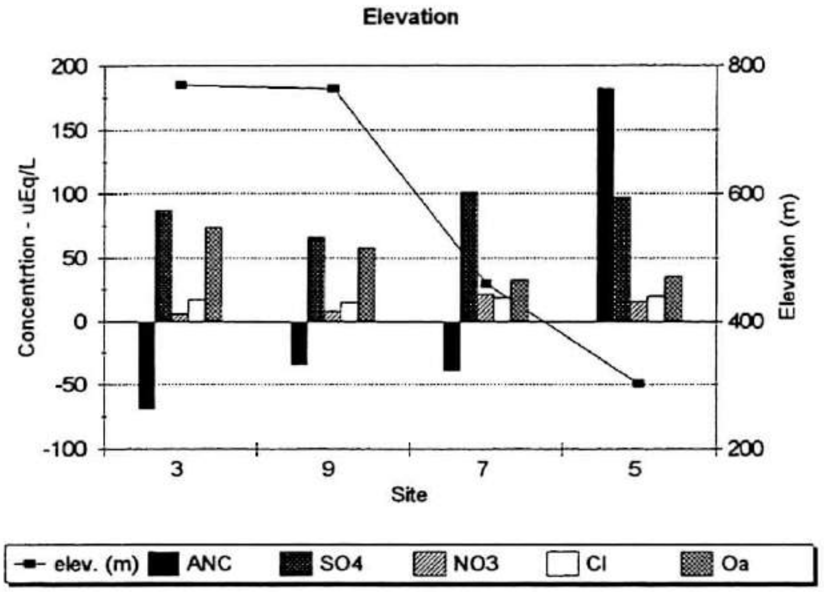


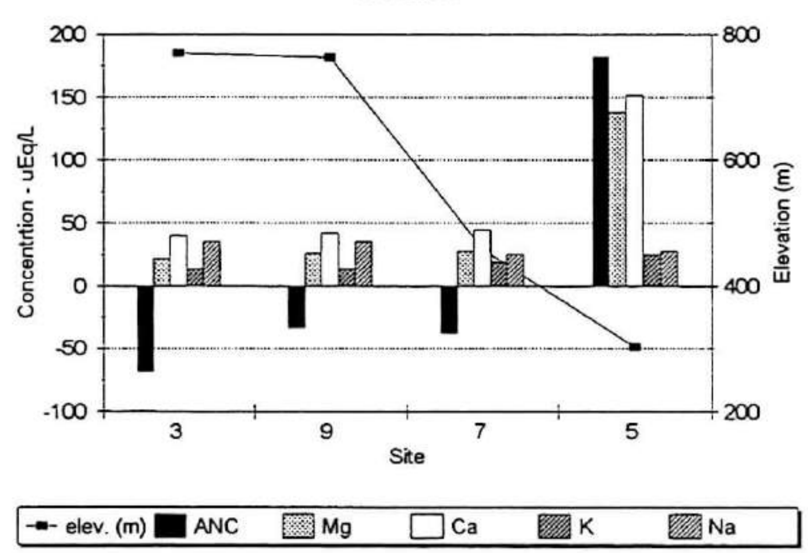
Elevational Trends

Sampling sites 3, 5, 7 and 9 were used to investigate trends in streamwater chemistry on an elevational gradient. There is a 468m difference between site 3 (highest) and site 5 (lowest). Sites 9, 7 and 5 (listed by decreasing elevation) are all located along the main branch of Lye Brook. Site 3 is the highest site and is located in the headwaters of the main branch of the Lye Brook. Streamwater at site 3 passes through several wetland areas before reaching site 9. Figure 34 shows the average concentration of anions and cations at each location for the sampling period in addition to the ANC and elevation of each site. The results of this analysis indicate that there appears to be an inverse relationship between elevation and ANC. The highest site had the lowest ANC value (-68.71 μeq/L) and the lowest site had the highest ANC value (182.19 μeq/L).

Concentrations of NO_3^- and SO_4^{2-} were lower at higher elevations and the contribution of organic acids appeared to decrease with elevation. The range of Cl^- for all sites was relatively narrow (15 μeq/L to 20 μeq/L) and no major elevational trends were apparent for this anion. Base cations were also relatively stable at all sites except for site

Figure 34. - Elevational trends for average chemical concentrations.





5. This site had extremely high concentrations of Ca^{2+} and Mg^{2+} due to the local influence of exposed dolomite.

V. DISCUSSION

The Lye Brook Wilderness is characterized by a variety of factors that make it an interesting study site for evaluating processes that control the acid-base status of surface waters. The site has a broad elevational range and contains different types of soil, geology and forest cover. In addition, many of the streams in the wilderness have headwaters that originate in wetlands and beaver ponds. These distinctive features contribute to differences in the chemical composition of streamwater among sampling sites. In addition to site-related features, other factors can influence the streamwater chemistry. These are typically related to seasonal changes that affect biological activity and stream discharge. Furthermore, events such as rainstorms have substantial short-term impacts that can ultimately lead to a reduction in stream pH.

It is beyond the scope of this research to consider all the factors that control the acid-base chemistry of streams. For example, variations in atmospheric loading among sites were not considered here because atmospheric chemistry data are currently not available. However, regardless of the omission of some components, this report does investigate the major temporal and spatial controls on stream chemistry. In many cases the interactions among these influences are complex and the impact of one factor may be augmented by another. This makes it difficult to isolate individual causes of acidification. Despite these complexities many influences are obvious and predictable.

Acid Neutralizing Capacity

Acid neutralizing capacity measurements describe the buffering capacity of streamwater and indicate the vulnerability of sites to acid deposition. Based on this premise, Adams et al. (1991) developed an ANC screening procedure to assess the effects of air pollution on streamwater in Class I wilderness areas. The purpose of their effort was to establish values, based on streamwater ANC, that could be used by land managers to evaluate emission permits. They determined that aquatic ecosystems that have ANCs above 25 μeq/L, are generally not adversely affected by acidification. However, some adverse effects would be expected below an ANC of 10 μeq/L. In the Lye Brook Wilderness, 8 out of 9 streams sampled had ANCs below the critical value for much of the year. Therefore, much of the Lye Brook Wilderness has an extremely low buffering capacity and is subsequently vulnerable to acid deposition.

Acid neutralizing capacity values change according to the balance between cations and anions; therefore, when strong acid anions are supplied in excess of base cations, acidic cations (H^+ and Al) are transported to streams (Cronan and Schofield 1979). The degree of acid neutralization depends on a complex series of biogeochemical reactions that occur as water moves through the watershed system. By investigating reactions and processes that affect concentrations of individual anions and cations, explanations for variations in ANC become more obvious.

Chemical and Physical Controls on Inorganic Elements

Weathering of primary minerals is.one of the major factors controlling the concentration of ions in streamwater because weathering releases anions and cations into solution (Johnson and Reynolds 1977). Rock type, and the process by which rocks are formed, strongly determines the rate of chemical weathering and the type of secondary minerals formed (Schlesinger 1991).

The weathering of dolomite bedrock appears to be the overriding factor causing increases in stream ANC and pH. Dolomitic rock ($MgCa(Co_3)_2$) is composed of one layer of calcite ($CaCO_3$) combined with one layer of magnesite ($MgCO_3$). This rock type weathers rapidly, releasing large amounts of Ca^{2+} and Mg^{2+} into streamwater. These reactions are coupled with the release of carbonate which reacts with H^+ to form HCO_3^-.

Therefore, sites that contain dolomite have a high buffering capacity because there is a constant supply of base cations and HCO_3^- consumes H^+.

The highest average ANC value occurred at site 5 which is due to dolomite bedrock located upstream from the site. Although Figure 5 indicates that the site is underlain by quartzite, there is an abundance of dolomitic rock in the streambed that has washed down from higher elevations.

Site 1 also had a slightly positive ANC, suggesting a possible dolomite influence. The geologic map did not indicate that this rock type was present; however, a visual inspection of the area revealed that sporadic dolomitic rocks were in the streambed. In addition to the relatively high ANC, there were high concentrations of Ca^{2+} and Mg^{2+} in streamwater which also suggests that dolomite is present. Concentrations of Ca^{2+} and Mg^{2+} at site 1 were lower than site 5 and as a consequence the ANC was lower. Moreover, unlike site 5, the charge balance at site 1 does not indicate a major presence of HCO_3^- in the water (Table 2).

The high concentrations of Ca^{2+} and Mg^{2+} found at sites overlying dolomite is consistent with other stream chemistry studies where dolomite is present in the watershed. An analysis of cation input-output budgets at the Walker Branch watershed in Tennessee revealed that the concentration of Ca^{2+} and Mg^{2+} in streamwater exports far exceeded inputs (Henderson et al. 1978). This indicated that much of the Ca^{2+} and Mg^{2+} in streamwater was supplied by the chemical weathering of bedrock.

Other rock types in the Lye Brook Wilderness consist of geologic substrates that are more resistant to chemical weathering. Therefore, weathering rates are generally not fast enough to completely buffer incoming acids. These rocks contain lower concentrations of Ca^{2+}, Mg^{2+}, Na^+ and K^+ and higher concentrations of Fe and Al resulting in leachates that are low in base cations and high in metals.

Geologic investigations in the Lye Brook Wilderness have found evidence of schist and quartzite rocks that have been stained by iron oxide (Ayuso and Day 1984). These Fe impurities are prominent in the Mendon Formation, which may explain why elevated concentrations of Fe were found at site 8. Other elements such as SO_4^{2-} and Mn also varied among sites, which may be attributed to differences in bedrock geology.

In addition to bedrock weathering, concentrations of ions in streamwater may be affected by watershed soils. For example, soils derived from dolomite rock contain high concentrations of Ca^{2+}, Mg^{2+} and CO_3^- and are well-buffered against acidity. In this study, it is difficult to determine if the acids are being buffered in the stream channel or in the watershed soils because total and exchangeable nutrients in soils were not measured.

In areas with a high cation exchange capacity (CEC), soils may be resistant to changes in pH (Federer and Hornbeck 1985). Soil CEC is largely dependent on the type of secondary mineral formed through weathering and the depth of the soil (Newton et al. 1987, Peters and Driscoll 1987). In this region, soils at higher elevations tend to be thin and have a low CEC. This causes a subsequent reduction of base cations in soil leachates and ultimately results in low concentrations of base cations in streamwater.

Soils that are highly affected by acid deposition are characterized by the movement of NO_3^- and SO_4^{2-} in soil water. As these mobile anions are exported to streams they are balanced by mobile cations. Unless these cations are replaced by atmospheric deposition or weathering inputs, the base saturation of the soil will decrease and the soil will become acidified. In areas where base saturation is severely reduced, Al concentrations in soil water and streamwater increase. In the Lye Brook wilderness, inorganic Al concentrations pose the greatest threat to aquatic systems, particularly at higher elevations and during high discharge when pH levels are lowest. During these periods, inorganic Al levels appear to be high enough to cause damage to acid-sensitive species.

Johnson et al. (1981) determined that at higher elevations H^+ is neutralized by Al dissolution, resulting in high concentrations of inorganic Al in streamwater. As water moves through the soil, base cations are released and concentrations of H^+ and Al are reduced. Therefore, acid neutralization is largely dependent on the residence time of water in soil. If the residence time is sufficient to dissolve silicate minerals, then acids are neutralized. Lye Brook exhibited a pattern that was similar to that described by Johnson et al. (1981), specifically for base cations and pH. However, concentrations of inorganic Al did not follow this elevational trend, presumably because of the influence of wetlands at higher elevations.

A comparison of sites along an elevational gradient in the main Lye Brook channel revealed that concentrations of Ca^{2+}, Mg^{2+} and K^{+} increased slightly with decreasing elevation (Figure 34). Site 8 had the lowest ANC values, presumably because this site is located at a high elevation ridge where soils are thin. At this site concentrations of Ca^{2+}, Mg^{2+} and K^{+} were low, indicating that these weathering products are not readily available. Sodium behaved somewhat differently from the other base cations, exhibiting a decrease with decreasing elevation. This may be due to a low Na^{+} content in weathering materials which would mean Na^{+} sources are predominantly atmospheric. At downstream locations, Na^{+} could be diluted by groundwater inputs resulting in low concentrations in streamwater.

Although both soil depth and weathering have a substantial impact on ion concentrations, these factors are also closely linked to flow paths and hydrology. In this research, SiO_2^{+} , which is derived primarily from mineral soils, was used as a general indicator to show typical patterns for weathered materials. Generally, SiO_2^{+} is not biologically important; therefore, it can be used to show how weathered materials are affected by hydrology (Peters and Driscoll 1987). During high discharge events, SiO_2^{+} was diluted indicating that dilution is important for other materials supplied by weathering. Concentrations of SiO_2^{+} also followed a seasonal pattern with highest concentrations occurring during warmer months and low concentrations occurring during winter.

A regression of SiO_2^{+} on sum of base cations (Ca^{2+}, Mg^{2+}, Na^{+}) was significant ($p<0.05$) at all sites except for 1, 5 and 7, suggesting that weathering is the primary source of these base cations. Potassium was omitted from the regression because it is rapidly taken up by vegetation during the growing season which confounds the availability of K^+ supplied by weathering (Likens and Bormann 1995). The poor correlation at site 7 is interesting, because the ANC was low at this site, as were concentrations of Ca^{2+} and Mg^{2+}. A closer analysis of the regression revealed that outliers were related to low discharge, particularly during the summer of 1995. This suggests that carbonate-bearing rock is present at site 7, and although it is not sufficiently prevalent to alter the ANC at this site, it is a factor during base flow.

One of the most prominent trends that caused acidity during high discharge was the dilution of base cations. During rain storms, hydrologic flow paths shift from groundwater to shallow soil and surface water; therefore, ion exchange is reduced and fewer base cations are weathered (Johnson et al. 1969; Peters and Murdoch 1985; Peters and Driscoll 1987). It is also possible that the reduction in base cations is due to a reduction in soil and streamwater temperature, with slower weathering rates occurring during cold periods (Aber and Melillo 1991).

The relationship between discharge and strong acid anions was not as clear. Sulfate concentrations appeared to increase during high discharge, which may have been caused by the release of SO_4^{2-} that accumulated in the snowpack (Hornbeck 1986). Chloride and NO_3^- did not have consistent discharge responses, suggesting that other factors were important. Chloride was diluted during high discharge at other research locations (Stoddard and Murdoch 1991). However, Cl^- concentrations in this study were highest during mid-discharge suggesting that there was not an obvious discharge-related trend. Nitrate is an important nutient and is also affected by denitrification. These factors may have obscured the effect of discharge on NO_3^-.

Despite the potential for high acidity during high discharge events such as rainstorms, streams draining wetlands had more stable chemical concentrations. This stabilization is presumably caused by the regulation of discharge (Loucks 1990). A comparison of ANC values at sites 2, 5 and 8 illustrates the effect of wetlands on ANC (Figure 9). Since site 2 is located at an outlet from a wetland, stream discharge regulation at this site is quite important and has a strong effect on the stream chemistry. At site 2, the coefficient of variation was -0.319. In contrast, site 5, which does not drain wetland, had a coefficient of variation of 0.622. The higher coefficient of variation at this site was caused by the large changes in ANC that occurred over the sampling period. During high discharge events, the ANC at site 5 decreased sharply. In summary, the average acidity of sites draining wetlands is quite low; however, the acidity at non-wetland sites is more erratic and may have a more detrimental effect on stream biota during storms and snowmelt runoff.

The influence of organic acids may partially explain the low pH of sampling sites located in the high elevation wetland areas (McKnight et al. 1985). However, these low pH values may also be linked to the origin and flow paths of the water in wetlands. Rain water generally has a low pH that is neutralized as it contacts the soil and reacts with cations. In wetlands, rain water has less contact with mineral soil and often flows directly into streams (Munson and Gherini 1991). Therefore, streams that drain wetlands can be even more acidic than rain water because cation exchange with organic soil causes a loss of cations.

In addition to discharge-related trends, concentrations of anions and cations vary from year to year as a result of changes in climatic conditions. The summer of 1995 was extremely hot and dry compared to the summer 1994, which resulted in low base flow conditions in 1995. The effect of dry conditions appeared to differ according to the source of ions. Concentrations of dissolved substances weathered from the stream channel, such as Ca^{2+} and Mg^{2+}, were generally higher during the dry summer, whereas dissolved substances weathered from the watershed, such as Fe and Mn, were generally lower.

Concentrations of Ca^{2+} and Mg^{2+} were high during base flow because water in the stream channel had more contact with the bedrock. Other weathering products such as Fe and Mn were substantially lower during the dry summer because soil leaching was reduced. This result varied considerably among sites depending on the source of the weathering product.

Biotic Controls on Inorganic Elements

Many of the ions that were unaffected by discharge-related trends were influenced by factors other than chemical weathering. Biological reactions can also increase or decrease acidity in surface waters. For example, biotic factors such as uptake by vegetation and microbial decomposition can have a strong impact on inorganic elements.

In Lye Brook streams, inorganic N was heavily influenced by vegetation during the growing season, which led to a reduction in streamwater NO_3^-. Concentrations of NO_3^- generally peak in early spring because soil temperatures increase and mineralization and subsequent nitrification of N begins before vegetation initiates nutrient uptake (Likens et al. 1970; Galloway et al 1987; Rascher et al. 1987). At the Lye Brook Wilderness, concentrations of NO_3^- increased during the spring and caused a subsequent reduction in pH. Despite this increase, SO_4^{2-} remained the dominant strong acid, unlike some other areas where NO_3^- acidity exceeds SO_4^{2-} (Stoddard and Murdoch 1991).

Potassium is also a biologically important nutrient that is sequestered by vegetation during the growing season. Some studies have shown a seasonal trend in K^+, with lower concentrations occurring during summer months (Likens and Bormann 1995). At Lye Brook, K^+ did not respond clearly to seasonal growth patterns and did not follow discharge-related trends consistent with other base cations. It is possible that cation dilution associated with high discharge may not have affected K^+ because of its tendency to be leached from plant matter during rainfall (Buso et al. 1987; Likens and Bormann 1995).

The biological effect of microbes appeared to have the greatest impact on sites that drain wetlands because both denitrification and SO_4^{2-} reduction are enhanced in semisaturated areas. The process of denitrification reduces stream acidity as NO_3^- is converted to N_2O and N_2 gases. Denitrification is an anaerobic process; therefore, historically wetlands have been considered to be the most suitable areas for microbial denitrifiers, although denitrification can occur in upland soils if oxygen is absent (Post et al. 1985; Groffman et al. 1993).

Johnston et al. (1990) found that concentrations of NO_3^- in streamwater were lower at sample sites located in close proximity to wetlands. This finding was attributed to a combination of plant uptake and denitrification. The productivity of wetlands generally exceeds that of terrestrial systems which results in a greater uptake of NO_3^-. When this factor is coupled with NO_3^- loss through denitrification, wetland outlet streams typically have NO_3^- concentrations that are substantially lower than non-wetland streams.

At Lye Brook, the effect of plant uptake and denitrification on NO_3^- in wetlands was not as obvious as the effect of SO_4^{2-} reduction on SO_4^{2-}. Wetland sites did appear to have lower concentrations of NO_3^- throughout the year; however, unlike SO_4^{2-}, there were no major differences in the seasonal pattern of NO_3^- between wetland and nonwetland sites. During the summer, low NO_3^- concentrations occurred at both wetland and non-wetland sites as a result of vegetative uptake. This uptake may have depressed NO_3^- levels to a point where denitrification was insignificant. Burford and Bremner (1975) found that dentrification was most rapid in areas where NO_3^- is readily available; therefore, during the summer when NO_3^- levels are low, denitrification may not play a major role.

Average SO_4^{2-} concentrations were highest during the winter and spring, presumably because of the occurrence of SO_4^{2-} reduction in wetlands. Several studies have found a similar reduction in SO_4^{2-} concentrations in water passing through wetlands (Wieder and Lang, 1984; Bayley et al. 1986; Driscoll et al. 1987). A comparison of SO_4^{2-} concentrations among sampling sites revealed that non-wetland sites had relatively stable SO_4^{2-} concentrations throughout the year, whereas wetland sites had concentrations that were much lower during the summer. The SO_4^{2-} reduction reaction is important because it consumes both SO_4^{2-} and H^+, thereby reducing the acidity of streams draining wetlands.

Once SO_4^{2-} is reduced, climatic conditions can favor oxidation of reduced S compounds. Bayley et al. (1986) found that during dry periods, O_2 penetrates deeper into wetland soils, causing reduced S, in soils that are typically saturated and reduced, to become oxidized. During rain storms, the oxidized S is flushed out resulting in a reduction in the pH of outlet streams. In Lye Brook streams, SO_4^{2-} was diluted during rain storms at upland sites and at wetland sites during the winter. However, during the summer SO_4^{2-} concentrations at wetland sites increased with high discharge events as a result of the pulsed release of oxidized S from wetlands.

Organic Matter Exports

Nutrients are found in both inorganic and organic forms as they cycle through ecosystems. The export of inorganic elements has been discussed in the preceding section; however, organic elements can also be discharged in streamwater. The concentration of organic matter in lotic systems varies considerably according to production, consumption and discharge. Organic fluxes are highly affected by biotic uptake and subsequent release through decomposition. During periods of high discharge, decomposed organic matter is flushed from the watershed resulting in a pulsed release into streams.

Organic Carbon

Surface water TOC at Lye Brook was much higher at sites draining wetlands compared to non-wetland sites, indicating that wetland systems are a source of organic C (Figure 24). Depressional wetland areas produce a large amount of biomass and also trap organic matter that washes down from higher elevations. In addition, decomposition is slow in saturated areas; therefore organic matter accumulates in relatively large quantities and leads to high TOC concentrations in outlet streams (Mullholland and Kuenzler 1979; Dalva and Moore 1991; Mann and Wetzel 1995).

The concentrations of TOC at sites in close proximity to wetlands also varied seasonally with highest concentrations occurring during the summer months. This is likely the result of a combination of primary productivity and microbial decomposition, both of which are enhanced during warmer periods (Dalva and Moore 1991). In addition, during base flow conditions, low TOC groundwater inputs are greatly reduced; therefore, much of the streamwater is composed of wetland drainage.

For non-wetland sites, TOC concentrations were typically low and they appeared to be influenced by discharge-related events rather than by seasonality. During rain storms organic C is leached from litter and water travels through organic soil horizons, carrying organic C to the streams (Meyer et al. 1988). Although site 8 is a non-wetland site, it is an exception because TOC concentrations at this location rivaled that of wetland sites. Therefore, site 8 contains a source of streamwater TOC other than decomposition associated with wetlands.

In other studies, concentrations of organic C have been linked to forest cover with higher concentrations occurring in softwood stands and lower concentrations in hardwood stands (Lawrence et al. 1986). This is attributed to litter decay rates which are slower for softwood species, resulting in greater organic matter accumulation (Gosz et al. 1973; Melillo et al. 1982). Soil leachates become enriched with TOC in organic horizons; therefore, sites with thick organic layers exhibit high TOC concentrations. Although site 8 is located in a hardwood stand, this tributary drains stands dominated by red spruce and balsam fir which could cause an increase in the concentration of organic C in streamwater.

Site 6 is similar to site 8, in that it is a first order stream with coniferous vegetation in the watershed; however, concentrations of TOC at site 6 are relatively low in comparison to site 8. Therefore, the differences in TOC between these two sites are most likely the result of differences in soil depth associated with elevation. Site 8 is located on an exposed ridge at a high elevation where soils are thin, whereas site 6 is located at a lower elevation with thicker soils. Mineral soils absorb organic C; therefore, streams draining thick soils generally have lower organic C concentrations (Lawrence et al. 1988; Cronan 1985).

Factors regulating organic C concentrations are important because organic C may influence mineral weathering, cation leaching and trace metal speciation. Streams with high concentrations of TOC typically exhibit low pH values because of the contribution of organic acids (Table 5). The low pH values of wetland sites in this study are probably the result of organic acids associated with TOC.

In addition to contributing to stream acidity, organic acids can also increase weathering rates through chelation (Huang 1988). In this process, organic acids form complexes with Fe and Al, which subsequently affects the form and concentration of these elements in solution. When chelation occurs it causes a reduction in the concentration of inorganic Fe and Al because these metals are bound in non-labile, organic forms.

In this research, Fe and Al chelation appeared to occur at some streams indicated by the correlation of TOC with total Fe ($r^2 = 0.287$, $p<0.0001$) and Al ($r^2 = 0.27$, $p<0.0001$) at all sites. A regression analysis shows that Fe was significantly correlated with TOC at 8 of the 9 sampling locations. The exception was site 8 which also had substantially higher concentrations of Fe compared to other sites. It is probable that the lack of correlation between Fe and TOC at site 8 is due to the presence of inorganic forms of Fe weathered from the stream channel. This type of weathering would reduce the contact between Fe and organic matter resulting in high concentrations of free Fe. However, no strong conclusions can be made regarding the presence of inorganic Fe because Fe was not speciated in this research.

The strong correlation between TOC and organic Al ($r^2 = 0.77$, $p<.0001$) at all sites suggests that organic matter is influencing the concentration of organic Al in streamwater. In general, waters dominated by naturally occurring acids are less likely to cause damage to acid-sensitive biota, primarily because of the tendency of these waters to form Al complexes (Driscoll et al. 1980). Therefore, wetland sites had low inorganic Al concentrations, whereas non-wetland sites had high inorganic Al, particularly those with low pH values.

Organic Nitrogen

The N cycle is similar to the C cycle in that N can also exist in organic phases. DON compounds range from simple nutrients, such as urea and amino acids, to more complex molecules whose roles are poorly understood. Few streamwater studies have addressed the significance of DON; however, DON can comprise a substantial portion of N exported in streamwater (Qualls et al. 1991; McDowell and Asbury 1994; Hedin et al. 1995).

In this study, a relatively large portion of TDN consisted of DON (average of all sites = 62%) with the rest being composed of DIN. Although few DON data exist for temperate zone streams, the Lye Brook values are higher than expected for streams in the northeastern United States where N deposition is high. The N saturation hypothesis states that inorganic N losses increase as levels of deposition increase because mature stands lack the ability to retain NO_3^- (Aber et al. 1989). Therefore, a smaller fraction of organic N in stream exports would be expected in areas affected by acid deposition.

The %DON in TDN varied seasonally as the availability of different forms of N changed. The ratio of DON:DIN was greatest during the summer months and peaked during the early fall (Figure 26). This peak may have been caused by leaf senescence which would increase DON leached from litter and decrease NO_3^- through microbial immobilization (Qualls et al. 1991). The ratio of DON:DIN also appeared to be influenced by the concentration of TOC, with higher ratios occurring at wetland sites. This may have been the result of greater biological uptake of DIN in wetlands followed by release of DON through decomposition. It is also possible that denitrification could have caused inorganic N to be lost from the system, resulting in an increase in the DON:DIN ratio.

Site 8, which does not drain a wetland, also had a high DON:DIN ratio, suggesting that factors other than high plant productivity and denitrification may be important. Another possible factor that could cause a reduction in the ratio is the non-biological incorporation of inorganic N into soil humus. Although this process has been documented, the mechanisms are poorly understood (Johnson 1992).

There was a high correlation between TOC and DON which shows that patterns of production and loss of organic elements are similar. In order to compare ratios of organic C and organic N with other studies, a subset of samples (n=27) was analyzed for DOC to determine the approximate fraction of DOC in TOC. This analysis revealed that TOC was approximately 72% DOC resulting in a mean DOC:DON ratio of 24. This is higher than values for world rivers (~20; Meybeck 1982) and for streams in Puerto Rico (9-16; McDowell and Asbury 1994) and lower than values of streams in unpolluted, old-growth forests in Chile (39-49; Hedin 1995). The high ratios in Chile are not surprising because in areas with low N deposition, less N is available for incorporation into soil organic matter.

The Effect of Disturbance

In addition to factors discussed previously, the retention and loss of dissolved substances in streamwater can also be strongly affected by disturbances such as fire and logging (Vitousek 1975; Tiedemann et al. 1978; Martin et al. 1984; Martin et al. 1986). Although much of the Lye Brook Wilderness was logged in the early 1900's, some areas were cut as recently as the 1950's. A lack of logging records and historical land use maps makes it impossible to determine the extent and effect of deforestation. Fire records in the region are also lacking; however, the remains of the fire that occurred in 1916 are still evident. Much of the vegetation in the burned area consists of open fields containing early successional species. Regrowth has responded slowly, presumably because of the severity of the burn and also because it occurred on an exposed ridge.

Sampling site 4 was chosen with the intent of determining the effects of fire on stream chemistry; however, no clear effects were evident. Poor accessibility hindered location of the sampling site closer to the burn and the distance between the burn and the sampling location (approximately 400m) may have obscured ionic responses in streamwater. Site 4 did have higher concentrations of SO_4^{2-} compared to other sites; however, SO_4^{2-} is generally not affected by fire for long periods of time. Therefore, the high concentrations of SO_4^{2-} are probably due to other factors such as geology.

Regional Comparison

Annual mean stream chemistry data from the Lye Brook Wilderness was compared to similar stream surveys at Hubbard Brook and Cone Pond, New Hampshire (Table 5). Mean SO_4^{2-} concentrations at Lye Brook were generally lower compared to the other sites. This is partially due to SO_4^{2-} reduction occurring in wetlands. However, site 4 which had the highest concentration of SO_4^{2-} (5.6 mg/L) was still lower than the average New Hampshire study sites.

Lye Brook NO_3^- concentrations were lower than Hubbard Brook but higher than Cone Pond. At Lye Brook, the highest average NO_3^- value was 1.3 mg/L (site 7) which was lower than average values at Hubbard Brook. Concentrations of Cl^- and base cations were similar at all sites except Cone Pond which generally had low concentrations of Ca^{2+}, Mg^{2+} and K^+. Inorganic Al was lowest at Lye Brook and highest at Cone Pond. Iron; however, was found in relatively low concentrations at Cone Pond compared to Lye Brook.

TOC is not included in table 8, because DOC was measured at Hubbard Brook and Cone Pond, making comparisons difficult. At Lye Brook it was determined that TOC is 72% DOC in the streams sampled, which would equal an average DOC value of 7.4

mg/L. At both Hubbard Brook and Cone Pond, average values are generally less than 5.0 mg/L. The higher value at Lye Brook is due to the presence of wetlands in headwater streams.

While these comparisons are of interest, it is important to realize that some of the differences between sites are probably related to the relative lengths of the sample periods. For example, during the winter Lye Brook samples were collected, there was very little snow accumulation and temperatures were warmer than usual. This may have resulted in lower streamwater NO_3^- concentrations which could be misinterpreted.

Table 6. - Comparison of regional stream chemistry at Lye Brook, Vermont and Hubbard Brook and Cone Pond, New Hampshire.

	Concentration in streamwater (mg/L)		
Substance	Lye Brook*	Hubbard Brook**	Cone Pond***
SO_4^{2-}	4.46	6.23	6.33
NO_3^-	0.735	1.93	0.003
Cl^-	0.64	0.54	0.71
Ca^{2+}	1.06	1.65	0.52
Mg^{2+}	0.46	0.38	0.13
K^+	0.64	0.23	0.05
Na^+	0.66	0.88	0.63
Ali	0.09	0.23	0.41
Fe	0.47	----	0.05
NH_4^+	0.02	0.04	0.02
H^+	0.0195	0.0126	0.039

* Based on data from 25 May 1994 through 23 May 1995.

** Based on data from 1963 - 1974 (Likens and Bormann 1995).

*** Based on data from 1 January 1994 through 12 December 1994.

Conclusion

This research indicates that most of the streams in the Lye Brook Wilderness are acidic and have a low ANC, except where dolomite is present. Sites that are not affected by dolomite, have a low buffering capacity and are consequently susceptible to acid deposition. Increases in air pollution in the Lye Brook Wilderness would increase streamwater concentrations of NO_3^- and SO_4^{2-}, causing a reduction in pH. These reductions are most pronounced during rain storms and snowmelt runoff. During these episodes, sites without a wetland influence had concentrations of inorganic Al that were at levels that can be toxic to aquatic biota. Wetlands regulate discharge; therefore, episodic acidification was less of a factor at sites with a wetland influence. In addition, wetlands are a source of organic C which can form complexes with inorganic Al. Consequently, concentrations of the more toxic, inorganic forms of Al were low at wetland sites because Al complexed with carbon, creating less toxic organic forms of Al.

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APPENDIX A

Stream Chemistry in mg/L at sample sites from May 1994 through August 1995.

SITE 1

Date (dd/mm/yy)	ANC (μeq/L)	SO_4^{2-}-S (mg/L)	NO_3^--N (mg/L)	Cl^- (mg/L)	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	Na^+ (mg/L)	K^+ (mg/L)	H^+ (mg/L)
05/25/94	-13.0	1.19	0.04	0.26	1.04	0.44	0.63	2.13	0.013
06/07/94	-5.3	1.12	0.10	1.16	1.00	0.49	0.76	1.43	0.008
06/22/94	3.2	0.97	0.04	0.93	1.43	0.61	0.75	0.50	0.006
07/05/94	4.2	0.93	0.11	0.34	1.17	0.54	1.01	0.41	0.010
07/20/94	20.2	0.83	0.12	0.79	1.26	0.64	0.95	0.45	0.004
08/02/94	29.7	0.69	0.14	0.69	1.27	0.67	1.11	0.39	0.006
08/17/94	5.7	1.30	0.08	0.49	1.54	0.75	0.93	0.41	0.010
09/01/94	11.1	0.92	0.15	0.77	1.15	0.59	1.04	0.68	0.006
09/14/94	34.1	1.22	0.14	0.68	1.21	0.73	1.05	0.55	0.002
09/27/94	-53.6	1.38	0.05	0.51	1.47	0.59	0.47	0.54	0.040
10/12/94	6.1	1.32	0.03	0.53	1.16	0.62	0.77	0.33	0.010
10/25/94	NA	1.23	0.04	0.61	1.12	0.65	0.92	0.39	0.004
11/08/94	-15.4	1.70	0.05	0.92	1.52	0.73	0.84	0.40	0.016
11/21/94	41.2	1.45	0.10	0.56	1.20	0.69	0.96	0.38	0.002
12/07/94	-80.7	1.57	0.15	0.42	1.16	0.51	0.57	0.34	0.063
12/21/94	6.2	1.52	0.14	0.37	1.15	0.61	0.95	0.37	0.008
01/04/95	-9.1	1.52	0.15	0.37	1.16	0.60	0.82	0.35	0.013
01/16/95	-29.6	1.15	0.27	0.34	0.98	0.41	0.52	0.33	0.025
02/03/95	12.2	1.49	0.27	0.35	1.06	0.58	0.82	0.52	0.003
02/17/95	14.7	1.48	0.35	0.80	1.34	0.70	0.97	0.69	0.002
03/02/95	8.4	1.66	0.26	1.17	1.45	0.71	0.92	0.77	0.003
03/16/95	-23.3	1.56	NA	0.42	1.04	0.43	0.62	0.50	0.020
03/31/95	-5.6	1.42	0.24	0.57	1.06	0.49	0.75	0.56	0.013
04/13/95	-32.7	1.46	0.20	0.42	1.07	0.47	0.60	0.68	0.032
04/27/95	-21.6	1.35	0.07	0.88	1.04	0.49	0.72	0.52	0.020
05/10/95	9.9	1.53	0.20	1.60	1.06	0.57	0.94	0.54	0.006
05/23/95	15.9	1.12	0.12	0.39	1.05	0.55	1.01	0.63	0.004
06/07/95	-7.3	1.05	0.15	0.49	1.26	0.59	0.84	0.36	0.010
06/21/95	17.1	0.97	0.21	0.45	1.16	0.59	1.05	0.51	0.005
07/05/95	18.4	0.89	0.33	0.50	1.19	0.59	1.11	0.59	0.006
07/19/95	-11.7	1.24	0.07	0.56	1.72	0.73	0.75	0.34	0.016
08/03/95	24.9	0.79	0.29	0.62	1.47	0.73	1.09	0.49	0.006
08/15/95	23.3	0.86	0.17	0.58	1.54	0.59	1.13	0.54	0.008
08/29/95	17.0	0.96	0.23	0.49	1.01	0.54	1.25	0.42	0.006
Mean	0.4	1.23	0.15	0.62	1.22	0.59	0.87	0.56	0.012
Std. Dev.	25.2	0.28	0.09	0.29	0.19	0.09	0.19	0.34	0.012

SITE 1 (Continued)

Date (dd/mm/yy)	Ali (mg/L)	Alo (mg/L)	NH_4^+ (mg/L)	Fe (mg/L)	DON (mg/L)	TOC (mg/L)	SiO_2 (mg/L)	Cond. (μS/L)	Temp. (°C)
05/25/94	0.04	0.14	0.012	0.29	0.36	8.7	3.7	37.2	NA
06/07/94	0.03	0.13	0.010	0.36	0.28	9.8	4.0	22.8	NA
06/22/94	0.05	0.20	0.012	0.58	0.70	16.0	4.4	23.6	15.0
07/05/94	0.04	0.17	0.019	0.66	0.31	14.4	5.2	20.1	17.2
07/20/94	0.02	0.17	0.014	0.41	0.57	14.3	5.9	15.8	18.5
08/02/94	0.02	0.19	0.014	0.87	0.46	14.5	6.0	19.3	18.0
08/17/94	0.03	0.19	0.016	0.66	0.36	17.2	5.9	25.5	14.9
09/01/94	0.02	0.19	0.011	0.79	0.32	15.0	6.9	20.5	13.2
09/14/94	0.01	0.11	0.009	0.38	0.27	10.5	6.9	21.3	13.4
09/27/94	0.08	0.29	0.020	0.51	0.48	20.7	4.7	36.0	12.2
10/12/94	0.03	0.15	0.008	0.38	0.30	12.5	6.9	30.9	4.1
10/25/94	0.01	0.11	0.008	0.27	0.30	10.2	7.6	21.0	7.3
11/08/94	0.06	0.18	0.009	0.45	0.36	15.5	7.8	31.7	5.7
11/21/94	0.02	0.09	0.008	0.23	0.20	8.7	8.5	22.4	3.0
12/07/94	0.10	0.22	0.011	0.45	0.39	16.5	4.8	42.5	2.2
12/21/94	0.00	0.12	0.007	0.23	0.42	10.0	8.3	21.3	NA
01/04/95	0.02	0.13	0.009	0.28	0.32	9.5	7.8	21.8	NA
01/16/95	0.07	0.18	0.013	0.30	0.41	11.8	4.0	26.9	NA
02/03/95	0.01	0.12	0.006	0.23	0.30	8.0	8.1	18.8	NA
02/17/95	0.02	0.11	0.009	0.20	0.12	7.8	8.0	24.3	0.2
03/02/95	0.01	0.12	0.011	0.33	0.22	6.9	7.9	40.6	0.2
03/16/95	0.06	0.15	0.015	0.22	NA	8.8	4.6	24.9	NA
03/31/95	0.04	0.14	0.010	0.22	0.39	8.5	5.8	21.8	1.2
04/13/95	0.07	0.14	0.014	0.27	0.36	10.6	3.7	28.1	1.2
04/27/95	0.05	0.15	0.011	0.27	0.30	10.0	3.3	25.6	6.2
05/10/95	0.02	0.14	0.006	0.29	0.39	7.5	4.0	30.7	6.3
05/23/95	0.02	0.14	0.015	0.27	0.39	9.1	3.5	18.7	13.1
06/07/95	0.06	0.23	0.019	0.49	0.33	11.9	4.4	24.1	NA
06/21/95	0.03	0.18	0.017	0.42	0.60	11.5	5.9	20.9	15.3
07/05/95	0.03	0.19	0.011	0.55	0.39	11.6	6.1	19.6	15.6
07/19/95	0.06	0.24	0.012	0.59	0.37	19.1	4.5	30.6	16.7
08/03/95	0.06	0.25	0.022	0.98	0.46	13.2	7.1	21.4	16.8
08/15/95	0.04	0.21	0.017	0.70	0.44	14.3	7.4	25.6	17.5
08/29/95	0.06	0.18	0.009	0.61	0.29	10.5	NA	20.8	13.4
Mean	0.04	0.17	0.012	0.43	0.37	11.9	5.9	25.2	10.3
Std. Dev.	0.02	0.05	0.004	0.20	0.11	3.5	1.7	6.4	6.4

SITE 2

Date (dd/mm/yy)	ANC (μeq/L)	SO_4^{2-}-S (mg/L)	NO_3^--N (mg/L)	Cl^- (mg/L)	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	Na^+ (mg/L)	K^+ (mg/L)	H^+ (mg/L)
05/26/94	-51.6	0.98	0.01	0.20	0.75	0.27	0.54	1.00	0.032
06/07/94	-44.0	0.48	0.00	0.85	0.66	0.23	0.62	0.99	0.032
06/22/94	-58.9	0.65	0.00	0.43	0.72	0.26	0.61	0.29	0.032
07/05/94	-48.2	0.27	0.00	0.46	0.72	0.25	0.78	0.29	0.032
07/20/94	-36.4	0.28	0.00	1.71	0.69	0.24	1.38	0.85	0.020
08/02/94	-53.0	0.22	0.05	0.80	0.74	0.28	0.88	0.29	0.032
08/17/94	-68.7	0.78	0.00	0.57	0.86	0.38	0.84	0.24	0.040
09/01/94	-49.3	0.35	0.00	0.53	0.74	0.26	0.85	0.17	0.032
09/14/94	-56.6	1.86	0.00	0.34	0.72	0.31	1.05	0.61	0.040
09/27/94	-68.9	1.07	0.03	0.66	0.69	0.32	0.59	1.02	0.050
10/12/94	-77.0	1.16	0.03	0.53	0.73	0.33	0.79	0.32	0.063
10/25/94	-59.4	1.03	0.03	0.99	0.66	0.28	0.85	0.28	0.050
11/08/94	-64.9	1.55	0.03	0.76	0.92	0.45	0.86	0.46	0.050
11/21/94	-47.5	1.49	0.03	0.54	0.83	0.39	0.89	0.28	0.040
12/07/94	-82.3	1.56	0.10	0.34	1.08	0.42	0.55	0.25	0.063
12/21/94	-49.1	1.75	0.04	0.41	0.90	0.39	0.98	0.43	0.040
01/04/95	-54.1	1.77	0.05	0.32	0.93	0.41	0.81	0.37	0.050
01/16/95	-17.0	1.19	0.29	0.29	0.90	0.36	0.55	0.27	0.040
02/03/95	-33.9	1.75	0.07	0.36	0.89	0.38	0.84	0.66	0.032
02/17/95	-33.4	1.85	0.23	0.87	1.00	0.45	1.04	0.89	0.025
03/02/95	-31.3	1.87	0.19	0.99	0.97	0.45	0.92	0.86	0.025
03/16/95	-38.2	1.36	0.36	0.44	0.88	0.37	0.70	0.63	0.040
03/31/95	-39.2	1.49	0.13	0.38	0.87	0.36	0.81	0.73	0.040
04/13/95	-41.7	1.96	0.29	1.51	0.96	0.40	0.64	0.79	0.040
04/27/95	-37.1	1.52	0.05	0.98	0.81	0.32	0.76	0.72	0.032
05/10/95	-32.0	1.85	0.10	0.76	0.75	0.32	0.86	0.84	0.032
05/23/95	-28.1	0.92	0.04	0.27	0.72	0.30	0.89	0.68	0.025
06/08/95	-41.7	0.59	0.06	0.32	0.79	0.31	0.76	0.95	0.025
06/21/95	-35.5	0.24	0.00	0.47	0.72	0.26	0.76	0.29	0.025
07/06/95	-29.3	0.22	0.06	0.58	0.71	0.26	0.71	0.27	0.020
07/19/95	-60.1	1.08	0.00	0.51	1.11	0.42	0.69	0.15	0.050
08/03/95	-37.8	0.17	0.03	0.68	0.85	0.31	0.85	0.32	0.025
08/15/95	-42.5	0.29	0.02	0.51	0.77	0.30	0.73	0.11	0.025
08/29/95	-34.2	0.71	0.00	0.54	0.80	0.34	1.03	0.20	0.025
Mean	-46.6	1.07	0.07	0.61	0.82	0.33	0.81	0.51	0.036
Std. Dev.	14.9	0.61	0.09	0.33	0.12	0.07	0.17	0.29	0.011

SITE 2 (Continued)

Date (dd/mm/yy)	Ali (mg/L)	Alo (mg/L)	NH_4^+ (mg/L)	Fe (mg/L)	DON (mg/L)	TOC (mg/L)	SiO_2 (mg/L)	Cond. (μS/L)	Temp. (°C)
05/26/94	0.07	0.19	0.009	0.39	0.48	13.1	3.0	28.0	NA
06/07/94	0.05	0.22	0.073	0.65	0.37	15.3	3.0	23.7	NA
06/22/94	0.06	0.20	0.012	0.79	0.57	17.3	3.8	19.5	18.3
07/05/94	0.06	0.23	0.011	1.09	0.43	18.2	3.7	26.3	19.0
07/20/94	0.06	0.20	0.014	0.84	0.60	17.9	4.1	21.8	21.4
08/02/94	0.06	0.23	0.023	1.17	0.49	18.5	4.3	22.5	20.0
08/17/94	0.06	0.23	0.013	0.73	0.52	19.6	4.0	30.5	15.2
09/01/94	0.05	0.26	0.020	0.93	0.45	19.2	5.0	24.6	13.9
09/14/94	0.06	0.18	0.012	0.45	0.45	16.9	4.8	31.6	13.7
09/27/94	0.06	0.20	0.011	0.42	0.38	17.4	4.7	39.1	12.3
10/12/94	0.08	0.17	0.010	0.34	0.30	17.2	7.1	33.1	5.9
10/25/94	0.05	0.17	0.009	0.32	0.31	14.5	7.9	28.5	7.5
11/08/94	0.08	0.18	0.008	0.32	0.31	15.6	8.0	38.3	4.7
11/21/94	0.05	0.13	0.010	0.28	0.23	10.1	9.8	31.2	2.9
12/07/94	0.09	0.20	0.010	0.26	0.37	15.8	5.1	38.7	1.7
12/21/94	0.03	0.14	0.011	0.16	0.37	11.1	9.2	29.1	NA
01/04/95	0.05	0.15	0.016	0.16	0.30	10.0	8.6	29.4	NA
01/16/95	0.07	0.16	0.010	0.21	0.49	11.4	4.1	29.3	NA
02/03/95	0.05	0.13	0.041	0.24	0.58	9.6	9.2	26.2	NA
02/17/95	0.05	0.13	0.018	0.20	0.14	8.6	9.0	27.2	0.1
03/02/95	0.03	0.12	0.019	0.26	0.21	7.5	8.4	34.6	0.1
03/16/95	0.06	0.15	0.011	0.17	0.14	9.6	5.4	28.2	0.1
03/31/95	0.04	0.14	0.020	0.18	0.28	9.2	6.6	28.0	1.2
04/13/95	0.05	0.14	0.014	0.21	0.28	7.8	4.1	31.1	0.6
04/27/95	0.04	0.15	0.017	0.18	0.34	8.8	3.1	28.3	6.5
05/10/95	0.05	0.17	0.060	0.25	0.37	10.2	3.9	28.7	5.9
05/23/95	0.05	0.19	0.039	0.31	0.39	10.8	3.8	21.1	12.0
06/08/95	0.06	0.26	0.024	0.54	0.42	14.2	3.5	21.8	13.4
06/21/95	0.04	0.25	0.018	0.67	0.57	15.0	4.6	16.9	17.5
07/06/95	0.05	0.22	0.031	0.68	0.71	16.0	4.6	15.0	18.1
07/19/95	0.08	0.24	0.011	0.48	0.42	19.5	4.0	38.5	17.4
08/03/95	0.09	0.29	0.020	1.20	0.54	16.8	5.9	18.8	18.2
08/15/95	0.04	0.25	0.023	0.80	0.59	18.4	5.4	23.5	19.2
08/29/95	0.07	0.18	0.013	0.58	0.42	14.5	NA	22.3	13.6
Mean	0.06	0.19	0.019	0.48	0.41	14.0	5.5	27.5	10.7
Std. Dev.	0.02	0.05	0.014	0.31	0.13	3.9	2.1	6.2	7.3

SITE 3

Date (dd/mm/yy)	ANC (μeq/L)	SO_4^{2-}-S (mg/L)	NO_3^--N (mg/L)	Cl^- (mg/L)	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	Na^+ (mg/L)	K^+ (mg/L)	H^+ (mg/L)
05/25/94	-13.0	1.19	0.04	0.26	1.04	0.44	0.63	2.13	0.013
06/07/94	-5.3	1.12	0.10	1.16	1.00	0.49	0.76	1.43	0.008
06/22/94	3.2	0.97	0.04	0.93	1.43	0.61	0.75	0.50	0.006
07/05/94	4.2	0.93	0.11	0.34	1.17	0.54	1.01	0.41	0.010
07/20/94	20.2	0.83	0.12	0.79	1.26	0.64	0.95	0.45	0.004
08/02/94	29.7	0.69	0.14	0.69	1.27	0.67	1.11	0.39	0.006
08/17/94	5.7	1.30	0.08	0.49	1.54	0.75	0.93	0.41	0.010
09/01/94	11.1	0.92	0.15	0.77	1.15	0.59	1.04	0.68	0.006
09/14/94	34.1	1.22	0.14	0.68	1.21	0.73	1.05	0.55	0.002
09/27/94	-53.6	1.38	0.05	0.51	1.47	0.59	0.47	0.54	0.040
10/12/94	6.1	1.32	0.03	0.53	1.16	0.62	0.77	0.33	0.010
10/25/94	NA	1.23	0.04	0.61	1.12	0.65	0.92	0.39	0.004
11/08/94	-15.4	1.70	0.05	0.92	1.52	0.73	0.84	0.40	0.016
11/21/94	41.2	1.45	0.10	0.56	1.20	0.69	0.96	0.38	0.002
12/07/94	-80.7	1.57	0.15	0.42	1.16	0.51	0.57	0.34	0.063
12/21/94	6.2	1.52	0.14	0.37	1.15	0.61	0.95	0.37	0.008
01/04/95	-9.1	1.52	0.15	0.37	1.16	0.60	0.82	0.35	0.013
01/16/95	-29.6	1.15	0.27	0.34	0.98	0.41	0.52	0.33	0.025
02/03/95	12.2	1.49	0.27	0.35	1.06	0.58	0.82	0.52	0.003
02/17/95	14.7	1.48	0.35	0.80	1.34	0.70	0.97	0.69	0.002
03/02/95	8.4	1.66	0.26	1.17	1.45	0.71	0.92	0.77	0.003
03/16/95	-23.3	1.56	0.83	0.42	1.04	0.43	0.62	0.50	0.020
03/31/95	-5.6	1.42	0.24	0.57	1.06	0.49	0.75	0.56	0.013
04/13/95	-32.7	1.46	0.20	0.42	1.07	0.47	0.60	0.68	0.032
04/27/95	-21.6	1.35	0.07	0.88	1.04	0.49	0.72	0.52	0.020
05/10/95	9.9	1.53	0.20	1.60	1.06	0.57	0.94	0.54	0.006
05/23/95	15.9	1.12	0.12	0.39	1.05	0.55	1.01	0.63	0.004
06/07/95	-7.3	1.05	0.15	0.49	1.26	0.59	0.84	0.36	0.010
06/21/95	17.1	0.97	0.21	0.45	1.16	0.59	1.05	0.51	0.005
07/05/95	18.4	0.89	0.33	0.50	1.19	0.59	1.11	0.59	0.006
07/19/95	-11.7	1.24	0.07	0.56	1.72	0.73	0.75	0.34	0.016
08/03/95	24.9	0.79	0.29	0.62	1.47	0.73	1.09	0.49	0.006
08/15/95	23.3	0.86	0.17	0.58	1.54	0.59	1.13	0.54	0.008
08/29/95	17.0	0.96	0.23	0.49	1.01	0.54	1.25	0.42	0.006
Mean	-68.71	1.40	0.08	0.61	0.80	0.27	0.81	0.55	0.059
Std. Dev.	29.49	0.42	0.07	0.27	0.20	0.05	0.26	0.34	0.022

SITE 3 (Continued)

Date (dd/mm/yy)	Ali (mg/L)	Alo (mg/L)	NH_4^+ (mg/L)	Fe (mg/L)	DON (mg/L)	TOC (mg/L)	SiO_2 (mg/L)	Cond. (μS/L)	Temp. (°C)
05/26/94	0.07	0.21	0.027	0.36	0.41	15.7	3.8	38.0	NA
06/07/94	0.06	0.22	0.025	0.35	0.39	14.4	5.6	37.9	NA
06/22/94	0.08	0.28	0.020	0.54	0.59	22.8	4.7	25.9	16.0
07/05/94	0.06	0.24	0.023	0.68	0.46	18.8	6.6	34.0	17.1
07/20/94	0.04	0.27	0.023	0.68	0.57	20.4	7.2	26.0	19.2
08/02/94	0.04	0.27	0.025	0.78	0.51	18.7	7.3	28.0	18.5
08/17/94	0.06	0.28	NA	0.64	0.30	22.2	6.2	41.3	14.2
09/01/94	0.03	0.26	0.023	0.74	0.37	17.7	8.2	31.4	12.6
09/14/94	0.09	0.27	0.022	0.61	0.43	23.3	6.4	47.1	12.2
09/27/94	0.08	0.27	0.021	0.43	0.47	26.7	3.4	60.0	11.8
10/12/94	0.07	0.21	0.014	0.35	0.38	11.2	7.9	40.3	5.4
10/25/94	0.08	0.21	0.012	0.31	0.31	16.9	8.5	37.0	7.2
11/08/94	0.09	0.23	0.015	0.36	0.30	18.4	7.6	51.1	5.4
11/21/94	0.07	0.16	0.016	0.26	0.28	12.2	9.7	36.8	3.2
12/07/94	0.06	0.19	0.014	0.23	0.36	16.4	4.7	55.0	1.9
12/21/94	0.05	0.16	0.017	0.20	0.44	11.0	8.7	35.2	NA
01/04/95	0.06	0.16	0.018	0.17	0.37	10.5	8.1	34.9	NA
01/16/95	0.05	0.17	0.013	0.16	0.23	11.1	3.9	34.3	NA
02/03/95	0.07	0.13	0.025	0.24	0.40	9.7	8.7	32.3	NA
02/17/95	0.08	0.14	0.021	0.25	0.20	9.9	7.9	38.7	0.1
03/02/95	0.05	0.14	0.020	0.22	0.24	8.5	7.6	38.4	0.1
03/16/95	0.05	0.16	0.015	0.21	0.33	10.2	5.7	38.8	0.1
03/31/95	0.06	0.16	0.022	0.22	0.39	9.3	6.9	36.8	0.9
04/13/95	0.04	0.14	0.016	0.18	0.35	9.2	3.6	41.3	0.2
04/27/95	0.04	0.16	0.018	0.20	0.29	9.6	5.1	37.5	4.3
05/10/95	0.06	0.19	0.035	0.24	0.51	10.3	6.8	33.9	4.2
05/23/95	0.06	0.21	0.033	0.24	0.31	12.1	6.9	31.7	10.9
06/08/95	0.06	0.28	0.029	0.41	0.38	16.8	5.7	34.6	NA
06/21/95	0.05	0.20	0.053	0.36	0.44	13.4	8.5	29.4	15.7
07/06/95	0.03	0.24	0.049	0.51	0.92	14.9	9.1	23.4	20.9
07/19/95	0.11	0.28	0.023	0.43	0.41	22.2	4.4	69.3	14.6
08/03/95	0.05	0.31	0.094	0.82	0.54	17.8	9.0	27.2	17.6
08/15/95	0.05	0.29	0.034	0.65	0.65	21.9	7.1	35.7	17.8
08/29/95	0.04	0.19	0.025	0.39	0.40	11.5	8.9	26.4	14.6
Mean	0.06	0.21	0.025	0.39	0.41	15.2	6.8	37.3	9.9
Std. Dev.	0.02	0.05	0.015	0.20	0.14	5.1	1.8	9.8	7.0

SITE 4

Date (dd/mm/yy)	ANC (μeq/L)	SO_4^{2-}-S (mg/L)	NO_3^--N (mg/L)	Cl^- (mg/L)	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	Na^+ (mg/L)	K^+ (mg/L)	H^+ (mg/L)
06/09/94	-19.5	1.93	0.06	1.07	1.19	0.49	0.41	1.13	0.016
06/22/94	-30.6	1.76	0.04	0.54	1.07	0.39	0.45	0.66	0.025
07/05/94	-26.7	1.74	0.07	0.55	1.13	0.44	0.55	0.62	0.020
07/20/94	-22.6	1.71	0.10	0.61	1.22	0.47	0.69	0.99	0.016
08/02/94	-26.5	1.70	0.16	0.67	1.21	0.51	0.56	0.71	0.020
08/17/94	-27.7	1.71	0.13	0.58	1.23	0.45	0.45	0.58	0.020
08/31/94	-28.3	1.74	0.12	0.77	1.07	0.42	0.40	0.47	0.020
09/14/94	-16.0	1.20	0.15	0.57	1.30	0.53	0.41	0.57	0.013
09/28/94	-92.9	1.78	0.07	0.76	0.60	0.21	0.29	0.35	0.079
10/12/94	-21.5	1.81	0.07	0.81	1.06	0.43	0.41	0.42	0.016
10/26/94	-12.6	1.75	0.05	0.53	1.08	0.49	0.41	0.53	0.010
11/07/94	-16.1	1.66	0.09	0.67	1.20	0.44	0.42	0.55	0.013
11/22/94	-8.4	1.74	0.13	0.64	1.17	0.49	0.44	0.50	0.006
12/07/94	-74.2	1.90	0.23	0.50	0.82	0.25	0.37	0.33	0.063
12/20/94	-23.9	2.02	0.16	0.56	1.16	0.43	0.49	0.38	0.020
01/03/95	-26.2	2.01	0.17	0.73	1.15	0.42	0.45	0.42	0.020
01/16/95	-13.2	1.69	0.28	0.51	0.75	0.23	0.38	0.35	0.040
02/04/95	-19.1	2.08	0.23	0.52	1.18	0.46	0.48	0.59	0.020
02/17/95	-13.8	2.05	0.31	1.86	1.27	0.51	0.52	0.57	0.013
03/02/95	-13.4	1.99	NA	0.99	1.30	0.48	0.50	0.56	0.013
03/16/95	-31.4	2.02	0.40	0.78	0.98	0.29	0.57	0.76	0.025
03/23/95	-42.3	1.93	0.28	0.57	0.89	0.29	0.41	0.52	0.032
03/30/95	-24.4	1.96	0.24	0.58	1.13	0.40	0.47	0.53	0.025
04/13/95	-35.3	2.27	0.21	0.52	0.85	0.28	0.40	0.49	0.040
04/27/95	-27.0	1.68	0.20	0.57	1.08	0.39	0.46	0.50	0.025
05/10/95	-15.1	2.21	0.13	0.66	1.21	0.47	0.50	0.52	0.016
05/24/95	-16.0	2.23	0.12	0.77	1.24	0.51	0.54	0.59	0.016
06/08/95	-18.4	1.77	0.12	0.82	1.15	0.43	0.46	0.56	0.016
06/22/95	-16.9	1.91	0.15	0.54	1.29	0.55	0.45	0.52	0.016
07/06/95	-17.1	1.99	0.20	1.03	1.43	0.64	0.49	0.53	0.016
07/19/95	-18.1	1.93	0.13	0.63	1.52	0.54	0.40	0.48	0.016
08/02/95	-18.2	2.04	0.16	0.61	1.53	0.65	0.50	0.58	0.016
08/16/95	-19.9	1.97	0.14	0.63	1.25	0.54	0.00	0.00	0.016
08/30/95	-17.7	2.15	0.15	0.84	1.44	0.69	0.73	0.79	0.016
Mean	-25.02	1.88	0.16	0.70	1.15	0.45	0.45	0.55	0.022
Std. Dev.	16.64	0.21	0.08	0.25	0.20	0.11	0.12	0.19	0.015

SITE 4 (Continued)

Date (dd/mm/yy)	Ali (mg/L)	Alo (mg/L)	NH_4^+ (mg/L)	Fe (mg/L)	DON (mg/L)	TOC (mg/L)	SiO_2 (mg/L)	Cond. (μS/L)	Temp. (°C)
06/09/94	0.04	0.07	0.014	0.24	0.13	3.9	4.5	27.5	NA
06/22/94	0.06	0.09	0.001	0.51	0.41	5.3	4.1	17.2	14.0
07/05/94	0.04	0.09	0.013	0.59	0.16	6.9	4.6	24.2	16.0
07/20/94	0.02	0.11	0.010	0.73	0.18	7.6	5.1	20.7	17.9
08/02/94	0.04	0.11	0.014	1.23	0.18	8.1	5.5	22.6	17.5
08/17/94	0.03	0.12	0.015	1.37	0.14	8.2	5.1	25.6	14.3
08/31/94	0.05	0.13	0.018	1.83	0.18	7.5	5.0	26.6	13.6
09/14/94	0.03	0.11	0.023	1.00	0.20	8.0	5.5	24.5	14.4
09/28/94	0.22	0.15	0.010	1.11	0.24	13.0	3.5	45.6	13.0
10/12/94	0.04	0.08	0.005	0.64	0.12	6.0	5.1	23.9	5.5
10/26/94	0.03	0.07	0.003	0.67	0.13	5.7	5.5	20.2	6.5
11/07/94	0.03	0.08	0.003	0.70	0.13	5.8	5.1	21.7	6.0
11/22/94	0.01	0.06	0.004	0.67	0.11	4.6	5.5	26.5	5.9
12/07/94	0.24	0.13	0.007	0.53	0.18	9.5	4.4	47.2	4.2
12/20/94	0.06	0.06	0.006	0.16	0.25	4.0	5.6	24.6	NA
01/03/95	0.08	0.07	0.013	0.17	0.25	2.7	5.5	23.2	NA
01/16/95	0.27	0.11	0.006	0.43	0.27	7.0	4.0	33.9	NA
02/04/95	0.08	0.05	0.009	0.18	0.21	3.5	6.0	22.7	NA
02/17/95	0.05	0.05	0.004	0.15	0.09	3.3	5.6	21.4	0.7
03/02/95	0.04	0.05	0.003	0.12	NA	3.0	5.3	41.4	0.7
03/16/95	0.19	0.10	0.019	0.29	0.20	5.8	4.2	29.2	NA
03/23/95	0.22	0.11	0.007	0.32	0.21	5.4	4.1	20.3	2.3
03/30/95	0.13	0.08	0.009	0.18	0.15	3.7	4.9	27.0	2.8
04/13/95	0.19	0.09	0.004	0.28	0.07	5.2	3.8	27.6	3.0
04/27/95	0.11	0.07	0.000	0.14	0.00	4.0	4.2	27.5	6.7
05/10/95	0.04	0.07	0.002	0.10	0.35	3.5	4.5	23.7	7.1
05/24/95	0.02	0.07	0.005	0.13	0.09	4.0	4.8	22.3	10.4
06/08/95	0.04	0.09	0.006	0.33	0.22	5.7	4.5	22.1	NA
06/22/95	0.04	0.08	0.007	0.24	0.13	5.7	5.4	26.4	13.4
07/06/95	0.03	0.11	0.061	0.40	0.07	7.1	6.1	23.3	NA
07/19/95	0.04	0.13	0.007	0.43	0.08	7.3	4.8	30.6	16.2
08/02/95	0.06	0.15	0.011	0.70	0.22	7.2	6.3	26.2	18.0
08/16/95	0.05	0.12	0.010	0.82	0.22	6.8	5.7	26.6	17.8
08/30/95	0.05	0.12	0.008	0.72	0.15	6.2	6.5	27.1	14.2
Mean	0.08	0.09	0.010	0.53	0.17	5.9	5.0	26.5	10.1
Std. Dev.	0.07	0.03	0.010	0.41	0.08	2.1	0.7	6.7	5.9

SITE 5

Date (dd/mm/yy)	ANC (μeq/L)	SO_4^{2-}-S (mg/L)	NO_3^--N (mg/L)	Cl^- (mg/L)	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	Na^+ (mg/L)	K^+ (mg/L)	H^+ (mg/L)
05/26/94	169.7	1.47	0.11	0.28	2.94	1.58	0.54	NA	0.000
06/08/94	273.4	1.54	0.19	NA	4.13	2.33	0.53	NA	0.000
06/23/94	266.6	1.54	0.17	0.52	4.04	2.26	0.62	0.78	0.000
07/06/94	264.5	1.50	0.22	0.51	4.02	2.20	0.71	0.74	0.000
07/20/94	299.8	1.52	0.21	0.56	4.12	2.28	0.69	0.93	0.000
08/02/94	343.9	1.39	0.22	0.48	4.20	2.48	0.71	0.73	0.000
08/17/94	140.7	1.38	0.12	0.54	2.57	1.39	0.75	0.72	0.000
08/31/94	252.2	1.44	0.19	0.67	3.78	2.10	0.64	0.67	0.000
09/13/94	266.6	1.42	0.18	0.50	3.51	2.12	0.69	0.55	0.000
09/28/94	-19.0	1.46	0.05	0.58	1.59	0.72	0.51	0.60	0.025
10/11/94	204.3	1.55	0.03	0.44	2.98	1.73	0.67	0.56	0.003
10/26/94	204.8	1.51	0.06	0.54	2.69	1.61	0.74	0.58	0.000
11/07/94	125.7	1.71	0.07	0.71	2.34	1.22	0.76	0.70	0.001
11/22/94	144.7	1.63	0.13	0.75	2.29	1.30	0.77	0.60	0.000
12/06/94	-23.3	1.48	0.22	0.41	1.35	0.62	0.54	0.49	0.025
12/20/94	242.8	1.70	0.24	0.51	3.40	1.99	0.68	0.55	0.000
01/03/95	149.4	1.70	0.21	0.40	2.53	1.44	0.70	0.50	0.000
01/16/95	-5.7	1.31	0.28	0.31	1.21	0.56	0.51	0.40	0.008
02/04/95	217.1	1.79	0.32	0.41	3.60	2.09	0.66	0.59	0.000
02/18/95	175.5	1.66	0.28	0.55	3.04	1.69	0.77	0.72	0.000
03/03/95	189.6	1.79	0.33	1.03	2.94	1.63	0.74	0.69	0.000
03/16/95	-3.8	1.46	0.42	0.59	1.35	0.62	0.53	0.71	0.008
03/23/95	13.5	1.34	0.26	0.44	1.39	0.65	0.57	0.68	0.004
03/30/95	75.8	1.76	0.30	0.46	2.04	1.08	0.66	0.68	0.001
04/13/95	15.2	1.53	0.22	0.66	1.43	0.68	0.60	0.74	0.005
04/27/95	64.7	1.60	0.13	0.52	1.90	1.02	0.67	0.69	0.001
05/10/95	197.6	1.68	0.20	0.57	3.26	1.84	0.68	0.67	0.002
05/24/95	172.1	1.60	0.20	0.54	2.93	1.63	0.75	0.75	0.000
06/07/95	214.6	1.34	0.19	0.39	3.37	1.87	0.66	0.58	0.000
06/22/95	385.8	1.58	0.35	0.46	5.02	2.88	0.63	0.67	0.000
07/06/95	267.3	1.71	0.38	0.56	4.06	2.23	0.63	0.63	0.000
07/20/95	126.3	1.61	0.16	0.46	2.69	1.35	0.72	0.65	0.000
08/02/95	322.0	1.64	0.29	0.48	4.69	2.56	0.68	0.65	0.000
08/16/95	284.1	1.60	0.21	0.43	3.93	2.26	0.14	NA	0.000
08/30/95	358.4	1.79	0.26	0.58	4.86	2.76	0.70	0.58	0.000
Mean	182.2	1.56	0.21	0.52	3.03	1.68	0.64	0.66	0.002
Std. Dev.	113.3	0.14	0.09	0.14	1.08	0.66	0.12	0.10	0.006

SITE 5 (Continued)

Date (dd/mm/yy)	Ali (mg/L)	Alo (mg/L)	NH_4^+ (mg/L)	Fe (mg/L)	DON (mg/L)	TOC (mg/L)	SiO_2 (mg/L)	Cond. (μS/L)	Temp. (°C)
05/26/94	0.01	0.07	0.004	0.22	0.22	7.0	4.2	31.4	NA
06/08/94	0.00	0.06	0.012	0.09	0.13	5.0	4.4	72.0	NA
06/23/94	0.00	0.06	0.005	0.11	0.31	6.2	4.9	18.4	NA
07/06/94	0.00	0.06	0.008	0.16	0.22	6.0	4.9	43.2	NA
07/20/94	0.00	0.06	0.008	0.12	0.23	6.4	5.5	36.1	17.9
08/02/94	0.01	0.06	0.008	0.18	0.24	7.0	5.7	42.0	17.8
08/17/94	0.00	0.09	0.014	0.25	0.24	9.1	5.0	29.9	13.9
08/31/94	0.01	0.07	0.007	0.19	0.20	7.8	5.4	43.3	13.8
09/13/94	0.01	0.04	0.007	0.13	0.28	6.6	5.6	43.6	13.8
09/28/94	0.08	0.27	0.012	0.60	0.39	21.1	4.4	38.1	13.1
10/11/94	0.01	0.06	0.006	0.16	0.22	7.9	6.2	36.8	7.8
10/26/94	0.00	0.05	0.005	0.09	0.18	6.0	6.0	36.9	8.0
11/07/94	0.01	0.09	0.008	0.29	0.21	10.1	7.1	31.3	7.5
11/22/94	0.01	0.05	0.005	0.15	0.17	6.3	7.3	31.8	5.5
12/06/94	0.09	0.20	0.010	0.38	0.29	13.2	4.8	29.0	4.5
12/20/94	0.00	0.05	0.007	0.04	0.32	5.1	7.0	46.4	NA
01/03/95	0.00	0.06	0.007	0.11	0.18	5.8	7.1	30.2	NA
01/16/95	0.08	0.17	0.008	0.27	0.43	8.7	4.5	19.8	NA
02/04/95	0.02	0.03	0.006	0.14	0.22	4.2	7.1	34.5	NA
02/18/95	0.01	0.05	0.004	0.17	0.19	4.9	7.4	30.2	0.6
03/03/95	0.00	0.06	0.005	0.17	0.16	4.8	7.5	29.6	0.3
03/16/95	0.08	0.17	0.007	0.25	0.30	7.6	5.0	21.3	2.8
03/23/95	0.06	0.16	0.008	0.25	0.33	7.9	4.7	31.3	2.3
03/30/95	0.00	0.09	0.009	0.15	0.22	5.4	5.7	26.4	2.7
04/13/95	0.06	0.16	0.011	0.26	0.30	7.3	4.2	20.2	2.9
04/27/95	0.02	0.08	0.003	0.10	0.20	5.6	3.8	24.6	8.9
05/10/95	0.01	0.06	0.007	0.07	0.25	4.6	4.6	36.2	8.0
05/24/95	0.01	0.06	0.008	0.03	0.17	5.3	4.6	32.4	12.8
06/07/95	0.01	0.10	0.011	0.21	0.17	8.9	4.2	34.4	14.6
06/22/95	0.01	0.07	0.005	0.08	0.31	7.9	5.4	49.9	13.3
07/06/95	0.01	0.06	0.018	0.08	0.32	7.1	6.0	40.1	18.9
07/20/95	0.00	0.13	0.007	0.18	0.19	7.2	5.2	32.5	17.3
08/02/95	0.00	0.10	0.010	0.13	0.05	5.3	6.3	49.5	18.3
08/16/95	0.02	0.07	0.007	0.13	0.26	7.1	6.0	43.4	19.1
08/30/95	0.02	0.07	0.004	0.08	0.15	5.6	6.2	49.2	14.3
Mean	0.02	0.09	0.008	0.17	0.24	7.2	5.5	35.6	10.4
Std. Dev.	0.03	0.05	0.003	0.11	0.08	3.0	1.1	10.6	6.1

SITE 6

Date (dd/mm/yy)	ANC (μeq/L)	SO_4^{2-}-S (mg/L)	NO_3^--N (mg/L)	Cl^- (mg/L)	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	Na^+ (mg/L)	K^+ (mg/L)	H^+ (mg/L)
05/26/94	-46.3	1.66	0.23	0.37	0.68	0.22	0.45	1.21	0.032
06/08/94	-33.0	1.65	0.15	1.12	0.67	0.23	0.47	1.50	0.025
06/23/94	-35.9	1.65	0.11	0.47	0.65	0.23	0.53	1.02	0.025
07/06/94	-33.2	1.66	0.12	0.48	0.71	0.24	0.58	0.87	0.025
07/20/94	-39.3	1.74	0.11	1.05	0.72	0.25	0.57	1.14	0.025
08/02/94	-30.6	1.57	0.16	0.45	0.73	0.25	0.61	0.89	0.025
08/18/94	-92.6	1.52	0.11	0.40	0.78	0.20	0.34	0.61	0.063
08/31/94	-23.1	1.59	0.14	0.56	0.75	0.26	0.55	0.90	0.016
09/13/94	-21.3	1.58	0.14	0.53	0.78	0.30	0.57	0.90	0.016
09/28/94	-146.2	1.70	0.17	0.83	0.61	0.17	0.28	0.47	0.100
10/11/94	-25.8	1.61	0.08	0.41	0.79	0.27	0.49	0.88	0.020
10/26/94	-27.3	1.63	0.09	0.44	0.79	0.29	0.52	0.87	0.025
11/07/94	-36.1	1.75	0.14	0.58	0.99	0.31	0.45	0.86	0.032
11/22/94	-19.0	1.65	0.15	0.51	0.89	0.30	0.49	0.83	0.016
12/06/94	-115.5	1.71	0.61	0.61	0.69	0.20	0.39	0.64	0.100
12/20/94	-29.6	1.70	0.27	0.45	0.84	0.27	0.51	0.77	0.025
01/03/95	-37.3	1.71	0.29	0.45	0.90	0.27	0.49	0.77	0.032
01/16/95	-77.0	1.52	0.61	0.46	0.58	0.17	0.35	0.56	0.063
02/04/95	-27.6	1.71	0.36	0.43	0.81	0.27	0.55	0.89	0.025
02/18/95	-28.5	1.64	0.31	0.60	0.79	0.27	0.56	0.98	0.025
03/03/95	-23.3	1.79	0.35	1.08	0.86	0.28	0.64	1.04	0.020
03/16/95	-73.0	1.40	0.66	0.60	0.57	0.16	0.36	0.78	0.063
03/23/95	-64.2	1.44	0.51	0.75	0.59	0.18	0.40	0.82	0.050
03/31/95	-39.7	1.87	0.46	0.52	0.74	0.23	0.47	0.84	0.040
04/13/95	-56.4	2.36	0.95	0.53	0.63	0.19	0.40	0.82	0.063
04/27/95	-37.7	1.64	0.28	0.58	0.74	0.23	0.52	0.88	0.040
05/10/95	-26.0	2.15	0.29	0.95	0.80	0.26	0.57	0.98	0.025
05/24/95	-25.2	1.66	0.18	0.57	0.74	0.26	0.55	0.96	0.025
06/07/95	-51.2	1.60	0.23	0.79	0.85	0.26	0.54	0.88	0.040
06/22/95	-25.1	1.62	0.19	0.52	0.79	0.27	0.54	0.87	0.025
07/06/95	-24.2	1.62	0.19	0.70	0.92	0.29	0.58	0.86	0.025
07/20/95	-22.0	1.61	0.16	0.53	0.97	0.31	0.57	0.87	0.020
08/02/95	-21.4	1.70	0.14	0.65	0.82	0.29	0.59	0.89	0.020
08/16/95	-25.7	1.70	0.15	0.46	0.89	0.30	0.58	0.21	0.025
08/30/95	-18.3	1.68	0.14	0.64	1.00	0.34	0.64	0.89	0.016
Mean	-41.7	1.68	0.26	0.60	0.77	0.25	0.50	0.86	0.035
Std. Dev.	28.5	0.17	0.20	0.20	0.11	0.05	0.09	0.21	0.021

SITE 6 (Continued)

Date (dd/mm/yy)	Ali (mg/L)	Alo (mg/L)	NH_4^+ (mg/L)	Fe (mg/L)	DON (mg/L)	TOC (mg/L)	SiO_2 (mg/L)	Cond. (µS/L)	Temp. (°C)
05/26/94	0.20	0.11	0.005	0.22	0.19	5.0	5.2	48.0	NA
06/08/94	0.13	0.08	0.005	0.23	0.14	4.2	6.3	26.5	NA
06/23/94	0.14	0.09	0.005	0.26	0.25	4.5	6.5	19.4	12.7
07/06/94	0.10	0.08	0.005	0.26	0.15	4.1	7.4	26.0	NA
07/20/94	0.06	0.09	0.005	0.21	0.24	4.0	7.2	20.8	15.3
08/02/94	0.06	0.09	0.009	0.27	0.17	4.8	7.7	19.5	16.3
08/18/94	0.22	0.26	0.018	1.41	0.36	16.4	5.2	38.8	13.8
08/31/94	0.05	0.10	0.006	0.32	0.11	4.6	7.6	25.3	11.8
09/13/94	0.06	0.07	0.005	0.22	0.10	4.1	7.8	23.8	12.2
09/28/94	0.32	0.38	0.014	1.20	0.44	22.8	5.4	60.7	11.4
10/11/94	0.07	0.09	0.004	0.26	0.17	5.3	7.3	23.6	5.3
10/26/94	0.04	0.07	0.003	0.13	0.11	4.0	7.7	21.2	5.5
11/07/94	0.13	0.14	0.008	0.97	0.14	8.5	7.6	28.7	4.5
11/22/94	0.05	0.07	0.007	0.22	0.11	4.4	7.7	22.5	4.8
12/06/94	0.42	0.31	0.014	0.70	0.24	12.5	6.0	55.2	5.4
12/20/94	0.16	0.10	0.006	0.14	0.24	4.0	7.4	26.7	0.7
01/03/95	0.19	0.10	0.005	0.19	0.21	3.8	7.2	25.5	NA
01/16/95	0.43	0.21	0.006	0.48	0.42	9.6	5.4	36.8	NA
02/04/95	0.22	0.07	0.004	0.16	0.19	3.6	7.5	22.6	NA
02/18/95	0.18	0.06	0.005	0.16	0.15	3.4	7.3	21.4	1.1
03/03/95	0.14	0.07	0.003	0.10	0.23	3.4	7.3	23.3	0.4
03/16/95	0.51	0.24	0.007	0.55	0.23	8.2	4.7	41.3	3.8
03/23/95	0.41	0.17	0.005	0.40	0.42	7.1	5.4	25.3	2.5
03/31/95	0.29	0.12	0.005	0.23	0.22	4.8	6.3	28.3	2.2
04/13/95	0.34	0.19	0.014	0.48	0.30	7.3	4.9	35.4	2.7
04/27/95	0.21	0.11	0.002	0.17	0.14	4.3	6.1	28.0	4.3
05/10/95	0.13	0.10	0.003	0.14	0.16	3.7	6.5	24.0	6.6
05/24/95	0.09	0.08	0.007	0.12	0.18	3.6	6.8	22.8	11.5
06/07/95	0.13	0.11	0.014	0.28	0.14	5.4	6.9	25.4	12.9
06/22/95	0.08	0.08	0.004	0.12	0.11	4.2	7.8	21.8	13.5
07/06/95	0.05	0.10	0.011	0.18	0.06	4.4	8.1	21.2	15.7
07/20/95	0.07	0.11	0.006	0.20	0.05	4.2	7.9	24.5	14.9
08/02/95	0.05	0.10	0.010	0.28	0.24	4.7	8.6	24.2	16.7
08/16/95	0.07	0.09	0.008	0.26	0.21	5.0	8.2	23.1	17.6
08/30/95	0.05	0.10	0.013	0.26	0.21	4.9	8.5	22.5	12.4
Mean	0.17	0.12	0.007	0.34	0.20	6.0	6.9	28.1	8.9
Std. Dev.	0.13	0.07	0.004	0.30	0.09	4.0	1.1	9.8	5.6

SITE 7

Date (dd/mm/yy)	ANC (μeq/L)	SO_4^{2-}-S (mg/L)	NO_3^--N (mg/L)	Cl^- (mg/L)	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	Na^+ (mg/L)	K^+ (mg/L)	H^+ (mg/L)
05/26/94	-42.3	1.57	0.12	0.34	0.59	0.19	0.41	0.82	0.032
06/08/94	-43.6	1.70	0.25	0.82	0.72	0.25	0.47	1.12	0.032
06/23/94	-43.0	1.71	0.19	0.39	0.73	0.25	0.54	0.98	0.032
07/06/94	-42.2	1.71	0.21	0.43	0.75	0.26	0.59	0.65	0.032
07/20/94	-39.1	1.73	0.20	0.59	0.73	0.26	0.55	1.14	0.025
08/02/94	-39.4	1.63	0.20	0.48	0.76	0.27	0.58	0.88	0.032
08/18/94	-76.8	1.59	0.15	0.36	0.81	0.23	0.39	0.63	0.050
08/31/94	-35.5	1.66	0.19	0.60	0.75	0.27	0.52	0.79	0.025
09/13/94	-35.1	1.72	0.22	0.75	0.78	0.31	0.56	0.82	0.025
09/28/94	-126.5	1.72	0.14	0.47	0.69	0.20	0.29	0.43	0.079
10/11/94	-23.7	1.45	0.04	1.24	1.04	0.43	0.73	0.60	0.016
10/26/94	-30.3	1.71	0.17	0.49	0.77	0.30	0.50	0.82	0.025
11/07/94	-39.4	1.76	0.18	0.63	0.92	0.32	0.47	0.89	0.032
11/22/94	-21.8	1.62	0.15	0.72	1.01	0.41	0.76	0.63	0.016
12/06/94	-94.9	1.60	0.43	0.52	0.80	0.26	0.47	0.59	0.079
12/20/94	-41.0	1.72	0.41	0.66	0.83	0.28	0.53	0.75	0.032
01/03/95	-43.9	1.75	0.40	0.52	0.82	0.28	0.49	0.74	0.040
01/16/95	-68.0	1.54	0.60	0.43	0.64	0.20	0.38	0.56	0.050
02/04/95	-33.9	1.72	0.53	0.61	0.82	0.30	0.62	0.92	0.032
02/18/95	-22.9	1.78	0.40	1.04	0.97	0.38	0.73	0.85	0.020
03/03/95	-30.7	1.78	0.47	1.07	0.89	0.33	0.63	0.92	0.025
03/16/95	-60.6	1.42	0.71	0.52	0.67	0.22	0.47	0.75	0.050
03/23/95	-47.8	1.36	0.36	0.50	0.76	0.27	0.54	0.75	0.040
03/31/95	-43.0	1.66	0.51	0.52	0.74	0.25	0.49	0.83	0.040
04/13/95	-50.2	2.07	0.45	1.36	0.71	0.24	0.54	0.98	0.050
04/27/95	-37.4	1.90	0.33	0.61	0.81	0.29	0.57	0.79	0.040
05/10/95	-22.0	2.01	0.33	2.75	0.97	0.39	0.71	0.81	0.020
05/24/95	-11.9	1.49	0.19	0.35	1.01	0.46	0.80	0.67	0.010
06/07/95	-27.6	1.24	0.19	0.57	0.96	0.38	0.68	0.52	0.020
06/22/95	-14.2	1.48	0.39	0.40	1.25	0.56	0.67	0.58	0.010
07/06/95	-10.9	1.58	0.46	0.43	1.43	0.64	0.71	0.62	0.008
07/20/95	-22.1	1.21	0.05	0.40	1.33	0.52	0.72	0.55	0.016
08/02/95	-12.3	1.41	0.30	0.48	1.30	0.58	0.73	0.59	0.008
08/16/95	-16.3	1.38	0.23	0.40	1.24	0.52	0.75	0.50	0.010
08/30/95	1.7	1.61	0.31	0.47	1.39	0.63	0.88	0.74	0.008
Mean	-38.5	1.63	0.30	0.65	0.90	0.34	0.58	0.75	0.030
Std. Dev.	24.6	0.19	0.16	0.44	0.23	0.13	0.13	0.17	0.018

SITE 7 (Continued)

Date (dd/mm/yy)	Ali (mg/L)	Alo (mg/L)	NH_4^+ (mg/L)	Fe (mg/L)	DON (mg/L)	TOC (mg/L)	SiO_2 (mg/L)	Cond. (μS/L)	Temp. (°C)
05/26/94	0.20	0.12	0.009	0.33	0.23	5.2	5.2	30.1	NA
06/08/94	0.20	0.11	0.005	0.15	0.10	4.1	5.9	29.8	NA
06/23/94	0.19	0.12	0.006	0.12	0.40	4.5	6.1	24.1	14.2
07/06/94	0.15	0.11	0.004	0.23	0.18	4.5	6.4	28.5	15.2
07/20/94	0.14	0.10	0.010	0.13	0.13	4.1	6.7	24.4	16.4
08/02/94	0.11	0.11	0.008	0.19	0.19	4.5	7.2	23.9	17.0
08/18/94	0.26	0.29	0.017	0.78	0.32	14.2	5.5	36.7	14.9
08/31/94	0.13	0.12	0.007	0.17	0.15	4.8	6.9	29.1	13.0
09/13/94	0.13	0.09	0.023	0.13	0.11	4.1	7.0	28.7	12.8
09/28/94	0.43	0.32	0.014	0.93	0.42	20.3	5.5	53.8	12.3
10/11/94	0.07	0.14	0.006	0.28	0.28	9.6	6.2	23.9	7.0
10/26/94	0.09	0.10	0.006	0.10	0.11	4.2	7.2	25.6	6.7
11/07/94	0.15	0.15	0.006	0.31	0.13	6.9	7.3	30.2	6.1
11/22/94	0.05	0.11	0.012	0.25	0.17	7.6	7.8	25.3	5.0
12/06/94	0.27	0.26	0.013	0.52	0.27	12.9	5.5	48.1	4.4
12/20/94	0.25	0.11	0.004	0.04	0.24	4.0	6.9	29.8	NA
01/03/95	0.24	0.10	0.004	0.12	0.19	3.7	6.9	27.8	NA
01/16/95	0.39	0.19	0.007	0.30	0.25	8.8	5.4	34.0	NA
02/04/95	0.30	0.09	0.006	0.10	0.29	3.4	7.1	26.0	NA
02/18/95	0.15	0.10	0.007	0.19	0.13	4.9	7.7	22.3	0.5
03/03/95	0.22	0.11	0.003	0.12	0.17	3.6	7.3	23.7	0.3
03/16/95	0.30	0.16	0.011	0.34	0.12	8.0	4.9	35.8	3.4
03/23/95	0.19	0.18	0.007	0.28	0.26	7.7	5.1	53.1	2.3
03/31/95	0.32	0.13	0.008	0.13	0.26	4.3	6.2	31.0	2.3
04/13/95	0.29	0.18	0.007	0.30	0.18	7.0	5.2	33.2	2.8
04/27/95	0.19	0.12	0.004	0.15	0.11	5.1	5.0	28.8	7.8
05/10/95	0.10	0.13	0.004	0.13	0.28	4.8	5.1	23.7	7.3
05/24/95	0.05	0.12	0.011	0.23	0.24	6.8	4.5	20.1	11.9
06/07/95	0.07	0.17	0.011	0.38	0.22	9.1	3.9	22.2	14.0
06/22/95	0.05	0.13	0.012	0.23	0.30	7.1	5.5	23.5	13.5
07/06/95	0.02	0.13	0.011	0.22	0.26	6.6	6.3	21.1	15.9
07/20/95	0.08	0.17	0.010	0.34	0.38	9.3	4.7	26.2	16.1
08/02/95	0.05	0.13	0.011	0.31	0.38	7.3	6.4	22.6	17.9
08/16/95	0.06	0.15	0.007	0.33	0.34	4.9	6.0	22.9	18.3
08/30/95	0.04	0.12	0.004	0.22	0.28	7.1	6.8	22.6	13.8
Mean	0.17	0.14	0.008	0.26	0.23	6.7	6.1	28.9	10.1
Std. Dev.	0.11	0.05	0.004	0.18	0.09	3.5	1.0	8.2	5.8

SITE 8

Date (dd/mm/yy)	ANC (μeq/L)	SO_4^{2-}-S (mg/L)	NO_3^--N (mg/L)	Cl^- (mg/L)	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	Na^+ (mg/L)	K^+ (mg/L)	H^+ (mg/L)
05/26/94	-115.3	1.37	0.00	0.29	0.46	0.17	0.87	NA	0.079
06/08/94	-85.5	1.53	0.02	0.77	0.53	0.22	0.67	1.09	0.063
06/23/94	-105.8	1.47	0.02	0.48	0.52	0.21	0.68	0.53	0.079
07/06/94	-85.2	1.49	0.05	0.54	0.48	0.21	0.88	0.67	0.063
07/20/94	-94.3	1.33	0.03	0.55	0.53	0.21	0.79	0.96	0.063
08/02/94	-84.8	1.35	0.10	0.51	0.51	0.22	0.84	0.93	0.063
08/18/94	-253.5	1.85	0.00	0.33	0.59	0.20	0.46	0.26	0.158
08/31/94	-76.3	1.34	0.07	0.74	0.47	0.21	0.74	0.75	0.050
09/13/94	-57.4	1.29	0.07	0.56	0.50	0.23	0.73	0.57	0.040
09/28/94	-295.3	1.88	0.03	0.69	0.58	0.21	0.34	0.40	0.200
10/11/94	-114.1	1.53	0.00	0.62	0.58	0.24	0.60	0.54	0.079
10/26/94	-77.5	1.38	0.03	0.70	0.53	0.23	0.66	0.61	0.063
11/07/94	-187.4	2.15	0.03	0.97	0.63	0.24	0.59	0.57	0.158
11/22/94	-116.0	1.79	0.03	0.90	0.59	0.23	0.64	0.62	0.079
12/06/94	-242.1	1.74	0.12	0.53	0.55	0.20	0.46	0.58	0.158
12/20/94	-101.5	1.92	0.03	0.60	0.54	0.23	0.67	0.64	0.079
01/03/95	-107.1	1.91	0.07	0.58	0.52	0.22	0.59	0.59	0.100
01/16/95	-121.4	1.35	0.22	0.38	0.40	0.16	0.37	0.49	0.100
02/04/95	-61.8	1.89	0.11	0.46	0.54	0.24	0.74	0.86	0.050
02/18/95	-65.1	1.99	0.34	0.67	0.58	0.24	0.73	0.93	0.050
03/03/95	-80.0	1.06	0.29	0.97	0.56	0.24	0.74	0.93	0.079
03/16/95	-117.0	1.66	0.27	0.65	0.41	0.16	0.54	1.12	0.100
03/23/95	-115.0	1.31	0.23	1.65	0.42	0.17	0.45	0.81	0.100
03/31/95	-91.1	1.63	0.14	0.90	0.47	0.19	0.55	0.80	0.079
04/13/95	-109.1	1.75	0.40	0.83	0.42	0.18	0.46	0.88	0.126
04/27/95	-92.8	1.76	0.04	0.64	0.42	0.17	0.55	0.78	0.100
05/10/95	-68.6	2.51	0.05	1.50	0.52	0.22	0.72	0.86	0.063
05/24/95	-63.7	1.69	0.04	1.04	0.46	0.20	0.81	0.95	0.063
06/07/95	-95.2	1.51	0.07	0.43	0.51	0.21	0.75	0.77	0.079
06/22/95	-57.8	1.58	0.13	0.51	0.58	0.25	0.86	0.83	0.050
07/06/95	-49.3	1.55	0.15	0.80	0.64	0.26	0.96	0.84	0.040
07/20/95	-91.6	1.89	0.04	0.48	0.67	0.26	0.66	0.55	0.079
08/02/95	-51.6	1.60	0.12	1.13	0.66	0.27	1.19	0.95	0.050
08/16/95	-58.0	1.53	0.08	0.57	0.56	0.25	0.83	0.68	0.050
08/30/95	-39.0	1.63	0.09	0.64	0.62	0.28	0.94	0.82	0.032
Mean	-103.6	1.63	0.10	0.70	0.53	0.22	0.69	0.74	0.082
Std. Dev.	57.5	0.29	0.10	0.30	0.07	0.03	0.18	0.19	0.038

SITE 8 (Continued)

Date (dd/mm/yy)	Ali (mg/L)	Alo (mg/L)	NH_4^+ (mg/L)	Fe (mg/L)	DON (mg/L)	TOC (mg/L)	SiO_2 (mg/L)	Cond. (µS/L)	Temp. (°C)
05/26/94	0.11	0.23	0.013	1.30	0.48	23.7	5.0	50.3	NA
06/08/94	0.10	0.17	0.014	1.31	0.32	13.1	7.0	43.1	NA
06/23/94	0.12	0.21	0.016	1.88	0.43	17.3	7.3	43.2	12.5
07/06/94	0.10	0.18	0.018	1.92	0.33	13.8	8.9	42.1	14.3
07/20/94	0.11	0.25	0.016	2.58	0.35	16.3	8.7	35.9	14.5
08/02/94	0.09	0.23	0.016	2.81	0.26	14.0	9.9	31.6	15.1
08/18/94	0.19	0.41	0.023	1.75	0.71	34.0	5.3	85.2	13.0
08/31/94	0.08	0.22	0.019	2.56	0.25	14.3	10.2	40.7	11.4
09/13/94	0.09	0.17	0.012	1.75	0.23	10.3	10.6	33.6	11.2
09/28/94	0.22	0.41	0.028	1.64	0.71	40.3	5.1	97.7	11.4
10/11/94	0.15	0.23	0.014	1.62	0.39	18.0	10.0	49.4	6.2
10/26/94	0.11	0.19	0.014	1.57	0.24	14.9	10.9	35.9	5.5
11/07/94	0.25	0.31	0.019	1.48	0.40	21.5	9.4	74.0	6.5
11/22/94	0.16	0.19	0.012	1.56	0.26	15.0	11.0	49.8	4.7
12/06/94	0.14	0.34	0.021	1.21	0.55	27.8	5.3	82.4	3.7
12/20/94	0.13	0.15	0.009	0.94	0.34	11.5	9.7	44.9	NA
01/03/95	0.16	0.14	0.012	0.95	0.33	10.2	9.0	45.9	NA
01/16/95	0.11	0.26	0.019	0.88	0.55	18.0	4.4	50.2	NA
02/04/95	0.12	0.12	0.012	0.66	0.36	8.0	9.8	35.3	NA
02/18/95	0.12	0.12	0.013	0.69	0.03	8.9	9.2	37.4	0.4
03/03/95	0.13	0.14	0.015	0.75	0.12	8.6	9.1	36.2	0.4
03/16/95	0.11	0.23	0.022	0.90	0.51	16.2	5.0	53.8	0.5
03/23/95	0.09	0.25	0.016	0.94	0.48	17.2	4.5	35.9	0.9
03/31/95	0.11	0.20	0.024	0.82	0.41	12.7	6.8	47.7	1.1
04/13/95	0.11	0.21	0.017	0.76	0.16	13.0	4.1	57.5	0.6
04/27/95	0.09	0.18	0.012	0.76	0.30	5.3	5.7	47.6	7.0
05/10/95	0.09	0.16	0.012	0.75	0.33	9.3	6.6	41.0	5.2
05/24/95	0.06	0.11	0.013	0.63	0.25	9.8	6.7	36.8	10.8
06/07/95	0.09	0.23	0.014	1.32	0.26	14.8	7.1	42.7	11.9
06/22/95	0.08	0.15	0.016	0.98	0.24	9.6	9.8	37.6	12.6
07/06/95	0.05	0.16	0.019	1.13	0.12	9.4	10.4	29.6	14.4
07/20/95	0.11	0.20	0.015	1.36	0.25	11.8	8.6	47.8	NA
08/02/95	0.07	0.18	0.016	1.51	0.33	10.0	11.4	36.1	15.5
08/16/95	0.08	0.19	0.016	1.64	0.29	11.7	11.4	34.4	15.8
08/30/95	0.07	0.14	0.014	1.13	0.16	8.2	11.9	28.6	12.0
Mean	0.11	0.21	0.016	1.33	0.33	14.8	8.2	46.3	8.5
Std. Dev.	0.04	0.07	0.004	0.56	0.15	7.3	2.4	15.9	5.4

SITE 9

Date (dd/mm/yy)	ANC (μeq/L)	SO_4^{2-}-S (mg/L)	NO_3^--N (mg/L)	Cl^- (mg/L)	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	Na^+ (mg/L)	K^+ (mg/L)	H^+ (mg/L)
05/26/94	-42.0	0.94	0.03	0.14	0.71	0.25	0.64	0.56	0.032
06/08/94	-27.5	0.82	0.05	0.71	0.70	0.26	0.65	0.92	0.025
06/23/94	-36.7	0.76	0.07	0.30	0.78	0.28	0.72	0.39	0.025
07/06/94	-35.1	0.66	0.11	0.23	0.75	0.27	0.77	0.33	0.025
07/20/94	-30.4	0.63	0.12	0.46	0.70	0.25	0.87	0.92	0.020
08/02/94	-31.8	0.51	0.15	0.51	0.75	0.27	0.84	0.67	0.020
08/18/94	-100.9	1.29	0.00	0.38	1.12	0.38	0.87	0.47	0.063
08/31/94	-33.1	0.70	0.10	0.57	0.83	0.30	0.81	0.39	0.020
09/13/94	-23.9	0.74	0.09	0.65	0.70	0.28	0.82	0.43	0.016
09/28/94	-84.7	1.26	0.03	0.76	0.98	0.37	0.58	0.64	0.063
10/11/94	-36.4	1.17	0.03	0.51	0.88	0.34	0.81	0.40	0.025
10/26/94	-25.1	1.08	0.05	1.49	0.80	0.32	0.93	0.45	0.020
11/07/94	-45.3	1.47	0.04	0.95	1.00	0.39	0.88	0.58	0.040
11/22/94	-31.2	1.46	0.07	0.65	0.92	0.38	0.91	0.52	0.020
12/06/94	-70.1	1.22	0.12	0.39	0.89	0.33	0.58	0.37	0.050
12/20/94	-36.3	1.56	0.11	0.55	0.92	0.37	0.96	0.41	0.032
01/03/95	-38.3	1.53	0.10	0.38	0.86	0.34	0.85	0.45	0.032
01/16/95	-35.7	1.15	0.20	0.28	0.75	0.29	0.62	0.37	0.025
02/04/95	-17.4	1.55	0.16	0.37	0.93	0.38	1.00	0.69	0.013
02/18/95	-21.3	1.57	0.22	0.92	0.94	0.37	1.00	0.81	0.016
03/03/95	-25.7	1.55	0.20	0.91	0.93	0.37	0.96	0.79	0.020
03/16/95	-35.0	1.09	0.17	0.47	0.69	0.26	0.64	0.60	0.032
03/23/95	-35.7	0.29	0.05	0.36	0.76	0.28	0.67	0.60	0.032
03/31/95	-28.1	1.21	0.23	0.41	0.82	0.31	0.76	0.65	0.025
04/13/95	-35.9	1.70	0.20	0.64	0.75	0.30	0.68	0.75	0.040
04/27/95	-26.7	1.29	0.06	0.75	0.77	0.28	0.99	0.74	0.025
05/10/95	-22.1	1.17	0.12	0.56	0.75	0.29	0.91	0.66	0.020
05/24/95	-21.2	0.97	0.12	0.51	0.69	0.27	0.97	0.66	0.016
06/07/95	-34.5	0.84	0.09	0.31	0.78	0.28	0.75	0.33	0.025
06/22/95	-25.7	0.74	0.24	0.25	0.84	0.30	0.80	0.45	0.020
07/06/95	-21.2	0.64	0.00	0.25	0.90	0.33	0.83	0.54	0.016
07/20/95	-35.2	1.59	0.12	0.45	1.11	0.39	0.81	0.39	0.032
08/02/95	-22.7	0.64	0.19	0.47	0.87	0.31	0.91	0.43	0.016
08/16/95	-26.6	0.73	0.11	0.41	0.87	0.31	0.86	0.35	0.020
08/30/95	2.1	0.67	0.13	0.60	0.85	0.33	0.90	0.43	0.010
Mean	-34.2	1.06	0.11	0.53	0.84	0.31	0.82	0.55	0.027
Std. Dev.	18.3	0.38	0.07	0.26	0.11	0.04	0.12	0.17	0.012

SITE 9 (Continued)

Date (dd/mm/yy)	Ali (mg/L)	Alo (mg/L)	NH_4^+ (mg/L)	Fe (mg/L)	DON (mg/L)	TOC (mg/L)	SiO_2 (mg/L)	Cond. (μS/L)	Temp. (°C)
05/26/94	0.04	0.17	0.036	0.37	0.43	11.8	2.3	24.3	NA
06/08/94	0.05	0.14	0.015	0.37	0.37	10.9	2.1	21.9	NA
06/23/94	0.04	0.17	0.013	0.66	0.57	13.5	2.8	21.2	15.9
07/06/94	0.04	0.16	0.015	0.74	0.40	13.5	2.8	21.1	19.2
07/20/94	0.03	0.17	0.015	0.62	0.46	13.0	3.6	17.1	17.9
08/02/94	0.03	0.17	0.012	0.75	0.45	14.4	4.0	16.9	18.9
08/18/94	0.08	0.29	0.020	0.73	0.53	21.8	4.2	41.1	14.3
08/31/94	0.03	0.17	0.010	0.66	0.33	13.7	3.8	20.9	13.4
09/13/94	0.03	0.13	0.007	0.42	0.34	11.3	3.5	19.6	12.9
09/28/94	0.09	0.24	0.017	0.49	0.42	22.2	3.7	42.5	12.2
10/11/94	0.05	0.15	0.008	0.33	0.35	13.0	4.8	25.8	6.4
10/26/94	0.05	0.13	0.009	0.28	0.30	11.4	5.1	21.6	4.9
11/07/94	0.07	0.17	0.010	0.36	0.28	12.2	6.3	31.1	6.1
11/22/94	0.06	0.13	0.014	0.31	0.14	10.2	7.8	26.3	4.1
12/06/94	0.07	0.17	0.015	0.26	0.32	14.8	4.3	37.2	2.1
12/20/94	0.05	0.13	0.020	0.23	0.32	9.7	8.4	26.7	0.3
01/03/95	0.14	0.15	0.020	0.25	0.25	8.3	8.4	24.2	NA
01/16/95	0.06	0.15	0.021	0.24	0.34	10.2	4.5	24.0	NA
02/04/95	0.05	0.12	0.021	0.24	0.24	7.9	8.9	20.9	NA
02/18/95	0.04	0.13	0.043	0.27	0.19	8.7	8.8	21.4	NA
03/03/95	0.05	0.13	0.043	0.30	0.25	7.1	8.7	20.6	NA
03/16/95	0.05	0.15	0.019	0.22	0.30	8.9	5.0	25.1	0.3
03/23/95	0.05	0.15	0.016	0.22	0.52	10.0	4.4	33.0	0.7
03/31/95	0.04	0.12	0.015	0.15	0.18	7.9	5.2	23.9	1.2
04/13/95	0.05	0.14	0.018	0.19	0.25	9.2	3.5	27.8	1.3
04/27/95	0.04	0.14	0.009	0.19	0.24	9.0	2.2	24.3	9.8
05/10/95	0.04	0.14	0.007	0.26	0.36	8.1	2.6	20.8	7.2
05/24/95	0.05	0.15	0.012	0.27	0.34	9.9	2.6	19.3	12.7
06/07/95	0.06	0.21	0.017	0.44	0.40	13.8	2.1	22.3	16.6
06/22/95	0.06	0.19	0.015	0.48	0.49	12.3	3.1	19.3	15.5
07/06/95	0.05	0.20	0.015	0.63	NA	12.3	3.7	17.0	17.3
07/20/95	0.07	0.19	0.010	0.45	0.34	13.0	3.1	28.5	17.3
08/02/95	0.08	0.19	0.011	0.70	0.51	12.4	4.0	18.5	18.6
08/16/95	0.05	0.19	0.011	0.62	0.48	14.4	4.5	21.3	19.7
08/30/95	0.04	0.16	0.009	0.53	0.37	13.0	4.7	17.4	12.9
Mean	0.05	0.16	0.016	0.41	0.35	11.8	4.6	24.1	10.7
Std. Dev.	0.02	0.04	0.009	0.19	0.11	3.3	2.1	6.3	6.8

APPENDIX B

Stream Chemistry in μeq/L at sample sites from May 1994 through August 1995.

SITE 1

Date (dd/mm/yy)	SO_4^{2-} (μeq/L)	NO_3^- (μeq/L)	Cl^- (μeq/L)	Ca^{2+} (μeq/L)	Mg^{2+} (μeq/L)	Na^+ (μeq/L)	K^+ (μeq/L)	H^+ (μeq/L)	$Ali^{(2-3)+}$ (μeq/L)	Mn^{2+} (μeq/L)
05/25/94	7			5	3	2	5	1	4	
06/07/94	7		3	5	4	3	3		3	
06/22/94	6		2	7	5	3	1		5	
07/05/94	5		1	5	4	4	1	1	4	
07/20/94	5		2	6	5	4	1		2	
08/02/94	4	1	1	6	5	4	1		2	
08/17/94	8		1	7	6	4	1	1	3	
09/01/94	5	1	2	5	4	4	1		2	
09/14/94	7	1	1	6	6	4	1		1	
09/27/94	8		1	7	4	2	1	3	9	
10/12/94	8		1	5	5	3		1	3	
10/25/94	7		1	5	5	4	1		1	
11/08/94	10		2	7	6	3	1	1	6	
11/21/94	9		1	6	5	4	1		1	
12/07/94	9	1	1	5	4	2		6	11	
12/21/94	9	1	1	5	5	4			0	
01/04/95	9	1	1	5	4	3		1	2	
01/16/95	7	1	1	4	3	2		2	6	
02/03/95	9	1	1	5	4	3	1		1	
02/17/95	9	2	2	6	5	4	1		1	
03/02/95	10	1	3	7	5	4	2		1	
03/16/95	9	NA	1	5	3	2	1	2	6	
03/31/95	8	1	1	5	4	3	1	1	4	
04/13/95	9	1	1	5	3	2	1	3	8	
04/27/95	8		2	5	4	3	1	2	5	
05/10/95	9	1	4	5	4	4	1		2	
05/23/95	7		1	5	4	4	1		2	
06/07/95	6	1	1	6	4	3		1	6	
06/21/95	6	1	1	5	4	4	1		3	
07/05/95	5	2	1	5	4	4	1		3	
07/19/95	7		1	8	6	3		1	6	
08/03/95	5	2	1	7	6	4	1		6	
08/15/95	5	1	1	7	4	4	1		4	
08/29/95	6	1	1	5	4	5	1		6	
Mea	7	1	1	6	4	3	1	1	4	
Std. Dev	1			1				1	3	

SITE 2

Date (dd/mm/yy)	SO_4^{2-} (μeq/L)	NO_3^- (μeq/L)	Cl^- (μeq/L)	Ca^{2+} (μeq/L)	Mg^{2+} (μeq/L)	Na^+ (μeq/L)	K^+ (μeq/L)	H^+ (μeq/L)	$Al_i^{(2-3)+}$ (μeq/L)	Mn^{2+} (μeq/L)
05/26/94	6			3	2	2	2	3	8	
06/07/94	3		2	3	1	2	2	3	6	
06/22/94	4		1	3	2	2		3	7	
07/05/94	1		1	3	2	3		3	7	
07/20/94	1		4	3	2	6	2	2	6	
08/02/94	1		2	3	2	3		3	7	
08/17/94	4		1	4	3	3		3	7	
09/01/94	2		1	3	2	3		3	6	
09/14/94	11			3	2	4	1	3	7	
09/27/94	6		1	3	2	2	2	5	7	
10/12/94	7		1	3	2	3		6	9	
10/25/94	6		2	3	2	3		5	6	
11/08/94	9		2	4	3	3	1	5	9	
11/21/94	9		1	4	3	3		3	6	
12/07/94	9		1	5	3	2		6	10	
12/21/94	10		1	4	3	4	1	3	3	
01/04/95	11			4	3	3	1	5	6	
01/16/95	7	2		4	2	2		3	8	
02/03/95	10		1	4	3	3	1	3	6	
02/17/95	11	1	2	5	3	4	2	2	5	
03/02/95	11	1	2	4	3	4	2	2	3	
03/16/95	8	2	1	4	3	3	1	3	7	
03/31/95	9	1	1	4	2	3	1	3	4	
04/13/95	12	2	4	4	3	2	2	3	6	
04/27/95	9		2	4	2	3	1	3	4	
05/10/95	11		2	3	2	3	2	3	6	
05/23/95	5			3	2	3	1	2	5	
06/08/95	3			4	2	3	2	2	6	
06/21/95	1		1	3	2	3		2	4	
07/06/95	1		1	3	2	3		2	5	
07/19/95	6		1	5	3	3		5	9	
08/03/95	1		1	4	2	3		2	8	
08/15/95	1		1	3	2	3		2	4	
08/29/95	4		1	4	2	4		2	6	
Mea	6		1	4	2	3	1	3	6	
Std. Dev	3							1	2	

SITE 3

Date (dd/mm/yy)	SO_4^{2-} (μeq/L)	NO_3^- (μeq/L)	Cl^- (μeq/L)	Ca^{2+} (μeq/L)	Mg^{2+} (μeq/L)	Na^+ (μeq/L)	K^+ (μeq/L)	H^+ (μeq/L)	$Ali^{(2-3)+}$ (μeq/L)	Mn^{2+} (μeq/L)
05/26/94	6			3	1	2		6	8	
06/07/94	7		4	4	2	3	4	3	7	
06/22/94	5		1	4	2	2	1	5	9	
07/05/94	6		2	4	2	4	1	3	7	
07/20/94	10		1	3	2	4	2	3	4	
08/02/94	4		2	3	2	4	1	5	4	
08/17/94	6		1	4	2	3	1	6	7	
09/01/94	5		1	3	2	3	1	3	3	
09/14/94	8		2	4	2	2		7	10	
09/27/94	7		1	4	2	1	1	9	9	
10/12/94	7		1	3	2	2		7	8	
10/25/94	7		1	3	2	3		6	9	
11/08/94	10		2	4	2	3		9	10	
11/21/94	9		1	4	2	3	1	3	8	
12/07/94	9		1	3	1	2		7	7	
12/21/94	11		1	4	2	3		6	6	
01/04/95	11		1	4	2	3		6	7	
01/16/95	7	1		3	1	2		6	6	
02/03/95	11		1	4	2	3	1	5	8	
02/17/95	11	2	2	4	2	3	1	6	9	
03/02/95	11	1	3	4	2	3	1	5	6	
03/16/95	10	1	1	3	1	3	1	6	6	
03/31/95	10	1	1	3	2	3	1	6	7	
04/13/95	9	1	1	3	1	2	1	7	4	
04/27/95	9		2	3	1	3	1	6	4	
05/10/95	11		2	4	2	3	1	5	7	
05/23/95	8			4	2	3	1	5	7	
06/08/95	6		1	4	2	3	1	5	7	
06/21/95	8		1	3	2	4	2	3	6	
07/06/95	6		2	2	1	6	3	2	3	
07/19/95	17		2	8	3	3		12	12	
08/03/95	4		1	3	1	4	1	3	6	
08/15/95	6		1	4	2	1		5	6	
08/29/95	7		1	2	1	6	2	3	4	
Mea	8		1	4	2	3	1	5	7	
Std. Dev	2			1		1		2	2	

SITE 4

Date (dd/mm/yy)	SO_4^{2-} (μeq/L)	NO_3^- (μeq/L)	Cl^- (μeq/L)	Ca^{2+} (μeq/L)	Mg^{2+} (μeq/L)	Na^+ (μeq/L)	K^+ (μeq/L)	H^+ (μeq/L)	$Ali^{(2-3)+}$ (μeq/L)	Mn^{2+} (μeq/L)
06/09/94	12		3	5	4	1	2	1	4	
06/22/94	11		1	5	3	2	1	2	6	
07/05/94	10		1	5	3	2	1	2	4	
07/20/94	10		1	6	3	3	2	1	2	
08/02/94	10	1	1	6	4	2	1	2	4	
08/17/94	10		1	6	3	2	1	2	3	
08/31/94	10		2	5	3	1	1	2	5	
09/14/94	7	1	1	6	4	1	1	1	3	
09/28/94	11		2	3	1	1		7	24	
10/12/94	11		2	5	3	1	1	1	4	
10/26/94	10		1	5	4	1	1	1	3	
11/07/94	10		1	6	3	1	1	1	3	
11/22/94	10		1	5	4	1	1		1	
12/07/94	11	1	1	4	2	1		6	27	
12/20/94	12	1	1	5	3	2	1	2	6	
01/03/95	12	1	2	5	3	2	1	2	7	
01/16/95	10	2	1	3	1	1		3	30	
02/04/95	13	1	1	5	3	2	1	2	7	
02/17/95	12	2	5	6	4	2	1	1	5	
03/02/95	12	NA	2	6	3	2	1	1	4	
03/16/95	12	2	2	4	2	2	1	2	18	
03/23/95	12	2	1	4	2	1	1	3	24	
03/30/95	12	1	1	5	3	2	1	2	12	
04/13/95	14	1	1	4	2	1	1	3	21	
04/27/95	10	1	1	5	3	2	1	2	10	
05/10/95	13		1	6	3	2	1	1	4	
05/24/95	13		2	6	4	2	1	1	2	
06/08/95	11		2	5	3	2	1	1	4	
06/22/95	11	1	1	6	4	2	1	1	4	
07/06/95	12	1	2	7	5	2	1	1	3	
07/19/95	12		1	7	4	1	1	1	4	
08/02/95	12	1	1	7	5	2	1	1	6	
08/16/95	12	1	1	6	4			1	5	
08/30/95	13	1	2	7	5	3	2	1	5	
Mea	11	1	2	5	3	2	1	2	8	
Std. Dev	1			1				1	8	

SITE 5

Date (dd/mm/yy)	SO_4^{2-} (μeq/L)	NO_3^- (μeq/L)	Cl^- (μeq/L)	Ca^{2+} (μeq/L)	Mg^{2+} (μeq/L)	Na^+ (μeq/L)	K^+ (μeq/L)	H^+ (μeq/L)	$Ali^{(2-3)+}$ (μeq/L)	Mn^{2+} (μeq/L)
05/26/94	9			14	13	2	14		1	
06/08/94	9	1	N	20	19	2	N		0	
06/23/94	9	1	1	20	18	2	2		0	
07/06/94	9	1	1	20	18	3	1		0	
07/20/94	9	1	1	20	18	3	2		0	
08/02/94	8	1	1	21	20	3	1		1	
08/17/94	8		1	12	11	3	1		0	
08/31/94	9	1	1	18	17	2	1		1	
09/13/94	8	1	1	17	17	3	1		1	
09/28/94	9		1	7	5	2	1	2	7	
10/11/94	9		1	14	14	2	1		1	
10/26/94	9		1	13	13	3	1		0	
11/07/94	10		2	11	10	3	1		1	
11/22/94	10		2	11	10	3	1		1	
12/06/94	9	1	1	6	5	2	1	2	8	
12/20/94	10	1	1	17	16	3	1		0	
01/03/95	10	1	1	12	11	3	1		0	
01/16/95	8	2		6	4	2	1		7	
02/04/95	11	2	1	18	17	2	1		1	
02/18/95	10	2	1	15	13	3	1		1	
03/03/95	11	2	2	14	13	3	1		0	
03/16/95	9	3	1	6	5	2	1		7	
03/23/95	8	1	1	6	5	2	1		6	
03/30/95	11	2	1	10	8	2	1		0	
04/13/95	9	1	1	7	5	2	1		6	
04/27/95	10		1	9	8	2	1		1	
05/10/95	10	1	1	16	15	3	1		1	
05/24/95	10	1	1	14	13	3	1		1	
06/07/95	8	1	1	16	15	2	1		1	
06/22/95	9	2	1	25	23	2	1		1	
07/06/95	10	2	1	20	18	2	1		1	
07/20/95	10	1	1	13	11	3	1		0	
08/02/95	10	2	1	23	21	2	1		0	
08/16/95	10	1	1	19	18				1	
08/30/95	11	1	1	24	22	3	1		1	
Mea	9	1	1	15	13	2	2		2	
Std. Dev				5	5		2		3	

SITE 6

Date (dd/mm/yy)	SO_4^{2-} (µeq/L)	NO_3^- (µeq/L)	Cl^- (µeq/L)	Ca^{2+} (µeq/L)	Mg^{2+} (µeq/L)	Na^+ (µeq/L)	K^+ (µeq/L)	H^+ (µeq/L)	$Ali^{(2-3)+}$ (µeq/L)	Mn^{2+} (µeq/L)
05/26/94	10	1	1	3	1	1	3	3	22	
06/08/94	10	1	3	3	1	2	3	2	12	
06/23/94	10		1	3	1	2	2	2	13	
07/06/94	10		1	3	2	2	2	2	9	
07/20/94	10		3	3	2	2	2	2	6	
08/02/94	9	1	1	3	2	2	2	2	6	
08/18/94	9		1	3	1	1	1	6	24	
08/31/94	9	1	1	3	2	2	2	1	5	
09/13/94	9	1	1	3	2	2	2	1	6	
09/28/94	10	1	2	3	1	1	1	9	36	
10/11/94	10		1	3	2	2	2	2	6	
10/26/94	10		1	3	2	2	2	2	4	
11/07/94	10	1	1	4	2	1	2	3	14	
11/22/94	10	1	1	4	2	2	2	1	5	
12/06/94	10	4	1	3	1	1	1	9	47	
12/20/94	10	1	1	4	2	2	2	2	15	
01/03/95	10	2	1	4	2	2	2	3	21	
01/16/95	9	4	1	2	1	1	1	6	48	
02/04/95	10	2	1	4	2	2	2	2	20	
02/18/95	10	2	1	3	2	2	2	2	17	
03/03/95	11	2	3	4	2	2	2	2	13	
03/16/95	8	4	1	2	1	1	2	6	57	
03/23/95	9	3	2	2	1	1	2	5	46	
03/31/95	11	3	1	3	1	2	2	3	32	
04/13/95	14	6	1	3	1	1	2	6	38	
04/27/95	10	2	1	3	1	2	2	3	23	
05/10/95	13	2	2	4	2	2	2	2	12	
05/24/95	10	1	1	3	2	2	2	2	8	
06/07/95	10	1	2	4	2	2	2	3	14	
06/22/95	10	1	1	3	2	2	2	2	7	
07/06/95	10	1	2	4	2	2	2	2	5	
07/20/95	10	1	1	4	2	2	2	2	6	
08/02/95	10	1	1	4	2	2	2	2	5	
08/16/95	10	1	1	4	2	2		2	6	
08/30/95	10	1	1	5	2	2	2	1	5	
Mea	10	1	1	3	2	2	2	3	17	
Std. Dev	1	1						2	15	

SITE 7

Date (dd/mm/yy)	SO_4^{2-} (μeq/L)	NO_3^- (μeq/L)	Cl^- (μeq/L)	Ca^{2+} (μeq/L)	Mg^{2+} (μeq/L)	Na^+ (μeq/L)	K^+ (μeq/L)	H^+ (μeq/L)	$Ali^{(2-3)+}$ (μeq/L)	Mn^{2+} (μeq/L)
05/26/94	9		1	2	1	1	2	3	22	
06/08/94	10	1	2	3	2	2	2	3	22	
06/23/94	10	1	1	3	2	2	2	3	21	
07/06/94	10	1	1	3	2	2	1	3	17	
07/20/94	10	1	1	3	2	2	2	2	13	
08/02/94	10	1	1	3	2	2	2	3	12	
08/18/94	9	1	1	4	1	1	1	5	29	
08/31/94	10	1	1	3	2	2	2	2	12	
09/13/94	10	1	2	3	2	2	2	2	12	
09/28/94	10	1	1	3	1	1	1	7	48	
10/11/94	9		3	5	3	3	1	1	6	
10/26/94	10	1	1	3	2	2	2	2	8	
11/07/94	10	1	1	4	2	2	2	3	17	
11/22/94	10	1	2	5	3	3	1	1	5	
12/06/94	10	3	1	4	2	2	1	7	30	
12/20/94	10	2	1	4	2	2	1	3	28	
01/03/95	10	2	1	4	2	2	1	3	27	
01/16/95	9	4	1	3	1	1	1	5	43	
02/04/95	10	3	1	4	2	2	2	3	33	
02/18/95	11	2	2	4	3	3	2	2	14	
03/03/95	11	3	3	4	2	2	2	2	20	
03/16/95	8	5	1	3	1	2	1	5	33	
03/23/95	8	2	1	3	2	2	1	3	21	
03/31/95	10	3	1	3	2	2	2	3	36	
04/13/95	12	3	3	3	1	2	2	5	32	
04/27/95	11	2	1	4	2	2	2	3	21	
05/10/95	12	2	7	4	3	3	2	2	9	
05/24/95	9	1	1	5	3	3	1	1	5	
06/07/95	7	1	1	4	3	3	1	2	6	
06/22/95	9	2	1	6	4	2	1	1	5	
07/06/95	9	3	1	7	5	3	1		2	
07/20/95	7		1	6	4	3	1	1	7	
08/02/95	8	2	1	6	4	3	1		5	
08/16/95	8	1	1	6	4	3	1	1	6	
08/30/95	10	2	1	6	5	3	1		4	
Mea	10	2	1	4	2	2	1	3	18	
Std. Dev	1	1	1	1	1			1	12	

SITE 8

Date (dd/mm/yy)	SO_4^{2-} (μeq/L)	NO_3^- (μeq/L)	Cl^- (μeq/L)	Ca^{2+} (μeq/L)	Mg^{2+} (μeq/L)	Na^+ (μeq/L)	K^+ (μeq/L)	H^+ (μeq/L)	$Ali^{(2-3)+}$ (μeq/L)	Mn^{2+} (μeq/L)
05/26/94	8			2	1	3	9	7	12	
06/08/94	9		2	2	1	2	2	6	11	
06/23/94	9		1	2	1	3	1	7	13	
07/06/94	9		1	2	1	3	1	6	11	
07/20/94	8		1	2	1	3	2	6	12	
08/02/94	8		1	2	1	3	2	6	10	
08/18/94	11			2	1	2		15	21	
08/31/94	8		2	2	1	3	1	5	9	
09/13/94	8		1	2	1	3	1	3	10	
09/28/94	11		1	2	1	1	1	19	24	
10/11/94	9		1	2	1	2	1	7	17	
10/26/94	8		2	2	1	2	1	6	12	
11/07/94	13		2	3	2	2	1	15	28	
11/22/94	11		2	3	1	2	1	7	18	
12/06/94	10		1	2	1	2	1	15	16	
12/20/94	12		1	2	1	2	1	7	14	
01/03/95	11		1	2	1	2	1	9	0	
01/16/95	8	1	1	2	1	1	1	9	12	
02/04/95	11		1	2	2	3	2	5	13	
02/18/95	12	2	1	2	2	3	2	5	13	
03/03/95	6	2	2	2	2	3	2	7	14	
03/16/95	10	1	1	2	1	2	2	9	12	
03/23/95	8	1	4	2	1	1	2	9	10	
03/31/95	10	1	2	2	1	2	2	7	12	
04/13/95	10	2	2	2	1	2	2	12	12	
04/27/95	11		1	2	1	2	2	9	10	
05/10/95	15		4	2	1	3	2	6	10	
05/24/95	10		2	2	1	3	2	6	7	
06/07/95	9		1	2	1	3	2	7	10	
06/22/95	9		1	2	2	3	2	5	9	
07/06/95	9	1	2	3	2	4	2	3	6	
07/20/95	11		1	3	2	2	1	7	12	
08/02/95	9		3	3	2	5	2	5	8	
08/16/95	9		1	2	2	3	1	5	9	
08/30/95	10		1	3	2	4	2	3	8	
Mea	10		2	2	1	3	1	8	12	
Std. Dev	1							3	5	

SITE 9

Date (dd/mm/yy)	SO_4^{2-} (μeq/L)	NO_3^- (μeq/L)	Cl^- (μeq/L)	Ca^{2+} (μeq/L)	Mg^{2+} (μeq/L)	Na^+ (μeq/L)	K^+ (μeq/L)	H^+ (μeq/L)	$Ali^{(2-3)+}$ (μeq/L)	Mn^{2+} (μeq/L)
05/26/94	5			3	2	2	1	3	4	
06/08/94	5		2	3	2	2	2	2	5	
06/23/94	4			3	2	3	1	2	4	
07/06/94	4			3	2	3		2	4	
07/20/94	4		1	3	2	3	2	2	3	
08/02/94	3	1	1	3	2	3	1	2	3	
08/18/94	8		1	5	3	3	1	6	9	
08/31/94	4		1	4	2	3	1	2	3	
09/13/94	4		1	3	2	3	1	1	3	
09/28/94	7		2	4	3	2	1	6	10	
10/11/94	7		1	4	2	3	1	2	5	
10/26/94	6		4	4	2	4	1	2	5	
11/07/94	9		2	5	3	3	1	3	8	
11/22/94	9		1	4	3	4	1	2	6	
12/06/94	7		1	4	2	2		5	8	
12/20/94	9		1	4	3	4	1	3	6	
01/03/95	9		1	4	2	3	1	3	16	
01/16/95	7	1		3	2	2	1	2	6	
02/04/95	9	1	1	4	3	4	1	1	5	
02/18/95	9	1	2	4	3	4	2	1	4	
03/03/95	9	1	2	4	3	4	2	2	5	
03/16/95	6	1	1	3	2	2	1	3	6	
03/23/95	1		1	3	2	2	1	3	6	
03/31/95	7	1	1	4	2	3	1	2	4	
04/13/95	10	1	1	3	2	3	1	3	6	
04/27/95	8		2	3	2	4	1	2	4	
05/10/95	7		1	3	2	3	1	2	4	
05/24/95	6		1	3	2	4	1	1	5	
06/07/95	5			3	2	3		2	6	
06/22/95	4	1		4	2	3	1	2	6	
07/06/95	4			4	2	3	1	1	5	
07/20/95	9		1	5	3	3	1	3	8	
08/02/95	4	1	1	4	2	3	1	1	7	
08/16/95	4		1	4	2	3		2	5	
08/30/95	4	1	1	4	2	3	1	1	4	
Mea	6		1	4	2	3	1	2	5	
Std. Dev	2							1	3	