Final Report

Episodic Acidification of Lakes in the Sierra Nevada

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May 30, 2002

California Air Resources Board Project #A132-048
Prepared for the California Air Resources Board

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Sickman, J. O., J. M. Melack, and J. L. Stoddard. In press-b. Regional analysis of inorganic-nitrogen yield and retention in high-elevation ecosystems of the Sierra Nevada and Rocky Mountains. *Biogeochemistry.*

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Sickman, J. O., A. Leyedecker, J. M. Melack, and M. T. Colee. In press-a. Do variable source-area dynamics control N export from high elevation catchments? *Water Resources Research*.

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Abstract

The lakes and streams of the Sierra Nevada mountains are vulnerable to acidic deposition because of the predominance of granitic rocks and thin acidic soils in their catchments, and the large quantity of precipitation in the region. Ten lakes and their watersheds were chosen for intensive monitoring. During two snowmelt and summer runoff seasons, automated samplers were installed at each lake outlet, along with stream gauging equipment and automated data recorders. Outlet samples were collected for chemical analysis, and discharge measurements were recorded. This study confirmed that nitrate is the key elements controlling episodic acidification in Sierran watersheds. This study also found that episodic acidification can occur in high elevation Sierran watersheds, but only in the most extreme conditions. Lake watersheds most likely to be affected by episodic acidification have extreme elevation, little or no soil development, low summer acid neutralizing capacity, and extensive granitic talus.

Executive Summary

Background

The ARB is responsible for establishing ambient air quality standards for the protection of ecosystems. The lakes and streams of the Sierra Nevada mountains are vulnerable to acidic deposition due to the predominance of granitic rocks and thin acidic soils in lake catchments, and the large quantity of precipitation in the region. Although most of the precipitation to the Sierras falls as very dilute snow, the precipitation during the spring, summer, and autumn is more acidic. Therefore, the relatively small loads of acidic deposition in Sierra snowpacks can supply high concentrations of acidic ions during snowmelt. Although the Sierra watersheds produce sufficient acid neutralizing capacity (ANC) to neutralize current levels of acid loading during summer and fall, the production of ANC is often only just sufficient to neutralize runoff acidity during the snowmelt season. In one extreme event, surface ANC values reached zero. ANC values at or near zero produce elevated concentrations of aluminum, in forms that are toxic to sensitive biota. The potential existence of episodically acidified lakes in the Sierra has important implications for the biological integrity of the lakes, as well as for the potential for future increases in emissions and deposition, especially of nitrogen.

Methods

Ten Sierra lakes and their watersheds were chosen for intensive monitoring. During the snowmelt and summer runoff seasons of 1993 and 1994, automated samplers were installed at each lake outlet, along with stream gauging equipment and automated data recorders. At the initiation of snowmelt each year, daily outlet samples were collected for chemical analysis, and hourly average discharge measurements were recorded. Samples from lake outlets were removed from the automated samplers at least once per week, and transported to the laboratory for measurements. Each sample was analyzed for pH, ANC, negative and positive ions, dissolved aluminum, and conductivity.

Results

During the first sampling season (1993), a pulse of nitrate during very early snowmelt was associated with negative ANC values at High Lake, demonstrating episodic acidification of a Sierra lake. At all other lakes, minimum ANC values were always above zero, and were associated with peak snowmelt runoff and maximum chemical dilution. Many lakes exhibited nitrate pulses, but in each case these where buffered by increases in positive ions, and none was associated with ANC minima. Results for the second field season were very similar to those of 1993. An analysis of the results showed that nitrate, and the process that controlled its export from high elevation watersheds, were key elements controlling episodic acidification in Sierra watersheds. Several of the watersheds export more nitrate during snowmelt than can be accounted for by snowpack concentrations. Inputs of nitrogen other than as snow, and storage of nitrogen in soil and/or talus, are plausible mechanisms for these observations. These results indicate that reduction of nitrogen oxide emissions in California should provide a benefit for the ecosystems of Sierra lakes that are vulnerable to acidification.

Conclusions

This study was designed to test whether the combination of (1) very base-poor lakes with (2) large volumes of relatively dilute snow is sufficient to produce acidic conditions during the early phases of snowmelt. As a result of evaluating several environmental features, several conclusions were drawn from this project. Episodic acidification can occur in high elevation Sierra watersheds, but only in the most poorly buffered lakes. Nitrate is released in a pulse during the early stages of snowmelt in almost all high-elevation watersheds. The highest amounts of nitrogen export, and the highest peak nitrate concentrations during snowmelt, are associated with the lowest amounts of soil cover in the watersheds. The mechanisms controlling nitrogen export, and nitrate pulses during snowmelt, are unique to the types of watersheds found at high elevations in the Sierra Nevada Mountains. Together with other studies, this work suggests that lake watersheds most likely to be affected by episodic acidification have extreme elevation, little or no soil, low acid neutralizing capacity in the summer, and extensive talus.

Introduction

The lakes and streams of the Sierra Nevada are vulnerable to acidic deposition because of the predominance of granitic rocks and thin acidic soils in their catchments, and the large quantity of precipitation in the region. Most of the precipitation to the Sierra Nevada falls as very dilute snow. When this is combined with the more acidic spring, summer, and autumn rain or wet snow, annual volume-weighted mean pH values of precipitation are between 5.2 and 5.5. Annual deposition ($meq \cdot m^{-2}$) ranges from 2 to 14 for H^+, 2 to 12 for NO_3^- and 1.5 to 13 for SO_4^{2-}.

Best available data suggest that Sierran watersheds produce sufficient acid neutralizing capacity (ANC) to neutralize current levels of H^+ loading during baseflow seasons (i.e., summer and fall; (Melack and Stoddard 1991, Melack et al. 1997). In many cases, however, the production of ANC is only just sufficient to neutralize runoff acidity during the snowmelt season. In one extreme event, for example (Emerald Lake during snowmelt in 1986), surface ANC values reached zero µeq/L (Sickman and Melack 1989). Acid Neutralizing Capacity values at or near zero produce elevated concentrations of aluminum, in forms that are toxic to sensitive biota (Baker and Christensen 1991).

The Sierran hydrologic cycle is strongly dominated by snowfall and snowmelt, with 90-99% of the annual loads falling as snow between the months of November and April. Through the process of preferential elution, the relatively small loads of acidic deposition in Sierran snowpacks can supply high concentrations of acidic anions during snowmelt (Johannessen and Henriksen 1978, Williams and Melack 1991). In the Sierra Episodes Study, summarized in this report, we set out to test whether the combination of (1) very base-poor lakes with (2) large volumes of relatively dilute snow is sufficient to produce acidic conditions during the early phases of snowmelt. The potential existence of episodically acidified lakes in the Sierra has important implications for the biological integrity of the lakes, as well as for the potential for future increases in emissions and deposition, especially of nitrogen.

Methods

On the basis of existing summer chemical and watershed data, 10 lakes and their watersheds were chosen for intensive monitoring (Table 1). During the snowmelt and summer runoff seasons of 1993 and 1994, automated samplers (ISCO Model 2900) were installed at each lake outlet, along with stream gauging equipment and automated data recorders. At the initiation of snowmelt in each year, daily outlet samples were collected for chemical analysis, and hourly average discharge measurements were recorded. An example of the type of data produced is shown in Figure 1 for High Lake.

Lake outlet samples were removed from the automated samplers a minimum of once per week, and transported to the laboratory for immediate filtering, and pH and ANC measurements. Each sample was analyzed for pH, ANC, acid anions (NO_3^-, SO_4^{2-}, and Cl^-), basic cations (Ca^{2+}, Mg^{2+}, Na^+, and K^+), dissolved aluminum and conductivity. For details on the sample handling, chemical methods, and quality assurance protocols utilized throughout the study, please refer to any of the papers included in this report. Results for all chemical analyses are listed in Appendix 1 (for 1993) and Appendix 2 (for 1994).

Results

The paper by Stoddard (1995) details the results of the first sampling season. At High Lake, a pulse of NO_3^- during very early snowmelt was associated with negative ANC values – this is the first observation of episodic acidification of any lake in the Sierra. At all other lakes (the paper uses Treasure Lake as a typical example) minimum ANC values were always above zero, and were associated with peak snowmelt runoff and maximum chemical dilution. Many lakes exhibited NO_3^- pulses (though smaller in magnitude than at High Lake), but in each case these where buffered by increases in base cations (particularly Ca^{2+}), and none was associated with ANC minima.

Results for the second field season (1994) were very similar to those of 1993. Again, High Lake was the only site to exhibit episodic acidification (Figure 2, Appendix 2). All other sites showed minimum ANC values at the point of maximum snowmelt runoff and dilution.

It became clear after the first year of the study that NO_3^-, and the process that controlled its export from high elevation watersheds, were key elements controlling episodic acidification in Sierran watersheds. Stoddard (1995) points out that several of the watersheds export more NO_3^- during snowmelt than can be accounted for by snowpack concentrations. Inputs of nitrogen other than as snow (e.g., rain and dry deposition during the non-winter months), and storage of N in soil and/or talus, are plausible mechanisms for these observations. Each of the other papers included in this report explores these mechanisms.

Sickman et al. (In press-b) use data from watersheds in both the Sierra Nevada and the Colorado Rocky Mountains to explore potential mechanisms controlling nitrogen export. Nitrogen concentrations in deposition (snow and rain) in the Rockies are roughly twice those in the Sierra, and several of the watersheds export large amounts of NO_3^-, especially during snowmelt. Sickman et al. evaluated eight environmental features (catchment elevation, slope, aspect, roughness, area, runoff, soil cover and nitrogen loading) to test whether they were significantly correlated with nitrogen yield, nitrogen retention and peak NO_3^- concentrations during snowmelt.

For the Sierra Nevada, elevation and soil cover had significant ($p<0.1$) Pearson product moment correlations with catchment nitrogen yield, mean NO_3^- and peak snowmelt nitrate concentrations, as well as dissolved inorganic nitrogen (DIN) retention rates. Log-linear regression models were developed using soil cover as the independent variable; the models explained 82% of the variation in catchment nitrogen retention, 92% of the variability in mean NO_3^- and 85% of snowmelt peak NO_3^-. The highest amounts of nitrogen export, and the highest peak NO_3^- concentrations during snowmelt, were associated with the lowest amounts of soil cover in the watersheds.

The clear importance of soil in controlling NO_3^- export in the Sierra led Sickman et al. (In press-a) to explore the use of Variable Source-Area (VSA) models in explaining nitrogen dynamics. Variable-source area regulation of N flushing from soils was proposed by Creed et al. (1996) to explain variations in nitrogen export from temperate forests in Ontario, Canada. In these catchments, NO_3^- in the upper soil layers was flushed when infiltrating event water (snowmelt) caused the water table to rise to the soil surface, generating return flow. The authors found that the amount of NO_3^- flushed was proportional to the catchment's flushing time and proposed that the length of the flushing period was regulated by topography. I.e., more complex terrain leads to a greater lateral expansion of the nitrate-contributing source areas with time ($d\text{VSA}/dt$) and, therefore, a longer flushing time and greater nitrate export.

There have been few tests of the NO_3^- VSA concept in other catchments, but steep, alpine watersheds, which typically lack a well-developed groundwater system and are dominated by shallower flowpaths, may be prime candidates for using VSA models to help explain the timing and amount of NO_3^- during snowmelt.

Using a large set of alpine and subalpine catchments in the Sierra, Sickman et al. (in press b) found two different relationships between catchment flushing times and annual nitrogen export: (1) catchments with greater than 20% soil coverage had below average nitrogen export and flushing times proportional to annual export (consistent with the VSA hypothesis) and (2) catchments with less than 20% soil cover and abundant talus had above average nitrogen export and flushing times inversely related to annual export (inconsistent with the VSA hypothesis). These data suggest that, while subalpine catchments have functional analogues at lower elevations, nitrogen export from steep high-elevation catchments, with little soil and abundant talus, are regulated by processes that may be specific to alpine ecosystems.

Conclusions

The Sierra Episodes Project has demonstrated that:

1. Episodic acidification can occur in high elevation Sierran watersheds, but only in the most extreme conditions (e.g., in the most poorly buffered lakes);

2. NO_3^- is released in a pulse during the early stages of snowmelt in almost all high elevation watersheds;

3. in most cases, NO_3^- pulses are not associated with minimal ANC values, which typically occur during the period of maximum snowmelt runoff and maximum dilution;

4. the highest amounts of nitrogen export, and the highest peak NO_3^- concentrations during snowmelt, are associated with the lowest amounts of soil cover in the watersheds;

5. the mechanisms controlling nitrogen export, and NO_3^- pulses during snowmelt, are unique to the types of watersheds found at high elevations in the Sierra, with little soil development and large amounts of talus; and

6. combined data and analyses from the Sierra Episodes Project and other studies suggest a profile for lake watersheds most likely to be affected by episodic acidification: extreme elevation (associated with higher rates of deposition), little or no soil development, low baseflow (summer) ANC, with extensive granitic talus.

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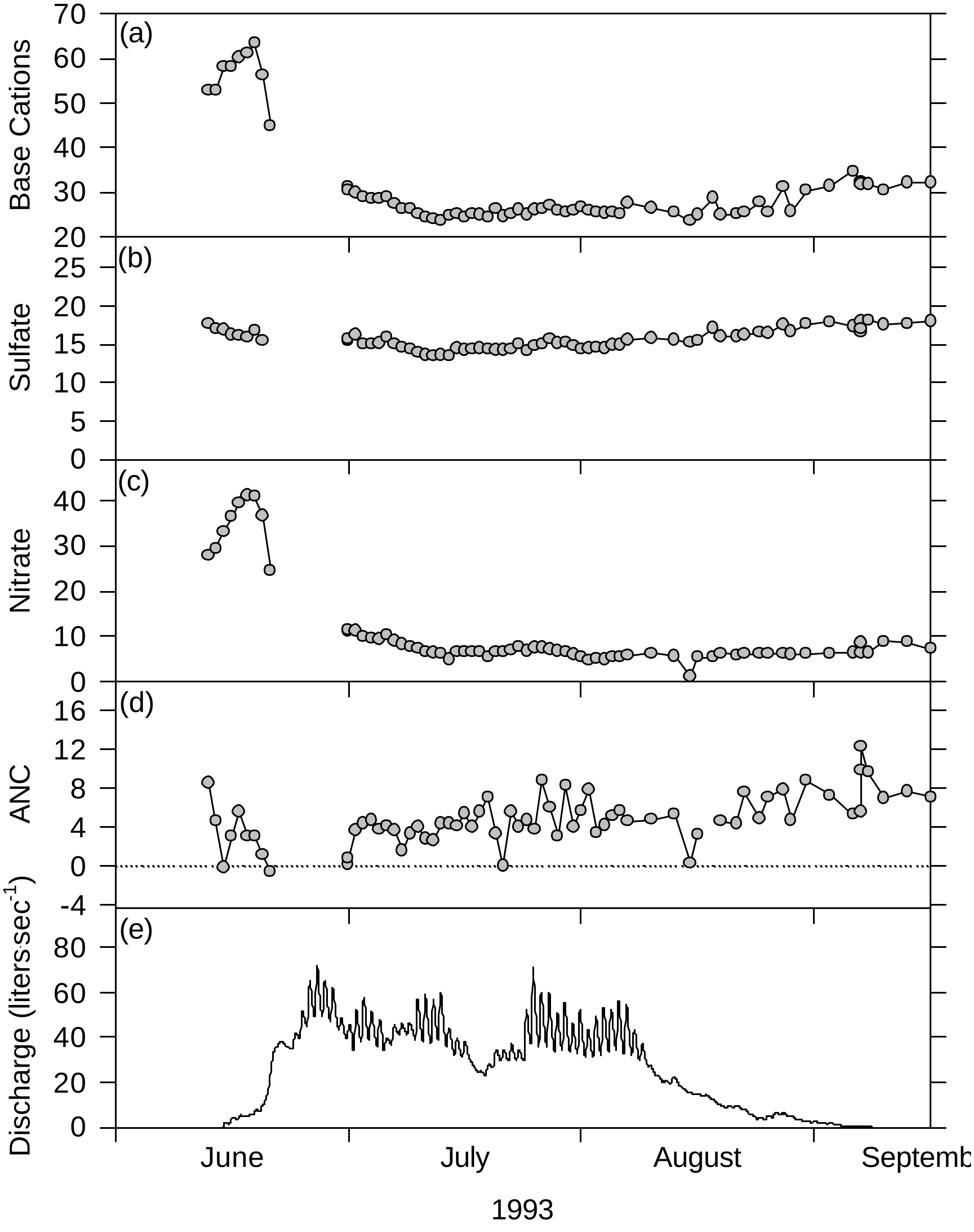
Table 1. Lakes included in the Sierra Episodes Project and their location and watershed information.

	ANC (µeq/L)	Latitude	Longitude	Watershed Area (ha)	Lake Area (ha)	Location
HIGH LAKE (Long Lake Watershed)	1.0	37-23-50"	118-46'00"	16.9	1.00	John Muir
LOW LAKE (Ruby Lake Watershed)	27.2	37-24'30"	118-46'16"	224.7	0.16	John Muir
MILLS LAKE (Ruby Lake Watershed)	29.7	37-24'07"	118-46'01"	177.2	2.38	John Muir
RUBY LAKE	54.0	37-24'50"	118-46'15"	424.0	12.60	John Muir
SPULLER LAKE	48.0	37-56'42"	119-17'06"	43.0	0.90	Hall RNA
UPPER TREASURE LAKE (Long Lake Watershed)	20.4	37-23'30"	118-46'00"	177.6	2.70	John Muir
M-1 (Marble Fork Watershed)	40.8	36-36'25"	118-39'30"	58.5	0.55	Sequoia
M-2 (Marble Fork Watershed)	26.4	36-36'30"	118-38'50"	74.4	0.50	Sequoia
M-3 (Marble Fork Watershed)	24.6	36-36'20"	118-38'45"	46.5	0.50	Sequoia
EMERALD LAKE	25.6	36-35'49"	118-40'30"	120.0	2.72	Sequoia

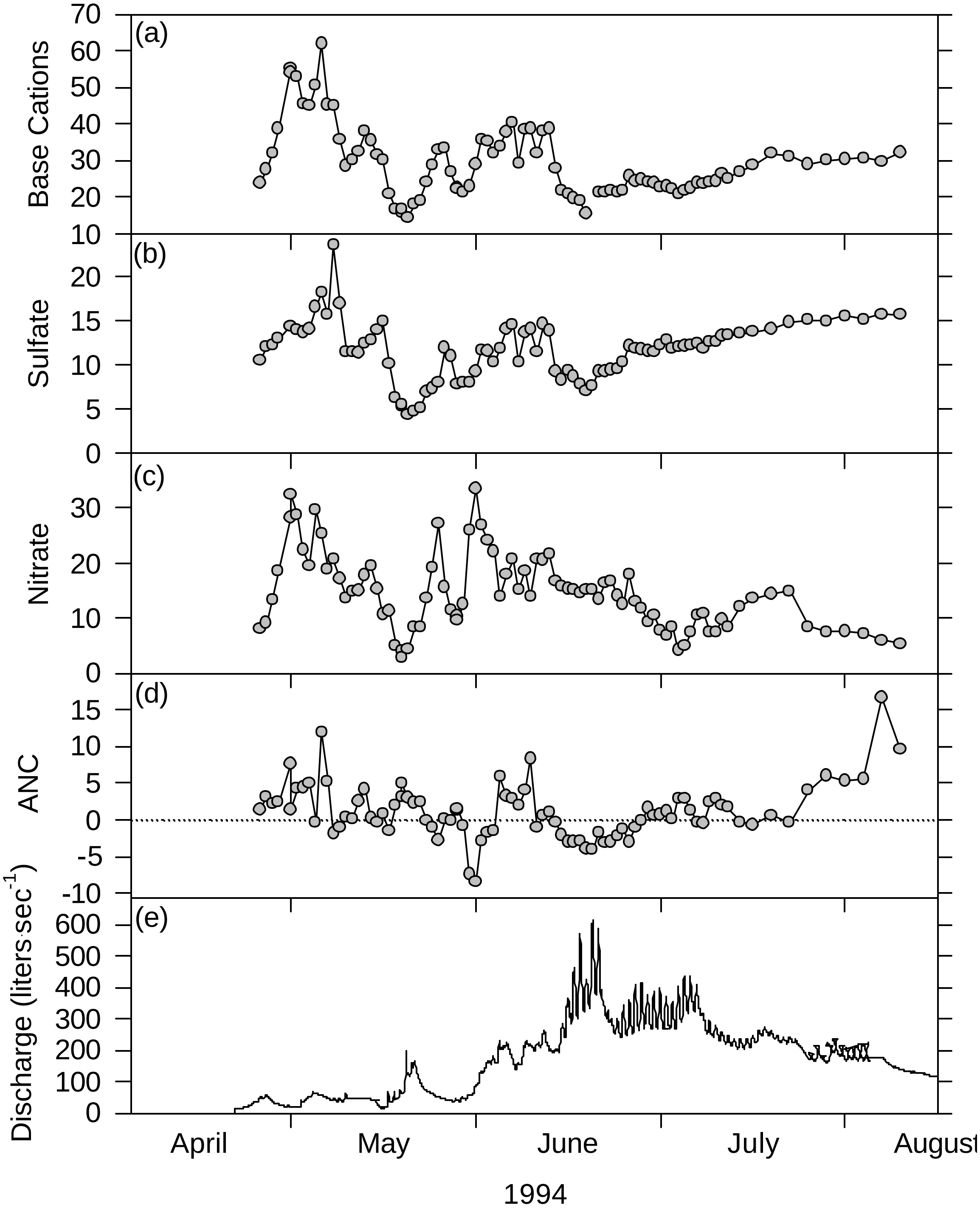
Figure 1. Time series data High Lake during snowmelt seasons of 1993 for: (a) base cations (sum of calcium, magnesium, sodium and potassium); (b) sulfate; (c) nitrate; (d) acid neutralizing capacity; and (e) discharge at the lake outlet. All concentrations are μeq/L.

Figure 2. Time series data High Lake during snowmelt seasons of 1994 for: (a) base cations (sum of calcium, magnesium, sodium and potassium); (b) sulfate; (c) nitrate; (d) acid neutralizing capacity; and (e) discharge at the lake outlet. All concentrations are μeq/L.

High Lake


(a)
Base Cations
70
60
50
40
30
20
(b)
Sulfate
25
20
15
10
5
0
(c)
Nitrate
40
30
20
10
0
(d)
ANC
16
12
8
4
0
-4
(e)
Discharge (liters·sec^{-1})
80
60
40
20
0
June
July
August
Septemb
1993

High Lake



(a)
(b)
(c)
(d)
(e)
Base Cations
70
60
50
40
30
20
10
Sulfate
20
15
10
5
0
Nitrate
30
20
10
0
ANC
15
10
5
0
-5
-10
Discharge (liters·sec^{-1})
600
500
400
300
200
100
0
April
May
June
July
August
1994

EPISODIC ACIDIFICATION DURING SNOWMELT OF HIGH ELEVATION LAKES IN THE SIERRA NEVADA MOUNTAINS OF CALIFORNIA*

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Abstract. Atmospheric loads to dilute lakes in the Sierra Nevada mountains of California are very low, and fall almost entirely as snow. When acidic anions preferentially elute from melting snow, these low loads may nontheless be enough to acidify low ANC lakes. Two of the ten lakes included in the Sierra Episodes Study are discussed here: High Lake, the only lake in the study to become acidic during snowmelt; and Treasure Lake, typical of the remainder of the lakes. All lakes exhibited increases in NO_3^- concentrations during early snowmelt; these were accompanied by increases in base cations, primarily Ca^{2+}. In the first few days of snowmelt, NO_3^- concentrations at High Lake increased more rapidly than concentrations of base cations, resulting in ANC values below zero. Export of both NO_3^- and SO_4^{2-} from the watersheds exceeded the inputs from the snowpack, suggesting that other sources (e.g., watershed minerals, stored inputs from the previous summer, transformations of other inputs) of these anions are important.

Keywords: Sierra Nevada, alpine lakes, episodic acidification, nitrate, sulfate

1. Introduction

The Sierra Nevada mountains of California contain hundreds of dilute lakes, located at elevations up to 4000 m, with watersheds underlain by slowly-weathering granite and granodiorite bedrocks (Melack and Stoddard, 1991). As a group, the lakes and streams of the Sierra are extremely base-poor and classically “acid sensitive.” Surveys indicate that no lakes are chronically acidic (Melack *et al*., 1985; Eilers *et al*., 1987), perhaps due to low rates of acidic deposition, relative to areas downwind of industrial areas. Typical rates of sulfur and nitrogen deposition are near 1 kg ha^{-1} yr^{-1} (Williams and Melack, 1991a).

The Sierran hydrologic cycle is strongly dominated by snowfall and snowmelt, with 90-99% of the annual loads falling as snow between the months of November and April. Through the process of preferential elution, the relatively small loads of acidic deposition in Sierran snowpacks can supply high concentrations of acidic anions during snowmelt (Johannessen and Henriksen, 1978; Williams and Melack, 1991b). In the Sierra Episodes Study we set out to test whether the combination of (1) very base-poor lakes with (2) large volumes of relatively dilute snow is sufficient to produce acidic conditions during the early phases of snowmelt.

2. Methods

We selected 10 lake watersheds for monitoring in this study (Table I), based on their predicted sensitivity to episodic acidification, and their winter accessibility. A simple index of sensitivity was used to rank the roughly 400 Sierran lakes with existing data, according to the likelihood that they would experience episodic acidification. The index assumes that 80% of the snow chemical load (a function of watershed area) melts in the first 20% of the snowmelt season, and titrates the ANC pool in the lake (a function of baseflow ANC and lake volume).

We conducted snow surveys at the point of maximum snow accumulation in 1993 (early April), including both depth transects and snow pits. In each pit we measured two profiles of snow density (Elder *et al*., 1991), and collected two 50 cm interval snow cores for chemistry. We combined aerial photographs, used to delineate snow-free areas, with the snow survey data and used simple kriging (Golden Software Inc., 1994) to map the distribution of snow and snow water equivalence (SWE) throughout each basin.

Automated samplers (ISCO Model #2900) were used to collect daily lake outlet samples. In almost all cases, the ISCOs collected their first samples within a few hours of the onset of snowmelt. Pressure transducers and data loggers were used to record hourly stage data. We used a constant salt injection technique (Kilpatrick and Cobb, 1985) to measure stream discharge and to develop rating curves for each site.

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*Full Citation: Stoddard, J. L. 1995. Episodic acidification during snowmelt of high elevation lakes in the Sierra Nevada Mountains of California. Water Air and Soil Pollution **85**:353-358.

TABLE I
List of lakes included in this study, with their watershed characteristics.

Lake	Latitude	Longitude	Elevation (m)	Watershed Area (ha)	Lake Area (ha)	ANC ($\mu eq \cdot L^{-1}$)
High L.	37°23'50"	118°46'00"	3603	14.8	1.0	1
Treasure L.	37°23'30"	118°46'00"	3420	175.2	2.7	20
Mills L.	37°24'07"	118°46'01"	3554	177.2	2.4	30
Low L.	37°24'30"	118°46'16"	3444	224.7	0.2	27
Ruby L.	37°24'50"	118°46'15"	3390	424.0	12.6	54
Spuller L.	37°56'42"	119°17'06"	3131	43.0	0.9	48
False L.	37°56'42"	119°17'06"	3164	37.6	0.4	44
M-1	36°36'25"	118°39'30"	3078	105.8	0.6	41
M-2	36°36'30"	118°39'30"	3188	89.6	0.5	26
M-3	36°36'20"	118°38'45"	3249	66.6	0.5	25

Sampling crews transported water samples to field laboratories within one week of collection. Within 2 days, lab analysts made measurements of pH, ANC and conductivity. Filtered aliquots (0.4 µ Nuclepore filters) were then analyzed according to U.S. EPA methods for acidic deposition research (U.S. Environmental Protection Agency, 1987).

3. Results and Discussion

The discussion of results from this study will focus on 2 of the 10 lakes, one whose snowmelt chemistry typifies the majority of high elevation lakes in the study (Treasure Lake), and one whose response is more extreme (High Lake).

The kriged and summed SWE data were applied to snowpack chemistry to compute the loads to each watershed that came in the form of snow in 1993 (Table II). Greater amounts of snow in the High Lake watershed led to higher loads than at Treasure Lake. However, by most standards the loadings of nitrogen (23 to 34 $eq \cdot ha^{-1} \cdot yr^{-1}$, or 0.3 to 0.5 kg $N \cdot ha^{-1}\ yr^{-1}$) and sulfur (15 to 23 $eq \cdot ha^{-1} \cdot yr^{-1}$, or 0.2 to 0.4 kg $S \cdot ha^{-1}\ yr^{-1}$) are very low.

TABLE II
Inputs and outputs of major ions and of nitrogen (combined NO_3^- and NH_4^+) in 1993 for Treasure and High Lakes. Units are $eq \cdot ha^{-1} \cdot yr^{-1}$. Loads are from snow only.

Watershed	NO_3^-	NH_4^+	Nitrogen	SO_4^{2-}	Cl^-	Base Cations
Treasure Lake						
Inputs	13.1	10.0	23.1	15.2	9.4	22.2
Outputs	51.3	0.9	52.1	43.3	9.9	264.2
High Lake						
Inputs	19.4	14.8	34.1	22.5	13.9	32.8
Outputs	84.5	2.2	86.7	143.5	14.8	268.2

At Treasure Lake the outflow was dry throughout the winter; the first water appeared on April 29 with the onset of snowmelt, and the first sample was collected within two hours. The rate of melt remained very low until mid-May (Figure 1g) and peak runoff occurred in early July. The ANC of the lake outlet began declining immediately (Figure 1a). The ANC minimum (ca. 20 $\mu eq \cdot L^{-1}$) coincided with peak runoff and minimum values of base cations (Figure 1b), nitrate (Figure 1c), sulfate (Figure 1d), pH (Figure 1e), and Al (Figure 1f). At no point did Treasure Lake become acidic.

At High Lake, snowmelt began in mid-June (Figure 2). Values of ANC fell to zero and to below zero (-1 µeq·L^{-1}) twice in the first 10 days (Figure 2a). Unlike Treasure Lake, the ANC minimum at High Lake coincided with maximum concentrations of base cations (Figure 2b), NO_3^- (Figure 2c) and Al (Figure 2f). After this initial 10-day period, snow melted rapidly enough that the ISCO sampler at the lake outlet was knocked over and one week's worth of samples was lost. Values for SO_4^{2-} (Figure 2d) and pH (Figure 2e) showed little relative variation.

The snowpack loads and snowmelt exports of major ions from each watershed are shown in Table II. With the exception of NH_4^+ and Cl^-, the watersheds are net sources of all major ions during snowmelt. Both NO_3^- and SO_4^{2-} appear to be supplied either from the watershed, or from deposition occurring outside of the season accounted for by snowpack loads. Including NH_4^+ deposition as a source of NO_3^- for export does not balance the nitrogen budget, nor can the inclusion of winter dry deposition, since it is already included in measurements of the snowpack. Small watershed sources of SO_4^{2-} are relatively common in the Sierra (Stoddard, 1987; Melack and Stoddard, 1991). The High Lake watershed exports more SO_4^{2-} per unit area than Treasure Lake, which may contribute to the lower baseflow ANC in High Lake, but not to episodic acidification. Significant inputs from nitrogen fixation (the only watershed source of nitrogen) seem unlikely, especially in the High Lake watershed where there is no visible vegetation, and talus and bedrock outcrops dominate the landscape. A more likely mechanism is the storage of nitrogen inputs from rain and dry deposition during the previous summer, and subsequent export during snowmelt. Concentrations of NO_3^- and NH_4^+ in rain can be very high in the Sierra (Williams and Melack, 1991a), and typically small rain volumes may increase the likelihood that inputs would be stored in the watershed (e.g., in soil pockets under talus fields).

4. Conclusions

Episodic acidification appears to occur only in Sierran watersheds with the most extreme characteristics. Only one lake in this study exhibited negative ANC values during snowmelt. High Lake had the lowest baseflow ANC of any lake in the study, and the High Lake watershed produced snowmelt runoff that was both later and more rapid than any other, perhaps due to a combination of high elevation and small watershed size (Table I). These factors combine to produce increases in NO_3^- during snowmelt that exceed concurrent increases in base cations. All other lakes had more prolonged snowmelt seasons and their ANC minima coincided with peak runoff.

Loads of acid anions in the snowpack cannot account for the amounts of NO_3^- and SO_4^{2-} that leave either of the lakes during snowmelt. I hypothesize that watershed sources of SO_4^{2-}, and unmeasured inputs of nitrogen from summer rain and dry deposition, contribute to exports during snowmelt.

5. References

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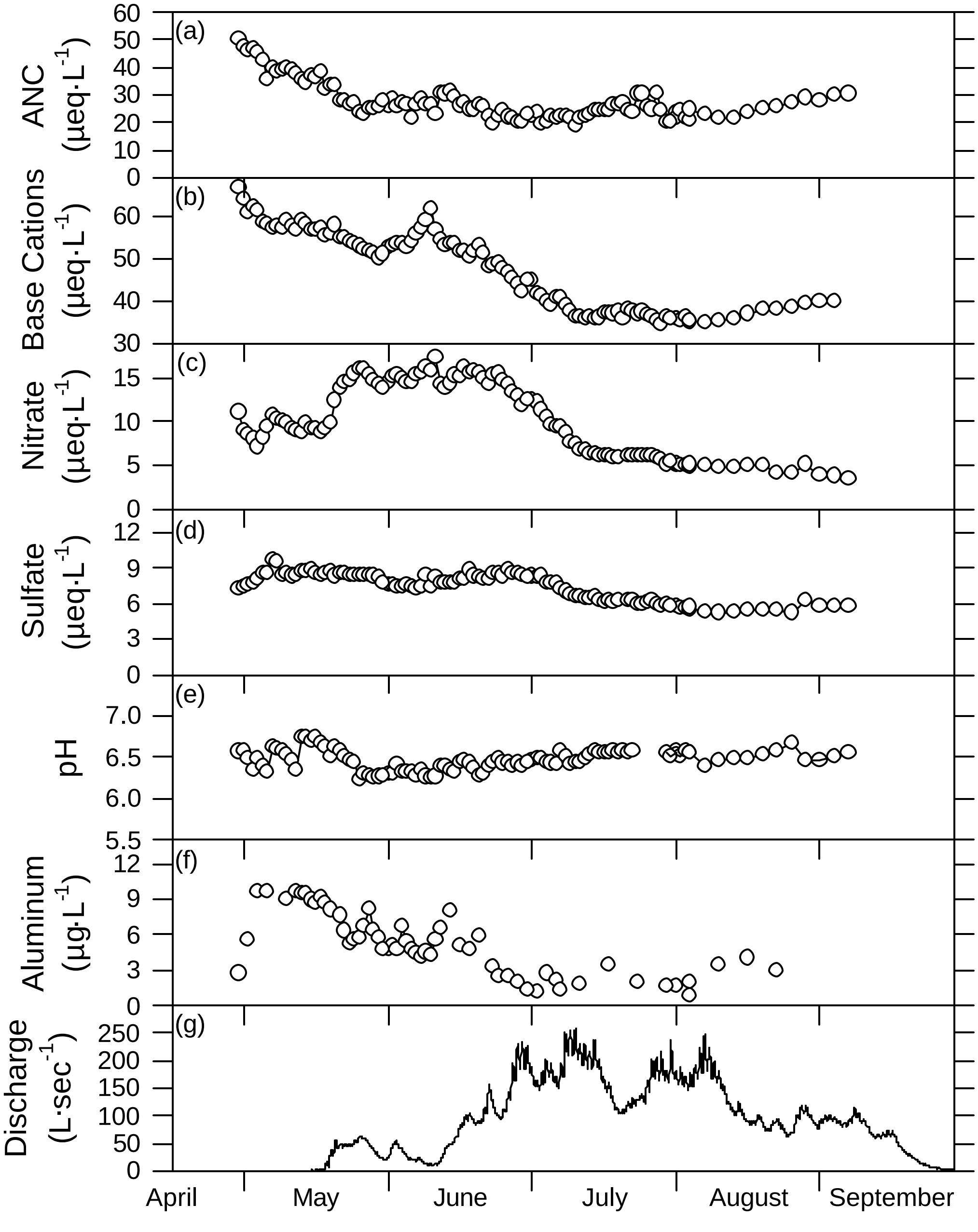

Fig. 1. Time series of major ions and discharge in Treasure Lake during snowmelt in 1993.

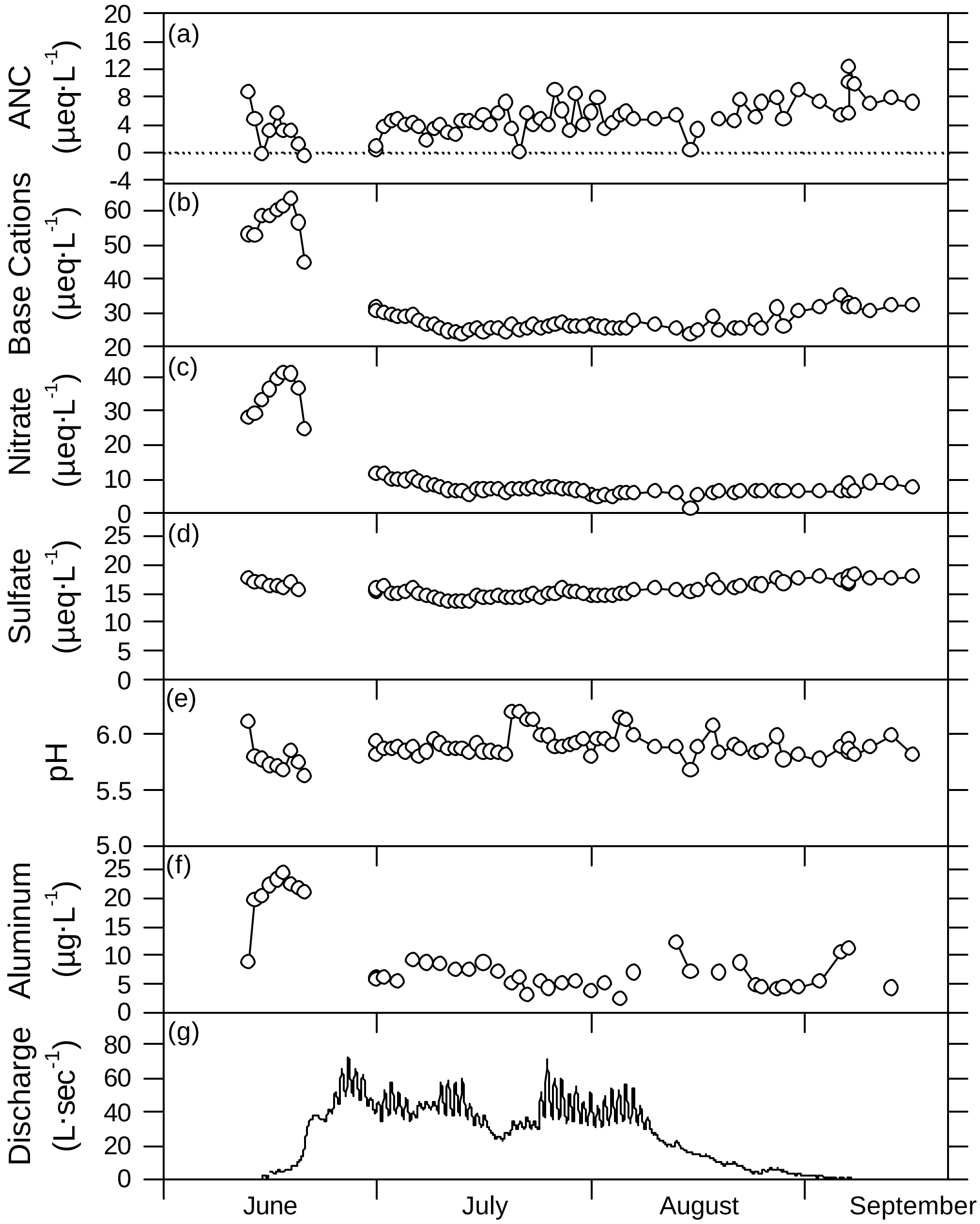

Fig. 2. Time series of major ions and discharge in High Lake during snowmelt in 1993.

Regional analysis of inorganic-nitrogen yield and retention in high-elevation ecosystems of the Sierra Nevada and Rocky Mountains[*]

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September 15, 2000

Key words: Sierra Nevada, Rocky Mountains, nitrogen, nitrogen retention, nitrogen yield, catchment features

[*]Full Citation: Sickman, J. O., J. M. Melack, and J. L. Stoddard. In press-b. Regional analysis of inorganic-nitrogen yield and retention in high-elevation ecosystems of the Sierra Nevada and Rocky Mountains. *Biogeochemistry.*

Abstract

Yields and retention of inorganic nitrogen (DIN) and nitrate concentrations in surface runoff are summarized for 28 high elevation watersheds in the Sierra Nevada, California and Rocky Mountains of Wyoming and Colorado. Catchments ranged in elevation from 2475 to 3603 m and from 15 to 1908 ha in area. Soil cover varied from 5% to nearly 97% of total catchment area. Runoff from these snow-dominated catchments ranged from 315 to 1265 mm per year. In the Sierra Nevada, annual volume-weighted mean (AVWM) nitrate concentrations ranged from 0.5 to 13 µM (overall average 5.4 µM), and peak concentrations measured during snowmelt ranged from 1.0 to 38 µM. Nitrate levels in the Rocky Mountain watersheds were about twice those in the Sierra Nevada; average AVWM NO_3^- was 9.4 µM and snowmelt peaks ranged from 15 to 50 µM. Mean inorganic N (DIN) loading to Rocky Mountain watersheds, 3.6 kg ha^{-1} yr^{-1}, was double the average measured for Sierra Nevada watersheds, 1.8 kg ha^{-1} yr^{-1}. Dissolved inorganic nitrogen yield (DIN: NO_3^- + NH_4^+) in the Sierra Nevada, 0.69 kg ha^{-1} yr^{-1}, was about 60% that measured in the Rocky Mountains, 1.1 kg ha^{-1} yr^{-1}. Net inorganic N retention in Sierra Nevada catchments was 1.2 kg ha^{-1} yr^{-1} and represented about 55% of annual DIN loading. DIN retention in the Rocky Mountain catchments was greater in absolute terms, 2.5 kg ha^{-1} yr^{-1}, and as a percentage of DIN loading, 72%.

A correlation analysis using DIN yield, DIN retention and surface water nitrate concentrations as dependent variables and eight environmental features (catchment elevation, slope, aspect, roughness, area, runoff, soil cover and DIN loading) as independent variables was conducted. For the Sierra Nevada, elevation and soil cover had significant ($p<0.1$) Pearson product moment correlations with catchment DIN yield,

AVWM and peak snowmelt nitrate concentrations and DIN retention rates. Log-linear regression models were developed using soil cover as the independent variable; the models explained 82% of the variation in catchment DIN retention, 92% of the variability in AVWM nitrate and 85% of snowmelt peak NO_3^-. In the Rocky Mountains, soil cover was significantly ($p<0.05$) correlated with DIN yield, AVWM NO_3^- and DIN retention expressed as a percentage of DIN loading (%DIN retention). Catchment mean slope and terrain roughness were positively correlated with steam nitrate concentrations and negatively related to %DIN retention. About 91% of the variation in DIN yield and 79% of the variability in AVWM NO_3^- were explained by log-linear models based on soil cover. A log-linear regression based on soil cover explained 90% of the variation of %DIN retention in the Rocky Mountains.

Introduction

Ecosystem sensitivity to atmospheric N deposition may be particularly acute in seasonally snow-covered catchments of the western United States. Short growing seasons, extensive and deep snow cover and sparse vegetation result in low N retention capacity and a large temporal disconnection between N availability (spring snowmelt) and vegetative N demand (summer). Atmospheric N deposition, while lower than in regions of the eastern United States and Europe, has the potential to alter N-limited aquatic and terrestrial ecosystems in the high elevations of the Sierra Nevada and Rocky Mountains. Episodic declines in acid neutralizing capacity (ANC) have been observed in most catchments studied and results largely from ionic dilution following an initial pulse of nitrate and base cations (Melack and Stoddard 1991, Stoddard 1995); episodic acidification (ANC values < 0) may occur when these nitrate pulses are sufficiently large (Stoddard 1995, Leydecker et al. 1999). Increasing N deposition to alpine and subalpine ecosystems in the Colorado Front Range has resulted in increases of inorganic N in surface waters and current modeling studies suggest that alpine tundra and subalpine forests may experience nitrogen saturation at N deposition greater than 4-6 kg-N ha^{-1} yr^{-1} (Baron et al. 1994, Williams et al. 1996, Heuer et al. 2000, Williams and Tonnessen in press). To date, negative impacts from N deposition appear to be restricted to the Front Range, but as urbanization increases in and near the Rocky Mountains the extent of N-affected ecosystems may increase. In the Sierra Nevada, recent shifts in limitation of algal growth at Lake Tahoe and Emerald Lake have been associated with alterations in N supply (Jassby et al. 1994, Sickman and Melack 1998).

Given the current status of high elevation ecosystems in the western United States and the likelihood that N deposition will increase (Galloway et al. 1994), it would be valuable to predict, on a regional basis, the N retention capacity of these ecosystems. If critical and target loads for nitrogen are to be determined, data from a regionally extensive set of catchments is required (Williams 1997, Williams and Tonnessen in press). To date, however, there have been few process-level studies on N cycling in alpine/subalpine watersheds (e.g., Brooks et al. 1996 & 1998, Meixner et al. 1998 & 1999) of sufficient detail to model accurately the impact of increased N loading. Furthermore, it will be difficult to extrapolate results from plot-scale modeling studies to larger regions despite recent improvements in biogeochemical modeling (Baron et al.1994, Kiefer and Fenn 1997, Magill et al. 1997) given the potentially large temporal and spatial variability of N sources, sinks and transformations at the landscape scale.

In contrast, there is a wealth of catchment-scale data on the input and loss of nitrogen from alpine and subalpine watersheds in the Sierra Nevada and Rocky Mountains. We propose that this information can provide a basis for predicting the N retention capacity of high elevation ecosystems over large areas. Nitrogen budgets for alpine and subalpine watersheds in the western United States have been accumulating since the early 1980s and the dataset is now of a size that allows for a statistical analysis of environmental and catchment features influencing the N retention capacity of high elevation ecosystems. Similar analyses, using variables such as runoff, catchment area and elevation, have been successful in predicting elemental fluxes and chemical concentrations in surface runoff across large regions and over a broad range of conditions (Meybeck 1982, Hedin et al. 1995, Howarth et al. 1996, Lewis et al. 1999).

Using previously published and unpublished data from high elevation watersheds in the western United States, we investigate the relationships between catchment N export and retention and seven watershed variables: elevation, watershed area, runoff, % soil cover, inorganic nitrogen loading, and catchment aspect, slope and roughness. Our goal is to test the hypothesis that nitrogen yields, retention capacity and surface water chemistry (NO_3^-) can be predicted on the basis of general environmental and terrain variables in high elevation ecosystems. If successful, these variables will provide a basis for assessing the sensitivity of high elevation ecosystems to increased N deposition and may prove useful in regional-scale modeling of N biogeochemistry and setting of critical nitrogen loads.

Methods

Our statistical analyses are restricted to alpine and subalpine catchments of the Sierra Nevada and Rocky Mountains and to inorganic nitrogen budgets, i.e., inputs and losses of nitrate and ammonium. Little data are available on the fluxes of organic nitrogen in high elevation catchments, although there is growing evidence that organic N is an important component in atmospheric deposition and ecosystem nitrogen losses (Church 1999, Neff et al. in press). Current studies show that forested watersheds at low to middle elevations have high N retention rates and little DIN yield and, for that reason, are not included in our analyses.

Chemical data used were drawn primarily from previously published watershed N budgets. For some Sierra Nevada catchments, fluxes were computed based on unpublished records of stream chemistry, stream discharge and loading and methods from Melack et al. (1998) (Table 1). In all cases the raw data underlying the N budgets were evaluated for completeness and quality. All catchments had comprehensive estimates of annual inorganic N loading, in wet deposition and in some instances dry deposition (Table 1). In cases where no dry deposition estimates were available we conservatively assumed that dry N loading was 25% of wet inorganic N deposition; we based this percentage on dry deposition measurements made at Niwot Ridge and Emerald Lake (Sievering et al. 1996, Williams et al. 1995, Sickman et al. in press). Outflow DIN losses are based on at least biweekly chemistry during snowmelt runoff (the period of greatest N yield) and periodic sampling during the remainder of the year; for the majority of the Sierra Nevada catchments, automated samplers were used to collect samples every 1-2 days during snowmelt runoff. Data had to span at least one annual cycle to be included and in most cases several years were available (Table 1).

Data from sub-regions of larger catchments were included in the analysis (e.g., Andrews Creek and Icy Brook) if measurements of N fluxes and surface water chemistry were available. A lower limit of 10 ha was used as a cut-off for subcatchments.

Independent Variables

Watershed features used as independent variables in the statistical analyses, i.e., elevation, area, runoff and soil cover, were chosen because they were easily obtainable and are surrogates for complex environmental processes that are known to control N cycling in catchments. These processes include both the size of and fluxes between the major watershed nitrogen pools, the transit time and pathways for water movement and the degree of soil and groundwater flushing. Elevation (at catchment outlet), for example, captures several catchment features including, vegetation biomass and type, length of growing season and vegetative N demand (Fisk et al. 1997). Area is a proxy for time and distance of N transport in a watershed (Lovett et al. 2000) and may provide a surrogate for hydrologic flowpaths and variable source-area dynamics; all of which exert control on nitrogen cycling in watersheds (Creed and Band 1998). Runoff reflects the amount of flushing experienced by catchment soil, the amount of water available to vegetation and soil moisture properties that may affect N processes such as denitrification; runoff is also highly correlated with precipitation. The rationale behind including soil cover in the analysis is based on several recent studies suggesting that soil microbial processes control N cycling in high elevation ecosystems (Brooks et al. 1999, Brooks and Williams 1999, Heuer et al. 1999). Soil cover was computed as a percentage of total catchment area. Soil depths and development are most likely positively related to soil area, thus soil area may approximate soil volume, soil N content and the magnitude of soil microbial N processes. Inorganic nitrogen loading (expressed in units of kg ha^{-1} yr^{-1}) was included, because it provides a basis for testing whether current N loads are affecting surface water chemistry and N yields, and sets the baseline against which potential future increases in N loading may be gauged.

Three additional terrain indices, mean slope, mode aspect and mean roughness, were computed from the U.S. Geological Survey National Elevation Dataset (NED), and used as independent variables in the correlation analysis. The NED is a seamless, 30 m-resolution, gridded elevation dataset that has been filtered to minimize artifacts. Slope was calculated by fitting a plane to the elevation values of a 3x3 neighborhood of cells around each NED cell; the direction the fitted plan faces is the aspect for the cell. Terrain roughness (Andrew et al. 1999) reflects variation in slope and aspect at each cell of the NED and was computed as follows:

$$R_{ij} = ((V_s/V_m)*100) + ((A_n/8)*100)$$

Where R_{ij} is the roughness at cell row i, column j; V_s is the standard deviation of slope in a 3x3 cell neighborhood around cell ij; V_m is the maximum standard deviation in slope for any 3x3 cell neighborhood for all of the 28 study watersheds; and A_n is the number of different aspect classes (binned into eight, 45 degree sectors) found within each 3x3 cell neighborhood. Any NED cell with a high variation in slope and many different aspect classes within the 3x3 cell neighborhood would have a high roughness value. The mean roughness value for each of the 28 watersheds was used in the correlation analysis.

Slope was included in the correlation analyses as a measure of the steepness of the catchment, which may influence hydrologic residence time or flow-routing in mountainous terrain (Clow et al. 2000). Aspect controls the input and distribution of solar radiation in a catchment (Dozier and Frew 1990) and may capture variations in the relative timing of snowmelt (Cline et al. 1998) and patterns of soil moisture among the study sites which could effect N cycling (Sickman et al. in press). Mean roughness is a measure of the relative terrain complexity among the study sites and may provide an index for time and distance of N transport in a watershed, hydrologic flowpaths and residence time, and variable source-area dynamics.

Dependent Variables

Five dependent variables were used in the statistical analyses: dissolved inorganic nitrogen yield (DIN: $NO_3^- + NH_4^+$), AVWM nitrate concentration, peak snowmelt nitrate concentration, and inorganic nitrogen (DIN) retention. In cases where there was more than one year of data, we averaged the annual estimates to obtain a single value for each variable. Averaging was necessary in order to balance the influence of catchments with many years of data (i.e., Emerald and Loch Vale) with catchments with few years of data.

DIN yield is the amount of dissolved inorganic nitrogen exported via catchment outflow and was expressed in kg-N ha^{-1} yr^{-1} (i.e., nitrogen fluxes are expressed in terms of the mass of elemental N and not compound mass). With the exception of Green Lakes #4, DIN yield was computed by the authors of the original study. DIN yield at Green Lakes #4 was computed from raw data (discharge and chemical concentrations) obtained from the Niwot Ridge LTER database. DIN yield estimates from the Hourglass catchments include only nitrate losses and were included because ammonium concentrations in high elevation watersheds are typically at or near the detection limit (Landers et al. 1985).

Annual volume-weighted mean nitrate concentrations are discharge-weighted averages of outflow nitrate concentrations. In the case of Snake River and Deer Creek, AVWM nitrate was computed from nitrate yields and catchment runoff. For Green Lakes #4 we computed AVWM nitrate from raw data (discharge and chemical concentrations) obtained from the Niwot Ridge LTER database. Peak nitrate concentrations were determined from time-series data during snowmelt runoff when available; the average of all available years was used for each catchment. The intensity of chemical sampling allowed us to make accurate estimates of peak concentrations at all catchments since peak concentrations occurred only slightly before peak runoff (i.e., 1 to 3 weeks). Nitrate concentrations were included in the analyses because they provide a means for judging the N saturation status of catchment and the degree of strong acid-anion acidification during snowmelt. These variables are integrally related to the N retention capacity of watersheds.

Inorganic nitrogen retention was computed by subtracting DIN yield from DIN loading. For the analyses we expressed retention both in absolute terms (net DIN retention: kg-N ha^{-1} yr^{-1}) and as a fraction of loading (% DIN retention: % of DIN loading). Expressing retention as a fraction of loading allowed us to compare the N retention efficiency of catchments with widely varying rates of N loading.

Correlation and Regression Procedures

Pearson product moment correlations were used to measure the strength of association between the dependent and independent variables within the Sierra Nevada and Rocky Mountain datasets. The Pearson correlations were tested with Bonferroni's method to evaluate the statistical significance of the associations. Due to the conservative nature of the test we assigned a threshold of $p<0.1$ to determine whether variables were significantly correlated. Once significant correlations were identified, linear and log-linear models were developed between the dependent and independent variables using standard regression and multiple regression procedures. In the multiple regression analysis, multi-colinearity between independent variables was assessed by computing a variance inflation factor (VIF) to ensure that independent variables were not significantly correlated to one another.

We also performed a regression tree analysis (least squares fitting method: Systat version 7.01) on the pooled dataset (Rocky Mountain plus Sierra Nevada, n=26 to 28 depending on dependant variable – see Table 3) to determine whether the watershed and terrain variables could explain differences in dependant variables at larger spatial scales. Owing to our relatively small sample size, tree growth was severely constrained. Regression trees were limited to 5 end-nodes with a minimum of 4 catchments per end-node. The minimum proportional reduction in error allowed at any tree-split was 0.1.

General Site Descriptions

The catchments used in the analysis are located in the alpine and subalpine zones of the Sierra Nevada of California and Rocky Mountains of Colorado and Wyoming. They capture a wide range of the geographic, geologic and hydrochemical variation among high elevation watersheds in the western United states (Tables 1 & 2). For the Sierra Nevada watersheds, elevations ranged from 2,475m to 3,603m and the mean elevation was 3,135m (Table 1). The Rocky Mountain catchments were of similar elevation with an overall average outlet elevation of 3,186m (Table 2). Soil coverage in the Sierra Nevada watersheds tended to be lower than in the Rocky Mountains; in all of the Sierra catchments, including those with higher soil coverage such as Crystal, most of the watershed was above treeline. The overall average soil percentage in Sierra Nevada catchments was 23% and ranged from 5 to 53% (Table 1). In the Rocky Mountains, average soil cover was 59% with a range from 5 to 97% (Table 2). In catchments with low soil coverage, talus and bedrock comprise the majority of the watershed area.

Mean slope of the study catchments ranged from 10° to 29° in the Sierra Nevada and from 6° to 35° in the Rocky Mountains; the overall mean slope in each data set was 20° (Tables 1 & 2). Catchments in both mountain ranges had a wide variety of aspects (Tables 1 & 2). On average the Sierra Nevada catchments had higher terrain roughness (mean = 39) than the Rocky Mountain watersheds (mean = 34), although the most topographically complex watershed, Andrews Creek (R=47), is located in the Rocky Mountains (Tables 1 & 2).

At all sites, precipitation fell predominately as snow during the winter and the accumulated snowpack underwent little melt or evaporative losses until spring snowmelt (Williams and Melack 1991, Leydecker and Melack 1998, Leydecker and Melack in press, Baron 1992). Rainfall was sparse, comprising on average about 10-25% of annual precipitation. The snowmelt period accounted for nearly all stream discharge and solute export; winter snowmelt in the Sierra Nevada accounted for less than 5% of annual runoff (Melack et al. 1998); we assume a similar relationship is true for the Rocky Mountains owing to comparable environmental conditions. Average catchment runoff was slightly higher in the Sierra Nevada (mean 882 mm) than in the Rocky Mountains (755 mm).

The Emerald, Pear, Topaz and M-site watersheds are all located along the western slope of the southern Sierra Nevada within the Tokopah Valley of Sequoia National Park. This valley comprises the headwaters of the Marble Fork of the Kaweah River. Crystal and Spuller watersheds lie along the eastern slope of the central Sierra. Lost watershed is situated near the crest of the Sierra Nevada near Lake Tahoe. The remainder of the Sierra Nevada watersheds are located along the eastern slope within Rock Creek canyon. Mills and Low are nested subcatchments within the Ruby watershed.

Loch Vale watershed and its two subcatchments, Icy Brook and Andrew Creek, are located in Colorado Front Range of Rocky Mountain National Park. East and West Glacier watersheds are in the Glacier Lakes Ecosystem Experiment Site (GLEES) area of southeastern Wyoming. Rabbit Ears Pass watershed is situated in the North Fork Walton Creek basin southeast of Steamboat Springs, Colorado. The two Hourglass catchments are tributaries of the Cache la Poudre River and lie outside the northern boundary of Rocky Mountain National Park. Green Lake #4 is one of a series of lakes located near

Niwot Ridge in the Colorado Front Range near Denver, Colorado. East St. Louis and Fool Creek are study areas in the Fraser Experimental Forest (FEF), 137 km west of Denver. The Snake and Deer Creek catchments are located west of the continental divide near FEF.

Results

Nitrate Chemistry, DIN Yields and DIN Retention

On the whole both AVWM and peak nitrate concentrations were higher in the Rocky Mountains than in the Sierra Nevada. Average AVWM nitrate for the Sierra Nevada watersheds was 5.4 µM and for the Rocky Mountain catchments it was 9.4 µM (Table 3). Peak snowmelt concentrations averaged 14 µM in the Sierra and 27 µM in the Rocky Mountains. There was, however, a large overlap in these concentrations. Several of the highest elevation sites in the Sierra Nevada, High Lake, Low Lake and the M-sites, had nitrate concentrations greater than Rocky Mountain catchments located in Wyoming and west of the continental divide i.e., the GLEES watersheds, the Snake River and Dear Creek watershed. For the entire dataset, Loch Vale watershed and its subcatchments had by far the highest AVWM nitrate levels. Peak concentrations were greatest at Rabbit Ears Pass in the Rocky Mountains, 50 µM, and at High Lake watershed in the Sierra Nevada, 38 µM.

Atmospheric deposition of nitrogen in the Rocky Mountain dataset, 3.6 kg ha^{-1} yr^{-1}, was double the rate measured for the Sierra Nevada catchments, 1.8 kg ha^{-1} yr^{-1} (Table 3). Atmospheric N deposition to catchments along the Front Range of the Rocky Mountains has increased over the past decade and catchments within these regions are at or near nitrogen saturation (Williams et al. 1996). At Niwot Ridge, N loading as high as 7 kg ha^{-1} yr^{-1} has been measured in recent years (Fenn et al. 1998).

DIN export from the Rocky Mountain catchments, 1.1 kg ha^{-1} yr^{-1} , was greater than the rate of 0.69 kg ha^{-1} yr^{-1} measured for the Sierra Nevada watersheds. The Loch Vale watersheds and subcatchments stand out with yields in the range of 1.7 to 3.1 kg ha^{-1} yr^{-1}.

In the Sierra Nevada, relatively high DIN yields, 1.2 to 1.5 kg ha^{-1} yr^{-1}, were measured at High Lake, Low Lake and Mills; these catchments are adjacent to one another and located along the eastern slope of the Sierra Nevada in the Rock Creek drainage. Other Rock Creek catchments such as Ruby and Treasure, had yields similar to watersheds along the western slope of the Sierra: <1.0 kg ha^{-1} yr^{-1}.

Despite higher rates of N loading, the Rocky Mountain catchments were more efficient at retaining DIN than the Sierra Nevada watersheds. Overall net DIN retention for the Rocky Mountain dataset was 2.5 kg ha^{-1} yr^{-1}, which represents 72% of loading. In the Sierra Nevada, overall DIN retention was 1.2 kg ha^{-1} yr^{-1} or 55% of DIN loading. At several locations, including the GLEES watersheds, catchments in the Fraser Experimental Forest (East St. Louis and Fool Creek), and the Crystal, Lost and Topaz watersheds, DIN retention was greater than 90%. At the other extreme, three Sierra Nevada watersheds, High, Low and Mills, had no retention or had a net export of DIN, i.e., losses of DIN exceeded inputs. The negative retentions at Low Lake watershed are within the expected errors for the N budgets; however, the net DIN export at High Lake is well outside these errors (errors for fluxes were estimated by combining error in analytical chemistry, waters fluxes and sampling frequency using standard error propagation techniques, see Sickman et al. in press and Melack et al. 1998). For the Rocky Mountain sites, the Loch Vale catchments retained the lowest percentage of DIN loading, i.e., 21 to 56%.

Correlations and Regression Analysis

Prior to using the independent variables in the correlation and regression analyses we tested for significant correlations among these variables (Tables 4 & 5). For the Sierra

Nevada, elevation was found to be negatively correlated with DIN loading (Pearson r = -0.755, Bonferroni p = 0.032) and positively correlated with catchment roughness (Pearson r = -0.71, Bonferroni p = 0.079). The relationship between elevation and roughness is intuitive and demonstrates that topographic complexity generally increases with elevation in the Sierra Nevada. The elevation:DIN loading correlation is probably an artifact of the concentration of watersheds in the Rock Creek basin (i.e., Ruby, Low, Mills, Treasure, High) which are at high elevation but receive lower rates of DIN loading. The correlation between elevation and soil cover in the Sierra Nevada (Pearson r=-0.693, p=0.118) was nearly significant and suggests that soil cover generally decreases with elevation.

In the Rocky Mountains soil cover was negatively correlated with both mean slope (Pearson r = -0.885, Bonferroni p = 0.008) and mean roughness (Pearson r = -0.933, Bonferroni p = 0.001), suggesting that steeper, more topographically complex watersheds contain less soil (Table 5). Mean slope was also positively correlated with mean roughness (Pearson r = 0.778, Bonferroni p = 0.048).

The correlation analysis showed that soil cover was strongly related to stream nitrate concentrations, DIN yield and DIN retention for watersheds in both the Sierra Nevada and Rocky Mountains (Tables 6 & 7). In addition, elevation showed strong correlations with nitrate concentrations and DIN retention for Sierra Nevada catchments. No significant relationships were found between elevation and any dependent variables in the Rocky Mountains. As was the case with the correlation between DIN loading and elevation, the cluster of sites in the Rock Creek basin is probably responsible for the negative correlation between DIN loading and nitrate concentrations observed within the Sierra dataset (Table 6).

Mean slope was positively correlated with the DIN yield, and AVWM nitrate and mean roughness were positively related to AVWM nitrate in the Rocky Mountains; both of these topographic indices were negatively correlated with % DIN retention (Table 7). In contrast, there were no statistically significant correlations between the topographic indices and dependant variables in the Sierra Nevada (Table 6).

DIN yield was positively related to elevation in the Sierra Nevada, although the linear model did not explain most of the variation in DIN yield (Figure 1a). Soil cover was negatively correlated with DIN yield. Linear models using soil cover were much better predictors of DIN yield for both the Sierra Nevada and Rocky Mountain watersheds; 82-91% of the variation in yield was explained by the log-linear equations (Figure 1b). The slopes of the regression equations between soil cover and DIN yield were significantly different ($p<0.05$) and show that DIN yield in the Rocky Mountains increased more rapidly as soil cover declined.

Net DIN retention was inversely related to elevation and positively related to soil cover in the Sierra dataset (Figures 2a & b). No significant relationship was found between net DIN retention and catchment features in the Rocky Mountains. For the Sierra Nevada catchments, asymptotes of DIN retention (~2.0 kg ha^{-1} yr^{-1}) occurred in catchments below ca. 3000 m elevation and >25% soil cover. Zero or negative retentions were found in high elevation catchments with sparse soils.

In the Sierra Nevada, %DIN retention generally decreased with elevation (Figure 3a). The effect of soil cover on DIN retention was similar between the Sierra Nevada and

Rocky Mountains when DIN retention was expressed as a percentage of DIN loading (Figure 3b). Percent DIN retention declined with decreasing soil cover in a logarithmic fashion with a high degree of overlap between the two mountain ranges. Natural logarithmic models using soil cover explained about 87% and 90% of the variation in %DIN retention for the Sierra Nevada and Rocky Mountains, respectively. The slopes of the equations were significantly different ($p<0.05$) and show that retention increased more rapidly in the Sierra Nevada with expanded soil cover than in the Rocky Mountains. Based on the log-linear models, 80% retention was reached in the Sierra Nevada with catchment soil cover of 30%, whereas this threshold was reached in the Rocky Mountains when soils covered 60% of catchment area.

Annual AVWM nitrate concentrations were predictable on the basis of elevation and soil cover in the Sierra Nevada and on the basis of soil cover in the Rocky Mountains (Figures 4 a and b). In the Sierra Nevada, AVWM nitrate increased with elevation ($R^2 = 0.62$). In both mountain ranges, AVWM nitrate decreased in a logarithmic fashion as soil cover increased; these models explained about 80-90% of the variation in AVWM. The increase in AVWM nitrate with declining soil cover was more rapid in the Rocky Mountains.

The regression-tree results are summarized in Table 8. In the case of DIN yield, peak nitrate and %DIN retention, DIN loading and soil cover were first and second variables, respectively, in tree growth; these models explained from 72 to 87% of the variation in the dependant variables. A five node tree using DIN loading, elevation and soil cover explained 92% of the variation in DIN retention. For AVWM nitrate, mean roughness was the primary split variable in the regression tree.

Discussion

Landscape Controls on N Cycling in Alpine and Subalpine Ecosystems

At the catchment scale, soil cover and elevation had substantial predictive value for stream chemistry and N fluxes in alpine and subalpine ecosystems of the Rocky Mountains and Sierra Nevada. High nitrate concentrations and low inorganic nitrogen retention rates were measured in watersheds with little soil and at high altitudes. Neither catchment runoff or area, which were hypothesized to act as surrogates for hydrologic controls on N cycling, had statistically significant relationships to the watershed-scale N parameters used in our analysis. More sophisticated indices of catchment topography (i.e., slope, aspect and roughness) were only useful in predicting nitrate concentration and DIN retention in the Rocky Mountains; however, multiple regression analysis showed that most of these relationships were due to covariance of slope and topographic roughness with soil cover (see Table 5).

Our findings are consistent with general ecological theories of environmental controls on biological sequestration and release of nitrogen in alpine soils (Stanton et al. 1994, Fisk et al. 1998, Beiber et al. 1998, Brooks and Williams 1999). Elevation influences the extent and timing of snow cover (snow regime) in high elevation systems. Snow regime in turn, through its effect on moisture and temperature patterns in soils, exerts control on plot-to-catchment scale rates of microbial N transformations in soils and N sequestration by plants (Schimel et al. 1996, Brooks et al. 1999, Sickman et al. in press). Lack of soil-cover constrains N uptake in both higher plants and soil microbial populations by limiting the absolute size of these N pools in the Rocky Mountain and Sierra Nevada. In the Sierra Nevada, increasing elevation results in shorter growing seasons for plants through longer snow-lie and colder and perhaps drier soil conditions, thereby reducing plant N uptake. Short-term N storage (in labile N pools) is enhanced during years with high snowfall, because N mineralization and nitrification in snow-covered soils continue later into the spring as a result of delayed snowmelt.) The combination of lower N uptake by plants and greater labile N in soil results in higher stream nitrate concentrations and lower DIN retention during years with deep, late-melting snowpacks (Sickman et al. in press). For the Sierra Nevada watersheds, we hypothesize that low soil cover and high altitude worked synergistically in curtailing DIN retention by reducing the size of catchment N reservoirs and by decreasing the total flux between these reservoirs and atmospheric N deposition.

Soil cover exerted a quantitatively similar effect on net DIN retention and AVWM nitrate concentrations in both the Sierra Nevada and Rocky Mountains (Figures1b and 4b). The similarity of the Sierra Nevada and Rocky Mountain equations indicate a consistent effect of soil N processes across the alpine/subalpine regions of the western United States and over a 5 to 6 fold variation in DIN loading rates. The intercepts of the Rocky Mountain equations were about double the Sierra Nevada intercepts, which may reflect the overall 2x higher rate of DIN loading to alpine systems in the Rocky Mountains.

Current DIN yields and AVWM nitrate levels in the Rocky Mountain watersheds may be a forecast of conditions in the Sierra Nevada if atmospheric DIN loading were to double. No simple relationship likely exists between DIN deposition and stream water nitrate at a single catchment or on a year-to-year basis because there are so many factors governing the susceptibility of alpine watersheds to N saturation. However, our regional analysis suggests there may be a relationship between loading and N dynamics at a large spatiotemporal scale and that site specific changes in concentration are lost when examining regional variations. A similar argument is made by Williams and Tonnessen (in press) to justify their estimates of critical N loads in the Rocky Mountains. Annual variation in nitrate concentrations is driven by hydrological and biological factors at the catchment-scale (e.g., Creed and Band 1998, and the present study), but the influence of deposition may emerge when looking at N dynamics at the regional or continental scale over a number of years.

Recent studies of functionally-similar catchments have demonstrated that intersite differences in nitrate export behavior can exist without variations in DIN loading rates (Creed and Band 1998, Lovett et al. 2000, Clow and Sueker 2000). The regions examined in these analyses ranged in area from 10 to 2000 km^2. Similarly, in our analysis, DIN loading was not positively correlated with nitrate concentrations of DIN yield in either the Sierra Nevada or Rocky Mountains; regions on the order of 50,000 km^2 in area. However, when we examined these relationships at a larger spatial scale with the regression-tree analysis (> 1,000,000 km^2), small-scale variability was eliminated and large-scale simplicity emerged. DIN loading explained more of the differences in N dynamics for the combined data sets than any of the other terrain or topographic variables considered (Table 9). In an analysis of undisturbed watersheds in North America, Lewis (in press) found a positive relationship between catchment DIN loading and DIN yield; this study examined watersheds in a region >5,000,000 km^2. These findings suggest that the concept of representative elementary area (REA), proposed by Wood et al. (1988) may apply when examining the regional variability of N dynamics. The REA can be considered the scale at which a statistical treatment of spatial variability can replace a deterministic description. For empirical modeling of the relationship between DIN loading and yield or stream nitrate concentrations, we suggest that studies must examine regions greater than 100,000 km^2 to form valid conclusions.

Topographic and Terrain Modeling of N Biogeochemistry

Current concerns over the impact of nitrogen deposition on natural ecosystems has led to the need for evaluating global N biogeochemical cycles and for predicting the sensitivity of ecosystems over large regions (e.g., Fenn et al., 1998, Williams and Tonnessen, in press). In particular, there has been considerable effort to: 1) relate simple catchment features such as area, elevation and runoff to N yield from river basins in the context of global biogeochemical cycles (Meybeck, 1982, Howarth et al., 1996, Lewis et al., 1999, Lewis, in press) and 2) use more complex terrain parameters (e.g., slope, aspect, bedrock geology, vegetation, soil area, DIN deposition and land use) to predict N yield, retention and surface water nitrate concentrations in smaller watersheds (Creed and Band, 1998, Clow and Sueker, 2000, Sickman et al., in press). The goal of both types of analyses is to develop empirical models to describe complex biogeochemical processes that can currently only be deterministically modeled at small scales.

Empirical models based on catchment features have had mixed success in predicting stream nitrogen concentration in small catchments. Clow and Sueker (2000) were able to explain 97% of the variation in nitrate chemistry of nine subalpine catchment in Rocky Mountain National Park on the basis of regression equations based on catchment slope and surficial geology (i.e., extent of talus). However, when these equations were tested with existing synoptic stream-survey data from the Rocky Mountains (Western Lake Survey) the model could only explain 19% of the variation in nitrate concentrations. The authors attribute the model's poor performance to the fact that the synoptic-survey data contain a high proportion of small, high-elevation catchments with limited areas of subalpine soils compared to the calibration data. We would also, suggest that the data used to develop the regression equations were from an area (i.e., 10 km^2) below the REA for modeling stream nitrate concentration from topographic or terrain variables, hence the equations could not be scaled to larger regions of the Rocky Mountains. Catchment land-cover was used by Cooper et al. (2000) in modeling long-term stream chemistry in the Tywi catchment of South Wales, United Kingdom. In this study, the authors developed empirical relationships between stream chemistry and landscape types (i.e., based on catchment soil and vegetation) and used these relationships along with the spatial distribution of landscape types and a stream-mixing algorithm to model stream chemistry over a 2000 km^2 region. The coefficient of determination in a regression between measured and modeled nitrate concentrations was 0.65.

Artificial neural networks (ANN) were used by Lek et al. (1999) to predict stream DIN and TN concentration at 927 sites throughout the United States that were impacted by non-point source pollution. Independent variables used as inputs to the ANNs included catchment area, precipitation, runoff, livestock density and various landscape descriptors (forest, wetland, urban, agricultural). The ANNs were validated using hold-out data (i.e., data not used in the training procedure) and were shown to explain about 70% of the variation in stream N concentrations.

Lovett et al. (2000) found that variations stream nitrate concentrations among 39 streams in the Catskill Mountains of New York could not be explained by differences in catchment DIN loading, watershed topography or groundwater inputs. Instead, differences among the watersheds in forest composition which were induced by past land-use practices were believed to have produced the observed variation in nitrate concentrations. However, it should be noted that the variety of topography and DIN loading in these watersheds was much lower than in the current study and in the previously mentioned modeling studies; the region examined may be below the REA for modeling stream nitrate concentrations from DIN loading or topography. Thus, care must be taken in scaling the findings of Lovett et al. (2000) to larger montane regions of the United States (cf. Stoddard et al. 1998 and 1999).

Current N Saturation Status in Rocky Mountains and Sierra Nevada

Overall catchment DIN retention is higher in the Rocky Mountain watersheds than in the Sierra Nevada. We suggest that this difference is due primarily to greater soil cover in the Rocky Mountains and not due to greater rates of DIN retention per unit soil area. We base this conclusion on the relationship between DIN retention and soil cover which demonstrates that Sierra Nevada catchments with 20 to 40% soil cover are retaining equal amounts and percentages of DIN to catchments in the Rocky Mountains with >60% soil cover (Figures 2b and 3b). While it is possible that variations in climate and soil properties explain these differences, the data may imply that soils in the Rocky Mountains are less N limited because of higher rates of DIN loading. Alternatively, environmental conditions in the Rocky Mountains may be more severe than in the Sierra Nevada (e.g., greater extent of frozen soils), therefore terrestrial ecosystems in the Rocky Mountains may be less able to prevent N losses. Current ecological theory suggests that terrestrial communities are N limited because of N losses that are not under control of biota [Vitousek and Field, 1999]; these losses include leaching of dissolved organic N and denitrification [Vitousek et al., 1998]. The persistence of N limitation in high elevation ecosystems and the inability of biotic communities to prevent episodic nitrate losses may be related to microbial and hydrologic processes which conspire to induce temporal and spatial disconnections between inorganic N availability and demand.

Stoddard (1994) provided a framework to assess the degree to which ecosystems are affected by N deposition that is based on seasonal patterns in surface water nitrate concentrations. Our analyses suggest that rates of catchment-scale DIN retention are also indicative of N-saturation status and correspond well with this framework. Four stages were used in Stoddard's framework to describe the N saturation status of watersheds. At Stage 0, maximum spring episode concentrations are less than precipitation concentrations and growing season concentrations are near the detection limit. Watersheds that meet this criterion include the Crystal, Topaz, Lost, and Marble Fork basins in the Sierra Nevada and East Glacier, Dear Creek, East St. Louis and Fool Creek Alpine basins in the Rocky Mountains. Inorganic nitrogen retention for these stage 0 catchments ranged from 80-100%.

At the next step in the sequence towards N-saturation, Stage 1, nitrate concentrations in spring episodes exceed concentrations in precipitation and there is a delay in the decline of nitrate levels to later in the growing season. In the Sierra Nevada, catchments at Stage 1 of N-saturation would include Spuller, Ruby, Pear, and Emerald. Examples in the Rocky Mountains would include West Glacier. These catchments have DIN retention rates in the range of ca. 70-80%.

Stage 2 of N-saturation includes higher episodic concentrations and elevated nitrate concentrations well into and through the growing season. In the Sierra Nevada, the M-sites and Treasure watersheds can be classified at this stage. These catchments retained from ca. 20 to 60% of DIN loading. Stage 2 watersheds in the Rocky Mountains include Green Lakes #4, Rabbit Ears Pass, Snake River and the Loch Vale watersheds. These Rocky Mountains basins had variable rates of %DIN retention; the overall range was from ca. 20-75%.

Stage 3 of N-saturation differs from stage 2 in that the watershed becomes a net source of N rather than a sink. Two watersheds in the Sierra meet this criterion, High and Low, and one catchment, Mills, is on the verge of stage 3. In all three of these catchments DIN export equals or exceeds DIN inputs from atmospheric deposition. In the case of Low, negative DIN retention is within the expected errors of the N budgets, hence it is possible that the catchment is also still on the verge of stage 3. In the case of High the amount of net DIN export from the basin, is beyond expected errors in flux estimates. Some of the net export can explained by organic nitrogen in precipitation, but this input is more than balanced by organic and particulate nitrogen losses from the basin (Sickman et al. in press).

The conceptual model of Stoddard (1994) is based on data from forested temperate watersheds, primarily in the Northeastern U.S. and Europe. At first exposure, it may seem dubious to apply Stoddard’s N saturation stages to alpine watersheds, where the basins are above timberline, soils are thin (when present at all) and the annual hydrologic cycle is dominated by snow accumulation and rapid melt. Yet much of the recent data from alpine watersheds suggests strongly that the same processes that Stoddard used to explain the progression from Stage 0 to Stage 3 in forested watersheds are controlling N export from the alpine zone. In forested watersheds, N is largely immobilized by biotic uptake in soils {Tietema, 1998 #1566; Nadelhoffer, 1995 #1365}, especially the organic layer of soils {Gundersen, 1998 #1392}. In alpine watersheds, organic soils seem to play a role similar to the one they play in forested watersheds (as partially indicated by the relationships between N retention and soil cover reported in this paper), as do talus fields (Williams et al. 1997, Williams et al.1995), although they are largely unrecognizable to most scientists as soils. Studies indicate that the NO_3^- leaching from watersheds during snowmelt has an isotopic signature attributable to soil transformation (e.g., dominated by nitrification, rather than by atmospheric isotope ratios), in both forested <u>and</u> alpine watersheds (Kendall et al. 1995). It seems likely that similarities in N behavior between forested and alpine watersheds outweigh the dissimilarities. The types of pools and processes governing N retention and N leaching are nearly identical; it is only the size of the pools that differ. Smaller N pools in the limited soils of alpine watersheds create the potential for nitrogen saturation to occur at deposition rates that seem trivial when compared to those in the eastern U.S. and Europe.

Nitrogen deposition along the eastern slope of the Sierra Nevada is less than 1.5 kg ha^{-1} yr^{-1}. This rate of N loading is low compared to current inputs to other North American catchments experiencing adverse effects of N deposition (Fenn et al. 1998). At the High watershed, episodic acidification occurred during snowmelt (ANC < 0) and net export of ANC was exceeded by hydrogen ion export (Stoddard 1995, Sickman and Stoddard unpublished data). The Ruby watershed is adjacent to the High catchment and receives similar levels of N deposition, yet it did not experience acidic episodes and was a strong sink for N loading (Sickman and Melack 1998, Melack et al. 1998).

Differences in N cycling between the High and Ruby catchments are probably explained by greater soil cover in the Ruby watershed and a proportionally higher percentage of talus and boulders in the High watershed. Substantial pools of DIN nitrogen have been measured in talus deposits in the Rocky Mountains (Williams et al. 1997, Bieber et al. 1998). In addition, leaching from these pools may represent a large component of the nitrate exported from alpine watersheds such as Andrews Creek and Icy Brook (Campbell et al. 1995, Kendall et al. 1995). The fact that High watershed is exporting DIN in excess of atmospheric loading might be explained by release of N that has been held in long-term storage within the talus. Nitrogen inputs from dry deposition and organic N substrates supplied by small mammals (i.e., waste products and nesting materials) have the potential to build up and persist within talus since there is little or no N utilization by plants and denitrification is unlikely. However, more research, possibly employing detailed analyses of stable isotopes of C and N, will be needed to more fully understand N dynamics within talus fields.

Summary

The correlation analysis confirms that watershed features such as elevation and soil cover are good surrogates for complex N processes controlling catchment-scale N retention. Soil cover was an especially good predictor for catchment DIN yield, stream nitrate concentrations and DIN retention in alpine and subalpine ecosystems in both the Sierra Nevada and Rocky Mountains. The regression models provide a basis for predicting the status of high elevation ecosystems over large regions and under varying inputs of atmospheric N loading. Because the equations quantify the effect of DIN loading on surface water chemistry and nitrogen retention, they may also be useful for evaluating critical N loads in the western United States.

Acknowledgements

This synthesis was possible due to the efforts of many people working under arduous field conditions. We wish to thank the field and laboratory personnel whose labors went into collecting the data required for the nitrogen budgets in the Sierra Nevada and Rocky Mountains. In particular we wish to acknowledge Pete Kirchner, Kevin Skeen and Sage Root for their many years of field work in the Sierra Nevada. We thank Delores Lucero and Frank Setaro for laboratory measurements of Sierra Nevada sample and Randy Comeleo for computing the terrain indices. We are grateful to Jake Peters, Bob Stottlemyer and Bob Musselman for additional information on their study sites. Al Leydecker provided help with all aspects of our work and we thank him for his efforts and ideas over many years. Helpful comments on the manuscript were provided by Mark Williams, Tom Meixner, Bill Lewis and an anonymous reviewer. Financial support was provided by NASA and the California Air Resources Board. Data for Green Lake 4 was provided by the Niwot Ridge Long-term Ecological Database (BIR 9115097). This manuscript was initiated as part of the International SCOPE Nitrogen Project, which received support from both the Mellon Foundation and from the National Center for Ecological Analysis and Synthesis. The research described in this paper has also been funded by the U.S. Environmental Protection Agency. It has been subjected to the Agency's peer and administrative review, and it has been approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

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Table 1. Landscape characteristics of high elevation watersheds in the Sierra Nevada. Soil cover is expressed as a percentage of total catchment area. Mean slope and mode aspect are in degrees. Mean roughness is dimensionless.

Catchment	Elevation m	Area ha	Runoff mm yr^{-1}	Soil Cover	Mean Slope	Mode Aspect	Mean Roughness	Years of Record	Sources[1]
Crystal	2951	135	424	53%	21	105	42	1990-93	A
Emerald	2800	120	1120	22%	29	278	38	1985-98	A
Lost	2475	25	1210	36%	14	214	34	1990-93	A
Marble Fork-Kaweah	2621	1908	1245	40%	18	278	34	1993-94	A
Pear	2904	136	703	22%	24	281	37	1990-93	A
Ruby	3390	441	507	18%	27	108	42	1990-94	A
Spuller	3131	97	789	33%	22	60	37	1990-94	A
Topaz	3218	178	696	41%	10	108	32	1990-98	A
High	3603	15	811	5%	17	93	45	1993-94	B
Low	3444	225	926	8%	26	103	42	1993-94	B
M1	3078	106	1265	20%	18	318	36	1993-94	B
M2	3188	90	995	18%	11	315	39	1993-94	B
M3	3249	67	986	10%	11	360	39	1993-94	B
Mills	3554	177	912	6%	26	82	43	1993-94	B
Treasure	3420	175	636	10%	29	101	42	1993-94	B
Sierran Mean =	3135	260	882	23%	20	187	39		

[1] Sources: A: Melack et al. 1998; B: Stoddard 1995, Sickman and Stoddard unpublished data.

Table 2. Landscape characteristics of high elevation watersheds in the Rocky Mountains. Soil cover is expressed as a percentage of total catchment area. ND = no data available. Mean slope and mode aspect are in degrees. Mean roughness is dimensionless.

Catchment	Elevation m	Area ha	Runoff mm yr^{-1}	Soil Cover	Years of Record	Mean Slope	Mode Aspect	Mean Roughness	Sources[1]
Loch Vale	3050	660	750	18%	1984-93	33	5	44	C
Icy Brook	3225	290	815	15%	1992	34	311	44	C,D
Andrews Creek	3300	160	1082	5%	1992	35	310	47	C,D
East Glacier	3282	29	670	81%	1988-90	10	171	35	E
West Glacier	3276	61	1591	39%	1988-90	17	120	38	E
Rabbit Ears Pass	2910	200	609	95%	1991-92	6	198	32	F
Hourglass-Alpine	3192	99	1150	ND	1986-87	14	9	26	G
Hourglass-Subalpine	2871	924	720	ND	1986-87	16	9	24	G
Green Lakes #4	3550	200	857	50%	1985-93	27	341	39	H,I
East St. Louis	2878	803	315	95%	1987-88	18	310	29	J
Fool Creek Alpine	3180	67	400	97%	1987-88	13	27	25	J
Snake River	3350	1040	430	65%	1996	22	279	30	K
Deer Creek	3350	1170	420	85%	1996	18	327	30	K
Rocky Mt. Mean =	3186	439	755	59%		20	186	34	

[1] Sources: C: Baron and Campbell 1997; D: Campbell et al. 1995; E: Reuss et al. 1995; F: Peters and Leavesley 1995, N.E. Peters personal communication; G: Stednick 1989; H: Williams et al. 1996; I: Niwot Ridge Long-term Ecological Database (BIR 9115097); J: Stottlemyer and Troendle 1992, R. Stottlemyer personal communication; K: Heuer et al. 1999.

Sickman et al. in press-b

Table 3. Nitrogen chemistry and fluxes in high elevation watersheds in the Sierra Nevada and Rocky Mountains. Units for nitrate concentration are µM. Units for inorganic N (DIN) and dissolved inorganic N (DIN) are kg-N ha^{-1} yr^{-1}. Data for outflow mean nitrate are annual volume-weighted means. Outflow peak nitrate is the highest nitrate concentration measured during the annual snowmelt nitrate pulse. ND = no data available.

Catchment	Outflow Mean NO_3^-	Outflow Peak NO_3^-	DIN Load	DIN Yield	Net DIN Retention	% DIN Retention
Sierra Nevada:						
Crystal	0.5	1.0	2.0	0.03	2.0	98%
Emerald	4.9	7.0	2.6	0.80	1.8	69%
Lost	0.6	1.8	2.1	0.13	2.0	94%
Marble Fork-Kaweah	2.4	6.0	2.0	0.43	1.5	78%
Pear	4.0	9.0	2.5	0.40	2.1	84%
Ruby	4.1	11	1.5	0.32	1.2	79%
Spuller	4.1	13	1.8	0.44	1.4	76%
Topaz	1.8	1.5	2.4	0.18	2.3	93%
High	13	38	1.2	1.5	-0.3	-24%
Low	9.6	24	1.2	1.3	-0.1	-7%
M1	4.6	17	2.1	0.98	1.1	53%
M2	6.5	16	1.9	0.83	1.1	57%
M3	7.1	22	1.9	0.95	1.0	51%
Mills	9.3	22	1.2	1.2	0.0	0%
Treasure	8.9	17	1.1	0.82	0.3	27%
Sierran Mean =	5.4	14	1.8	0.69	1.2	55%
Rocky Mountains:						
Loch Vale	16	27	[c] 3.9	1.7	2.2	56%
Icy Brook	22	32	[c] 3.9	2.2	1.7	43%
Andrews Creek	24	38	[c] 3.9	3.1	0.8	21%
East Glacier	0.6	15	[a b] 2.6	0.08	2.5	97%
West Glacier	4.9	30	[a b] 4.9	1.25	3.6	74%
Rabbit Ears Pass	9.9	50	[a b] 2.8	0.69	2.1	75%
Hourglass-Alpine	11	ND	ND	1.8	ND	ND
Hourglass-Subalpine	5.2	ND	ND	0.55	ND	ND
Green Lakes #4	13	30	[a b] 5.9	1.6	4.3	73%
East St. Louis	2.1	ND	[a] 3.2	0.14	3.1	96%
Fool Creek Alpine	1.0	ND	[a] 3.9	0.14	3.7	96%
Snake River	5.7	5.7	[b] 2.3	0.54	1.8	77%
Deer Creek	7.1	16	[b] 1.9	0.39	1.5	79%
Rocky Mt. Mean =	9.6	27	3.6	1.1	2.5	72%

[a] Dry deposition was not measured directly but assumed to equal 25% of wet deposition.

[b] DIN loading was estimated by a combination of snow surveys and NADP data.

[c] DIN loading was estimated from NADP data.

Table 4. Summary of Pearson Product Moment correlations and Bonferroni probabilities among catchment landscape features for high elevation watersheds of the Sierra Nevada. Significant correlations ($p<0.1$) are underlined.

	Elevation	Area	Runoff	Soil Cover	DIN Loading	Mean Slope	Mode Aspect
Pearson Correlation:							
Area	-0.348						
Runoff	-0.448	0.272					
Soil Cover	-0.693	0.299	-0.103				
DIN Loading	-0.755	-0.015	0.138	0.654			
Mean Slope	0.185	-0.004	-0.306	-0.262	-0.208		
Mode Aspect	0.132	-0.032	0.250	-0.283	0.010	-0.238	
Mean Roughness	0.713	-0.293	-0.457	-0.598	-0.716	0.482	-0.035
Bonferroni Probability:							
Area	1.000						
Runoff	1.000	1.000					
Soil Cover	0.118	1.000	1.000				
DIN Loading	0.032	1.000	1.000	0.227			
Mean Slope	1.000	1.000	1.000	1.000	1.000		
Mode Aspect	1.000	1.000	1.000	1.000	1.000	1.000	
Mean Roughness	0.079	1.000	1.000	0.520	0.075	1.000	1.000

Table 5. Summary of Pearson Product Moment correlations and Bonferroni probabilities among catchment landscape features for high elevation watersheds of the Rocky Mountains. Significant correlations (p<0.1) are underlined.

	Elevation	Area	Runoff	Soil Cover	DIN Loading	Mean Slope	Mode Aspect
Pearson Correlation:							
Area	-0.202						
Runoff	0.257	-0.552					
Soil Cover	-0.303	0.179	-0.655				
DIN Loading	0.313	-0.566	0.619	-0.480			
Mean Slope	0.391	0.019	0.221	-0.885	0.433		
Mode Aspect	0.006	0.398	-0.140	-0.295	0.263	0.504	
Mean Roughness	0.427	-0.389	0.428	-0.933	0.518	0.778	-0.065
Bonferroni Probability:							
Area	1.000						
Runoff	1.000	1.000					
Soil Cover	1.000	1.000	0.800				
DIN Loading	1.000	1.000	1.000	1.000			
Mean Slope	1.000	1.000	1.000	0.008	1.000		
Mode Aspect	1.000	1.000	1.000	1.000	1.000	1.000	
Mean Roughness	1.000	1.000	1.000	0.001	1.000	0.048	1.000

Table 6. Summary of Pearson Product Moment correlations and Bonferroni probabilities between N fluxes, N retention and nitrate concentrations and catchment landscape features for high elevation watersheds of the Sierra Nevada. Significant correlations (p<0.1) are underlined. No correlations are shown between DIN loading and DIN retention because loading is used in the computation of retention.

	DIN Yield	AVWM NO_3^-	Peak NO_3^-	Net DIN Retention	% DIN Retention
Pearson Correlation:					
Elevation	0.644	0.787	0.750	-0.769	-0.740
Area	-0.193	-0.242	-0.240	0.104	0.175
Runoff	0.284	-0.008	0.061	-0.084	-0.088
Soil Cover	-0.867	-0.901	-0.848	0.836	0.829
DIN Loading	-0.665	-0.781	-0.747	-	-
Mean Slope	0.134	0.223	0.051	-0.189	-0.201
Mode Aspect	0.027	0.231	0.319	-0.175	-0.097
Mean Roughness	0.570	0.716	0.671	-0.700	-0.686
Bonferroni Probability:					
Elevation	0.385	0.020	0.052	0.032	0.065
Area	1.000	1.000	1.000	1.000	1.000
Runoff	1.000	1.000	1.000	1.000	1.000
Soil Cover	0.001	0.000	0.003	0.004	0.005
DIN Loading	0.273	0.024	0.056	-	-
Mean Slope	1.000	1.000	1.000	1.000	1.000
Mode Aspect	1.000	1.000	1.000	1.000	1.000
Mean Roughness	1.000	0.107	0.248	0.147	0.189

Table 7. Summary of Pearson Product Moment correlations and Bonferroni probabilities between N fluxes, N retention and nitrate concentrations and catchment landscape features for high elevation watersheds of the Rocky Mountains. Significant correlations (p<0.1) are underlined. No correlations are shown between DIN loading and DIN retention because loading is used in the computation of retention.

	DIN Yield	AVWM NO_3^-	Peak NO_3^-	DIN Retention	% DIN Retention
Pearson Correlation:					
Elevation	0.292	0.124	-0.514	0.104	-0.172
Area	-0.341	-0.096	-0.598	-0.367	0.110
Runoff	0.624	0.361	0.391	0.166	-0.481
Soil Cover	-0.924	-0.840	-0.213	0.326	0.881
DIN Loading	0.510	0.294	0.396	-	-
Mean Slope	0.765	0.823	0.036	-0.301	-0.811
Mode Aspect	0.294	0.360	-0.130	-0.000	-0.280
Mean Roughness	0.741	0.842	0.419	-0.279	-0.847
Bonferroni Probability:					
Elevation	1.000	1.000	1.000	1.000	1.000
Area	1.000	1.000	1.000	1.000	1.000
Runoff	0.911	1.000	1.000	1.000	1.000
Soil Cover	0.002	0.049	1.000	1.000	0.014
DIN Loading	1.000	1.000	1.000	-	-
Mean Slope	0.092	0.074	1.000	1.000	0.098
Mode Aspect	1.000	1.000	1.000	1.000	1.000
Mean Roughness	0.149	0.046	1.000	1.000	0.040

Table 8. Summary of regression-tree analysis of pooled Rocky Mountain and Sierra Nevada data sets (n= 26 to 28). Independent variables used in the analysis were: DIN loading (L), elevation (E), %soil cover (S), terrain roughness (R), area, slope, and runoff. Split variables are shown in order. Tree growth was limited to 5 end-nodes and a minimum of 4 catchments per end-node. The minimum proportional reduction in error allowed at any tree-split was 0.1.

Dependant Variable	Split Variable	# of End Nodes	Model Fit
DIN Yield	L-S	3	0.73
AVWM NO_3^-	R-E	3	0.79
Peak NO_3^-	L-S	3	0.72
DIN Retention	L-E-S-L	5	0.92
% DIN Retention	L-S	3	0.87

Figure Captions

Figure 1. Relationship between catchment DIN yield and elevation and soil cover for high elevation watersheds of the Sierra Nevada and Rocky Mountains. Solid circles (•) are Sierra Nevada and open circles (o) are Rocky Mountains.

Figure 2. Relationship between net catchment IN retention (i.e., IN loading – DIN yield) and elevation and soil cover for high elevation watersheds of the Sierra Nevada and Rocky Mountains. Solid circles (•) are Sierra Nevada and open circles (o) are Rocky Mountains.

Figure 3. Relationship between percent catchment IN retention (i.e., net IN retention ÷ IN loading) and elevation and soil cover for high elevation watersheds of the Sierra Nevada and Rocky Mountains. Solid circles (•) are Sierra Nevada and open circles (o) are Rocky Mountains.

Figure 4. Relationship between the annual volume-weighted mean nitrate concentration in catchment outflow and elevation and soil cover for high elevation watersheds of the Sierra Nevada and Rocky Mountains. Solid circles (•) are Sierra Nevada and open circles (o) are Rocky Mountains.

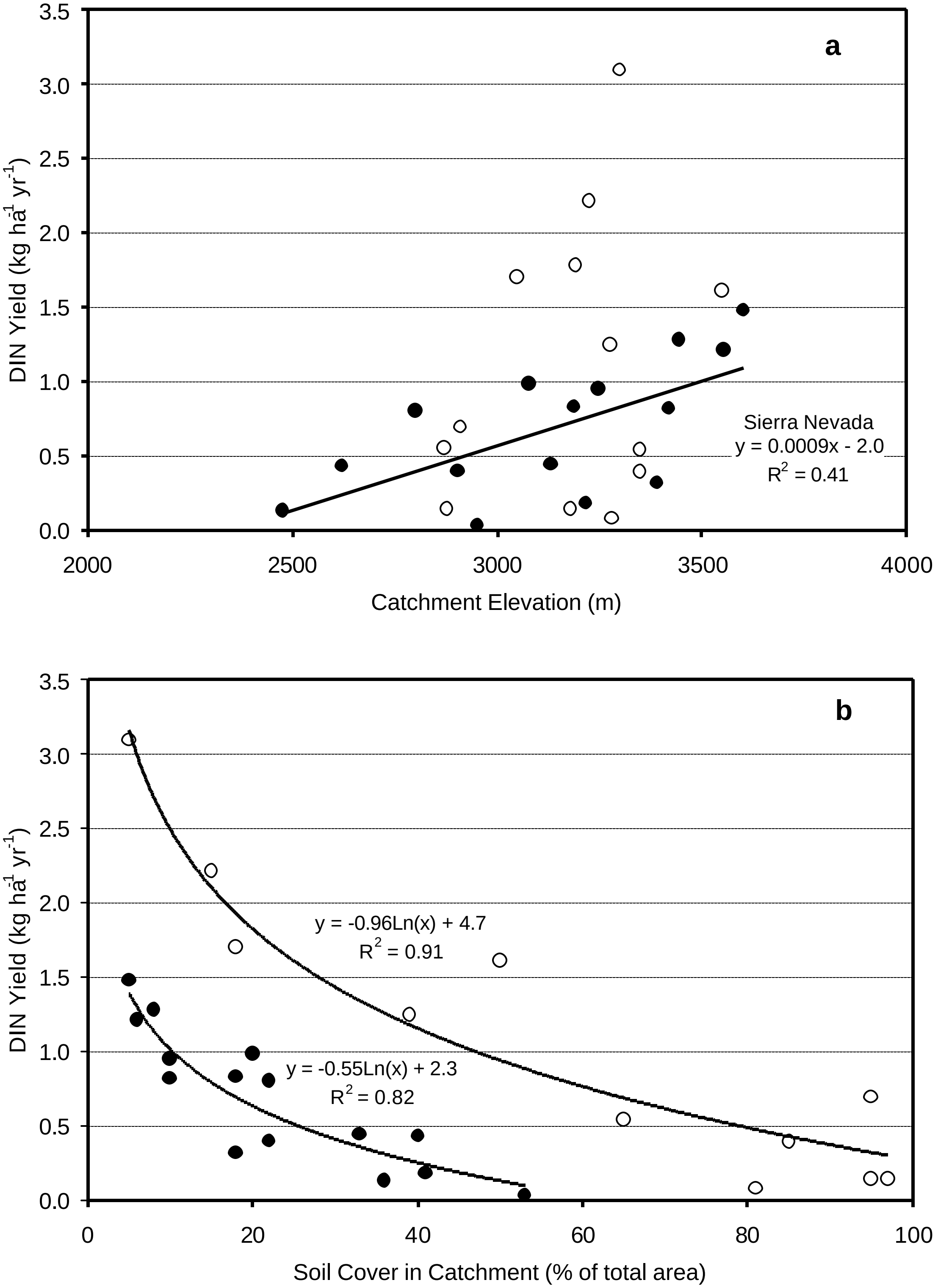
a
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
DIN Yield (kg ha^{-1} yr^{-1})
2000
2500
3000
3500
4000
Catchment Elevation (m)
Sierra Nevada
y = 0.0009x - 2.0
R^2 = 0.41
b
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
DIN Yield (kg ha^{-1} yr^{-1})
y = -0.96Ln(x) + 4.7
R^2 = 0.91
y = -0.55Ln(x) + 2.3
R^2 = 0.82
0
20
40
60
80
100
Soil Cover in Catchment (% of total area)

Figure 1

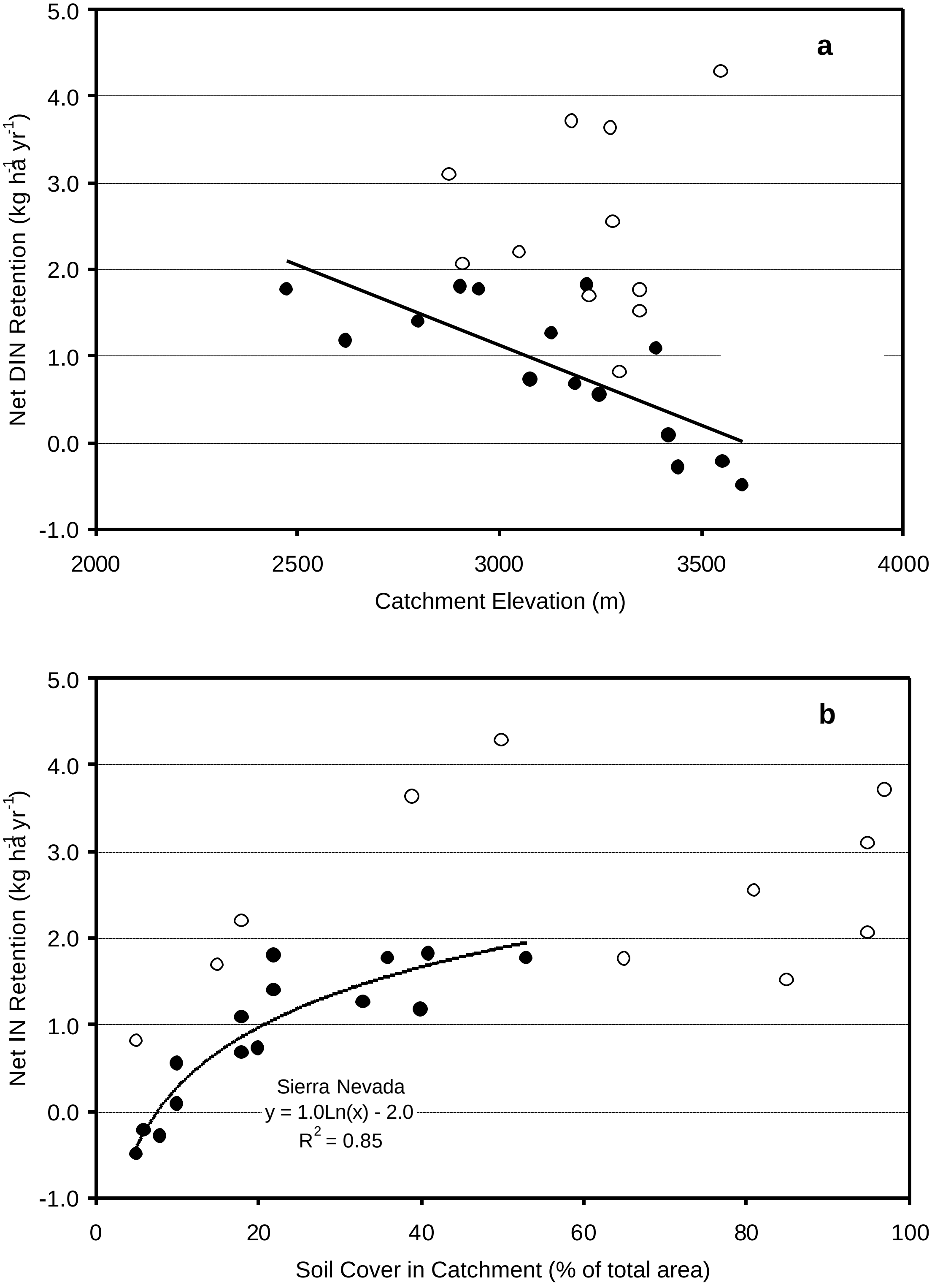
a
5.0
4.0
3.0
2.0
1.0
0.0
-1.0
Net DIN Retention (kg ha^{-1} yr^{-1})
2000
2500
3000
3500
4000
Catchment Elevation (m)
b
Net IN Retention (kg ha^{-1} yr^{-1})
0
20
40
60
80
100
Soil Cover in Catchment (% of total area)
Sierra Nevada
y = 1.0Ln(x) - 2.0
R^2 = 0.85

Figure 2

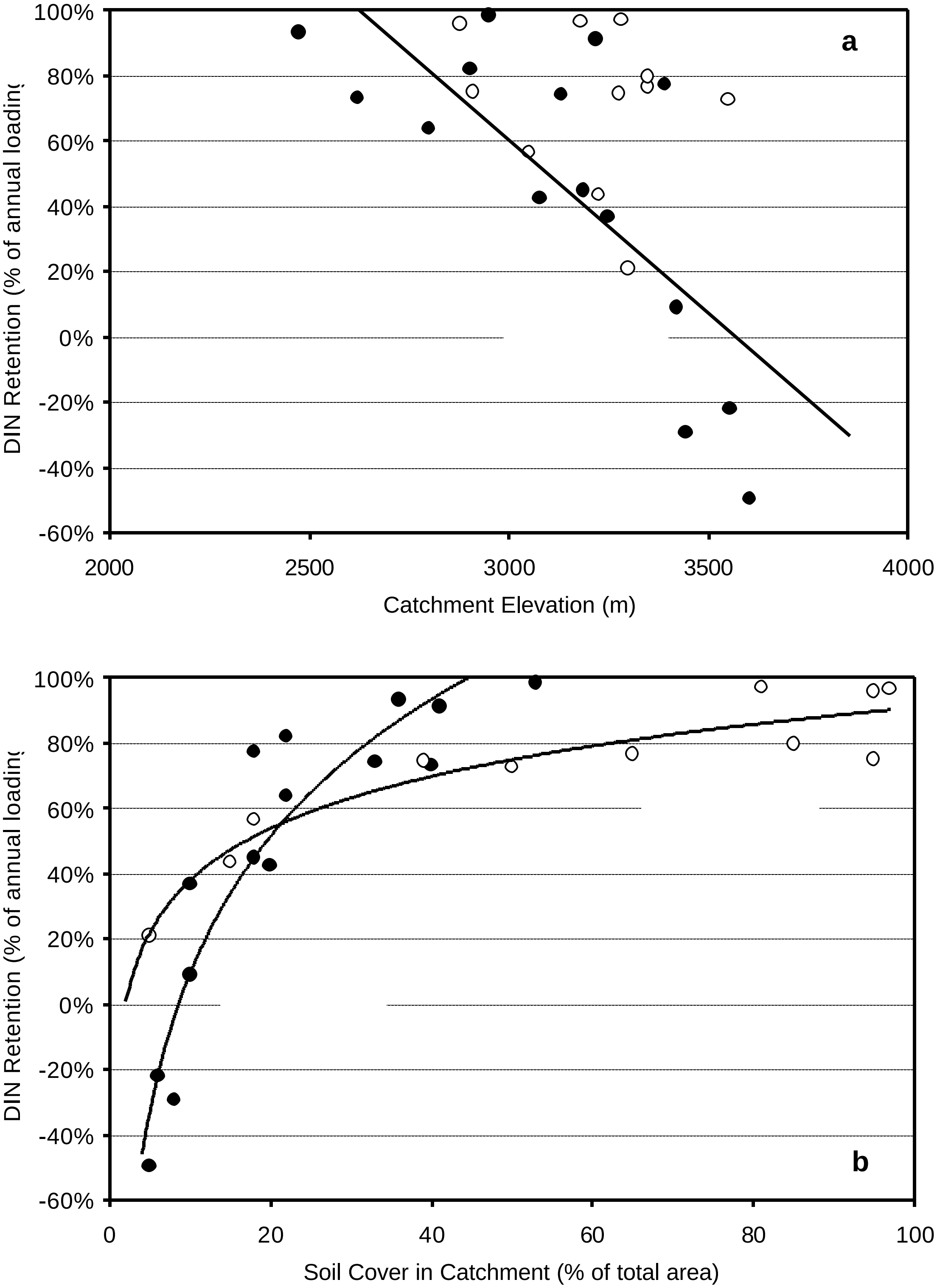
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
DIN Retention (% of annual loading
2000
2500
3000
3500
4000
Catchment Elevation (m)
a
100%
80%
60%
40%
20%
0%
-20%
-40%
-60%
DIN Retention (% of annual loading
0
20
40
60
80
100
Soil Cover in Catchment (% of total area)
b

Figure 3

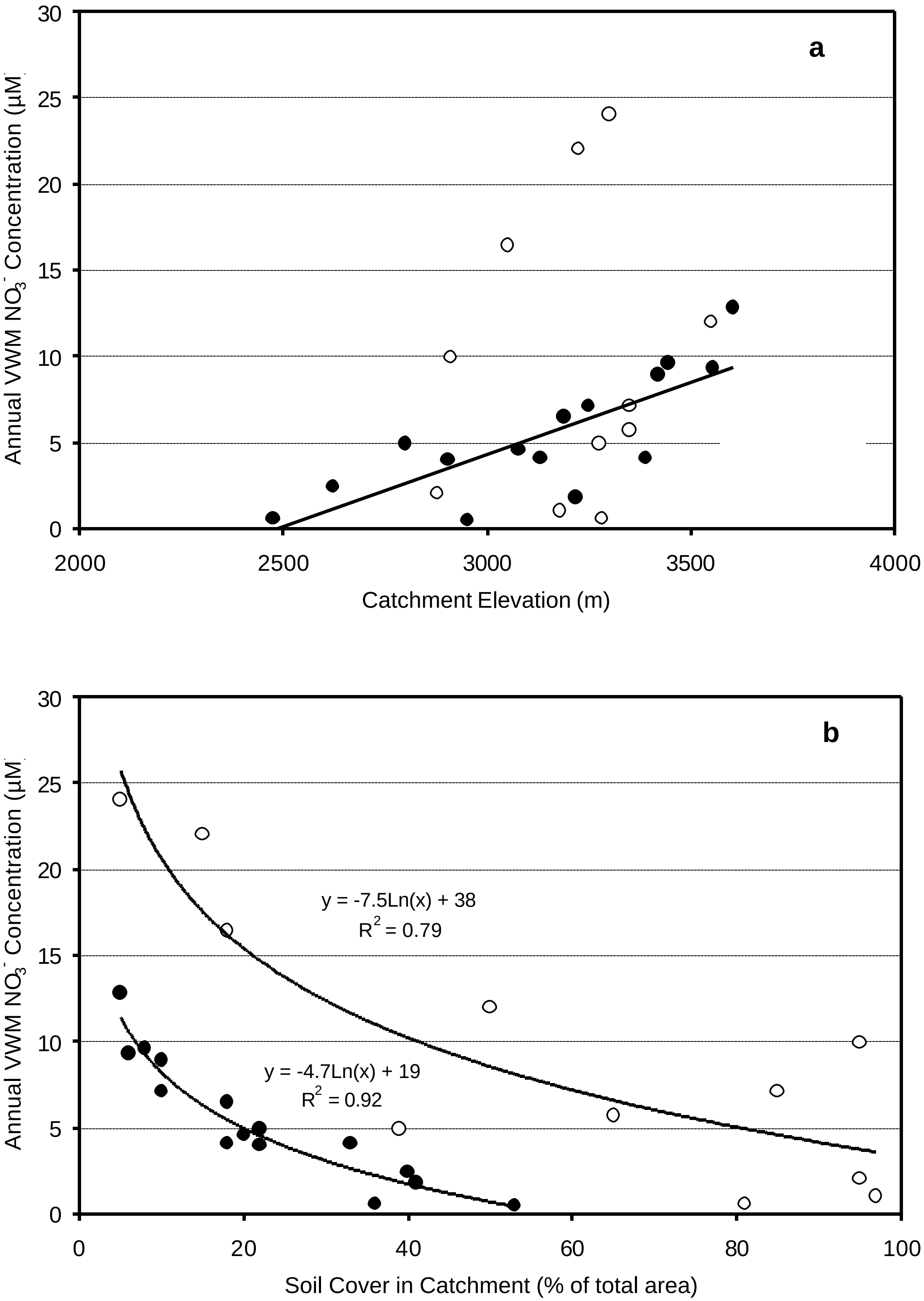
a
Annual VWM NO_3^- Concentration (µM
0
5
10
15
20
25
30
2000
2500
3000
3500
4000
Catchment Elevation (m)
b
Annual VWM NO_3^- Concentration (µM
0
5
10
15
20
25
30
0
20
40
60
80
100
Soil Cover in Catchment (% of total area)
y = -7.5Ln(x) + 38
R^2 = 0.79
y = -4.7Ln(x) + 19
R^2 = 0.92

Figure 4

Do Variable Source-Area Dynamics Control N Export from High Elevation Catchments?

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Submitted to Water Resources Research

September 28, 2001

Abstract

Using nitrogen (N) mass balances, detailed time-series of stream nitrate concentrations and a distributed snowmelt model, we tested whether the Variable Source-Area (VSA) Hypothesis of Creed and Band can explain variations in catchment N export and stream nitrate concentration in high-elevation catchments in the Sierra Nevada (California). The VSA hypothesis states that export of dissolved inorganic nitrogen (DIN) will be proportional to the duration of DIN flushing which, in turn, is primarily controlled by the rate of N source-area expansion (i.e., dVSA/dt). During the spring of 1997, maximum stream nitrate concentrations occurred in two subalpine watersheds (ca. 40% soil covered area) when daily increases in snowmelt contributing area were at maximum, suggesting that VSA flushing mechanisms may be applicable in some high-elevation watersheds. In a larger set of alpine and subalpine catchments we found two different relationships between catchment flushing times and annual DIN export: (1) catchments with greater than 20% soil coverage had below average DIN export and flushing times proportional to annual export (consistent with the VSA hypothesis) and (2) catchments with less than 20% soil cover and abundant talus had above average DIN export and flushing times inversely related to annual export (inconsistent with the VSA hypothesis). Our data suggest that, while subalpine catchments have functional analogues at lower elevations, DIN export from steep high-elevation catchments with little soil and abundant talus appear to be regulated by processes that may be specific to alpine ecosystems.

GAP index terms: biogeochemical processes (1615), chemistry of fresh water (1806), surface water quality (1871)

1. Introduction

Investigations in montane watersheds in the United States suggest that most of the nitrogen eluted from melting snowpacks is biologically assimilated and the spring nitrate pulse observed in streams is derived primarily from flushing of microbially transformed N from watershed soils [Kendall et al., 1995; Sickman, 2001; Campbell et al., in press]. Since most of the N exported from high elevation catchments during snowmelt is derived from soils it is likely that hydrologic flushing mechanisms are one control on the transport of dissolved inorganic nitrogen (DIN) from soils into streams and lakes.

The complex hydrological mechanisms of nitrate flushing from soils have been the focus of several recent studies. Variable-source area (VSA) regulation of N flushing from soils was proposed by Creed et al. [1996] and Creed and Band [1998a, b] to explain variations in DIN export from temperate forests in Ontario, Canada. In these catchments, nitrate in the upper soil layers was flushed when infiltrating event water (snowmelt) caused the water table to rise to the soil surface, generating return flow [Dunne and Leopold, 1978]. The authors found that the amount of nitrate flushed was proportional to the catchment's flushing time and proposed that the length of the flushing period was regulated by topography, i.e., more complex terrain leads to a greater lateral expansion of the nitrate-contributing source areas with time ($d\mathrm{VSA}/dt$) and, therefore, a longer flushing time and greater nitrate export.

There have been few tests of the nitrate VSA concept in other catchments, but a soil-flushing mechanism may not explain episodic nitrate export in regions with groundwater nitrate sources [Burns et al., 1998; McHale et al., in press]. However, since steep, alpine watersheds typically lack a well-developed groundwater system and are dominated by shallower flowpaths, VSA dynamics may explain the timing and amount of nitrate released from alpine and subalpine catchments. Moreover, flushing behavior has been observed in these catchments for less biologically labile elements such as calcium and silica, which are produced by over-winter weathering in subnivean soils [Leydecker et al., 1999; Leydecker, 2000]. The large topographic variation of high elevation watersheds provides a good setting to test the universality of the variable-source area concept and may explain the large variation in DIN export observed in alpine and subalpine watersheds of the western United States [Sickman et al., in press].

Using results from a distributed snowmelt model we examine the relationship between changes in snowmelt contributing area and temporal variations in stream nitrate concentrations in two subalpine watersheds (Sierra Nevada, California). With these data and an analysis of nitrate-flushing characteristics from 14 additional Sierra Nevada watersheds we test whether variable-source area dynamics can explain the timing of the snowmelt nitrate pulse and differences in DIN export among a regionally extensive set of watersheds. By testing the applicability of the VSA concept we hope to assess whether high-elevation watersheds are functional analogues of forested systems.

2. Site Descriptions

The Marble Fork of the Kaweah River basin and two of its major sub-catchments, Emerald Lake watershed and Topaz Lake watershed, are located along the western slope of the southern Sierra Nevada within Sequoia National Park. The other catchments used in the analysis are located in alpine (i.e., above treeline) and subalpine (at or below treeline) elevation zones and together they capture a wide range of the geographic, geologic and hydrochemical variation among high elevation watersheds within the Sierra

Nevada of California (Table 1). Catchment elevations varied from 2,475 to 3,603 m and soil cover ranged from 5 to 53% of total catchment area. In catchments with low soil cover, talus and bedrock predominate. Mean slope of the study catchments ranged from 10° to 29°. Lakes ranged in area from less than 1 ha to 12.5 ha and in volume from less than 10,000 to over 2×10^6 m^3.

3. Methods

3.1. Stream and Lake Chemical Sampling

Dissolved N yield from the catchments was computed from measurements of outflow stream chemistry and discharge. Particulate nitrogen (PN) yield was computed from measurements of lake chemistry and outflow discharge. Catchment outflows were sampled for ammonium, nitrate and dissolved organic nitrogen (DON) at various intervals over the course of the study (see Melack et al., 1998). Samples were typically collected at daily to biweekly intervals during snowmelt (ca. April through July), and biweekly to monthly during low runoff periods. Automated samplers (ISCO™) were used to collect samples on a daily basis during snowmelt in 1992 to 1999 at Emerald and from 1997 through 1999 at Topaz and Marble Fork. At the other catchments samples were collected manually. From 1985 through 1987, Emerald Lake PN samples were collected biweekly during the summer and autumn and monthly during the remainder of the year. PN samples were typically collected monthly to bimonthly at all lakes. Particulate samples were collected at three to four depths at a single station overlying the deepest part of the lakes. From 500 to 1000 ml of water were passed through an ashed Gelman A/E filter (in duplicate), stored in a petri dish and kept frozen at –20°C until analyzed. All samples were kept cool and in the dark during transport.

Ammonium and nitrate samples were held in a coldroom at 5°C and DON samples were stored frozen at –20°C. Ammonium was determined on filtered samples generally within 72 hours by the indophenol blue method [Strickland and Parsons, 1972]. The detection limit for the ammonium assay was 0.5 µmoles L^{-1} (i.e., µM). For water years 1986 through 1998, nitrate was measured on a DIONEX ion chromatograph, employing an AS4A or AS14 separation column and conductivity detection. During water year 1985, nitrate was determined colorimetrically within one week of collection using cadmium reduction [Strickland and Parsons, 1972]. Delays for nitrate determination were on the order of days during water years 1985 through 1987 and on the order of weeks from 1990 onward. Storage tests indicate that filtered, refrigerated samples of Sierra Nevada surface water can be held at least 3 months prior to nitrate analysis [Sickman and Melack, 1989]. The nitrate detection limit was 0.05 µM for the IC and 0.1 µM for the colorimetric assay.

Total dissolved nitrogen (TDN) was determined by the Valderrama [1981] method: filtered water samples were digested with a NaOH-persulfate oxidizing reagent under high heat (260°C) and pressure which converted all N forms to nitrate. Digested samples were adjusted to neutral pH with low-N NaOH and nitrate determined as nitrite after cadmium reduction. The nitrate determinations were done manually from 1985 through 1989 and on a Latchat autoanalyzer from 1990 onward. Dissolved organic nitrogen (DON) was computed as the difference between TDN and DIN (ammonium + nitrate). The detection limit for DON was 1.0 µM. Particulate N was determined by combustion of filters in an elemental analyzer.

3.2. Outflow Gauging

Stream stage (water depth recorded as transducer voltage) and temperature were continuously recorded with a datalogger. To convert stage to discharge (cubic meters per second), a stage-discharge relationship was established for each outlet stream based on dye or salt-dilution (slug and constant injection) [Melack et al., 1998]. All rating curves were based on 50 to 200 measurements of stage and discharge. From water year 1990 onward, discharge was measured with v-notch weirs at Emerald and Spuller; a weir was installed in the Topaz Lake outflow in 1997.

3.3. DIN Flux Measurements

In our evaluation of VSA dynamics, we used previously published nitrogen input-output budgets for 15 high-elevation watersheds in the Sierra Nevada (total of 64 catchment-years of data). Yearly DIN fluxes were computed as the product of annual discharge and annual volume-weighted mean concentrations of DIN in outflow and normalized to catchment area (i.e., kg N ha^{-1} yr^{-1}). More details on these computations, including an analysis of potential errors, are contained in Sickman et al. [2001] and Sickman et al. [in press].

4. Results and Discussion

4.1. Temporal Variations in Nitrogen Concentrations in Streams

Two intra-annual patterns of N concentration were observed in catchment streams. In the first, DIN (> 95% nitrate) was the predominant N species during the snowmelt period, with DON the dominant N loss at all other times. This was the N export pattern found at Emerald and all but one of the remaining study sites (Figure 1a; see also [Sickman and Melack, 1998]. In these catchment outflows, nitrate exhibited a clockwise hysteresis during snowmelt, i.e., concentrations increased on the rising limb of the snowmelt hydrograph, a peak was reached prior to peak runoff and then concentrations declined as snowmelt crested and declined (Sickman et al. 2001). DON concentrations were greatest during the winter months and were lowest during snowmelt. No significant relationships were observed between discharge and DON or PN levels in these catchments suggesting that, in most Sierra Nevada streams, flushing mechanisms do not control the concentration of these N-species [cf. Creed and Band, 1998b].

The second N export pattern was found only at Topaz and was in most respects the opposite of the pattern described above: DON typically exceeded DIN during snowmelt while DIN export was the major N loss mechanism from the late summer until the onset of snowmelt in the subsequent year (Figure 1b). DIN levels (> 95% nitrate) at Topaz increased near the end of the runoff season as the outflow ceased flowing. Winter concentrations in the lake typically ranged from 50 to 100 µM and reached 180 µM in February 1991. DON levels were usually highest in both the lake and outflow during the winter months and there was little variation in lake PN levels. As at the other study sites there was no coherent relationship between discharge and DON or PN concentrations at Topaz.

4.2. Annual N Export

At most of the catchments, annual DIN export exceeded losses of DON (Table 2). Among catchments, DIN export varied by a factor of ca. 50 (0.03 to 1.48 kg N ha^{-1} yr^{-1}). Crystal, Topaz and Lost had relatively low DIN export; organic nitrogen losses (DON +

PN) comprised the majority of annual N yield. On average, particulate nitrogen losses accounted for about a quarter of total N export.

4.3. A Test of the Variable Source-Area Hypothesis

In the variable source-area model of nitrate flushing from soils, the export of nitrate is regulated, not by the total area of nitrate sources, but by the rate of expansion of this area with time (i.e., $d\mathrm{VSA}/dt$; Creed and Band, 1998b). To evaluate the applicability of the VSA mechanism to the snowmelt nitrate pulse (the only N-species where discharge patterns affected concentration patterns), we used two methods.

The first method was similar to that used by Creed and Band [1998b]. Catchment-specific export coefficients were computed by regressing annual DIN export (dependant variable) vs. annual discharge (independent variable) for 15 watersheds (DIN_{export} = mQ; Table 3). Next, an exponential decay model was fitted to the decline in nitrate concentrations during snowmelt runoff:

$$N = N_i e^{-kt} \qquad (1)$$

Where N_i is the nitrate concentration at the peak of the snowmelt pulse, t is time in days and k is the exponential decay coefficient. Time constants ($t_c = 1/k$), the time required for peak concentrations to decrease by 37%, were calculated for each catchment-year; values for multiple years were averaged to yield a single catchment-specific value. The export coefficient residuals (i.e., catchment specific minus mean-catchment export behavior) were regressed against the time constants. With a variable source-area dynamic, the catchment residual should be proportional to the time-constant, i.e., the amount of nitrate exported will be proportional to the duration of DIN flushing which, in turn, is primarily controlled by the rate of nitrate source-area expansion. For additional explanation see Creed and Band [1998b].

Catchment DIN flushing coefficients varied by a factor of ca. 23 (8.0×10^{-5} kg-N ha^{-1} mm^{-1} at Crystal Lake watershed to 182×10^{-5} kg-N ha^{-1} mm^{-1}at High Lake watershed) with an average flushing coefficient for the 15 study sites of 77×10^{-5} kg-N ha^{-1} mm^{-1}. Flushing residuals (calculated as a percent of the overall mean) ranged from -90% at Crystal to +138% at High Lake. Catchment time-constants ranged from 13 days at Lost Lake to 101 days at Ruby; the mean catchment time constant was 26 ± 5 days.

A plot of export residuals vs. time constants (Figure 2), identified two relationships: (1) catchments with below average DIN export had a positive correlation between export and flushing time (i.e., consistent with VSA regulation); and (2) catchments with above average export had a negative correlation between export and flushing time (i.e., inconsistent with VSA regulation). Because of prolonged nitrate export from Ruby, and a large interannual variation in its time constant (38 to 153 days), this catchment was not included in either regression. The unusually long time-constant at Ruby may be a result of appreciable groundwater input into the lake's relatively large area and volume [Sickman and Melack, 1998], and we conclude that VSA dynamics are not an important control on DIN export or nitrate concentrations patterns at Ruby Lake watershed.

The second method used to evaluate the VSA concept used a distributed snowmelt model [Colee, 2000] to directly examine the relationship between increases in source-area and stream nitrate concentrations. The model is based on a point snowmelt model, SNTHERM [Jordan, 1991], regionalized using interpolated surfaces of solar and thermal radiation, wind speed, relative humidity and air temperature computed from multiple meteorological stations in the Marble Fork watershed. The model individually estimates snowmelt for each 30 m grid cell on a 1-hour time-step.

In the analysis we made the assumption that all areas of the catchment were equal contributors of nitrate. Source areas were not restricted to near-lake or riparian areas, although these landscape units likely contain the largest pools of flushable nitrate. This assumption was necessary because we lacked detailed information on the spatial heterogeneity of soil N sources (cf. Creed and Band, 1998a). Also, instead of using absolute increases in snowmelt contributing-area (SMA), we divided daily increases in contributing area by total snowmelt area which yielded a percentage increase in contributing area. This method of approximating changes in source areas is slightly different from the approach used by Creed and Band [1998b]: These substitutions can be expressed as:

$$dVSA/dt \approx (dSMA/SMA)/dt \qquad (2)$$

Increases in contributing area were expressed as a percentage to better capture the effect of newly flushed soil areas on stream nitrate concentrations. When there was little contributing area, a small absolute increase had a greater effect on stream nitrate levels than did a large absolute increase when the total contributing area was large.

Figure 3 shows the relationship among daily increases in snowmelt contributing area (computed using Equation 2), stream nitrate concentrations and discharge for a 46-day period from April 1, 1997 through May 15, 1997 at the Topaz and Marble Fork catchments. The analysis was not done at Emerald Lake because there were insufficient stream samples collected at Emerald during this period owing to an autosampler failure.

At Topaz, modeled snowmelt began on April 16, about 4 days later than the actual increase in discharge at the outlet (Figure 3). The two major increases in snowmelt area match both peaks in nitrate concentration, although the relative magnitudes are dissimilar. At the Marble Fork two major increases in snowmelt area were also observed, matching the timing and relative magnitude of the outflow nitrate peaks (Figure 3). As further increases in snowmelt area declined to low levels, outflow nitrate concentrations at Topaz and in the Marble Fork generally fell; nitrate increases near the end of the model run may be due to a May 13, rain-on-snow event. The discrepancy between predicted time of snowmelt onset and the actual increase in stream discharge at the Marble Fork was slightly larger than at Topaz, 7 days; in both cases it is believed that snowmelt production in the model was delayed because the model did not account for preferential flowpaths in the snowpack [Colee, 2000]. Overall, the correspondence between changes in contributing area and nitrate concentrations indicates that VSA dynamics may control nitrate export on the rising limb of the snowmelt hydrograph in these catchments.

4.4. VSA Dynamics and High-elevation Catchments

In the VSA analysis we found two different relationships between catchment flushing times and annual DIN export (Figure 2). One set of catchments, all with below average DIN export, had time constants proportional to annual export, i.e., consistent with the VSA hypothesis; all of these watersheds had greater than 20% soil cover (Table 1). In the other set, all with above average DIN export, the relationship between flushing time and DIN export was inconsistent with theory; these watersheds had less than 20% soil cover and contained abundant talus. It appears reasonable that catchments lacking appreciable soil area are not regulated by a mechanism based on soil flushing, although we lack the data needed to determine whether a soil-cover threshold exists for the application of VSA dynamics. Previous investigations of N dynamics and hydrological flowpaths have shown talus to be a major source of nitrate in high elevation catchments and that hydrologic transit times are rapid [Williams et al., 1997; Bieber et al., 1998; Campbell et al., 2000; Campbell et al., in press]. Short hydrologic residence times in rock and talus dominated catchments combined with the lack of soil to biologically mediate nitrate concentrations may explain the brief and intense nitrate pulse causing the dichotomy seen in Figure 2.

Although we lack process level measurements of N transformations in catchment soils, there is evidence that nitrate export patterns arise from a complex mosaic of N-sources and sinks through space and time. VSA dynamics can explain variations in annual DIN export from subalpine catchments. The correspondence between increases in snowmelt contributing-area and stream nitrate concentrations for the two catchments (with soil cover > 40%) shown in Figure 3 also suggests that VSA dynamics may partially explain the timing of the snowmelt nitrate pulse. However, plant and microbial uptake may be a dominant control on DIN export once snow-free areas form. In an earlier study we examined interannual variations in N export from Emerald and found lower N losses when snowpacks were shallow and snowmelt began earlier in the spring [Sickman et al., 2001]. This pattern was partly the result of reduced time for over-winter decomposition and mineralization of organic matter, and partly because snow-free areas formed earlier in the snowmelt period allowing for increased nitrate uptake by plants

The potential for plant uptake is demonstrated by examining the coincidental fall in nitrate levels in the three major inflows to Emerald during snowmelt runoff (Figure 4).

In all three streams, nitrate concentrations were relatively high in April and May and then decreased precipitously by mid June, despite originating in subcatchments that vary in aspect, elevation and progression of snowmelt (Figure 5). The unifying mechanism for this pattern could be biological N-assimilation in riparian zones (shaded areas in Figure 5) near the lake through which all three streams pass; we suggest the timing of snow ablation in this area controls the decline of nitrate concentrations in the inflows. Based on spatial models of snowmelt [Colee, 2000] and personal observation, this area of the watershed becomes snow-free relatively early during melt, thus it may have a disproportionate impact on catchment-scale nitrate losses. These findings suggest that depletion of nitrate-source areas may play a secondary role to biological uptake in determining nitrate export in some subalpine catchments, especially during the latter stages of snowmelt.

5.0 Summary and Conclusion

During the spring of 1997, maximum stream nitrate concentrations occurred in two subalpine watersheds (ca. 40% soil covered) when daily increases in snowmelt contributing area were at a maximum, suggesting that VSA flushing mechanisms may be applicable in some high-elevation watersheds. However, watersheds with less than 20% soil cover, and abundant talus, did not behave as predicted by the VSA hypothesis: catchment specific flushing times were inversely related to total DIN export (>95% nitrate), i.e., flushing times were short yet total DIN export was high. In catchments with greater than 20% soil cover, flushing times were proportional to DIN export (>95% nitrate), consistent with VSA dynamics. In the Emerald Lake watershed (22% soil covered), patterns of snow ablation in riparian areas near the lake probably controlled the timing of nitrate decline in streams during snowmelt, indicating that depletion of nitrate-source areas may play a secondary role to vegetation uptake in determining nitrate export in some subalpine catchments during the latter stages of snowmelt.

In the watershed-science community there appears to be a difference of opinion regarding how high-elevation systems fit into our global perspective of biogeochemistry and hydrology. Some researchers have promoted the idea that alpine ecosystems are somehow both hydrologically and biogeochemically distinct, owing to severe environmental conditions, steep terrain and landscape features such as talus, i.e., there are few, if any, functional analogues for alpine watersheds. Others believe that high elevation ecosystems are just at the end of a continuum beginning with low elevation grasslands, continuing through forest catchments and ending in alpine fell fields. If so, the same hydrological and biogeochemical processes control ecosystem function in all systems, and differences in N export are due mainly to the sizes of elemental pools and rates of flux among these pools rather than changes in underlying mechanisms or processes. Our data suggest that, while subalpine catchments have functional analogues at lower elevation, N-export from steep high-elevation catchments with little soil appear to be regulated by processes that may be specific to alpine ecosystems.

Acknowledgements

We appreciate the assistance of Pete Kirchner, Kevin Skeen, Brice Loose and a host of others who performed arduous fieldwork over many years. We thank Delores Lucero, Frank Setaro, Bill Clinton and Bob Petty for laboratory measurements. NASA (NAGW-2602) and the California Air Resources Board (A032-188) provided financial support. The cooperation of Sequoia and Kings Canyon National Parks and the Inyo and Eldorado National Forests was vital to the study and is gratefully acknowledged.

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Table 1. Landscape characteristics for 15 high-elevation watersheds in the Sierra Nevada. Soil cover is expressed as a percentage of total catchment area and mean slope is in degrees. No lake volumes or areas are presented for the Marble Fork river basin. Outlet elevations are shown.

Catchment	Elev. m	Area ha	Soil Cover	Mean Slope	Lake Area ha	Lake Vol. 10^3 m^3	Record
Crystal	2951	135	53%	21°	5.0	324	1990-93
Emerald	2800	120	22%	29°	2.7	162	1985-99
Lost	2475	25	36%	14°	0.7	12.5	1990-93
Marble Fork	2621	1908	40%	18°	-	-	1993-99
Pear	2904	142	22%	24°	8.0	591	1990-93
Ruby	3390	441	18%	27°	12.6	2,080	1990-94
Spuller	3131	97	33%	22°	2.2	34.7	1990-94
Topaz	3218	165	41%	10°	5.2	76.9	1990-99
High	3603	15	5%	17°	1.0	17	1993-94
Low	3444	225	8%	26°	0.2	1.1	1993-94
M1	3078	106	20%	18°	0.6	7.0	1993-94
M2	3188	90	18%	11°	0.5	5.2	1993-94
M3	3249	67	10%	11°	0.5	5.2	1993-94
Mills	3554	177	6%	26°	2.4	72	1993-94
Treasure	3420	175	10%	29°	2.7	88	1993-94

Table 2. Mean annual nitrogen export from 15 high-elevation watersheds of the Sierra Nevada. DIN is dissolved inorganic nitrogen (ammonium + nitrate), DON is dissolved organic nitrogen, PN is particulate nitrogen and TN is total nitrogen (DIN + DON + PN). Units are kg N ha^{-1} yr^{-1}. Missing data are denoted with a dash.

Catchment	DIN Export	DON Export	PN Export	TN Export
Crystal	0.03	0.13	0.06	0.22
Emerald	0.82	0.55	0.24	1.61
Lost	0.13	0.30	0.14	0.47
Marble Fork	0.43	-	-	-
Pear	0.40	0.19	0.21	0.83
Ruby	0.32	0.12	0.23	0.67
Spuller	0.44	0.30	0.15	0.89
Topaz	0.18	0.19	0.07	0.44
High	1.48	-	-	-
Low	1.28	-	-	-
M1	0.98	-	-	-
M2	0.83	-	-	-
M3	0.95	-	-	-
Mills	1.21	-	-	-
Treasure	0.82	-	-	-

Table 3. Summary statistics for linear regression models of annual catchment DIN export (dependant variable, in kg-N ha yr^{-1}) and annual runoff (independent variable, in mm yr^{-1}) for 15 Sierra Nevada watersheds. Residuals were computed as the difference between the catchment-specific regression coefficients and the mean regression coefficient. Residuals (Residual %) were normalized by dividing by the mean regression coefficient [Creed and Band, 1998]. N is the number of years used in the regression. All regression equations were forced through the origin (i.e., DIN = mQ). Catchments with positive residuals have greater DIN export than average; negative residuals indicate below average DIN export. Time Constants (± S.E.) describe the exponential decline (1/k) in the nitrate concentrations during snowmelt runoff, i.e., the number of days for a 37% concentration decline.

Catchment	Regression Coefficient	R^2	N	Residual	Residual %	Time Constant k^{-1} (days)
Emerald	73×10^{-5}	0.78	15	-4×10^{-5}	-5%	47 ± 11
Crystal	8.0×10^{-5}	0.89	4	-68×10^{-5}	-90%	15 ± 1.5
High	182×10^{-5}	0.93	2	106×10^{-5}	138%	9.2 ± 1.2
Lost	11.6×10^{-5}	0.93	4	-65×10^{-5}	-85%	13 ± 3.4
Low	138×10^{-5}	1.00	2	61×10^{-5}	80%	16 ± 4.2
M1	77×10^{-5}	0.99	2	1×10^{-5}	1%	24 ± 11
M2	77×10^{-5}	0.59	2	1×10^{-5}	1%	27 ± 5.9
M3	91×10^{-5}	0.84	2	15×10^{-5}	19%	23 ± 3.3
Marble	35×10^{-5}	0.83	7	-42×10^{-5}	-54%	23 ± 8.5
Mills	132×10^{-5}	0.99	2	55×10^{-5}	73%	15 ± 0.6
Pear	51×10^{-5}	0.67	4	-26×10^{-5}	-33%	25 ± 9.2
Ruby	72×10^{-5}	0.76	5	-5×10^{-5}	-6%	101 ± 19
Spuller	57×10^{-5}	0.23	5	-20×10^{-5}	-26%	29 ± 7.1
Topaz	22×10^{-5}	0.32	10	-54×10^{-5}	-71%	18 ± 4.2
Treasure	117×10^{-5}	0.78	2	41×10^{-5}	53%	17 ± 8.0
Mean	77×10^{-5}					26 ± 5.1

Figure Captions

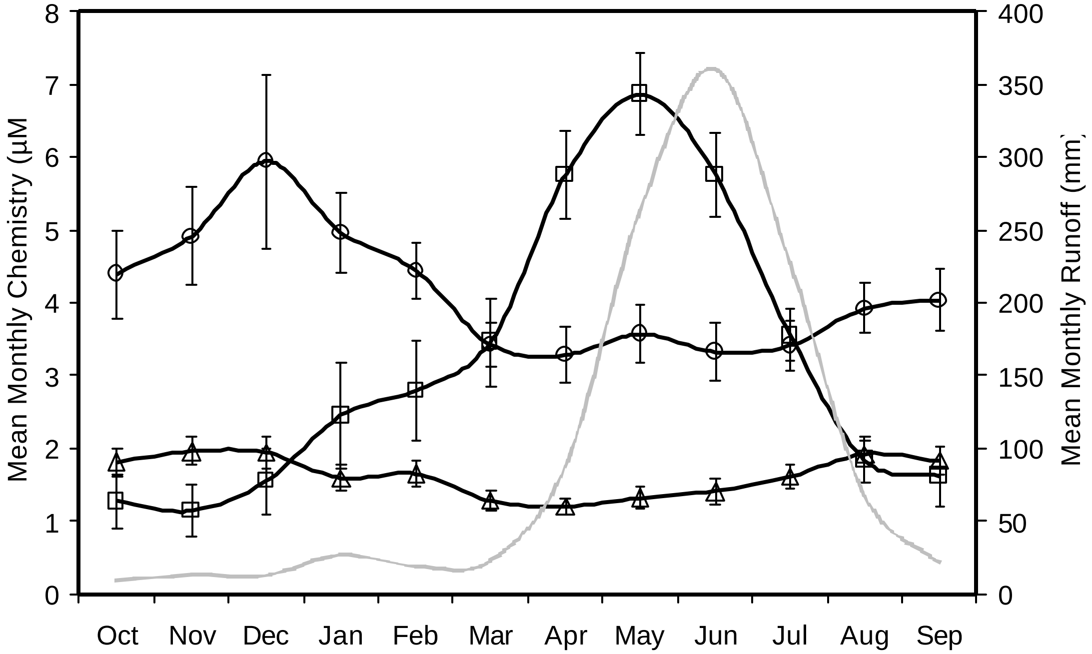
Figure 1. Mean monthly nitrogen outflow chemistry and discharge for Emerald (top panel) and Topaz lakes (bottom panel). Data for Emerald are the average of 1985 through 1999; 1986 through 1999 for Topaz. Standard errors are denoted with error bars. A logarithmic scale is used for Topaz owing to a wider range of chemical concentrations. DIN = ?, DON = ?, PN = Δ and runoff = —.

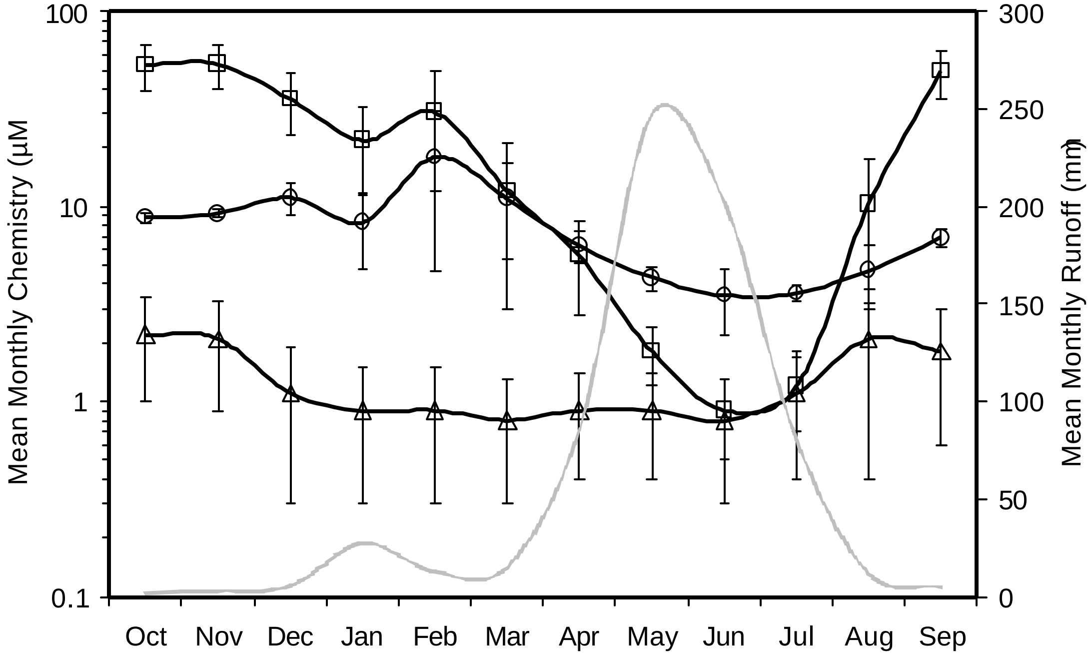
Figure 2. Relationship between catchment-specific flushing constants and DIN export residuals (the difference between catchment-specific regression coefficients and the overall mean) for high elevation watersheds of the Sierra Nevada. Lakes with < 20% and >20% soil cover are denoted with ? and ?, respectively. DIN is the sum of nitrate plus ammonium; in the study catchments nitrate composed >95% of DIN in streams.

Figure 3. Time series of nitrate, discharge and daily increased in snowmelt contributing area (% daily increase) for the Topaz (top panel) and Marble Fork (bottom panel) watersheds during a 45-day period from April 1, through May 15, 1997. Snowmelt contributing areas are from Colee, [2000]. For graphing purposes, units for daily runoff (mm) are divided by 20 and 40 in top and bottom panels respectively. Snowmelt contributing area (SMA) = ?, stream nitrate concentration = ? and runoff = —.

Figure 4. Time series of nitrate concentrations in the three major inflows to Emerald Lake during snowmelt in 1987. Inflow 1 = ?, Inflow 2 = ?, and Inflow 4 = ?.

Figure 5. Map of the Emerald Lake watershed showing the relative position of the major inflows and riparian areas (shaded areas).


Mean Monthly Chemistry (µM
Mean Monthly Runoff (mm
0
1
2
3
4
5
6
7
8
0
50
100
150
200
250
300
350
400
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep


Mean Monthly Chemistry (µM
Mean Monthly Runoff (mm
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1
10
100
0
50
100
150
200
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300
Oct
Nov
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Jun
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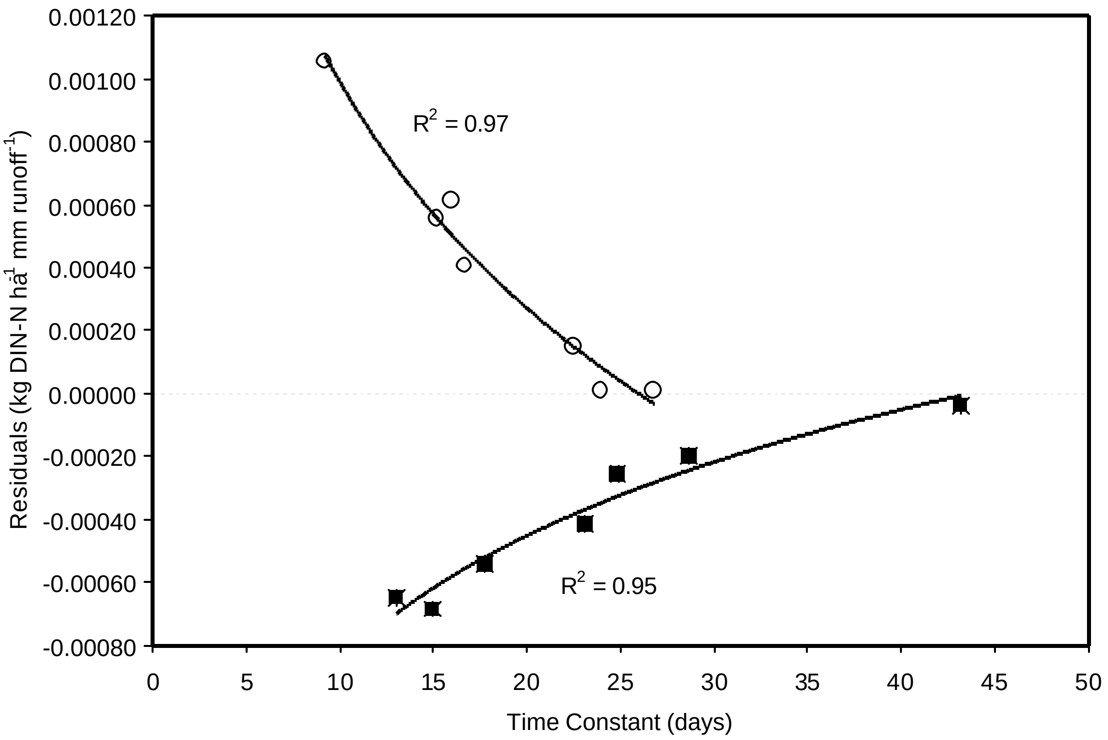
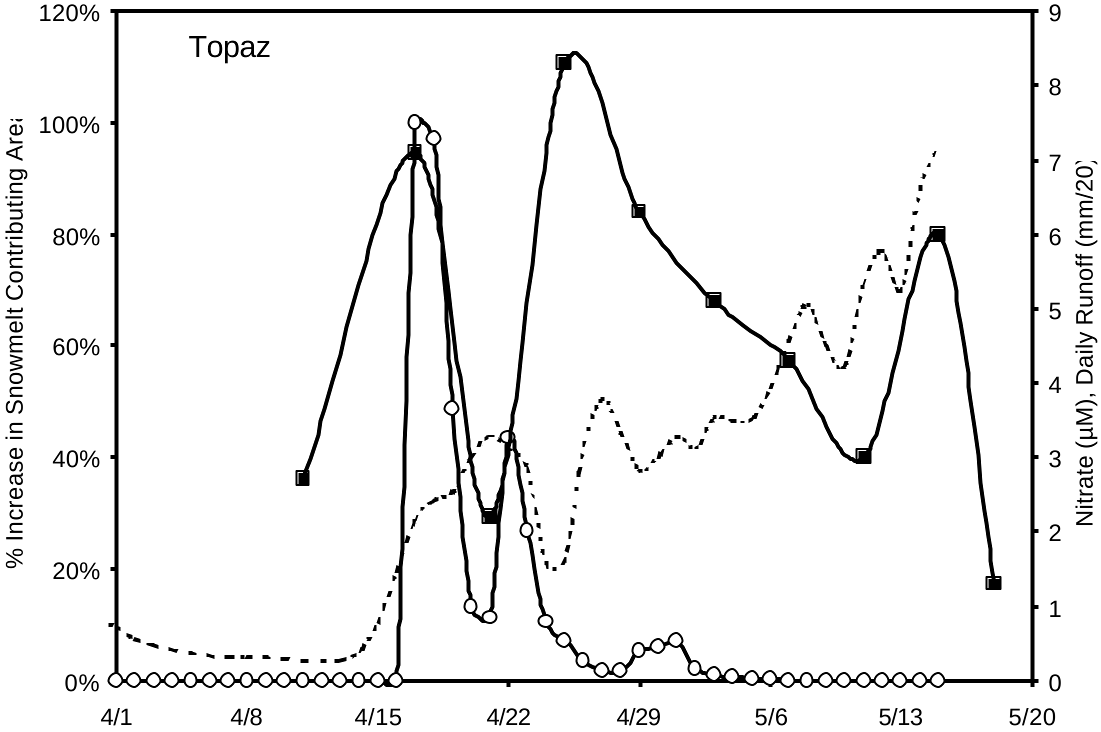
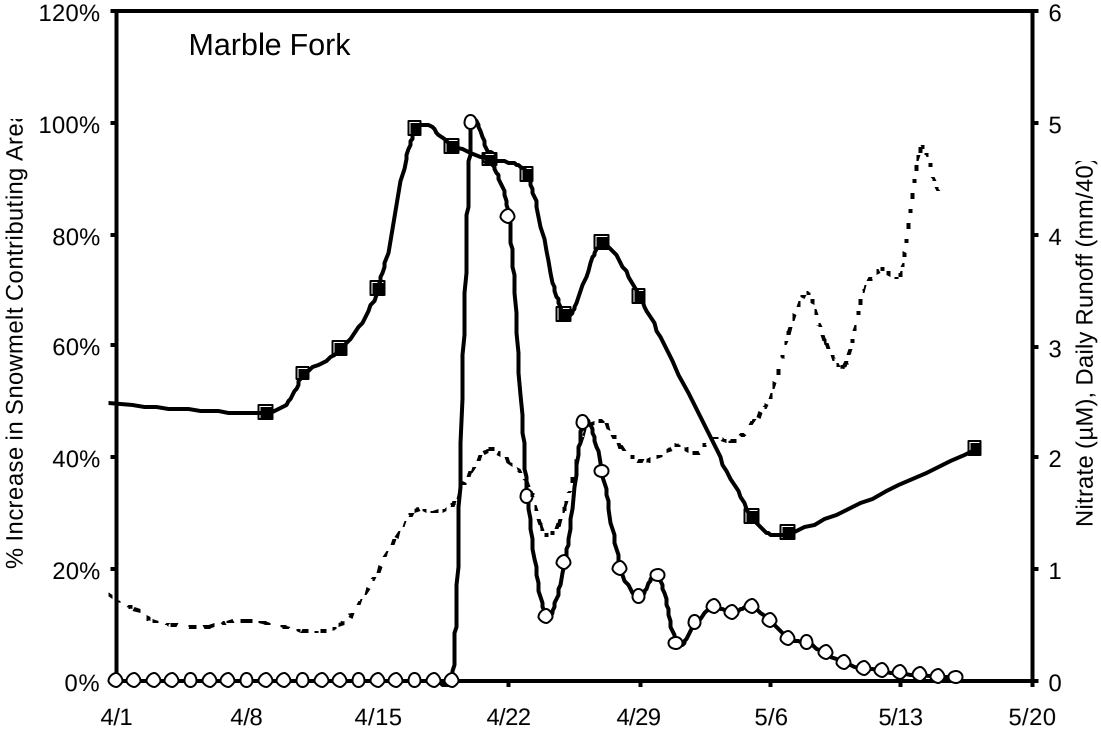
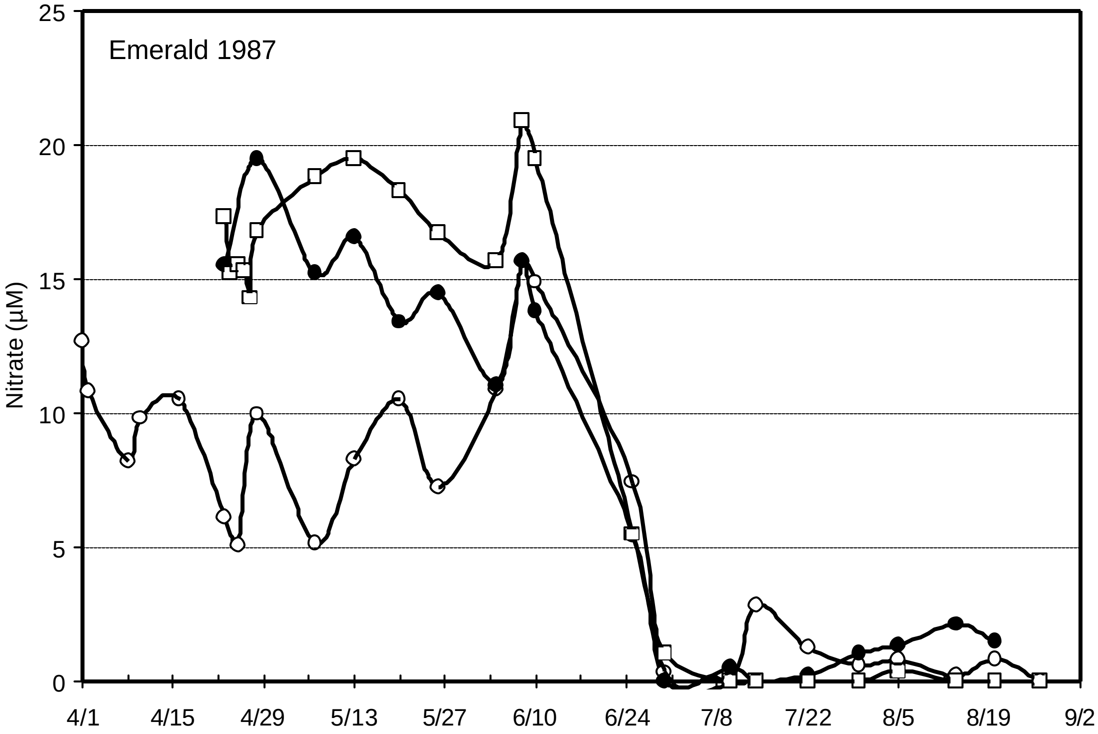

R^2 = 0.97
R^2 = 0.95
0.00120
0.00100
0.00080
0.00060
0.00040
0.00020
0.00000
-0.00020
-0.00040
-0.00060
-0.00080
Residuals (kg DIN-N ha-1 mm runoff-1)
0
5
10
15
20
25
30
35
40
45
50
Time Constant (days)


Topaz
120%
100%
80%
60%
40%
20%
0%
% Increase in Snowmelt Contributing Area
9
8
7
6
5
4
3
2
1
0
Nitrate (µM), Daily Runoff (mm/20)
4/1
4/8
4/15
4/22
4/29
5/6
5/13
5/20


Marble Fork
120%
100%
80%
60%
40%
20%
0%
% Increase in Snowmelt Contributing Area
6
5
4
3
2
1
0
Nitrate (µM), Daily Runoff (mm/40)
4/1
4/8
4/15
4/22
4/29
5/6
5/13
5/20


Emerald 1987
Nitrate (µM)
25
20
15
10
5
0
4/1
4/15
4/29
5/13
5/27
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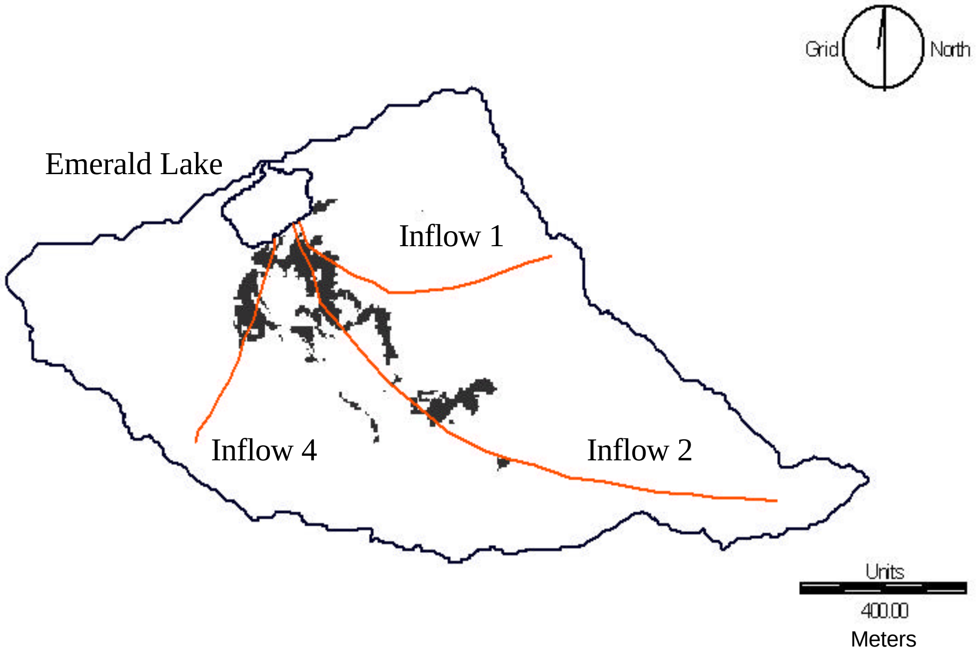
7/22
8/5
8/19
9/2


Grid
North
Emerald Lake
Inflow 1
Inflow 4
Inflow 2
Units
400.00
Meters

Appendix 1: Chemical concentrations at Sierra Episodes Sites, 1993

Site	Date	pH	Conductivity µS	ANC µeq/L	NH4 µeq/L	SiO2 mg/L	Cl µeq/L	NO3 µeq/L	SO4 µeq/L	µeq/L	Mg µeq/L	Ca µeq/L	K µeq/L	Aluminum µg/L
High Lake	06/12/93	6.11	8.1	8.6	0.7	37.9	2.6	27.8	17.6	9.2	4.6	35.2	3.9	8.7
High Lake	06/13/93	5.80	8.0	4.6	0.5	37.6	2.5	29.4	17.0	9.3	4.8	34.8	3.9	19.5
High Lake	06/14/93	5.77	8.0	-0.2	0.0	38.5	2.5	33.1	16.9	9.6	5.4	39.1	4.0	20.3
High Lake	06/15/93	5.72	8.3	3.1	0.1	37.8	2.5	36.3	16.2	9.8	5.6	38.6	4.1	22.1
High Lake	06/16/93	5.71	8.6	5.6	0.1	38.4	2.5	39.4	16.1	10.0	5.7	40.3	4.2	23.1
High Lake	06/17/93	5.68	8.8	3.1	0.0	38.5	2.4	41.1	15.9	10.1	6.0	40.8	4.2	24.4
High Lake	06/18/93	5.85	8.4	3.1	0.1	38.3	1.9	40.8	16.8	9.8	5.9	43.6	4.1	22.3
High Lake	06/19/93	5.75	7.7	1.1	0.0	31.2	1.7	36.7	15.6	8.8	5.2	38.5	3.8	21.7
High Lake	06/20/93	5.62	6.9	-0.6	0.0	32.0	1.7	24.5		8.5	4.1	28.5	3.7	20.9
High Lake	06/30/93	5.82	5.3	0.2	0.0	24.6	2.3		15.4	6.3	2.8	18.8	3.3	6.2
High Lake	06/30/93	5.93	4.7	0.8	0.4	24.8	1.6	11.5	15.7	6.1	2.9	18.6	2.9	5.7
High Lake	07/01/93	5.86	4.6	3.7	0.1	25.5	1.8	11.3	16.2	6.3	2.7	18.0	2.9	5.9
High Lake	07/02/93	5.86	4.5	4.4	0.1	26.0	1.5	9.9	15.0	5.6	2.6	18.1	2.7	
High Lake	07/03/93	5.88	4.6	4.7	0.1	26.7	1.5	9.6	15.0	5.6	2.5	17.8	2.7	5.3
High Lake	07/04/93	5.84	4.6	3.8	0.3	25.1	1.5	9.5	15.1	5.6	2.5	17.7	2.7	
High Lake	07/05/93	5.88	4.8	4.1	0.3	24.1	1.5	10.3	15.9	5.7	2.6	17.9	2.7	9.2
High Lake	07/06/93	5.80	5.7	3.7	0.0	22.0	1.2	9.0	15.0	5.3	2.4	17.0	2.6	
High Lake	07/07/93	5.84	4.6	1.6	0.1	21.1	1.1	8.3	14.6	5.2	2.3	16.3	2.5	8.6
High Lake	07/08/93	5.95	4.0	3.3	0.0	22.6	1.2	7.8	14.3	5.3	2.2	16.1	2.6	
High Lake	07/09/93	5.91	3.8	4.0	0.0	22.5	1.0	7.3	13.9	5.2	2.1	15.4	2.4	8.4
High Lake	07/10/93	5.87	3.8	2.8	0.0	20.9	1.7	6.6	13.6	5.0	2.1	14.9	2.4	
High Lake	07/11/93	5.87	3.6	2.6	0.0	20.6	1.0	6.5	13.5	4.9	2.1	14.5	2.4	7.5
High Lake	07/12/93	5.87	3.7	4.4	0.0	20.6	1.0	6.3	13.6	4.9	2.0	14.3	2.4	
High Lake	07/13/93	5.83	3.8	4.4	0.0	21.2	1.9	5.0	13.5	5.8	2.0	14.5	2.5	7.4
High Lake	07/14/93	5.91	3.5	4.1	0.0	22.6	1.2	6.7	14.5	5.4	2.0	15.5	2.3	
High Lake	07/15/93	5.84	3.5	5.4	0.3	22.9	1.0	6.6	14.2	5.2	2.0	14.8	2.3	8.6
High Lake	07/16/93	5.84	3.5	4.0	0.1	23.3	1.1	6.7	14.3	5.4	2.0	15.3	2.5	
High Lake	07/17/93	5.83	3.6	5.6	0.0	23.4	1.1	6.7	14.5	5.5	2.0	15.1	2.4	7.2
High Lake	07/18/93	5.82	3.6	7.1	0.0	23.6	1.4	5.5	14.3	5.5	2.0	14.5	2.3	
High Lake	07/19/93	6.20	4.2	3.3	8.3	22.4	1.8	6.7	14.2	6.2	2.2	15.3	2.5	4.9
High Lake	07/20/93	6.19	4.0	0.0	0.0	22.2	1.3	6.7	14.2	5.6	2.1	14.4	2.5	6.0
High Lake	07/21/93	6.13	4.1	5.6	0.0	22.3	1.4	6.9	14.4	5.7	2.2	14.7	2.5	3.0
High Lake	07/22/93	6.12	4.3	4.0	0.0	23.0	1.8	7.7	15.0	6.2	2.3	14.9	2.7	
High Lake	07/23/93	5.99	4.1	4.7	0.0	23.6	1.5	6.8	14.1	6.1	2.2	14.1	2.6	5.3
High Lake	07/24/93	5.98	4.4	3.8	0.7	22.3	1.6	7.5	14.8	6.4	2.2	14.6	2.8	4.2
High Lake	07/25/93	5.89	4.3	8.8	0.0	23.4	1.5	7.5	15.0	6.4	2.2	14.8	2.9	

High Lake	07/26/93	5.89	4.4	6.0	0.0	24.2	1.9	7.1	15.7	6.9	2.4	14.9	2.9	4.9
High Lake	07/27/93	5.90	4.3	3.1	0.0	23.8	1.7	6.8	15.1	6.5	2.3	14.1	2.9	
High Lake	07/28/93	5.92	4.3	8.3	0.0	22.8	1.5	6.6	15.2	6.4	2.3	14.1	2.8	5.4
High Lake	07/29/93	5.95	4.2	4.0	0.0	22.8	1.3	6.1	14.8	6.3	2.2	14.5	2.8	
High Lake	07/30/93	5.80	3.7	5.7	0.0	22.0	1.2	5.4	14.4	6.4	2.2	15.3	2.7	3.8
High Lake	07/31/93	5.96	3.8	7.9	0.0	21.6	1.2	4.7	14.5	6.4	2.2	14.4	2.9	
High Lake	08/01/93	5.96	3.5	3.4	0.0	22.6	1.2	5.2	14.6	6.2	2.1	14.4	2.8	5.1
High Lake	08/02/93	5.90	3.8	4.2	0.0	21.7	1.7	4.9	14.5	6.3	2.1	13.9	3.0	
High Lake	08/03/93	6.15	3.5	5.2	0.0	21.9	1.2	5.5	14.9	6.4	2.1	14.0	2.9	2.4
High Lake	08/04/93	6.13	3.6	5.7	0.0	22.0	1.3	5.5	14.9	6.4	2.1	13.7	2.9	
High Lake	08/05/93	5.99	3.7	4.6	0.0	21.8	1.1	5.8	15.6	6.3	2.1	16.3	2.9	6.9
High Lake	08/08/93	5.89	3.6	4.8	0.0	23.1	1.3	6.3	15.8	6.3	2.1	15.1	2.9	

Site	Date	pH	Conductivity µS	ANC µeq/L	NH4 µeq/L	SiO2 mg/L	Cl µeq/L	NO3 µeq/L	SO4 µeq/L	µeq/L	Mg µeq/L	Ca µeq/L	K µeq/L	Aluminum µg/L
High Lake	08/11/93	5.89	3.5	5.3	0.0	22.9	1.0	5.6	15.6	6.5	2.1	13.7	3.1	12.0
High Lake	08/13/93	5.68	4.7	0.3	0.5	22.5	1.1	1.3	15.2	5.8	2.1	12.5	3.1	7.2
High Lake	08/14/93	5.88	3.5	3.2	0.0	24.8	1.2	5.4	15.5	6.2	2.0	13.8	2.9	
High Lake	08/16/93	6.08	8.7		1.9	23.8	2.5	5.5	17.1		2.2	13.0	4.7	
High Lake	08/17/93	5.83	3.6	4.6	2.7	25.7	2.1	6.3	16.0	6.3	2.1	13.6	2.9	6.9
High Lake	08/19/93	5.90	4.1	4.4	0.0	24.6	1.2	5.9	16.0	6.9	2.2	13.0	3.0	
High Lake	08/20/93	5.86	3.6	7.6	0.0	26.8	1.1	6.2	16.2	6.3	2.1	14.1	2.9	8.6
High Lake	08/22/93	5.83	4.6	4.9	0.0	24.5	2.4	6.2	16.5	7.4	2.4	14.6	3.3	
High Lake	08/23/93	5.85	3.8	7.1	0.0	24.8	1.2	6.2	16.4	6.4	2.1	13.9	3.0	
High Lake	08/25/93	5.98	4.5	7.9	0.0	24.2	1.5	6.3	17.5	7.4	2.6	17.7	3.5	
High Lake	08/26/93	5.77	4.2	4.7	0.0	27.9	1.8	6.1	16.7	6.5	2.1	14.0	3.1	
High Lake	08/28/93	5.82	4.6	8.8	0.0	24.6	1.6	6.2	17.6	7.3	2.5	17.1	3.5	
High Lake	08/31/93	5.77	4.7	7.3	0.0	28.4	1.9	6.3	17.9	7.7	2.6	17.4	3.6	
High Lake	09/03/93	5.89	4.9	5.3	0.0	28.0	3.9	6.5	17.3	8.4	2.9	19.7	3.7	
High Lake	09/04/93	5.83	4.7	5.6	0.0	28.7	2.3	6.4	18.0	7.9	2.7	18.1	3.7	
High Lake	09/04/93	5.96	4.9	9.9	0.0		2.4	8.7	16.6	7.9	2.5	17.7	3.6	
High Lake	09/04/93	5.87	4.9	12.3	0.0		2.2	8.7	17.0	7.9	2.6	17.3	3.9	
High Lake	09/05/93	5.82	4.8	9.7	0.0	26.0	2.1	6.4	18.1	8.0	2.6	17.2	4.0	
High Lake	09/07/93	5.88	4.8	7.0	0.0		1.8	8.9	17.5	8.0	2.4	16.4	3.7	
High Lake	09/10/93	5.99	4.8	7.7	0.0	29.2	1.7	8.8	17.7	8.1	2.6	17.4	4.0	
High Lake	09/13/93	5.82	4.9	7.1	0.0	30.6	1.8	7.3	18.0	8.2	2.6	17.3	4.1	
High Lake	09/16/93	5.89	4.8	10.7	0.0	30.9	1.7	9.0	18.1	7.9	2.6	17.1	3.8	
High Lake	09/16/93	5.95	4.9	7.9	0.0	30.3	1.7	4.2	18.4	7.9	2.6	17.1	3.8	
High Lake	09/20/93	5.95	4.9	8.9	0.0	30.4	2.2	7.9	18.7	8.4	2.8	17.7	3.7	
High Lake	09/23/93	5.96	4.8	8.7	0.0	27.5	1.4	7.6	19.8	7.7	2.7	17.1	3.6	
Low Lake	04/30/93	6.68	12.5	67.9	0.3	71.6	2.6	22.6	14.5	18.6	6.6	73.0	6.8	

Low Lake	05/01/93	6.58	11.4	66.7	0.3	70.8	2.5	20.2	14.2	16.8	5.8	72.0	6.2	2.8
Low Lake	05/02/93	6.52	10.8	59.7	0.2	68.3	2.9	17.0	14.1		6.7	68.0	6.9	
Low Lake	05/03/93	6.57	10.7	62.9	0.2	69.8	4.6	16.0	14.4	14.8	6.6	67.0	6.1	2.9
Low Lake	05/04/93	6.64	10.6	64.2	0.2	68.4	2.9	15.3	14.0	14.5	6.6	68.0	6.1	
Low Lake	05/05/93	6.63	10.7	67.5	0.2	70.3	3.0	14.5	14.0	14.5	6.5	70.0	6.1	2.8
Low Lake	05/06/93	6.61	11.4	66.0	0.1	70.6	2.8	14.3	13.6	15.9	5.9	71.0	6.0	
Low Lake	05/07/93	6.59	11.3	67.2	0.2	72.1	2.7	14.2	13.5	15.9	5.9	69.0	5.9	1.0
Low Lake	05/08/93	6.63	11.1	66.5	0.1	72.8	2.8	13.9	13.6	15.4	5.8	68.0	5.8	
Low Lake	05/09/93	6.69	11.3	68.7	0.2	72.2	3.2	13.9	13.6	15.5	6.0	69.0	5.8	1.5
Low Lake	05/10/93	6.59	11.4	67.9	0.2	69.2	3.6	16.5	14.7	15.2	6.0	70.0	5.8	1.9
Low Lake	05/10/93	6.65	11.4	67.9	0.2	68.7	3.6	16.3	14.5	15.1	6.0	71.0	5.7	2.8
Low Lake	05/10/93	6.81	11.6	66.9	0.0	71.8	2.9	14.8	13.0	15.2	6.3	69.0	5.7	2.0
Low Lake	05/10/93	6.81	11.6	68.2	0.0	71.8	3.0	15.0	13.2	15.2	6.3	69.0	5.7	2.2
Low Lake	05/11/93	6.73	11.0	65.7	0.1	70.0	3.3	13.7	12.8	14.9	6.0	68.0	5.5	
Low Lake	05/12/93	6.61	10.8	66.3	0.1	69.5	3.7	13.2	12.8	15.3	5.8	73.0	5.7	2.1
Low Lake	05/13/93	6.66	10.7	65.8	0.0	69.6	2.8	12.2	12.5	14.6	5.5	72.0	5.4	
Low Lake	05/14/93	6.69	11.0	66.8	0.0	71.3	2.8	12.0	12.6	14.7	5.5	73.0	5.4	1.3
Low Lake	05/15/93	6.66	11.0	67.3	0.0	71.1	2.8	12.1	12.4	14.7	5.5	75.0	5.5	
Low Lake	05/16/93	6.65	11.0	66.3	0.0	70.8	2.6	12.2	12.2	14.6	5.4	73.0	5.5	2.7
Low Lake	05/17/93	6.58	10.8	63.3	0.0	67.1	2.3	11.9	12.4	15.0	5.3	65.9	5.8	
Low Lake	05/18/93	6.52	10.6	58.1	0.0	61.2	2.2	12.1	14.7	14.4	5.4	63.7	5.8	4.6
Low Lake	05/19/93	6.54	9.7	55.4	0.1	59.8	2.2	13.1	17.9	13.6	5.7	66.0	5.7	
Low Lake	05/20/93	6.67		47.1	0.0	59.0	3.1	14.9	21.3	13.0	6.2	62.8	4.6	3.1
Low Lake	05/21/93	6.55	10.1	43.8	0.0	58.6	4.2	15.6	24.6	13.0	6.6	62.8	4.6	
Site	Date	pH	Conductivity µS	ANC µeq/L	NH4 µeq/L	SiO2 mg/L	Cl µeq/L	NO3 µeq/L	SO4 µeq/L	µeq/L	Mg µeq/L	Ca µeq/L	K µeq/L	Aluminum µg/L
Low Lake	05/22/93	6.48	9.9	42.2	0.0	57.2	3.2	16.4	25.5	13.1	7.0	62.0	4.9	3.9
Low Lake	05/23/93	6.49	9.5	38.3	0.0	55.9	3.2	16.6	25.7	13.0	6.8	58.9	5.5	4.4
Low Lake	05/24/93	6.41	9.2	35.6	0.0	52.8	3.2	16.9	26.2	12.4	6.6	54.6	5.4	5.8
Low Lake	05/25/93	6.35	8.7	32.8	0.1	51.3	3.1	15.9	24.7	11.5	6.3	50.6	4.9	6.1
Low Lake	05/26/93	6.32	8.4	31.8	0.0	50.3	3.1	16.0	24.1	13.1	6.5	49.9	6.3	6.5
Low Lake	05/27/93	6.29	8.3	31.1	0.1	49.7	3.1	16.4	24.1	11.6	6.1	49.1	5.3	6.5
Low Lake	05/28/93	6.41	8.1	29.1	0.6	50.1	2.1	17.0	23.6	11.4	6.4	49.4	5.4	5.0
Low Lake	05/29/93	6.40					2.9	17.7	22.7	11.5	6.4	49.4	5.1	
Low Lake	05/30/93	6.47					2.3	18.1	22.2	11.9	5.6	50.6	5.2	
Low Lake	05/31/93	6.31	8.7		0.0	50.7	2.3	17.4	21.3	11.6	5.8	52.3	5.1	4.8
Low Lake	06/01/93	6.34	8.4		0.0	52.2	2.3	17.6	21.2	11.9	5.8	51.3	5.2	6.4
Low Lake	06/02/93	6.31	8.6	29.9	0.1	52.5	2.1	17.1	21.0	11.5	5.7	50.4	5.0	6.4
Low Lake	06/03/93	6.21	8.7	28.5	0.1	52.7	2.0	17.9	20.3	11.7	5.6	51.1	5.0	
Low Lake	06/04/93	6.27	8.8	29.7	0.0	53.4	2.3	19.0	21.6	12.0	5.9	52.3	5.2	4.8

Low Lake	06/05/93	6.27	8.5	29.0	0.0	53.1	2.2	19.2	21.6	11.8	5.9	51.5	4.9	
Low Lake	06/06/93	6.43	8.8	29.6	0.1	53.8	2.2	17.4	18.8	11.6	5.7	50.8	5.2	4.4
Low Lake	06/07/93	6.36	9.3	33.6	0.1	54.2	2.6	18.4	20.5	12.5	6.3	55.6	5.5	
Low Lake	06/08/93	6.42	8.9	34.5	0.3	54.1	2.1	17.3	19.3	12.3	6.0	54.6	5.3	7.1
Low Lake	06/09/93	6.49	9.5	34.2	0.5	54.8	2.4	18.7	20.4	12.3	5.9	53.6	5.0	
Low Lake	06/10/93	6.44	9.3	29.5	0.4	54.8	2.4	18.2	21.2	12.0	6.0	53.1	5.0	4.9
Low Lake	06/11/93	6.43	9.5	31.8	0.3	54.4	3.5	17.1	21.5	13.0	6.2	53.1	5.1	
Low Lake	06/12/93	6.48	9.0	29.2	0.4	51.3	1.4	17.3	19.4	11.1	5.2	49.1	4.6	
Low Lake	06/13/93	6.50	8.9	27.6	0.5	51.4	1.5	16.9	19.9	10.9	5.3	47.1	4.5	
Low Lake	06/14/93	6.50	8.6	29.6	0.0	50.1	3.3	15.2	19.9	11.9	5.7	49.1	4.9	
Low Lake	06/15/93	6.42	8.0	26.7	0.1	49.6	2.1	16.0	21.2	10.7	5.7	48.8	4.7	5.8
Low Lake	06/16/93	6.39	8.3	27.4	0.0	48.9	2.1	15.8	20.6	10.6	5.6	48.4	4.6	
Low Lake	06/17/93	6.43	8.3	27.5	0.1	49.0	2.4	16.3	20.2	10.6	5.6	47.6	4.8	
Low Lake	06/18/93	6.33	8.0	27.4	0.1	49.8	1.5	18.0	20.7	11.1	5.4	45.7	4.5	3.6
Low Lake	06/19/93	6.35	7.9	27.0	0.1	48.4	1.4	17.5	20.1	10.9	5.2	44.3	4.3	
Low Lake	06/20/93	6.34	7.9	26.4	0.1	46.6	2.1	16.7	21.6	10.6	5.3	43.7	4.4	
Low Lake	06/21/93	6.38	8.1	26.7	0.0	49.5	1.7	17.9	20.7	10.4	5.2	45.7	4.7	3.1
Low Lake	06/22/93	6.41	8.3	26.9	0.3	50.6	1.6	18.4	20.8	10.7	5.2	45.6	4.4	
Low Lake	06/23/93	6.40	8.6	26.5	0.0	51.9	2.2	18.3	21.2	10.6	5.3	46.4	4.4	
Low Lake	06/24/93	6.36	8.4	25.0	0.0	48.9	1.5	17.4	21.0	10.2	5.2	44.0	4.2	2.9
Low Lake	06/25/93	6.41	8.0	22.4	0.0	46.8	1.4	16.4	21.0	9.7	5.1	42.4	4.2	
Low Lake	06/26/93	6.39	7.9	23.0	0.0	45.7	2.7	15.9	21.2	9.9	4.9	41.0	4.2	
Low Lake	06/27/93	6.39	7.7	19.1	0.0	45.3	1.8	15.6	20.4	9.9	4.9	40.1	4.9	3.1
Low Lake	06/28/93	6.39	7.5	20.7	0.0	44.3	1.4	14.9	17.6	9.4	4.5	38.2	4.4	
Low Lake	06/29/93	6.44	7.7	22.5	0.0	46.4	1.5	15.7	19.4	9.7	4.8	41.5	4.5	
Low Lake	07/04/93	6.45	6.9	22.2	0.4	43.3	0.9	12.1	17.7	8.6	4.4	37.2	4.0	3.2
Low Lake	07/05/93	6.44	6.8	22.4	0.1	38.7	1.6	11.7	17.2	8.5	4.2	34.5	3.9	
Low Lake	07/06/93	6.46	6.3	22.2	0.0	37.2	1.4	9.9	17.5	8.1	4.0	32.3	3.7	
Low Lake	07/07/93	6.48	6.2	22.5	0.1	35.7	1.3	9.6	17.0	7.9	3.9	31.2	3.6	3.2
Low Lake	07/08/93	6.47	6.3	23.0	0.1	36.7	1.4	9.0	15.9	7.9	3.8	30.6	3.6	
Low Lake	07/09/93	6.53	5.8		0.2	36.5	1.4	9.3	16.0	7.8	3.6	33.9	3.5	
Low Lake	07/10/93	6.48	5.7	22.7	0.0	36.2	1.3	8.6	15.8	7.8	3.6	33.3	3.4	3.3
Low Lake	07/11/93	6.60	5.6	24.3	0.0	35.6	1.4	8.2	16.0	7.5	3.6	33.2	3.3	
Low Lake	07/12/93	6.59	5.6	22.9	0.0	35.7	1.2	7.7	16.3	7.4	3.6	32.9	3.3	
Low Lake	07/13/93	6.49	5.7	24.3	0.1	36.6	1.3	7.4	15.5	7.9	3.6	32.5	3.5	
Low Lake	07/14/93	6.45	5.5	23.4	0.0		1.2	8.2	16.0	8.3	3.7	31.7	3.4	6.8
Site	Date	pH	Conductivity µS	ANC µeq/L	NH4 µeq/L	SiO2 mg/L	Cl µeq/L	NO3 µeq/L	SO4 µeq/L	µeq/L	Mg µeq/L	Ca µeq/L	K µeq/L	Aluminum µg/L
Low Lake	07/16/93	6.53	5.5	26.6	0.0		1.4	8.1	16.2	8.6	3.7	32.7	3.5	
Low Lake	07/17/93	6.54	5.6	26.5	0.0	35.4	1.3	8.3	15.8	8.6	3.6	32.9	3.5	

Low Lake	07/18/93	6.53	5.6	24.1	0.0	36.4	1.3	8.0	15.9	8.7	3.7	32.5	3.6	
Low Lake	07/19/93	6.37	5.9	24.8	0.3	36.2	1.6	8.3	16.1	9.4	3.8	31.5	3.9	3.4
Low Lake	07/20/93	6.45	6.6	23.7	0.5	35.7	3.3	8.2	17.9	11.5	4.2	33.5	4.5	
Low Lake	07/21/93	6.47	6.4	23.0	0.6	37.2	1.4	7.8	18.1	9.7	4.2	33.7	4.0	
Low Lake	07/22/93	6.47	6.4	21.5	0.6	38.0	1.7	7.4	18.0	10.0	4.2	33.8	4.1	
Low Lake	07/23/93	6.46	6.0	23.4	0.2	37.4	1.4	6.7	18.7	9.4	4.2	31.9	3.9	3.5
Low Lake	07/24/93	6.47	6.0	24.5	0.2	37.7	2.2	7.0	19.9	10.0	4.4	33.3	4.1	
Low Lake	07/25/93	6.48	5.8	21.4	1.0	36.3	1.5	6.6	19.0	9.6	4.3	32.8	4.0	
Low Lake	07/26/93	6.45	5.8	20.9	2.6	36.1	2.1	6.3	18.4	10.1	4.2	32.2	4.1	
Low Lake	07/27/93	6.43	5.6	22.7	0.4	36.1	1.4	6.1	17.1	9.4	3.9	30.8	4.0	2.7
Low Lake	07/28/93	6.46	5.7	22.1	0.5	35.9	1.0	2.6	17.3	9.4	4.0	31.2	3.9	
Low Lake	07/29/93	6.55	5.7	23.4	17.6	35.0	1.6	5.7	17.1	9.2	3.9	30.7	3.9	
Low Lake	07/30/93	6.80	5.5	26.3	0.0	35.9	1.4	5.7	15.5	8.5	3.5	31.3	3.5	
Low Lake	08/02/93	6.85	5.5	21.1	0.0	35.9	1.9	4.9	15.2	8.7	3.3	28.0	3.3	2.9
Low Lake	08/05/93	6.52	4.7	22.1	0.0	35.6	1.1	5.0	15.0	8.0	3.2	29.0	3.4	
Low Lake	08/08/93	6.56	5.0	25.3	0.0	32.7	0.9	4.8	15.0	8.1	3.1	29.3	3.4	5.4
Low Lake	08/11/93	6.53	5.1	25.6	0.0	32.4	1.0	4.7	16.1	8.4	3.4	32.4	3.5	
Low Lake	08/14/93	6.55	6.6	26.6	0.0	33.0	1.1	5.6	17.2	9.4	3.7		3.7	7.5
Low Lake	08/17/93	6.55	6.8	27.8	0.0	32.4	1.0	5.9	18.6	9.4	4.1	31.8	3.8	
Low Lake	08/20/93	6.58	9.8	24.7	1.7	37.3		4.9	19.0		3.8	30.8	3.8	6.5
Low Lake	08/23/93	6.50		27.2	0.0	38.4	1.1	5.1	18.0	9.1	3.8	34.3	3.9	
Low Lake	08/26/93	6.48		26.0	0.1	37.7	0.9	5.1	17.9	9.0	3.9	34.6	3.8	
Low Lake	08/29/93	6.53		28.3	0.1	38.2	0.9	5.0	17.6	8.9	3.8	33.4	3.9	
Low Lake	09/01/93	6.39	6.0	29.4	0.3	37.4	1.6	5.5	17.1	9.2	3.5	31.4	3.8	
Low Lake	09/04/93	6.50	6.0	24.1	0.0	33.6	1.5	5.4	17.0	9.2	3.6	31.0	3.7	
Mills Lake	04/30/93	6.22	14.4	69.4	2.2	50.3		22.1	47.0		11.1	59.0	11.6	7.1
Mills Lake	05/01/93	6.23	11.6	25.7	2.0	44.4		20.2	41.7		9.0	56.0	6.6	5.3
Mills Lake	05/02/93	6.16	11.1	21.9	0.6	49.1	2.4	20.1	44.2	14.0	8.8	58.0	5.9	8.0
Mills Lake	05/03/93	6.12	10.9	22.0	0.3	48.3	1.7	20.8	42.9	13.2	8.7	58.0	6.1	8.6
Mills Lake	05/04/93	6.21	10.6	22.0			1.7	20.2	42.6	13.0	8.6	56.0	5.6	
Mills Lake	05/05/93	6.26	11.1	25.2	0.4	52.2	1.7	19.4	44.0	13.8	8.9	58.0	6.2	7.0
Mills Lake	05/06/93	6.38	11.5	24.6	0.2	50.8	2.0	20.7	44.4	13.7	8.8	62.0	7.0	7.6
Mills Lake	05/07/93	6.21	11.5	25.0	0.3	51.7	1.9	20.4	44.7	13.7	8.9	58.0	7.8	7.3
Mills Lake	05/08/93	6.22	11.5	26.4	0.4	51.9	1.8	20.4	45.2	13.7	9.0	58.0	5.9	7.8
Mills Lake	05/09/93	6.18	11.6	27.2	0.4	52.1	2.5	19.1	45.2	13.7	9.1	60.0	5.9	9.1
Mills Lake	05/10/93	6.24	11.6	27.1	0.4	53.6	1.8	19.4	44.7	13.0	8.8	65.0	5.5	5.9
Mills Lake	05/10/93	6.44	11.8	26.7	0.3		1.8	19.6	45.2	13.2	9.1	66.0	5.7	6.5
Mills Lake	05/10/93	6.38	11.6	26.6	0.3		1.8	19.0	44.1	13.1	9.1	64.0	5.6	
Mills Lake	05/10/93	6.18	11.4	23.3	0.5	51.4	2.0	20.1	44.6	13.5	8.9	58.0	5.7	7.9
Mills Lake	05/10/93	6.21	11.4	26.7	0.5	51.4	1.9	20.0	44.3	13.5	8.9	58.0	5.8	7.0

Site	Date	pH	Conductivity	ANC	NH4	SiO2	Cl	NO3	SO4		Mg	Ca	K	Aluminum
			µS	µeq/L	µeq/L	mg/L	µeq/L	µeq/L	µeq/L	µeq/L	µeq/L	µeq/L	µeq/L	µg/L
Mills Lake	05/11/93	6.34	11.5	26.0	0.5	52.3	1.6	17.8	44.0	12.9	9.1	63.0	5.4	
Mills Lake	05/12/93	6.27	11.4	26.1	0.8	53.2	1.6	16.8	44.0	12.9	9.2	62.0	5.5	11.6
Mills Lake	05/13/93	6.36	11.5	28.9	0.7	53.7	1.5	16.4	44.2	13.2	9.2	63.0	5.6	5.8
Mills Lake	05/14/93	6.29	11.6	30.1			1.7	16.9	44.7	13.2	9.2	62.0	5.6	
Mills Lake	05/15/93	6.31	11.6	29.1	0.7	55.3	1.4	15.9	44.8	13.2	9.3	57.0	5.6	
Mills Lake	05/16/93	6.32	11.6	28.3	0.8	55.1	1.5	15.8	44.9	13.2	9.2	59.0	5.6	6.3
Mills Lake	05/17/93	6.35	11.8	28.4	0.8	53.6	1.6	15.9	44.2	13.6	8.8	57.7	5.9	
Mills Lake	05/18/93	6.32	10.7	30.1	0.8	52.4	1.7	15.4	44.3	13.9	9.2	62.3	5.8	
Mills Lake	05/19/93	6.38	10.8	29.1	1.0	53.6	1.7	15.3	43.9	13.9	9.0	61.5	6.0	
Mills Lake	05/20/93	6.33	10.6	30.6	0.0	57.5	2.8	16.8	42.9	14.0	9.2	61.6	5.7	6.6
Mills Lake	05/21/93	6.25	10.3	30.3	0.1	53.9	3.0	16.9	37.6	13.1	8.4	56.2	5.8	
Mills Lake	05/22/93	6.18	9.9	26.2	0.0	54.9	3.2	17.3	35.2	12.8	8.4	55.0	5.7	10.5
Mills Lake	05/23/93	6.12	9.7	24.3	0.0	52.7	3.3	17.6	33.5	12.4	8.2	54.5	5.8	
Mills Lake	05/24/93	6.13	8.9	25.4	0.7	49.7	3.3	17.0	31.8	11.5	7.5	50.1	5.6	11.7
Mills Lake	05/25/93	6.27	8.0	23.3	0.4	47.0	3.1	15.9	25.8	10.6	6.4	44.4	5.2	
Mills Lake	05/26/93	6.27	8.0	23.2	0.4	47.5	3.1	16.0	25.8	10.6	6.2	44.7	5.1	
Mills Lake	05/27/93	6.12	8.0	24.4	0.3	47.7	3.0	16.4	25.2	10.5	6.3	44.3	5.0	
Mills Lake	05/28/93	6.14	8.0	25.9	0.7	49.5	2.5	18.1	23.6	11.0	5.8	46.9	5.0	8.9
Mills Lake	05/29/93	6.20	7.7	26.9	0.7	49.5	2.5	17.9	24.2	11.0	6.0	46.8	5.1	
Mills Lake	05/30/93	6.16	7.9	26.1	0.1	49.4	2.2	16.9	24.8	10.9	5.9	46.7	5.1	
Mills Lake	05/31/93	6.05	8.3	23.5	0.2	47.0	2.3	17.9	23.6	10.8	6.2	47.9	5.3	10.5
Mills Lake	06/01/93	6.06	8.0	24.8	0.1	46.9	2.3	17.0	22.4	10.4	6.1	46.0	5.0	
Mills Lake	06/02/93	6.07	8.1	23.9	0.1	46.9	2.3	17.7	23.2	10.5	6.2	46.9	4.9	
Mills Lake	06/03/93	6.29	8.1	23.8	0.2	47.5	2.4	18.2	23.4	10.9	6.4	48.3	5.2	11.0
Mills Lake	06/04/93	6.11	8.3	24.3	0.1	47.7	2.2	18.2	22.0	10.8	6.4	49.9	5.3	
Mills Lake	06/05/93	6.21	8.2	24.0	0.1	49.9	2.2	19.3	22.0	10.9	5.9	49.6	5.3	
Mills Lake	06/09/93	6.25	9.5	20.8	0.5	49.9	2.5	18.5	25.0	10.8	6.4	47.9	4.9	9.2
Mills Lake	06/10/93	6.30	9.7	24.4	0.6	51.0	3.0	18.0	26.6	11.2	6.6	50.5	5.0	
Mills Lake	06/11/93	6.24	9.7	22.2	0.5	51.6	2.7	17.8	25.8	12.3	6.6	52.2	5.9	
Mills Lake	06/12/93	6.27	8.8	28.6	0.5	48.4	2.2	17.9	21.1	10.6	5.5	47.6	4.7	8.6
Mills Lake	06/13/93	6.21	8.7	26.4	0.4	48.9	2.1	16.4	21.9	10.5	5.6	46.6	4.6	
Mills Lake	06/14/93	6.32	8.4	22.9	0.3	48.6	2.1	15.7	23.3	10.6	5.9	44.9	4.7	9.6
Mills Lake	06/15/93	6.36	8.4	22.4	0.6	48.6	2.0	16.0	24.3	10.4	5.7		4.7	
Mills Lake	06/16/93	6.31	8.4	22.5	0.3	46.3	2.1	16.4	24.0	10.7	6.0	45.9	4.8	
Mills Lake	06/17/93	6.28	8.7	21.8	0.6	46.0	2.0	17.3	22.8	10.6	5.8	45.8	4.7	
Mills Lake	06/18/93	6.30	8.1	22.8	0.2	46.9	1.4	18.3	22.7	10.0	5.7	46.5	4.6	6.5
Mills Lake	06/19/93	6.30	7.9	23.7	0.2	45.7	1.3	17.9	22.1	9.7	5.5	45.4	4.2	
Mills Lake	06/20/93	6.25	7.9	19.4	0.2	43.1	1.3	16.7	23.1	9.7	5.6	44.9	4.3	

Site	Date	pH	Conductivity μS	ANC μeq/L	NH4 μeq/L	SiO2 mg/L	Cl μeq/L	NO3 μeq/L	SO4 μeq/L	μeq/L	Mg μeq/L	Ca μeq/L	K μeq/L	Aluminum μg/L
Mills Lake	06/21/93	6.43	8.1	21.3	0.0	47.2	1.9	17.8	23.1	10.1	5.4	45.5	4.3	5.9
Mills Lake	06/22/93	6.37	8.1	25.0	0.0	47.0	1.6	18.7	22.5	10.3	5.4	46.3	4.3	
Mills Lake	06/23/93	6.34	8.0	24.1	0.0	46.6	1.6	18.3	21.9	10.1	5.3	45.4	4.0	
Mills Lake	06/24/93	6.40	8.7	21.2	0.0	45.0	1.5	17.4	23.1	9.7	5.4	44.5	4.0	6.0
Mills Lake	06/25/93	6.34	7.6	21.8	0.0	43.9	1.4	16.4	22.8	9.3	5.2	42.9	4.0	
Mills Lake	06/26/93	6.35	7.4	21.3	0.0	43.3	1.3	15.7	22.5	9.0	5.0	41.0	3.9	
Mills Lake	06/27/93	6.35	7.3	19.4	0.1	41.7	2.2	15.5	21.2	9.0	4.8	40.3	3.8	4.6
Mills Lake	06/28/93	6.28	6.8	21.1	0.0	39.8	1.2	14.9	18.3	8.4	4.3	37.4	3.6	
Mills Lake	06/29/93	6.23	7.7	20.5	0.0	44.0	1.4	15.8	24.9	9.2	5.4	43.6	4.0	
Mills Lake	06/30/93	6.46	7.5	18.6	0.2	44.5	2.0	15.8	21.2	8.9	4.9	40.8	4.1	4.5
Mills Lake	07/01/93	6.40	7.6	19.4	0.4	43.4	1.9	15.2	23.2	8.9	5.2	40.7	4.1	
Mills Lake	07/02/93	6.47	6.9	18.6	0.2	41.1	1.7	13.5	19.5	8.3	4.5	36.7	3.8	
Mills Lake	07/03/93	6.41	7.0	18.1	0.2	41.5	1.6	12.8	20.5	8.5	4.7	37.3	4.0	4.2
Mills Lake	07/04/93	6.34	6.8	21.3	0.2	41.0	1.5	11.9	19.5	8.2	4.4	35.7	3.8	
Mills Lake	07/05/93	6.30	6.6	20.5	0.4	36.1	1.4	11.8	19.2	7.9	4.1	36.0	3.5	
Mills Lake	07/06/93	6.44	6.2	20.0	0.3	33.9	1.5	10.6	18.6	7.5	4.0	34.7	3.4	4.0
Mills Lake	07/07/93	6.42	6.4	20.0	0.0	33.7	1.2	9.7	18.7	7.6	4.1	35.0	3.5	
Mills Lake	07/08/93	6.31	6.3	22.5	0.1	32.6	1.5	9.1	16.9	7.6	3.9	30.7	3.6	
Mills Lake	07/09/93	6.50	5.6	22.5	0.1	35.5	1.3	8.8	16.5	7.4	3.6	32.3	3.4	3.6
Mills Lake	07/10/93	6.48	5.5	19.9	0.0	35.0	2.3	7.9	16.1	8.1	3.5	31.7	3.2	
Mills Lake	07/11/93	6.50	5.4	21.8	0.1	34.9	1.2	7.7	16.6	7.1	3.6	31.4	3.2	
Mills Lake	07/12/93	6.43	5.5	18.9	0.0	33.8	1.7	7.1	17.5	7.5	3.6	31.3	3.2	4.6
Mills Lake	07/13/93	6.45	5.7	19.1	0.0	35.5	1.2	7.3	19.9	7.4	4.0	33.3	3.3	
Mills Lake	07/14/93	6.49	5.4	22.5	0.0	34.9	1.5		17.7	7.9	3.7	31.0	3.5	4.2
Mills Lake	07/15/93	6.40	5.4	22.9	0.0	35.2	1.5	7.6	17.6	7.7	3.8	31.3	3.3	4.4
Mills Lake	07/16/93	6.45	5.4	23.4	0.0	35.5	1.2	7.7	17.2	7.6	3.6	31.0	3.3	
Mills Lake	07/17/93	6.41	5.2	24.8	0.0	36.0	1.3	7.6	15.6	7.5	3.4	30.7	3.1	
Mills Lake	07/18/93	6.45	5.3	25.5	0.0	36.7	1.2	7.6	16.5	7.6	3.6	31.6	3.1	4.4
Mills Lake	07/19/93	6.86	6.4	22.7	1.1	33.1	1.6	7.2	17.4	8.5	3.9	31.2	3.8	
Mills Lake	07/20/93	6.75	6.7	30.0	0.0	34.1	1.8	7.4	20.6	9.5	5.4	32.8	5.1	
Mills Lake	07/21/93	6.45	6.3	26.8	0.0	32.6	1.4	7.2	19.4	8.6	4.4	31.3	3.8	
Mills Lake	07/22/93	6.60	6.7	28.0	0.0	32.0	1.7	7.4	21.2	9.5	4.7	33.3	4.0	5.4
Mills Lake	07/23/93	6.60	6.8	23.1	0.0	31.2	1.7	6.7	21.4	9.0	4.7	36.5	3.8	
Mills Lake	07/24/93	6.68	6.1	20.7	7.2	31.8	1.8	6.3	19.9	8.5	4.3	29.4	3.6	
Mills Lake	07/25/93	6.62	6.2	21.8	0.0	34.9	1.3	6.3	20.6	8.5	4.5	30.4	3.7	
Mills Lake	07/26/93	6.62	5.9	18.6	0.0	33.6	1.3	5.8	18.0	8.1	4.0	28.0	3.5	5.5
Mills Lake	07/27/93	6.50	5.6	22.2	0.0	28.7	1.2	5.8	18.0	8.0	3.9	27.0	3.5	
Mills Lake	07/28/93	6.51	5.6	21.1	0.0	32.0	1.1	5.5	17.8	7.5	3.8	29.4	3.2	

Site	Date	pH	Conductivity µS	ANC µeq/L	NH4 µeq/L	SiO2 mg/L	Cl µeq/L	NO3 µeq/L	SO4 µeq/L	µeq/L	Mg µeq/L	Ca µeq/L	K µeq/L	Aluminum µg/L
Mills Lake	07/29/93	6.50	6.5	16.7	0.0	31.1	1.5	5.4	18.3		3.8	29.4	3.4	
Mills Lake	07/30/93	6.52	5.4	20.3	0.0	30.2	1.4	5.3	17.1	7.7	3.6	29.5	3.3	5.0
Mills Lake	08/02/93	6.51	4.5	25.5	0.0	29.2	1.1	4.9	16.9	7.7	3.6	28.3	3.3	4.4
Mills Lake	08/05/93	6.27	4.7	22.7	0.1	29.2	0.9	4.7	14.9	7.1	3.1	25.6	3.1	5.3
Mills Lake	08/08/93	6.42	4.8	26.6	0.3	30.9	0.9	5.0	14.6	7.3	3.2	26.7	3.2	10.5
Mills Lake	08/11/93	6.46	5.1	24.0	0.2	29.7	1.0	5.2	16.3	7.6	3.3	27.0	3.4	
Mills Lake	08/14/93	6.56	5.7	25.0	0.0	28.5	1.1	5.4	18.8	8.1	3.6	31.3	3.3	5.5
Mills Lake	08/17/93	6.58	5.8	22.9	0.0	30.0	1.0	5.6	19.6	8.3	3.7	31.8	3.4	
Mills Lake	08/20/93	6.62	5.8	23.3	0.0	31.3	1.1	5.6	18.9	8.4	3.9	32.6	3.4	5.9
Mills Lake	08/23/93	6.57	7.9	24.1	0.0	32.4	1.4	5.3	20.4	8.6	4.3	34.5	3.8	
Mills Lake	08/26/93	6.52		28.8	0.0	32.6	1.7	5.2	19.6	8.6	4.2	33.2	3.8	
Mills Lake	08/29/93	6.37		25.8	0.0	33.2	1.7	4.5	18.6	8.9	4.2	34.2	3.6	
Mills Lake	09/01/93	6.40		26.2	0.0	30.3	1.5	4.8	18.6	8.4	4.2	33.6	3.6	
Mills Lake	09/04/93	6.17	6.5		0.0	32.3	1.4	4.0	18.1	8.3	3.9	31.6	3.3	
Ruby Lake	05/09/93	6.50	9.5	64.7	0.5	47.0	3.2	5.5	9.7	14.0	5.3	58.0	5.2	
Ruby Lake	05/10/93	6.41	10.0	67.0	0.5	52.6	4.9	6.2	10.9	15.9	5.2	62.0	5.4	
Ruby Lake	05/14/93	6.65	9.7	65.6	0.2	53.7	2.9	4.7	9.6	14.5	5.5	58.0	4.7	7.5
Ruby Lake	05/15/93	6.63	9.8	67.2	0.2	53.6	2.9	4.9	9.7	15.9	5.2	57.8	5.4	
Ruby Lake	05/16/93	6.57	9.7	64.9	0.3	49.5	3.4	5.1	9.9	15.6	5.1	58.9	5.3	7.4
Ruby Lake	05/17/93	6.45	10.3	66.7	0.3	49.0	2.6	5.0	9.9	15.5	5.0	59.0	5.4	7.1
Ruby Lake	05/18/93	6.40	9.6	64.2	0.5	48.1	2.6	4.9	9.9	15.3	4.9	57.9	5.3	
Ruby Lake	05/19/93	6.49	8.7	61.9	0.6	46.0	2.4	4.7	11.0	15.4	4.9	59.5	5.4	
Ruby Lake	05/24/93	6.63	8.8	65.7	1.2	42.6	3.2	5.4	11.5	14.9	4.7	59.4	4.8	
Ruby Lake	05/25/93	6.70	8.8	66.3	0.9	42.9	3.0	6.3	11.6	14.6	4.7	61.5	4.7	4.0
Ruby Lake	05/26/93	6.63	9.0	63.3	0.6	44.5	3.1	8.1	12.3	7.0	4.7	62.2	4.6	
Ruby Lake	05/27/93	6.63	8.7	60.3	0.5	42.8	3.0	8.2	12.2	14.3	4.7	58.0	4.3	6.1
Ruby Lake	05/28/93	6.74	9.6	63.9	0.7	43.7	2.6	8.3	12.1	14.4	4.7	74.2	5.0	
Ruby Lake	05/29/93	6.67	8.7	64.2	0.7	45.7	2.5	8.4	12.5	15.1	4.7	76.1	5.3	2.8
Ruby Lake	05/30/93	NA					2.3	8.7	12.9	14.2	4.7	74.2	5.0	
Ruby Lake	05/31/93	6.65	8.9	57.6	0.4	46.7	2.6	9.2	13.7	14.7	4.8	61.7	5.0	4.2
Ruby Lake	06/01/93	6.59	9.1	59.5	0.4	47.3	2.4	9.9	14.3	15.2	4.9	62.9	5.0	
Ruby Lake	06/02/93	6.61	9.1	57.5	0.4	47.8	2.4	9.8	13.3	14.7	4.7	63.7	4.9	4.9
Ruby Lake	06/03/93	6.60	9.1	57.5	0.3	47.4	2.5	10.0	13.8	14.8	4.7	63.1	4.9	
Ruby Lake	06/04/93	6.59	9.1	57.8	0.0		2.1	10.7	14.0	14.4	4.8	62.9	5.0	4.1
Ruby Lake	06/05/93	6.54	9.2	57.0	0.2	49.1	2.1	10.9	14.0	14.3	4.9	63.1	4.9	
Ruby Lake	06/06/93	6.54	9.1	59.3	0.3	49.9	2.4	10.7	13.9	14.5	4.8	63.6	4.8	4.3
Ruby Lake	06/07/93	6.57	9.2	55.3	0.3	50.6	2.4	11.5	14.4	14.4	4.9	63.8	4.9	
Ruby Lake	06/08/93	6.54	9.2	56.3	0.1	51.4	2.1	11.8	14.5	14.4	4.9	63.7	4.8	4.6

Ruby Lake	06/10/93	6.62	9.5	57.9	0.4	50.4	2.3	10.0	12.7	14.3	4.8	62.1	4.6	
Ruby Lake	06/11/93	6.67	8.6	55.0	0.5	49.3	2.7	9.5	12.0	13.4	4.4	55.6	4.6	3.7
Ruby Lake	06/12/93	6.66	8.5	58.0	0.5	48.6	2.2	9.9	12.4	14.5	4.7	59.0	4.6	
Ruby Lake	06/13/93	6.61	8.5	53.4	0.4	47.7	2.2	9.6	11.9	13.8	4.5	57.8	4.5	3.6
Ruby Lake	06/14/93	6.53	8.5	52.8	0.1	47.0	2.5	9.4	12.2	12.5	4.5	58.0	4.3	
Ruby Lake	06/15/93	6.54	8.8	53.7	0.2	46.7	2.2	10.1	12.1	12.7	4.5	58.4	4.4	4.2
Ruby Lake	06/16/93	6.83	8.7	50.7	0.1	47.0	2.3	10.1	12.5	12.4	4.4	56.6	4.3	
Ruby Lake	06/17/93	6.78	8.8	52.4	0.0	47.0	2.1	9.8	11.9	12.4	4.3	58.0	4.3	5.9
Ruby Lake	06/18/93	6.64	8.4	49.6	0.2	48.3	1.4	10.8	13.1	12.9	4.4	56.5	4.4	
Ruby Lake	06/19/93	6.68	8.3	48.6	0.0	48.3	1.3	11.0	13.0	12.8	4.3	56.2	4.3	4.3
Ruby Lake	06/20/93	6.66	8.3	49.6	0.1	48.5	1.3	10.8	12.6	12.9	4.2	56.3	4.4	
Ruby Lake	06/26/93	6.60	12.7	47.1	0.0	44.5		10.8	13.6		4.9	48.4	5.6	3.1
Ruby Lake	06/27/93	6.64	7.7	41.5	0.0	45.3	1.5	10.5	13.2	11.4	4.1	49.1	4.0	
Ruby Lake	06/28/93	6.70	7.5	41.7	0.0	43.7	1.5	9.9	12.7	11.1	3.8	48.5	3.9	3.0
Ruby Lake	06/29/93	6.72	8.2	45.2	0.0	47.0	5.3	9.8	12.9	15.6	4.2	52.4	4.5	
Ruby Lake	06/30/93	6.77	7.8	46.0	0.0	47.0	1.4	9.6	12.3	11.6	3.9	51.1	4.1	
Ruby Lake	07/01/93	6.69	7.9	43.3	0.3	45.4	1.1	9.3	12.0	10.8	4.0	46.9	4.4	2.7
Ruby Lake	07/02/93	6.72	8.3	51.6	0.2	45.9	2.0	7.1	11.5	12.5	4.1	52.3	4.6	
Ruby Lake	07/03/93	6.85	8.4	52.2	0.3	45.6	1.4	6.3	11.1	13.0	4.1	53.5	4.8	
Ruby Lake	07/04/93	6.80	8.2	54.3	0.4	44.4	1.6	6.4	11.4	12.5	4.2	52.6	4.7	2.0
Ruby Lake	07/05/93	6.78	8.2	50.7	0.3	39.4	1.7	6.0	11.2	11.7	4.0	44.7	4.1	
Ruby Lake	07/06/93	6.83	8.0	51.5	0.0	38.7	3.1	5.9	12.0	11.7	3.7	45.4	4.0	
Ruby Lake	07/07/93	6.82	8.1	52.4	0.0	38.1	1.7	5.4	11.2	11.8	3.7	45.3	3.9	2.8
Ruby Lake	07/08/93	6.85	8.2	56.7	0.0	38.7	1.9	4.9	11.2	12.2	3.7	46.6	3.9	
Ruby Lake	07/09/93	6.89	7.3	52.8	0.1	41.3	1.9	4.8	11.2	12.3	3.9	51.4	4.4	
Ruby Lake	07/10/93	6.85	8.0	57.7	0.2	40.5		4.7	11.3		3.7	36.0	4.3	2.0
Ruby Lake	07/11/93	6.73	7.3	55.0	0.0	40.3	1.8	2.3	11.0	12.4	4.0	53.6	4.6	
Ruby Lake	07/12/93	6.78	7.4	55.0	0.2	41.0	1.7	4.6	11.0	12.4	3.9	53.4	4.5	
Ruby Lake	07/13/93	6.81	7.4	49.5	0.0	38.7	1.7	4.5	11.2	12.0	3.9	46.0	4.4	2.2
Ruby Lake	07/14/93	6.82	7.4	56.5	0.1	41.1	1.7	4.6	11.1	12.4	3.8	52.3	4.4	
Ruby Lake	07/15/93	6.77	7.5	55.0	0.0	40.7	1.9	4.7	12.9	12.2	4.0	49.2	4.4	3.7
Ruby Lake	07/16/93	6.87	7.3	54.1	0.3	40.8	2.0	4.6	12.2	12.3	4.0	49.9	4.3	
Ruby Lake	07/17/93	6.81	7.3	53.6	0.1	41.0	1.9	4.3	11.7	12.3	4.1	49.4	4.3	
Ruby Lake	07/18/93	6.93	7.4	53.5	0.0	41.8	1.9	4.8	11.8	12.3	4.1	49.2	4.4	2.4
Ruby Lake	07/19/93	6.88	7.3	54.4	0.0	42.3	1.8	4.8	11.9	12.4	4.1	48.9	4.7	
Ruby Lake	07/20/93	6.83	7.4	50.8		34.4	1.9	4.5	10.7	12.6	3.9	46.5	4.5	5.4
Ruby Lake	07/21/93	6.83	7.7	50.6		37.4	2.0	4.7	11.2	12.9	4.1	48.5	4.6	
Ruby Lake	07/22/93	6.87	7.7	51.7		38.8	2.0	3.9	10.8	13.0	4.1	49.4	4.6	
Ruby Lake	07/23/93	6.86	11.3	50.7		38.7		4.6	11.4		4.2	48.6	4.7	
Ruby Lake	07/24/93	6.88	12.2	50.3		35.2		4.6	11.1		4.1	48.3	4.8	5.1

Site	Date	pH	Conductivity µS	ANC µeq/L	NH4 µeq/L	SiO2 mg/L	Cl µeq/L	NO3 µeq/L	SO4 µeq/L	µeq/L	Mg µeq/L	Ca µeq/L	K µeq/L	Aluminum µg/L
Ruby Lake	07/25/93	6.82	7.7	49.7		35.5	6.8	4.6	11.4	18.1	4.2	49.2	5.0	
Ruby Lake	07/26/93	6.81	7.5	48.4		39.2	2.4	4.2	11.4	13.1	4.0	42.4	4.9	
Ruby Lake	07/27/93	6.82	7.0	49.2	0.2	38.3	2.0	4.6	12.0	13.1	4.0	45.1	4.8	
Ruby Lake	07/28/93	6.80	7.0	48.2	0.0	36.4	2.1	4.9	12.0	12.9	4.0	47.2	4.7	3.2
Ruby Lake	07/29/93	6.85	7.2	45.3	0.4	39.6	1.9	4.4	11.6	12.8	3.9	45.8	4.5	
Ruby Lake	08/01/93	6.80	7.3	47.1	1.7	37.2	1.9	4.2	11.9	12.7	3.9	46.6	4.4	
Ruby Lake	08/04/93	6.82	7.1	42.8	0.0	36.5	2.0	4.1	11.9	12.4	3.8	45.5	4.3	3.2
Ruby Lake	08/07/93	6.67	6.1	45.5	0.2	33.9	1.5	3.9	12.3	12.1	3.7	43.4	4.4	
Ruby Lake	08/10/93	6.63	6.2	44.8	0.2	38.9	1.5	5.5	12.1	12.0	3.6	43.9	4.2	7.5
Ruby Lake	08/13/93	6.68	6.4	44.3	0.0	40.0	1.7	3.6	12.6	12.5	3.9	41.7	4.4	
Ruby Lake	08/16/93	6.72	6.9	44.2	0.0	38.9	1.5	3.2	12.1	12.4	3.9	41.9	4.3	8.0
Ruby Lake	08/19/93	6.75	6.8	45.3	0.6	38.6	1.6	2.7	12.7	12.8	4.0	43.1	4.4	
Ruby Lake	08/22/93	6.76	7.4	45.3	0.0	38.2	1.8	2.7	12.1	13.1	4.3	42.4	4.7	8.7
Ruby Lake	08/25/93	6.60		47.3	0.8	40.2	1.8	2.7	13.0	12.1	3.8	46.1	4.3	
Ruby Lake	08/28/93	6.68		47.5	0.0	38.4	1.8	2.4	12.9	12.6	4.0	44.2	4.9	
Spuller Lake	05/07/93	6.46	18.7	126.6	0.7	40.8	2.7	12.3	31.7	14.8	14.5	126.0	5.1	9.1
Spuller Lake	05/14/93	6.52	16.1	100.8	0.6	40.4	3.1	12.7	28.8	20.2	11.3	107.0	3.8	12.3
Spuller Lake	05/15/93	6.88	15.5	91.3	0.2	55.0	2.6	11.9	26.5	20.4	11.0	103.0	4.4	
Spuller Lake	05/16/93	6.92	15.2	99.9	0.3	54.8	2.7	12.0	26.0	20.4	10.9	103.0	4.3	
Spuller Lake	05/17/93	6.87	14.0	87.5	0.3	50.8	2.7	13.0	23.9	18.9	9.8	94.0	4.5	10.7
Spuller Lake	05/18/93	6.72	13.1	81.2	0.4	48.6	3.5	13.8	21.2	17.9	9.1	86.0	4.3	
Spuller Lake	05/19/93	6.63	11.9	71.4	0.3	44.8	3.4	12.9	19.4	16.0	8.4	83.4	4.0	
Spuller Lake	05/20/93	6.51	11.3	68.1	0.3	43.1	3.3	12.8	18.5	15.6	7.9	78.5	3.9	10.2
Spuller Lake	05/21/93	6.40	11.1	65.2	0.5	42.3	3.2	12.9	17.8	15.1	7.8	75.4	3.9	
Spuller Lake	05/26/93	6.64	9.0	55.3	0.4	42.6	2.0	13.0	15.5	13.5	6.7	76.8	3.0	7.7
Spuller Lake	05/27/93	6.51	9.1	61.7	0.5	42.8	2.0	12.3	16.1	14.1	6.9	81.1	3.2	
Spuller Lake	05/28/93	6.49	9.1	60.8	0.4	43.2	2.0	12.0	16.5	14.3	6.9	82.3	3.1	
Spuller Lake	05/29/93	6.51	9.4	64.2	0.4	45.4	2.1	12.2	17.1	14.9	7.2	84.2	3.2	7.4
Spuller Lake	05/30/93	6.51	9.1	60.6	0.5	39.6	2.4	11.3	16.9	14.3	6.9	81.1	3.4	
Spuller Lake	05/31/93	6.41	8.7	56.7	0.5	42.6	1.8	10.8	15.1	13.0	6.6	76.2	3.1	
Spuller Lake	06/01/93	6.61	10.3	59.0	0.1	43.7	5.6	11.4	14.7	17.2	7.1	68.5	3.4	7.1
Spuller Lake	06/02/93	6.57	10.7	61.4	0.1	45.5	5.7	11.4	15.2	18.3	7.5	72.0	3.6	
Spuller Lake	06/03/93	6.57	10.5	62.6	0.1	47.1	2.0	11.6	15.9	15.3	7.4	74.6	3.3	
Spuller Lake	06/04/93	6.49	10.9	66.6	0.1	48.3	2.1	11.1	16.4	16.3	7.7	78.1	3.3	6.5
Spuller Lake	06/05/93	6.59	11.0	69.0	0.2	48.9	2.6	11.4	17.1	16.8	7.9	80.5	3.4	
Spuller Lake	06/06/93	6.53	11.4	68.9	0.1	51.1	5.2	11.4	17.6	18.0	7.8	81.3	3.4	
Spuller Lake	06/07/93	6.41	11.6	71.0	0.3	51.5	2.3	11.5	18.1	16.8	8.0	79.5	3.2	6.0
Spuller Lake	06/08/93	6.45	11.7	74.6	0.3		2.0	10.6	18.4	16.7	8.0	80.4	3.3	

Site	Date	pH	Conductivity µS	ANC µeq/L	NH4 µeq/L	SiO2 mg/L	Cl µeq/L	NO3 µeq/L	SO4 µeq/L	µeq/L	Mg µeq/L	Ca µeq/L	K µeq/L	Aluminum µg/L
Spuller Lake	06/09/93	6.34	11.3	71.6	0.3	48.7	1.9	10.4	18.3	16.2	7.8	79.0	3.2	7.2
Spuller Lake	06/10/93	6.35	10.6	65.2	0.3	46.3	2.3	9.5	17.3	15.0	7.3	73.7	3.1	
Spuller Lake	06/11/93	6.73	9.8	60.0	0.2	42.4	1.7	10.1	15.4	13.1	6.5	65.1	2.9	7.7
Spuller Lake	06/12/93	6.75	9.6	59.4	0.2	41.8	2.6	9.5	15.3	13.2	6.4	64.9	2.9	
Spuller Lake	06/13/93	6.59	9.2	55.5	0.2	40.9	2.1	9.6	14.5	12.6	6.2	61.6	2.9	
Spuller Lake	06/15/93	6.70	8.2	40.7	0.2	38.4	1.0	10.1	13.4	11.6	5.6	50.5	2.9	6.9
Spuller Lake	06/16/93	6.73	8.0	41.6	0.2	38.1	1.1	9.8	13.0	11.7	5.5	51.5	2.9	
Spuller Lake	06/17/93	6.72	7.8	44.9	0.1	38.7	1.2	9.6	12.8	11.5	5.4	51.8	2.8	6.4
Spuller Lake	06/18/93	6.73	7.6	41.3	0.1	38.0	1.0	8.9	12.7	11.1	5.2	50.3	2.7	
Spuller Lake	06/19/93	6.72	7.3	41.2	0.1	37.2	0.8	8.5	12.4	10.7	5.0	47.6	2.7	
Spuller Lake	06/20/93	6.69	6.8	36.8	0.1	34.3	0.7	7.9	11.7	9.8	4.7	43.1	2.6	
Spuller Lake	06/21/93	6.66	7.1	41.7	0.1	35.9	0.9	7.3	12.0	10.4	4.8	45.2	2.6	6.1
Spuller Lake	06/22/93	6.69	7.2	44.1	0.1	37.4	0.7	7.7	12.4	10.9	5.0	45.2	2.7	
Spuller Lake	06/23/93	6.63	7.1	41.2	0.1	36.3	0.7	6.7	11.9	10.5	4.8	43.4	2.6	6.0
Spuller Lake	06/24/93	6.54	6.8	39.4	0.2	35.3	0.6	6.0	11.6	10.1	4.8	43.2	2.7	
Spuller Lake	06/25/93	6.68	5.6	35.7	0.2	36.5	0.9	6.7	11.1	9.5	4.3	39.3	2.6	5.8
Spuller Lake	06/26/93	6.69	5.6	35.0	0.2	33.6	1.2	6.0	10.7	9.2	4.2	39.6	2.6	
Spuller Lake	06/27/93	6.66	5.6	34.7	0.3	32.1	0.9	5.5	10.2	8.9	3.9	37.0	2.5	3.9
Spuller Lake	06/28/93	6.58	5.5	34.7	0.2	33.7	0.9	5.0	9.7	8.7	3.9	35.3	2.5	
Spuller Lake	06/29/93	6.70	6.4	33.3	0.2	33.6	1.1	5.6	10.4	8.9	4.1	35.6	2.6	5.0
Spuller Lake	06/30/93	6.61	6.6	36.8	0.2	34.4	1.2	5.4	10.5	9.5	4.4	38.8	2.7	
Spuller Lake	07/01/93	6.65	6.3	34.5	0.3	33.9	1.4	5.0	10.3	9.2	4.2	37.3	2.6	5.3
Spuller Lake	07/02/93	6.60	6.0	33.4	0.5	32.9	1.0	4.2	9.7	8.7	3.9	34.8	2.4	
Spuller Lake	07/03/93	6.61	5.8	31.7	0.2	32.8	1.0	4.0	9.4	8.7	3.8	33.0	2.5	5.1
Spuller Lake	07/04/93	6.59	5.9	32.7	0.7	34.3	0.9	3.4	9.3	8.7	3.8	32.9	2.4	
Spuller Lake	07/05/93	6.54	5.7	31.4	0.5	33.1	0.9	2.8	9.2	8.5	3.8	30.8	2.4	2.4
Spuller Lake	07/06/93	6.50	5.4	30.0	0.6	31.6	1.0	3.1	8.6	8.2	3.5	28.5	2.4	5.2
Spuller Lake	07/07/93	6.57	5.1	28.5	0.0	28.6	0.9	3.8	8.2	7.6	3.2	24.7	2.2	
Spuller Lake	07/08/93	6.56	5.0	27.0	0.2	27.9	1.5	3.6	8.6	7.9	3.2	24.3	2.3	3.4
Spuller Lake	07/09/93	6.57	5.0	30.6	0.0	29.3	0.9	3.4	8.0	7.6	3.3	29.0	2.1	
Spuller Lake	07/10/93	6.56	4.8	31.0	0.0	30.4	0.6	2.2	4.3	8.1	3.3	29.7	2.2	3.4
Spuller Lake	07/11/93	6.49	4.8	31.0	0.0	31.1	1.0	3.3	7.8	8.2	3.3	29.4	2.3	
Spuller Lake	07/12/93	6.52	4.6	30.5	0.0	30.7	1.0	2.7	7.8	8.1	3.3	28.9	2.3	3.0
Spuller Lake	07/13/93	6.51	4.8	31.4	0.0	30.6	1.2	3.1	7.9	8.1	3.3	30.0	2.2	
Spuller Lake	07/14/93	6.53	4.9	31.3	0.0	31.8	1.1	2.9	7.9	8.2	3.2	30.3	2.2	3.5
Spuller Lake	07/15/93	6.51	5.0	33.6	0.0	32.1	1.0	2.8	8.0	8.4	3.4	31.6	2.3	
Spuller Lake	07/16/93	6.66	5.3	31.3	0.0	35.3	1.3	3.4	7.4	9.5	3.5	27.9	2.2	6.2
Spuller Lake	07/17/93	6.68	5.3	35.2	0.0	36.6	2.0	3.9	7.9	10.3	3.8	30.1	2.5	

Site	Date	pH	Conductivity	ANC	NH4	SiO2	Cl	NO3	SO4		Mg	Ca	K	Aluminum
			µS	µeq/L	µeq/L	mg/L	µeq/L	µeq/L	µeq/L	µeq/L	µeq/L	µeq/L	µeq/L	µg/L
Spuller Lake	07/18/93	6.65	5.2	33.1	0.0	35.1	1.5	3.5	7.9	10.2	3.7	29.7	2.3	6.0
Spuller Lake	07/19/93	6.66	5.2	34.6	0.0	34.4	1.9	3.4	7.9	10.2	3.6	28.5	2.3	
Spuller Lake	07/20/93	6.65	5.3	34.9	0.0	33.3	1.6	3.2	8.2	9.7	3.7	30.2	2.3	5.5
Spuller Lake	07/21/93	6.63	5.3	35.0	0.0	31.0	1.7	3.3	8.2	10.0	3.8	30.1	2.7	
Spuller Lake	07/22/93	6.63	4.9	36.8	0.0	33.8	1.2	3.1	7.9	9.8	3.7	28.9	2.4	6.1
Spuller Lake	07/23/93	5.72	4.3	26.1		26.8	1.1	2.7	7.6	9.2	3.6	24.9	2.2	
Spuller Lake	07/24/93	5.88	5.1	35.3		25.8	1.1	2.4	7.7	9.5	3.6	27.0	2.3	4.6
Spuller Lake	07/25/93	5.85	5.0	31.7		24.0	1.1	2.8	7.5	9.3	3.5	27.3	2.3	
Spuller Lake	07/26/93	5.88	4.8	31.4		29.5	1.1	2.2	7.2	8.6	3.1	26.3	2.2	3.9
Spuller Lake	07/27/93	5.86	4.7	29.4		28.8	1.1	2.1	7.1	8.8	3.0	25.1	2.3	
Spuller Lake	07/29/93	6.66	4.3	28.7	0.0	26.5	1.1	3.1	6.7	9.2	3.0	25.1	2.4	2.8
Spuller Lake	07/31/93	6.70	4.5	30.5	0.0	27.9	1.1	2.7	6.5	9.7	3.1	26.1	3.1	
Spuller Lake	08/03/93	6.72	4.4	31.5	0.2	26.1	1.1	2.6	6.7	9.9	3.1	25.7	2.6	3.6
Spuller Lake	08/06/93	6.60	5.0	29.3	0.0	28.7	1.1	2.0	6.4	9.9	3.1	24.8	2.5	
Spuller Lake	08/09/93	6.74	4.6	28.3	0.0	30.6	1.5	1.8	7.2	10.2	3.1	25.9	2.5	8.1
Spuller Lake	08/12/93	6.69	5.9	30.8	0.0	31.5	1.4	1.1	7.1	10.5	3.2	26.5	2.5	
Spuller Lake	08/15/93	6.70	5.0	31.6	0.0	31.8	0.8	2.0	6.2	10.9	3.2	27.5	2.5	4.4
Spuller Lake	08/18/93	6.69	5.3	31.7	0.0	31.8	0.9	1.7	6.5	11.1	3.2	28.0	2.5	
Spuller Lake	08/21/93	6.72	5.2	34.7	0.0	34.1	0.8	1.3	6.6	10.7	3.2	28.7	2.4	4.1
Spuller Lake	08/24/93	6.74	5.2	36.0	0.0	35.7	0.8	1.0	6.6	10.9	3.3	29.2	2.6	
Spuller Lake	08/30/93	6.60	5.4	39.1	0.0	35.9	1.6	0.7	7.3	11.4	3.5	29.6	2.6	
Spuller Lake	09/02/93	6.63	5.8	37.6	0.0	36.3	2.4	1.3	8.0	12.8	3.5	29.0	2.7	
Spuller Lake	09/05/93	6.63	5.7	38.7	0.0	36.6	1.5	3.3	8.1	12.0	3.5	30.6	2.8	
Spuller Lake	08/27/93	6.63	5.2	36.7	0.3	37.1	1.4	1.3	7.8	11.4	3.6	29.8	2.8	
Treasure Lake	04/29/93	6.56	7.2	50.4	0.8	31.8	1.6	11.1	7.2	10.3	4.2	47.0	5.1	2.7
Treasure Lake	04/30/93	6.58	7.0	47.4	1.6	32.5	1.4	9.0	7.4	10.3	3.9	45.0	4.9	
Treasure Lake	05/01/93	6.48	6.9	46.3	1.5	33.4	1.5	8.5	7.5	9.6	4.1	42.7	4.5	5.5
Treasure Lake	05/02/93	6.35	7.0	46.7	1.4	34.9	1.4	8.0	7.7	9.9	4.3	43.3	4.8	
Treasure Lake	05/03/93	6.48	6.9	45.6	1.3	36.7	1.3	7.1	8.1	10.1	4.3	42.1	4.6	9.7
Treasure Lake	05/04/93	6.39	6.8	42.5	1.4	38.0	1.8	8.2	8.6	10.3	4.3	39.4	4.4	
Treasure Lake	05/05/93	6.32	6.8	35.8	1.1	39.3	1.9	9.4	8.6	10.5	4.3	38.4	5.0	9.6
Treasure Lake	05/06/93	6.62	6.9	39.5	1.1	41.5	2.1	10.7	9.7	8.5	4.5	39.8	4.2	
Treasure Lake	05/07/93	6.59	6.9	38.6			2.1	10.4	9.5	8.8	4.3	40.1	4.2	
Treasure Lake	05/08/93	6.58	6.9	39.3	0.9	40.3	2.0	10.1	8.4	9.7	4.4	39.0	4.0	
Treasure Lake	05/09/93	6.52	6.9	40.0	1.0	39.4	2.0	9.9	8.5	11.0	4.5	39.3	4.3	9.0
Treasure Lake	05/10/93	6.46	6.9	38.9	1.0	39.9	1.9	9.2	8.3	9.6	4.4	39.8	3.9	
Treasure Lake	05/11/93	6.33	7.0	37.8	0.9	39.6	2.0	9.0	8.4	9.5	4.2	39.4	3.8	9.6
Treasure Lake	05/12/93	6.73	6.8	35.8	0.7	40.1	2.7	8.8	8.7	10.2	4.2	40.0	4.5	9.5

Treasure Lake	05/13/93	6.74		6.8	34.5	0.9	39.5	2.2	9.8	8.7	9.9	4.2	39.5	4.5		9.5
Treasure Lake	05/14/93	6.69		6.7	37.0	0.8	39.9	2.0	9.3	8.9	9.8	4.1	38.5	4.4		8.9
Treasure Lake	05/15/93	6.73		6.6	36.0	0.9	40.2	1.9	9.2	8.5	10.1	4.2	37.7	4.7		8.7
Treasure Lake	05/16/93	6.67		6.7	38.1	0.8	40.0	1.9	8.7	8.4	10.3	4.2	38.0	4.7		9.2
Treasure Lake	05/17/93	6.61		6.6	32.1	0.6	41.9	2.2	9.1	8.6	10.1	4.4	36.3	4.5		8.6
Treasure Lake	05/18/93	6.50		6.7	33.3	0.8	41.2	2.1	9.8	8.7	10.1	4.3	37.1	4.3		8.1
Treasure Lake	05/19/93	6.62		6.3	33.5	0.0	42.3	3.1	12.4	8.3	9.5	4.3	40.0	4.0		
Treasure Lake	05/20/93	6.57			27.7	0.0	42.5	3.2	13.9	8.6	9.4	4.0	37.7	3.8		7.6
Treasure Lake	05/21/93	6.50			27.8	0.0	42.3	3.2	14.5	8.5	9.4	4.0	37.4	3.9		6.3
Treasure Lake	05/22/93	6.45		6.1	26.4	0.0	40.5	3.1	14.7	8.4	9.4	3.9	36.9	3.7		5.3
Treasure Lake	05/23/93	6.44			27.3	0.0	41.2	3.3	15.5	8.4	9.3	3.8	36.6	3.7		5.5
Treasure Lake	05/24/93	6.22		6.4	23.8	0.0	40.7	3.8	16.1	8.4	8.8	3.8	36.8	3.4		5.7
Treasure Lake	05/25/93	6.29		6.3	23.3	0.0	40.1	3.2	16.1	8.4	8.4	3.7	36.7	3.5		6.7
Treasure Lake	05/26/93	6.28		6.1	25.0	0.0	41.2	3.1	15.4	8.4	8.8	3.6	35.5	3.6		8.2
Treasure Lake	05/27/93	6.25		6.1	25.3	0.0	39.0	3.1	14.7	8.3	8.8	3.7	35.3	3.6		6.4
Treasure Lake	05/28/93	6.26		6.1	25.7	0.0	39.6	3.0	14.3	8.2	8.3	3.5	35.0	3.3		5.7
Treasure Lake	05/29/93	6.28		5.7	27.7	0.1	39.3	2.0	13.9	7.7	8.6	3.3	35.6	3.5		4.8
Treasure Lake	05/30/93	6.30		5.8	26.2	0.1	39.9	2.2	14.5	7.5	8.7	3.4	37.0	3.4		4.8
Treasure Lake	05/31/93	6.30		5.9	28.3	0.1	42.5	2.5	15.2	7.5	8.8	3.6	37.0	3.5		5.0
Treasure Lake	06/01/93	6.40		5.9	26.1	0.1	42.5	2.3	15.4	7.4	8.7	3.5	37.9	3.4		4.8
Treasure Lake	06/02/93	6.31		6.0	26.9	0.1	42.8	2.2	15.0	7.4	8.7	3.5	37.8	3.4		6.7
Treasure Lake	06/03/93	6.31		5.9	26.6	0.3	41.7	1.9	14.6	7.5	8.6	3.5	37.0	3.4		5.4
Treasure Lake	06/04/93	6.31		5.7	21.6	0.1	40.2	2.3	14.5	7.4	8.7	3.6	38.0	3.7		4.7
Treasure Lake	06/05/93	6.27		6.0	26.7	0.1	43.2	2.1	15.4	7.3	8.8	3.8	39.4	3.8		4.4
Treasure Lake	06/06/93	6.34		6.2	28.3	0.1	43.3	2.0	15.6	7.4	8.8	3.8	40.6	3.8		4.1
Treasure Lake	06/07/93	6.26		6.3	26.6	0.0	42.1	2.2	16.3	8.4	9.0	3.9	42.0	3.9		4.5
Treasure Lake	06/08/93	6.24		6.1	26.6	0.0	42.3	2.6	15.9	7.4	9.0	3.9	44.8	3.8		4.3
Treasure Lake	06/09/93	6.26		6.3	23.0	0.3	44.2	2.5	17.4	8.2	9.1	3.9	40.1	3.8		5.5
Treasure Lake	06/10/93	6.38		6.7	30.6	0.4	46.6	2.2	14.2	7.8	9.0	3.6	38.1	3.7		6.5
Treasure Lake	06/11/93	6.39		6.5	30.3	0.3	45.9	2.1	13.8	7.7	8.8	3.6	37.0	3.7		
Treasure Lake	06/12/93	6.34		6.6	31.4	0.3	45.5	2.1	14.4	7.7	8.9	3.6	37.2	3.7		8.0
Treasure Lake	06/13/93	6.31		6.7	29.4	0.1	42.4	2.2	15.3	7.8	8.7	3.4	37.9	3.6		
Treasure Lake	06/14/93	6.44		6.3	26.2	0.0	40.1	2.2	15.1	8.1	8.6	3.5	35.8	3.6		5.1
Treasure Lake	06/15/93	6.45		6.4	27.0	0.0	40.8	1.5	16.2	8.0	8.5	3.5	36.1	3.6		
Treasure Lake	06/16/93	6.42		6.2	24.8	0.0	39.8	3.0	15.7	8.8	8.5	3.5	34.8	3.6		4.7
Treasure Lake	06/17/93	6.37		6.4	24.8	0.0	39.8	1.5	15.9	8.3	8.4	3.6	35.9	3.6		
Treasure Lake	06/18/93	6.28		6.5	26.6	0.0	39.9	1.4	15.7	8.2	8.1	3.6	37.5	3.8		5.9
Treasure Lake	06/19/93	6.30		6.0	25.9	0.0	38.5	1.3	15.0	8.0	7.9	3.5	36.3	3.4		
Treasure Lake	06/20/93	6.39		5.8	22.4	0.1	37.6	1.4	14.2	8.1	7.6	3.4	33.9	3.3		
Treasure Lake	06/21/93	6.44		6.0	19.4	0.1	37.8	1.5	15.4	8.5	8.1	3.2	33.9	3.2		3.3

Site	Date	pH	Conductivity µS	ANC µeq/L	NH4 µeq/L	SiO2 mg/L	Cl µeq/L	NO3 µeq/L	SO4 µeq/L	µeq/L	Mg µeq/L	Ca µeq/L	K µeq/L	Aluminum µg/L
Treasure Lake	06/22/93	6.49	5.9	22.2	0.0	38.5	1.5	15.5	8.5	8.0	3.3	34.4	3.2	2.4
Treasure Lake	06/23/93	6.42	5.8	24.1	0.1	37.9	1.3	14.8	8.3	8.0	3.3	33.2	3.3	
Treasure Lake	06/24/93	6.44	5.7	22.0	0.1	35.8	1.8	14.3	8.9	7.6	3.2	32.9	3.2	2.5
Treasure Lake	06/25/93	6.38	5.5	21.9	0.1	34.2	1.6	13.4	8.6	7.3	3.1	31.8	3.1	
Treasure Lake	06/26/93	6.42	5.3	20.4	0.1	32.3	1.5	12.9	8.6	7.1	3.0	30.6	3.1	2.0
Treasure Lake	06/27/93	6.38	5.2	20.4	0.1	32.3	1.4	11.9	8.4	7.0	2.9	29.2	3.1	
Treasure Lake	06/28/93	6.44	6.1	22.9	0.0	34.0	2.7	12.6	8.2	7.8	2.9	30.5	3.5	1.4
Treasure Lake	06/29/93	6.46	6.0	22.5	0.0	35.4	1.7	12.5	8.3	7.1	3.1	31.2	3.4	
Treasure Lake	06/30/93	6.48	5.9	23.7	0.1	35.1	1.6	12.2	8.2	6.9	3.0	28.6	3.3	1.1
Treasure Lake	07/01/93	6.47	5.7	19.4	0.2	35.2	1.9	11.3	8.3	6.8	2.9	28.2	3.3	
Treasure Lake	07/02/93	6.44	5.6	19.9	0.0	34.1	1.5	10.5	7.8	6.6	2.9	27.2	3.1	2.7
Treasure Lake	07/03/93	6.42	5.4	22.5	0.0	33.5	1.6	9.7	7.7	6.6	2.9	26.3	3.3	
Treasure Lake	07/04/93	6.41	5.4	21.9	0.0	34.0	1.6	9.4	7.8	6.6	2.8	28.0	3.2	2.2
Treasure Lake	07/05/93	6.57	4.5	22.5	0.0	32.4	1.7	9.4	7.2	6.6	2.6	28.6	3.2	1.4
Treasure Lake	07/06/93	6.51	4.3	22.5	0.0	31.7	1.3	8.7	7.0	6.3	2.5	27.2	2.9	
Treasure Lake	07/07/93	6.41	4.3	21.4	0.0	31.5	1.2	7.7	6.8	6.1	2.3	26.2	2.9	
Treasure Lake	07/08/93	6.44	4.2	19.1	0.0	30.0	1.2	7.5	6.6	5.8	2.3	25.3	2.8	
Treasure Lake	07/09/93	6.44	4.2	21.6	0.0	31.3	1.6	6.8	6.6	5.9	2.3	25.3	2.7	1.8
Treasure Lake	07/10/93	6.47	4.0	22.5	0.0	30.0	1.1	6.7	6.4	6.1	2.3	24.3	3.0	
Treasure Lake	07/11/93	6.52	4.2	23.1	0.0	31.0	1.2	6.4	6.4	5.9	2.3	25.2	2.8	
Treasure Lake	07/12/93	6.57	4.5	24.3	0.0	30.4	1.4	6.4	6.6	6.8	2.5	23.3	3.0	6.7
Treasure Lake	07/13/93	6.55	4.5	24.1	0.0	29.8	1.7	6.1	6.2	6.8	2.7	23.5	3.0	
Treasure Lake	07/14/93	6.54	4.6	24.5	0.0	30.4	1.4	6.1	6.1	7.0	2.7	24.2	3.1	
Treasure Lake	07/15/93	6.55	4.5	24.1	0.1	30.5	1.5	6.1	6.3	7.0	2.7	24.4	3.2	3.5
Treasure Lake	07/16/93	6.58	4.5	26.7	0.0	30.5	1.4	5.9	6.1	6.9	2.7	24.2	3.1	
Treasure Lake	07/17/93	6.54	4.5	26.6	0.1	30.9	1.7	5.9	6.2	7.1	2.7	24.3	3.3	
Treasure Lake	07/18/93	6.58	4.5	26.9	0.0	31.1				6.9	2.4	23.6	3.0	6.1
Treasure Lake	07/19/93	6.54	4.5	24.5	0.0	30.9	1.7	6.0	6.2	7.1	2.6	25.0	3.2	
Treasure Lake	07/20/93	6.58	4.6	24.0	0.1	31.7	1.5	6.2	6.2	7.0	2.6	25.0	3.1	
Treasure Lake	07/21/93	5.89	4.7	30.4		28.7	1.5	6.2	5.9	7.0	2.4	24.4	3.1	2.0
Treasure Lake	07/22/93	5.83	4.6	30.4		27.6	1.4	6.1	6.0	7.0	2.4	25.0	3.0	
Treasure Lake	07/23/93	5.84	4.5	25.9		25.5	1.3	6.2	6.1	6.8	2.5	24.2	3.1	
Treasure Lake	07/24/93	5.78	4.4	24.8		28.1	1.5	6.2	6.2	6.9	2.5	23.8	3.1	5.5
Treasure Lake	07/25/93	5.79	4.4	30.5		28.0	1.3	5.8	5.9	6.5	2.3	23.4	3.0	
Treasure Lake	07/26/93	5.78	4.4	24.6		26.9	1.4	5.7	5.8	6.4	2.4	22.9	2.9	
Treasure Lake	07/27/93	6.54	4.3	20.4	4.7	29.0	1.3	5.1	5.9	6.8	2.4	23.9	3.0	1.6
Treasure Lake	07/28/93	6.50	4.2	20.2	0.2	27.1	1.2	5.5	5.8	6.6	2.3	23.9	3.0	
Treasure Lake	07/29/93	6.56		23.8	0.0	26.8	1.2	4.9	5.8	6.6	2.3	23.5	3.5	1.6

Site	Date	pH	Conductivity µS	ANC µeq/L	NH4 µeq/L	SiO2 mg/L	Cl µeq/L	NO3 µeq/L	SO4 µeq/L	µeq/L	Mg µeq/L	Ca µeq/L	K µeq/L	Aluminum µg/L
Treasure Lake	07/29/93	6.52	4.2	21.4	0.0	26.2	1.2	5.2	5.8	6.6	2.3	23.8	3.0	
Treasure Lake	07/30/93	6.51	4.2	24.5	0.8	27.6	1.2	5.0	5.6	6.6	2.3	23.5	2.9	
Treasure Lake	07/31/93	6.58	4.3	21.5	0.0	24.0	1.1	5.0	5.6	6.8	2.4	24.1	3.0	
Treasure Lake	08/01/93	6.55	4.1	21.2	0.2	27.8	1.2	4.8	5.5	6.9	2.2	22.9	3.1	0.8
Treasure Lake	08/01/93	6.55	4.4	24.8	0.0	23.6	1.2	5.1	5.7	6.5	2.3	23.7	2.9	2.0
Treasure Lake	08/04/93	6.38	3.6	22.8	0.0	25.1	1.0	5.0	5.3	6.5	2.2	23.1	2.9	
Treasure Lake	08/07/93	6.45	3.6	21.8	0.0	27.0	0.9	4.8	5.2	6.5	2.2	23.5	3.1	3.5
Treasure Lake	08/10/93	6.49	3.6	21.5	0.0	28.6	0.9	4.7	5.3	6.6	2.2	23.8	3.0	
Treasure Lake	08/13/93	6.49	3.8	24.0	0.8	27.2	0.9	5.0	5.5	6.9	2.3	24.6	3.1	4.0
Treasure Lake	08/16/93	6.53	3.8	25.2	0.0	26.0	1.0	4.9	5.5	7.0	2.3	25.5	3.2	
Treasure Lake	08/19/93	6.58	4.6	25.6	0.4	26.3	1.5	4.2	5.5	7.9	2.4	24.5	3.2	3.0
Treasure Lake	08/22/93	6.67	4.6	27.2	0.0	27.5	1.0	4.2	5.2	7.4	2.4	25.4	3.2	
Treasure Lake	08/25/93	6.46	4.3	29.0	0.0	28.8	1.9	5.1	6.3	7.2	2.6	26.2	3.3	
Treasure Lake	08/28/93	6.46	4.7	28.1	0.0	29.0	1.4	3.9	5.8	7.3	2.6	26.5	3.4	
Treasure Lake	08/31/93	6.50	4.8	30.1	0.1	30.1	1.5	3.8	5.8	7.1	2.6	26.7	3.3	
Treasure Lake	09/03/93	6.55	4.6	30.3	0.0	30.5	1.7	3.5	5.8	7.5	2.3		3.4	
M1	04/28/93	6.10	7.1	34.8	0.8	36.1	3.3	15.2	8.7	13.3	5.6	35.3	3.9	
M1	04/28/93	6.13	7.1	34.2	0.7	35.1	3.2	14.0	8.7	13.1	5.6	35.9	3.9	31.7
M1	04/30/93	6.14	5.2	20.1	0.7	33.7	3.3	15.7	8.6	12.3	5.3	33.2	3.8	23.6
M1	05/01/93	6.25	6.2	26.5	0.2	29.6	3.5	15.4	8.1	13.0	5.2	35.5	4.8	
M1	05/02/93	6.05	6.1	23.8	0.3	32.3	3.5	15.0	8.4	11.2	5.0	31.9	3.7	27.1
M1	05/03/93	5.98	6.1	26.3	0.2	33.2	3.6	14.7	8.6	11.3	5.0	34.6	5.1	
M1	05/03/93	5.97	5.9	27.5	0.6	29.8	3.4	14.0	8.6	11.0	4.6	33.6	4.7	
M1	05/03/93	5.92	6.2	28.9	0.6	30.4	3.8	14.8	8.7	11.4	4.9	34.7	5.3	29.4
M1	05/03/93	5.97	6.6	30.5	0.6	30.7	3.5	12.6	7.5	10.3	4.4	33.3	3.9	26.1
M1	05/03/93	6.18	6.1	28.6	0.0	31.2	3.7	13.9	8.2	11.6	5.0	36.1	4.1	21.0
M1	05/03/93	5.96	6.6	31.7	0.7	29.1	3.6	13.9	8.4	11.2	4.8	36.0	4.1	22.4
M1	05/04/93	6.17	5.5	24.0	0.3	32.9	3.5	13.4	8.6	10.9	4.7	34.7	4.1	
M1	05/05/93	6.29	5.7	24.7	0.0	33.5	3.4	11.8	8.1	11.9	4.8	35.2	4.0	24.7
M1	05/06/93	6.00	5.4	26.3	0.3	33.1	3.6	11.7	8.2	10.8	4.5	32.7	4.4	
M1	05/07/93	6.31	5.4	27.6	0.0	31.6	3.0	10.1	7.5	11.4	4.5	32.9	3.8	24.5
M1	05/08/93	6.20	5.3	26.8	0.0	32.0	3.0	9.7	7.9	11.3	4.4	32.3	4.0	
M1	05/09/93	6.23	5.0	25.8	0.0	27.6	3.0	8.9	7.8	10.7	4.3	30.6	3.4	24.6
M1	05/10/93	6.18	5.1	25.9	0.0	27.0	3.8	10.2	7.7	10.3	4.2	29.9	3.6	
M1	05/11/93	5.97	5.7	21.3	0.1	22.8	3.4	9.5	8.1	9.9	4.3	28.9	3.8	23.1
M1	05/12/93	6.16	5.9	24.4	0.0	26.9	3.2	9.6	7.9	10.2	4.2	29.9	3.6	
M1	05/13/93	6.28	5.2	24.3	0.0	24.6	3.2	7.9	7.3	9.5	3.9	26.8	3.0	24.4
M1	05/14/93	6.32	5.1	23.0	0.2	26.4	3.2	8.2	7.6	9.9	4.0	27.2	3.3	

M1	05/15/93	6.31	4.9	24.3	0.0	27.7	2.6	7.4	7.3	10.6	5.7	27.0	3.6	25.9
M1	05/16/93	6.14	5.0	23.7	0.0	25.0	2.8	7.6	7.3	9.9	3.8	26.0	3.3	
M1	05/17/93	6.09	4.8	22.4	0.0	23.1	2.4	6.4	7.0	9.4	3.5	31.0	3.7	24.5
M1	05/18/93	6.23	4.7	25.7	0.0	21.3	2.5	8.1	7.5	9.0	3.7	28.0	3.2	
M1	05/19/93	6.13	4.9	21.1	0.0	21.7	3.0	7.9	7.4	9.4	3.7	27.6	3.6	22.8
M1	05/26/93	5.91	4.0	18.5	0.0	19.5	2.0	3.6	6.1	7.0	2.9	21.6	2.7	
M1	05/27/93	6.29	3.5	16.2	0.0	19.2	1.9	3.7	6.5	7.8	2.9	20.8	2.5	
M1	05/27/93	6.29	3.7	18.5	0.0	21.1	1.9	4.4	6.6	8.0	3.0	21.8	2.6	18.8
M1	05/27/93	5.91	3.6	18.4	0.2	21.9	2.0	2.4	6.1	7.2	3.1	22.6	2.4	
M1	05/27/93	5.96	3.3	14.7	0.0	22.0	2.4	3.0	6.2	6.7	3.1	22.3	2.0	
M1	05/27/93	6.20	4.3	22.8	0.0	20.4	2.0	3.3	6.5	7.8	2.8	19.6	2.5	19.7
M1	05/28/93	6.27	3.5	21.0	0.0	20.2	1.9	4.0	6.3	8.7	3.1	22.4	2.6	
M1	05/29/93	6.26	3.5	20.4	0.1	21.0	1.6	4.2	6.1	8.3	3.0	23.1	2.5	21.6
M1	05/30/93	6.22	3.4	19.9	0.0	19.7	1.7	3.1	5.4	7.5	2.6	21.2	2.3	
M1	05/31/93	6.07	3.5	18.5	0.1	20.2	1.7	3.6	6.3	7.8	2.7	20.7	2.3	19.9
M1	06/01/93	6.08	3.8	21.3	0.0	20.7	2.0	3.9	6.4	8.2	2.8	21.5	2.5	
M1	06/02/93	6.10	3.8	20.6	0.0	19.8	1.9	2.7	5.5	7.6	2.7	21.3	2.2	20.9
M1	06/03/93	5.91	4.1	26.6	0.0	21.6	1.5	3.4	6.1	8.5	3.0	22.0	2.5	
M1	06/04/93	6.10	5.2	24.9	0.6	21.6		4.3	6.4		3.1	23.5	3.8	20.6
M1	06/05/93	6.06	4.6	19.8	0.0	20.8	1.4	4.0	6.1	8.3	2.8	21.7	2.4	
M1	06/06/93	6.11	4.3	23.8	0.0	22.4	1.3	4.0	6.1	8.3	3.0	21.7	2.4	22.8
M1	06/07/93	6.01	4.6	21.2	0.0	25.0	1.5	3.4	6.1	9.0	2.9	23.2	2.4	
M1	06/08/93	6.06	4.7	24.5	0.0	24.3	1.6	3.7	6.3	9.1	2.9	23.4	2.4	26.3
M1	06/09/93	6.04	4.7	24.0	0.0	23.9	1.5	3.9	6.3	8.9	3.0	23.6	2.4	

Site	Date	pH	Conductivity µS	ANC µeq/L	NH4 µeq/L	SiO2 mg/L	Cl µeq/L	NO3 µeq/L	SO4 µeq/L	µeq/L	Mg µeq/L	Ca µeq/L	K µeq/L	Aluminum µg/L
M1	06/10/93	6.03	4.6	23.1	0.0	23.1	1.5	4.1	6.3	8.6	2.9	22.7	2.3	21.0
M1	06/11/93	6.09	3.2	19.6	0.5	22.0	1.8	4.3	6.2	7.7	2.6	20.5	2.1	
M1	06/12/93	6.21	3.3	20.2	0.4	22.4	1.7	4.5	6.5	7.8	2.7	20.9	2.1	18.1
M1	06/13/93	6.26	3.2	17.7	0.3	18.7	1.4	5.2	6.1	7.2	2.6	19.5	2.0	
M1	06/14/93	6.19	3.0	16.0	0.0	16.7	1.4	4.5	5.8	6.5	2.4	17.8	2.0	17.6
M1	06/15/93	6.10	3.0	18.2	0.1	15.9	1.9	4.0	5.8	6.6	2.5	17.6	2.1	
M1	06/16/93	6.11	3.0		0.4	16.3	2.9	3.9	5.3	7.1	2.0	15.2	2.0	
M1	06/17/93	6.13	3.1	17.6	1.0	17.4	1.6	3.7	5.2	6.2	2.1	16.0	2.0	18.8
M1	06/18/93	6.19	2.8	14.5	1.3	15.9	1.6	3.0	5.0	5.7	2.0	15.2	2.2	
M1	06/19/93	6.13	2.7	15.9	1.9	16.6	1.4	3.1	4.9	5.8	2.0	15.1	1.9	
M1	06/20/93	6.08	3.3	15.0	3.4	15.9	1.4	3.0	4.7	5.4	1.9	13.4	1.9	17.8
M1	06/21/93	6.05	3.5	16.0	1.5	18.1	1.9	3.3	5.1	6.7	2.2	15.7	2.3	
M1	06/22/93	6.04	3.4	15.1	0.4	17.6	1.6	3.5	5.0	6.7	2.2	16.0	2.3	18.9
M1	06/29/93	5.89	3.6		0.3	14.5	1.3	2.6	4.1	5.4	1.8	17.4	1.8	14.1

M1	06/30/93	5.88	3.2		0.2	15.2	0.9	2.6	4.0	5.4	1.7	14.0	1.7	
M1	07/01/93	5.88	3.4	13.8	0.0	14.4	1.4	2.5	3.9	5.6	1.8	13.5	1.7	
M1	07/02/93	6.12	4.0		91.9	13.6								13.1
M1	07/03/93	6.05	3.3	12.2	0.0	13.5	0.8	2.3	3.7	5.1	1.8	13.0	1.7	
M1	07/04/93	6.01	3.6	8.8	0.0	14.3	0.7	2.4	3.8	5.0	1.8	13.5	1.6	
M1	07/05/93	5.93	2.7	13.0	0.0	13.1	0.7	2.0	3.7	4.9	1.8	12.4	1.6	
M1	07/05/93	5.93	2.9	10.1	0.0	13.6	1.4	1.9	3.7	5.5	1.7	11.8	1.7	15.5
M1	07/09/93	6.20	3.0	11.4	0.2	15.3	1.5	1.1	3.6	5.3	1.7	12.9	1.7	17.3
M1	07/23/93	6.13	2.7	17.3	0.0	16.5	0.9	0.6	2.9	5.6	1.7	13.2	1.7	12.1
M1	07/24/93	6.18	2.6	13.6	0.0	16.1	0.9	0.6	2.7	5.4	1.7	13.8	1.7	
M1	07/25/93	5.94	2.6	17.5	0.0	16.5	0.9	0.9	3.2	5.6	1.7	13.5	1.6	
M1	07/26/93	6.07	3.0	20.7	0.0	15.8	2.2	0.7	3.6	6.3	1.7	14.5	1.7	
M1	07/27/93	6.14	2.7	21.5	0.0	15.2	2.1	0.6	3.4	5.7	1.7	13.7	1.7	13.3
M1	07/28/93	6.18	3.0	16.8	0.0	15.7	1.0	0.6	3.1	5.9	1.7	14.4	1.7	
M1	07/29/93	6.15	2.9	17.1	0.0	18.1	1.0	0.6	3.3	6.2	1.7	14.5	1.7	
M1	07/30/93	6.13	2.7	17.7	0.0	17.6	1.2	0.6	3.4	6.4	1.7	14.2	1.9	
M1	08/01/93	6.23	2.7	13.8	0.0	18.5	1.1	0.6	3.3	6.4	1.7	14.7	1.8	
M1	08/03/93	6.35	2.7	19.3	0.0	18.1	1.0	0.6	3.0	6.4	1.8	14.4	1.8	
M1	08/05/93	6.20	2.9	15.7	0.0	19.8	1.1	0.6	3.2	7.0	1.9	16.0	1.9	
M1	08/07/93	6.28	3.0	19.5	0.0	20.4	1.4	0.6	3.1	7.7	2.0	16.3	2.1	
M1	08/09/93	6.30	3.0	18.5	0.0	21.4	1.1	0.6	3.3	7.7	2.0	17.2	1.9	
M1	08/11/93	6.41	3.1	20.0	0.0	21.8	1.1	0.6	3.2	8.2	2.1	17.8	1.9	
M1	08/13/93	6.47	4.2	21.7	0.0	21.1	0.8	0.6	3.6	8.3	1.9	16.5	1.7	12.0
M1	08/15/93	6.55		26.7	0.0	22.6	1.2	0.6	3.8	9.4	2.0	17.6	2.0	
M1	08/17/93	6.57		25.5	0.0	21.8	1.3	0.6	3.7	9.2	2.0	17.6	1.8	11.1
M1	08/19/93	6.56	3.8	26.4	0.0	25.5	1.9	0.6	3.7	10.2	2.2	18.1	2.1	
M1	08/21/93	6.51	5.6	28.5	0.0	25.2	15.2	0.6	4.2		2.2	18.9	1.9	10.9
M1	08/23/93	6.61	4.0	31.0	0.0	26.7	1.5	0.6	4.1	9.9	2.2	19.3	1.6	
M1	08/25/93	6.58	3.6	26.5	0.0	23.3	0.9	0.5	3.5	9.8	2.2	18.6	1.6	12.9
M1	08/27/93	6.49	3.9	31.1	0.0	25.2	0.6	0.5	3.7	9.9	2.3	18.5	1.8	
M1	08/29/93	6.57	3.9	30.5	0.0	35.1	2.3	0.5	3.8	10.4	2.3	29.7	1.9	15.0
M1	08/31/93	6.49	4.5	33.3	0.0	29.5	0.5	0.5	3.6	10.6	2.3	28.9	1.8	
M1	09/02/93	6.40	4.3	34.7	0.0	27.3	0.5	0.5	3.6	9.9	2.4	31.0	1.6	
M2	04/16/93	6.01	7.2	51.7	0.4	47.0	2.6	7.6	6.3	14.4	6.7	46.0	4.4	25.6
M2	04/20/93	6.38	6.4	47.6	0.5	45.1	2.7	9.3	6.9	14.0	6.0	43.0	4.1	
M2	04/21/93	6.21	6.1	45.6	0.5	45.2	2.7	9.9	7.0	14.0	6.2	43.0	4.3	24.7
Site	Date	pH	Conductivity µS	ANC µeq/L	NH4 µeq/L	SiO2 mg/L	Cl µeq/L	NO3 µeq/L	SO4 µeq/L	µeq/L	Mg µeq/L	Ca µeq/L	K µeq/L	Aluminum µg/L
M2	04/22/93	6.25	6.3	44.9	0.2	47.1	2.6	8.6	6.9	15.6	6.3	42.0	5.4	
M2	04/23/93	6.35	8.3	45.2	0.1	41.5		9.6	8.3		6.7	43.8	6.8	22.1

M2	04/23/93	6.13	6.3	41.1	0.3	45.1	2.5	9.1	7.1	12.8	6.0	43.0	3.2	
M2	04/23/93	6.39	7.3	43.7	0.0	43.8	4.2	9.9	7.6	14.1	6.2	43.3	4.2	21.1
M2	04/24/93	6.48	7.3	49.1	0.3	45.6		9.4	8.4		6.5	42.0	6.1	
M2	04/25/93	6.31	7.0	43.5	0.3	40.4	3.3	10.9	8.2	12.7	6.0	42.5	3.3	19.8
M2	04/26/93	6.22	7.2	36.3	0.6	35.7	3.5	15.4	9.5	12.2	6.8	41.6	4.6	
M2	04/27/93	6.24	6.6	35.6	0.7	34.0	4.0	14.0	9.2	12.0	6.3	39.4	4.1	29.5
M2	04/28/93	6.26	6.5	33.8	0.7	32.1	3.3	13.9	9.2	11.4	6.0	37.5	4.0	
M2	04/29/93	6.15	6.6	34.4	0.6	30.3	3.3	14.6	9.2	11.3	6.0	36.2	4.5	26.8
M2	04/30/93	6.35	6.5	28.3	0.7	31.6	3.4	15.3	9.9	11.0	5.9	37.7	5.7	
M2	05/01/93	6.19	6.3	25.6	0.6	29.7	3.7	15.6	10.9	10.5	5.8	36.5	5.3	21.2
M2	05/02/93	6.09	6.1	23.3	0.7	28.0	3.5	16.2	10.2	10.4	5.7	37.6	5.0	
M2	05/03/93	5.99	6.2	25.2	0.8	26.7	3.6	16.6	9.9	10.0	5.5	37.1	4.7	
M2	05/03/93	6.30	6.5	27.0	0.5	29.4	3.6	15.7	8.6	10.8	5.4	37.3	4.4	20.9
M2	05/03/93	6.13	7.0	31.9	1.5	27.9	3.9	15.7	9.7	10.6	5.5	39.9	4.7	18.8
M2	05/03/93	5.97	6.4	26.7	0.9	28.2	3.8	17.6	10.2	10.5	5.3	37.5	4.4	
M2	05/03/93	6.26	6.2	25.5	0.3	28.7	3.7	16.1	9.2	10.7	5.6	38.0	4.4	18.5
M2	05/04/93	6.36	6.3	24.8	0.7	29.6	3.7	15.9	9.0	11.3	5.4	38.2	4.4	
M2	05/05/93	6.29	6.4	25.7	0.4	29.8	3.9	16.0	8.9	11.3	5.4	38.5	4.4	17.0
M2	05/06/93	6.24	5.8	23.5	0.0	27.9	4.0	12.0	8.9	10.3	5.1	36.2	3.9	
M2	05/07/93	5.99	5.9	23.1	0.6	29.8	3.8	16.6	10.0	9.9	4.9	35.6	3.7	20.1
M2	05/08/93	6.12		25.2	0.0	28.3	3.7	13.3	8.4	10.2	5.0	30.6	3.9	
M2	05/09/93	6.07	6.3	22.9	0.0	27.6	3.5	12.6	8.5	10.0	5.0	30.5	4.0	21.6
M2	05/10/93	5.95	6.3	24.0	0.0	22.3	4.1	14.5	8.8	9.7	5.1	30.2	4.3	
M2	05/13/93	6.14	5.4	16.5	0.0	27.2	4.0	14.5	8.7	9.0	4.5	28.8	3.0	18.3
M2	05/14/93	6.07	5.2	22.1	0.1	26.2	3.4	12.0	8.1	8.5	4.2	28.9	2.9	
M2	05/15/93	6.05	5.1	19.7	0.0	25.8	3.4	11.6	7.9	8.4	4.2	29.2	2.8	20.5
M2	05/16/93	6.04	5.1	20.8	0.0	24.2	3.2	11.3	7.6	7.6	4.0	27.6	2.5	
M2	05/17/93	6.00	5.2	21.0	0.0	20.5	3.4	12.6	7.9	8.1	4.1	28.1	3.0	18.9
M2	05/18/93	6.06	5.5	16.8	0.4	20.3	3.4	13.6	8.5	8.0	4.0	27.8	3.0	
M2	05/19/93	5.99	5.3	16.0	0.1	20.0	3.9	13.5	9.4	8.2	4.1	27.5	3.4	22.3
M2	05/26/93	6.01	3.2	11.0	0.0	19.2	2.4	7.0	6.6	5.8	3.0	21.7	2.2	
M2	05/27/93	6.30	4.8	25.2	0.0	19.1	3.0	6.6	6.6	8.0	3.0	31.7	2.7	15.9
M2	05/28/93	6.23	3.8	15.4	0.0	18.3	2.3	7.4	6.6	6.9	2.9	23.3	2.3	
M2	05/29/93	6.18	3.6	17.3	0.0	19.0	1.9	7.0	6.5	6.6	2.8	22.2	2.3	13.9
M2	05/30/93	6.13	3.5	15.0	0.0	16.7	1.9	5.9	6.2	6.0	2.5	20.2	2.1	
M2	05/31/93	6.08	3.4	14.5	0.0	15.7	2.0	6.6	6.5	6.2	2.6	20.7	2.3	12.4
M2	06/01/93	6.11	3.6	16.7	0.0	17.9	2.0	6.2	6.4	6.8	2.7	21.4	2.3	
M2	06/02/93	6.08	3.8	15.5	0.0	17.9	1.9	5.0	6.3	7.0	2.8	22.3	2.3	14.8
M2	06/03/93	6.16	4.2	21.6	0.0	21.9	2.3	5.6	6.3	6.9	2.8	20.9	2.2	
M2	06/04/93	6.14	4.1	17.2	0.0	20.8	1.9	6.0	6.3	6.4	2.8	20.8	2.1	12.4

M2	06/05/93	6.18	4.7	23.2	0.0	22.1	2.6	6.3	6.4	7.3	2.9	22.0	2.2	
M2	06/06/93	6.18	4.5	20.7	0.0	23.3	1.9	6.1	6.4	6.8	3.0	22.1	2.1	12.7
M2	06/07/93	6.16	4.5	21.5	0.0	25.1	1.8	6.0	6.3	7.3	3.0	22.7	2.2	
M2	06/08/93	6.15	5.0	20.9	0.0	24.6	1.6	5.9	6.2	7.5	3.0	22.9	2.3	
M2	06/09/93	6.09	4.5	13.3	0.0	23.2	1.7	6.0	6.2	7.2	3.0	25.8	2.2	
M2	06/10/93	6.02	4.5	20.6	0.0	22.3	1.6	6.5	6.4	6.9	2.9	25.4	2.2	14.2
M2	06/11/93	6.13	3.6	16.4	0.0	19.3	2.0	6.4	6.2	7.2	2.9	21.9	2.2	12.2
M2	06/12/93	6.14	3.6	20.0	0.0	18.8	2.7	6.2	6.3	8.0	2.9	22.0	2.4	
Site	Date	pH	Conductivity µS	ANC µeq/L	NH4 µeq/L	SiO2 mg/L	Cl µeq/L	NO3 µeq/L	SO4 µeq/L	µeq/L	Mg µeq/L	Ca µeq/L	K µeq/L	Aluminum µg/L
M2	06/13/93	6.11	3.3	15.1	0.0	17.1	1.8	6.9	6.2	6.2	2.7	20.7	2.2	
M2	06/14/93	6.08	3.2	12.5	0.0	16.8	1.4	6.6	6.2	5.6	2.5	18.3	2.0	12.0
M2	06/15/93	6.04	3.1	16.4	0.0	15.2	1.9	5.1	6.0	5.4	2.4	17.9	2.0	
M2	06/16/93	6.01	3.1	13.0	0.0	14.2	1.7	4.9	5.9	5.2	2.3	17.8	2.0	
M2	06/17/93	6.10	3.1	14.5	4.4	14.6	1.4	4.2	5.2	4.7	2.0	14.7	1.8	15.6
M2	06/18/93	6.12	2.8	11.4	0.2	14.9	1.7	4.1	5.3	4.6	2.0	14.9	1.8	
M2	06/19/93	6.10	2.8	11.6	0.2	14.2	1.2	3.9	5.1	4.6	2.0	17.9	1.8	12.0
M2	06/20/93	6.07	2.7		0.3	12.8	1.7	3.8	5.0	4.6	1.9	17.3	1.9	10.6
M2	06/21/93	6.08	2.9	12.6	0.9	15.4	1.5	3.7	4.9	6.9	2.3	19.2	2.6	11.8
M2	06/22/93	6.00	3.1	18.7	0.4	14.6	1.5	4.0	4.9	5.0	2.0	15.2	1.8	
M2	06/23/93	5.97	2.9	11.4	1.0	14.1	1.5	4.2	5.1	4.3	1.8	14.7	1.7	
M2	06/24/93	5.92	3.4	17.0	0.2	13.2	1.2	3.9	4.9	4.4	1.9	15.2	1.8	
M2	06/25/93	5.95	2.7	13.1	0.5	12.6	1.5	3.6	4.9	4.2	1.7	11.1	1.7	
M2	06/26/93	5.92	2.7	12.9	0.7	12.1	1.6	3.1	4.8	4.7	1.8	13.8	1.8	10.1
M2	06/27/93	5.98	23.8	10.9	1.1	12.0		2.9	4.6		1.7	13.1	1.9	
M2	06/28/93	5.90	3.3	10.4	1.2	11.1	1.2	2.5	4.3	4.8	1.5	11.7	1.6	
M2	06/29/93	5.84	2.8		0.4	10.3	1.5	2.5	4.4	4.3	1.7	13.4	1.6	7.1
M2	07/06/93	6.23	3.2	8.3	0.4	10.8		2.4	3.6		1.5	11.5	1.4	
M2	07/07/93	6.22	2.8	9.4	0.5	10.8	2.1	2.3	3.5	4.8	1.6	11.7	1.9	
M2	07/08/93	6.14	3.0	9.4	0.0	10.2		2.3	3.6		1.5	10.8	1.5	8.4
M2	07/09/93	5.80	1.9	11.3	0.0	10.0	0.8	2.1	3.4	3.2	1.1		1.4	
M2	07/10/93	5.80	2.0	8.2	0.0	10.3	0.7	2.1	3.4	3.4	1.4	10.6	1.4	
M2	07/11/93	5.88	2.0		0.0	10.3	0.8	1.9	3.3	3.6	1.3	7.2	1.6	8.4
M2	07/12/93	5.81	2.1	12.5	0.0	9.9	1.4	1.4	3.4	3.9	1.4	10.5	1.7	
M2	07/13/93	5.84	2.0	9.6	0.0	9.9	1.0	1.1	3.3	3.6	1.4	10.1	1.5	
M2	07/14/93	5.83	2.0	10.2	0.2	9.7	0.7	1.1	3.1	3.3	1.4	9.5	1.5	6.8
M2	07/15/93	5.90	2.0	10.0	0.0	10.0	1.0	1.6	3.3	3.7	1.3	10.1	1.5	
M2	07/16/93	5.84	2.1	11.2	6.5	10.2	0.8	1.7	3.3	3.6	1.3	10.5	1.4	
M2	07/17/93	5.77	2.8	11.4	0.0	11.2	0.8	1.1	2.9	3.1	1.3	10.0	1.2	6.4
M2	07/18/93	5.82	2.4	11.7	0.0	10.6	0.7	1.5	3.0	3.4	1.4	10.7	1.2	

M2	07/19/93	5.91	2.2	9.7	0.0	11.1	1.3	1.7	3.2	3.7	1.4	10.7	1.3	
M2	07/20/93	5.92	3.0	11.8	1.8	10.9		1.5	3.2		1.4	12.3	1.4	6.7
M2	07/21/93	5.98	2.3	13.5	0.0	10.7	1.4	1.1	3.3	4.7	1.5	12.6	1.5	
M2	07/23/93	6.16	2.5	10.5	0.0	11.9	1.5	0.8	3.1	4.2	1.6	12.5	1.6	
M2	07/24/93	6.12	2.4	12.1	0.0	10.9	1.0	0.6	2.9	3.7	1.4	11.1	1.5	7.0
M2	07/25/93	6.20	2.5	14.4	0.0	12.8	1.4	1.0	3.4	4.1	1.6	12.2	1.5	
M2	07/26/93	6.15	2.5	12.0	0.0	11.5	1.1	0.9	3.2	3.9	1.5	11.5	1.5	
M2	07/27/93	6.09	2.7	17.0	0.0	11.6	1.6	0.6	3.2	4.5	1.5	12.2	1.9	7.0
M2	07/28/93	6.08	2.5	13.1	0.0	10.9	1.1	0.8	3.1	3.9	1.4	11.4	1.5	
M2	07/29/93	6.05	2.6	12.3	0.0	11.7	1.1	0.6	2.9	4.1	1.4	11.3	1.6	
M2	07/30/93	6.11	2.3	7.7	0.0	11.4	1.5	0.9	3.1	4.2	1.5	11.0	1.5	
M2	08/01/93	6.11	2.3	10.1	0.0	11.7	1.2	0.8	3.0	4.4	1.6	10.6	1.7	
M2	08/03/93	6.11	2.3	9.3	0.0	12.0	1.4	0.8	3.0	4.4	1.5	10.6	1.6	
M2	08/05/93	6.16	2.3	9.9	0.0	12.3	1.1	0.7	2.7	4.2	1.5	10.8	1.6	
M2	08/07/93	6.26	2.4	13.4	0.0	12.7	2.6	0.6	3.2	5.2	1.6	11.3	1.7	
M2	08/09/93	6.28	2.6	13.6	0.0	14.9	1.4	0.6	3.5	4.8	1.7	12.8	1.8	
M2	08/11/93	6.17	3.9	13.6	0.0	16.3	1.2	0.6	3.0	5.0	1.8	12.8	1.8	
M2	08/27/93	6.37	5.4	23.5	0.0	18.7	22.0	0.7	3.2		2.0	13.7	1.9	
M2	08/29/93	6.27		23.1	0.0	18.5	3.4	0.8	2.7	9.0	1.9	22.0	1.7	
M2	08/31/93	6.27		21.3	0.0	20.0	1.3	0.8	3.1	6.9	2.0	21.8	1.7	
Site	Date	pH	Conductivity	ANC	NH4	SiO2	Cl	NO3	SO4		Mg	Ca	K	Aluminum
			µS	µeq/L	µeq/L	mg/L	µeq/L	µeq/L	µeq/L	µeq/L	µeq/L	µeq/L	µeq/L	µg/L
M2	09/02/93	6.38	5.3	25.7	0.0	23.1	2.4	0.5	3.5	7.7	2.2	25.3	1.9	
M3	04/14/93	6.10	6.3	37.9	0.1	41.0	2.3	9.5	5.7	10.9	5.6	40.9	3.9	
M3	04/15/93	6.37	7.5	50.7	0.1	43.9		8.1	6.4		7.1	45.0	6.6	17.5
M3	04/15/93	6.00	6.6	42.8	0.4	43.5	2.6	10.4	5.9	12.3	6.1	42.0	4.2	
M3	04/16/93	5.94	7.4	44.0	1.1	42.8	3.4	10.2	5.7	13.8	5.6	43.3	4.5	
M3	04/17/93	5.91	6.9		1.3	39.8	2.3	10.4	6.0	11.8	5.8	40.8	3.8	21.8
M3	04/18/93	5.98	6.6	40.0	1.1	40.0	2.6	10.8	6.2	12.0	6.0	41.3	4.0	
M3	04/20/93	6.28	5.8	42.1	0.7	43.0	2.5	10.5	6.2	12.9	5.3	42.1	4.1	14.9
M3	04/21/93	6.34	6.0	38.7	0.5	42.2	2.5	10.9	6.4	12.9	5.4	41.4	3.9	
M3	04/22/93	6.26	5.9	38.8	0.3	37.3	2.7	10.7	6.4	11.9	5.6	39.9	3.4	
M3	04/22/93	6.24	5.9	40.7	0.3	36.4	2.8	10.7	6.4	11.8	5.5	39.4	3.2	18.2
M3	04/23/93	6.31	6.2	38.3	0.6	38.4	3.0	11.8	6.4	12.2	5.5	39.8	3.8	
M3	04/24/93	6.35	6.3	37.9	0.5	37.5	3.1	12.6	7.1	12.3	5.6	40.0	3.9	22.7
M3	04/25/93	6.45	6.2	36.8	0.7	34.4	3.1	12.7	7.0	12.1	5.5	38.5	3.6	
M3	04/26/93	6.08	7.1	35.6	1.1	32.9	3.8	17.7	8.6	12.2	6.3	38.7	4.8	30.9
M3	04/27/93	6.07	6.9	31.5	1.1	36.3	3.5	14.6	8.2	11.1	5.9	37.8	3.9	
M3	04/27/93	6.01	7.1	24.1	0.9	36.6	3.7	16.8	8.4	11.3	5.9	37.9	4.0	
M3	04/27/93	6.18	6.8	29.6	1.0	33.9	4.0	16.8	7.6	11.0	5.8	37.3	3.9	

M3	04/28/93	6.10	6.5	32.3	1.1	33.9	3.5	15.1	8.2	10.6	5.6	35.8	3.8	35.1
M3	04/29/93	6.04	6.7	26.4	1.2	31.2	3.7	16.2	8.7	11.4	6.0	36.9	6.1	
M3	05/03/93	6.06	7.3	26.4	0.7	27.7	4.1	21.0	9.4	11.1	5.8	39.9	4.7	
M3	05/03/93	6.29	7.0	25.1	0.8	29.5	4.1	21.3	9.5	10.9	5.7	42.1	4.6	
M3	05/03/93	5.84	7.8		1.3	26.2	4.9	18.0	10.2	10.5	5.5	42.5	4.9	18.3
M3	05/03/93	5.90	7.5		1.4	29.2	4.8	19.6	10.8	10.8	5.8	40.5	4.9	
M3	05/04/93	5.99	6.4	22.4	1.3	26.6	3.9	21.8	10.7	10.2	5.6	40.3	4.8	
M3	05/05/93	6.03	6.7	24.3	1.2	27.9	5.6	22.0	11.2	10.3	5.3	39.4	5.3	19.4
M3	05/06/93	6.19	6.6	27.3	0.7	29.2	4.2	19.3	9.3	11.1	5.2	39.2	4.4	
M3	05/07/93	6.08	6.8	21.7	0.3	26.5	4.1	19.2	9.7	10.7	5.0	37.4	4.3	15.4
M3	05/08/93	6.12	7.0	22.3	0.5	27.0	4.1	18.3	9.2	10.2	4.8	36.6	4.0	
M3	05/09/93	5.97	6.9	22.5	0.4	26.4	4.0	16.3	9.2	9.7	4.6	34.9	3.8	17.8
M3	05/10/93	5.86	7.1	20.9	0.1	24.8	4.3	19.3	9.0	10.1	4.9	37.3	4.4	
M3	05/11/93	5.99	6.4	18.6	0.0	23.8	4.4	18.9	8.8	9.0	4.9	30.9	3.9	18.8
M3	05/12/93	5.96	6.2	16.1	0.1	24.1	4.5	19.3	9.3	9.3	4.9	30.5	3.9	
M3	05/13/93	6.12	5.8	17.6	0.0	24.5	4.0	17.9	8.8	8.9	4.4	33.1	3.2	14.4
M3	05/14/93	6.09	5.8	17.5	0.0	24.8	3.8	16.5	8.4	9.5	4.3	32.8	3.9	
M3	05/15/93	6.03	6.1	19.0	0.0	25.4	3.8	16.0	8.2	8.9	4.3	32.3	3.6	16.6
M3	05/16/93	5.97	5.9	17.4	0.0	23.8	3.7	15.5	8.1	9.0	4.2	32.2	3.8	
M3	05/17/93	5.98	6.0	17.7	0.0	23.0	3.8	15.5	9.1	8.9	4.1	31.1	3.8	19.0
M3	05/17/93	5.96	5.9	17.4	0.0	18.9	3.8	15.8	8.1	8.8	4.1	31.8	3.7	
M3	05/20/93	5.97	4.2	9.6	0.2	19.2	3.3	13.5	8.6	6.8	3.8	27.1	2.7	17.5
M3	05/21/93	5.96	3.9	8.7	0.5	18.2	3.0	12.6	8.4	6.5	3.6	25.7	2.7	
M3	05/22/93	5.95	3.8	10.0	0.0	18.2	2.7	11.4	7.9	6.0	3.4	24.0	2.4	19.9
M3	05/23/93	5.94	3.6	10.1	0.0	17.7	2.5	10.3	7.8	5.9	3.4	23.8	2.5	
M3	05/24/93	5.93	3.7	12.9	0.0	15.6	2.5	9.5	7.6	5.7	3.2	22.6	2.6	14.1
M3	05/25/93	5.92	3.6	8.5	0.0	16.7	2.6	8.3	7.5	6.3	3.0	21.8	3.0	
M3	05/26/93	5.99	3.4	10.6	0.4	18.0	2.1	7.8	6.8	5.3	2.8	20.6	2.3	
M3	05/27/93	5.96	3.8	13.5	0.0	18.5	2.5	9.7	7.4	6.5	2.8	22.2	2.3	15.9
M3	05/28/93	5.95	3.9	12.8	0.0	16.0	2.3	8.2	6.8	6.2	2.6	21.1	2.2	
M3	05/29/93	5.94	3.8	14.0	0.0	19.2	2.4	8.8	7.2	6.8	2.8	21.9	2.4	
M3	05/30/93	5.91	3.8	15.1	0.0	16.8	1.9	7.6	7.0	6.1	2.6	20.9	2.2	12.5
Site	Date	pH	Conductivity	ANC	NH4	SiO2	Cl	NO3	SO4		Mg	Ca	K	Aluminum
			µS	µeq/L	µeq/L	mg/L	µeq/L	µeq/L	µeq/L	µeq/L	µeq/L	µeq/L	µeq/L	µg/L
M3	05/31/93	5.92	3.8	15.6	0.0	19.8	2.4	6.5	6.8	6.8	2.7	21.5	2.4	
M3	06/01/93	5.92	3.8	16.1	0.1	18.4	2.2	7.4	6.7	6.6	2.6	20.6	2.4	
M3	06/02/93	6.08	4.2	18.1	0.0	20.3	2.2	6.5	6.6	6.3	2.7	21.1	2.1	14.5
M3	06/02/93	5.94	4.0	12.9	0.3	16.8	2.3	8.0	7.0	6.5	2.7	21.1	2.4	
M3	06/03/93	5.99	4.4	17.2	0.0	19.7	1.8	7.1	6.5	6.6	2.7	21.5	2.3	
M3	06/07/93	5.97	4.6	17.1	0.0	21.2	1.7	7.2	6.5	6.9	2.9	22.8	2.2	11.0

M3	06/08/93	5.96	4.6	10.5	0.0	20.9	1.7	7.3	6.5	7.1	2.8	23.1	2.2	
M3	06/11/93	6.03	3.9	16.6	0.0	18.3	1.7	8.0	6.1	6.1	2.7	21.4	2.0	
M3	06/12/93	6.03	3.8	16.0	0.0	18.4	1.8	7.7	6.3	6.4	2.7	20.8	2.1	12.5
M3	06/13/93	6.02	3.7	14.1	0.0	17.1	1.7	6.5	6.2	5.9	2.6	20.0	2.1	
M3	06/14/93	5.98	3.5	12.3	0.0	15.8	2.0	6.2	6.3	5.2	2.2	16.6	2.0	
M3	06/15/93	5.96	3.3	11.0	0.0	15.4	1.9	5.3	6.1	5.1	2.0	17.0	2.0	12.9
M3	06/16/93	5.92	3.2	11.0	0.0	14.4	1.6	4.6	5.9	4.8	2.0	15.9	1.9	
M3	06/17/93	6.00	3.1	17.5	0.7	14.2	1.7	4.9	5.7	4.9	2.1	16.3	2.0	
M3	06/18/93	6.00	3.1	16.2	0.4	13.9	1.5	4.7	5.6	4.4	2.0	15.7	1.8	9.2
M3	06/19/93	6.00	2.9	12.1	0.2	12.8	1.5	4.4	5.5	4.1	1.8	15.3	1.7	
M3	06/20/93	5.96	3.0	14.3	0.5	12.5	1.5		4.8	3.8	1.7	14.2	1.7	9.2
M3	06/21/93	5.97	3.0	12.4	0.0	13.6	1.4	3.8	5.3	4.4	1.9	16.9	1.8	10.4
M3	06/22/93	5.93	3.1	14.7	0.4	13.8	1.2	4.3	5.1	4.7	1.8	16.1	1.8	
M3	07/05/93	5.86	2.2	6.6	0.0	9.5	1.9	1.6	3.8	4.0	1.3	10.5	1.4	
M3	07/06/93	5.76	2.1	10.5	0.4	9.5	1.0	1.8	3.7	3.1	1.3	10.6	1.3	8.3
M3	07/07/93	5.76	2.3	7.7	0.2	9.4	2.3	1.9	3.6	4.6	1.3	10.3	1.3	
M3	07/08/93	5.70	2.1	6.8	0.0	8.9	1.8	2.1	3.6	3.7	1.2	9.5	1.2	
M3	07/09/93	5.70	2.5	6.5	0.0	8.7	4.7	2.0	3.5	6.5	1.2	9.8	1.3	7.3
M3	07/10/93	5.73	1.9	8.0	0.0	8.4	1.0	2.1	3.4	3.1	1.2	9.7	1.2	
M3	07/11/93	6.05	2.0	10.4	0.6	8.1	1.6	1.7	3.3	3.6	1.2	9.8	1.1	
M3	07/12/93	6.14	2.5	9.3	4.0	8.8	3.6	2.0	3.7	4.8	1.1	9.8	1.2	6.1
M3	07/13/93	6.11	2.0	7.3	0.0	8.5	1.4	1.8	3.3	3.3	1.1	9.6	1.1	
M3	07/14/93	6.23	2.3	7.5	0.0	8.5	4.0	1.8	3.5	5.6	1.2	9.8	1.2	
M3	07/15/93	6.26	2.0	12.4	0.0	8.6	1.0	1.4	3.1	3.0	1.2	9.7	1.2	5.7
M3	07/16/93	6.24	2.2		6.6	9.5	1.9	1.5	3.3	3.9	1.3	10.1	1.2	8.0
M3	07/17/93	5.93	2.6	9.7	0.0	9.9	3.0	1.3	3.3	5.5	1.2	9.3	1.4	7.5
M3	07/18/93	5.92	2.1	8.2	0.0	9.5	0.9	1.2	3.2	3.1	1.2	11.4	1.2	
M3	07/19/93	5.93	2.1	7.6	0.0	10.0	1.2	0.7	2.9	3.2	1.2	11.5	1.3	6.5
M3	07/20/93	5.97	2.3	11.2	0.0	10.6	1.1	0.7	3.0	3.5	1.3	11.9	1.4	
M3	07/21/93	5.95	2.5		0.0	10.5	2.0	0.7	3.2	3.9	1.4	14.7	1.6	6.6
M3	07/23/93	6.11	2.5	13.3	0.0	11.0	1.1	0.6	3.2	3.9	1.5	13.2	1.5	
M3	07/24/93	6.03	2.5	14.4	0.0	11.0	1.1	0.6	3.0	3.6	1.4	13.1	1.5	
M3	07/25/93	6.03	2.6	14.7	0.0	11.4	1.6	1.0	3.3	3.7	1.5	12.3	1.5	7.8
M3	07/26/93	6.03	2.8	14.1	0.0	10.7	2.3	1.0	3.3	5.1	1.4	12.2	1.5	
M3	07/27/93	6.01	2.6	12.7	0.0	10.7	1.3	0.6	3.1	3.9	1.5	12.7	1.5	
M3	07/28/93	6.01	2.8	11.0	0.0	10.8	1.5	0.9	3.2	4.0	1.3	11.6	1.5	6.1
M3	07/29/93	6.04	2.6	13.2	0.0	10.8	1.3	0.7	3.1	3.8	1.2	10.6	1.6	
M3	07/30/93	5.73	3.1		0.0	10.1	1.1	0.6	3.3	3.9	1.2	10.2	1.5	
M3	08/01/93	6.16	2.3	13.7	0.0	9.8	1.1	0.9	3.2	3.6	1.5	11.1	1.4	
M3	08/03/93	6.16	2.2	9.7	0.0	10.0	1.3	0.9	3.5	3.6	1.3	10.9	1.4	

Site	Date	pH	Conductivity μS	ANC μeq/L	NH4 μeq/L	SiO2 mg/L	Cl μeq/L	NO3 μeq/L	SO4 μeq/L	μeq/L	Mg μeq/L	Ca μeq/L	K μeq/L	Aluminum μg/L
M3	08/07/93	6.23	2.6	10.3	0.0	11.1		0.6	3.1	4.7	1.4	11.3		
M3	08/09/93	6.23	2.6	9.6	0.0	11.5	1.2	0.7	3.6	3.9	1.3	10.7	1.5	
M3	08/11/93	6.28	3.4	11.4	0.0	12.3	1.4	0.6	3.0	4.4	1.4	11.3	1.5	
M3	08/13/93	6.23	2.4	12.5	0.0	13.3	1.2	0.8	3.9	5.5	1.6	17.0	1.6	
M3	08/15/93	6.23	2.5	15.6	0.0	15.0	1.4	0.9	3.0	5.0	1.5	17.3	1.6	6.9
M3	08/17/93	6.24	2.3	14.8	0.0	13.9	0.7	0.9	3.3	4.9	1.5	17.5	1.7	8.3
M3	08/19/93	6.28	2.4	12.2	0.0	16.2	0.7	1.0	3.4	5.0	1.5	14.2	1.6	
M3	08/21/93	6.19	2.4	17.0	0.0	15.8	0.5	1.0	3.5	4.9	1.6	18.6	1.6	7.5
M3	08/25/93	6.41	2.4	18.5	0.0	14.3	0.7	1.3	3.7	4.6	1.7	20.3	1.6	
M3	08/29/93	6.21		18.3	0.0	18.3	0.6	1.2	3.3	5.4	1.7	19.9	1.7	
M3	08/31/93	6.28		18.3	0.0	19.2	0.6	1.1	3.5	5.2	1.6	16.0	1.7	
M3	09/02/93	6.50		18.2	0.0	19.3	0.8	1.1	3.4	5.3	1.7	16.0	1.7	

Appendix 2: Chemical concentrations at Sierra Episodes Sites, 1994

Site	Date	pH	Conductivity	ANC	NH4	SiO2	Cl	NO3	SO4	Na	Mg	Ca	K
			µS	µeq/L	µeq/L	mg/L	µeq/L	µeq/L	µeq/L	µeq/L	µeq/L	µeq/L	µeq/L
High Lake	04/21/94	5.58	5.0	1.4	7.3	3.1	3.9	8.0	10.5	4.9	2.5	10.0	6.4
High Lake	04/22/94	5.41	6.0	3.1	7.4	5.4	3.3	9.2	12.1	4.4	3.1	13.3	6.8
High Lake	04/23/94	5.40	6.2	2.1	6.9	7.9	4.1	13.3	12.3	5.1	3.4	14.5	8.8
High Lake	04/24/94	5.46	6.7	2.4	7.7	10.6	4.5	18.6	13.0	5.9	4.1	19.0	9.6
High Lake	04/26/94	5.44	8.7	7.6	9.2	12.7	4.7	28.3	14.4	8.1	5.8	31.6	9.6
High Lake	04/26/94	5.38	8.9	1.4	9.8	13.9	5.7	32.5	14.4	7.1	5.3	32.4	9.2
High Lake	04/27/94	5.43	8.5	4.2	9.4	12.8	5.8	28.7	14.0	7.0	5.1	31.8	8.8
High Lake	04/28/94	5.40	7.8	4.4	9.8	10.7	5.0	22.4	13.7	5.9	4.4	27.6	7.6
High Lake	04/29/94	5.49	8.1	5.0	9.5	9.4	6.2	19.6	14.1	7.9	4.5	25.5	7.0
High Lake	04/30/94	5.57	9.0	-0.3	10.0	11.5	5.0	29.6	16.6	5.2	6.0	21.7	17.7
High Lake	05/01/94	5.57	10.1	11.9	7.9	19.6	6.4	25.4	18.2	7.1	7.0	28.9	18.9
High Lake	05/02/94	5.53	8.3	5.2	7.5	13.2	5.2	18.9	15.7	6.2	5.0	22.7	11.2
High Lake	05/03/94	5.23	9.9	-1.9	11.1	8.5	4.4	20.7	23.6	5.6	6.0	23.7	9.7
High Lake	05/04/94	5.33	7.3	-1.1	7.8	7.4	3.7	17.2	17.0	5.8	4.2	16.8	8.8
High Lake	05/05/94	5.38	5.8	0.3	4.7	7.4	3.0	13.6	11.5	4.0	3.7	12.5	8.3
High Lake	05/06/94	5.38	6.1	0.1	4.7	9.3	3.4	14.9	11.5	4.3	3.8	13.2	8.7
High Lake	05/07/94	5.38	6.5	2.5	4.9	11.2	3.5	15.0	11.4	4.7	3.9	15.1	8.8
High Lake	05/08/94	5.42	7.0	4.1	5.2	11.6	3.4	17.8	12.5	5.5	4.3	19.0	9.1
High Lake	05/09/94	5.46	6.9	0.2	4.9	9.9	3.0	19.5	12.8	4.9	4.1	19.6	6.9
High Lake	05/10/94	5.48	6.8	-0.4	7.4	7.4	3.0	15.3	14.0	4.5	4.0	15.1	8.0
High Lake	05/11/94	5.50	6.3	0.8	6.3	5.8	3.7	10.7	15.0	4.2	4.0	14.0	8.0
High Lake	05/12/94	5.50	4.8	-1.6	5.4	4.3	2.7	11.3	10.2	3.1	2.7	9.5	5.7
High Lake	05/13/94	5.60	3.8	2.0	5.6	2.7	3.2	5.1	6.3	3.0	2.0	6.6	5.0
High Lake	05/14/94	5.59	3.6	3.1	3.3	2.9	3.1	4.1	5.3	3.3	1.9	6.1	4.4
High Lake	05/14/94	5.65	3.6	5.0	4.1	2.9	3.4	2.8	5.5	3.6	2.0	6.4	4.7
High Lake	05/15/94	5.68	3.5	3.0	3.4	3.2	2.6	4.4	4.4	2.5	1.7	6.4	3.8
High Lake	05/16/94	5.54	4.0	2.3	3.0	6.0	2.6	8.3	4.8	2.7	2.2	8.3	4.8
High Lake	05/17/94	5.51	4.2	2.4	4.8	7.1	3.1	8.4	5.1	3.3	2.1	8.1	5.6
High Lake	05/18/94	5.53	5.5	-0.1	6.5	9.4	3.6	13.7	7.0	4.4	2.7	10.9	6.2
High Lake	05/19/94	5.38	6.2	-1.0	5.9	9.9	4.1	19.2	7.4	4.7	3.1	14.3	6.7
High Lake	05/20/94	5.37	6.9	-2.8	5.0	11.8	3.3	27.2	8.0	5.0	3.6	17.7	6.6
High Lake	05/21/94	5.45	7.5	0.1	11.7	11.1	5.7	15.6	12.0	6.4	3.9	15.2	7.9
High Lake	05/22/94	5.42	6.4	-0.2	8.2	9.5	4.8	11.5	11.0	4.1	3.7	12.1	6.9
High Lake	05/23/94	5.49	4.9	1.2	3.6	5.8	3.1	10.4	7.8	3.6	3.1	9.9	5.9
High Lake	05/23/94	5.46	4.9	1.5	3.3	6.1	3.2	9.7	7.9	3.7	3.1	9.8	5.7
High Lake	05/24/94	5.54	5.1	-0.8	4.8	5.2	2.4	12.6	8.0	3.7	2.5	11.0	4.2
High Lake	05/25/94	5.39	5.2	-7.4	4.2	6.2	3.7	25.9	8.0	4.1	2.4	12.2	4.2
High Lake	05/26/94	5.42	5.8	-8.5	3.3	12.6	3.1	33.5	9.3	5.6	2.9	16.9	3.6
High Lake	05/27/94	5.43	5.9	-2.9	1.8	20.4	2.9	26.9	11.7	6.6	3.3	22.2	3.5
High Lake	05/28/94	5.56	5.4	-1.8	0.9	22.5	2.7	24.2	11.6	6.6	3.2	22.0	3.3
High Lake	05/29/94	5.61	5.1	-1.5	0.8	21.6	2.4	22.1	10.3	5.9	2.9	20.1	2.9
High Lake	05/30/94	5.68	5.1	5.8	0.6	23.2	2.3	13.9	11.9	6.7	3.1	21.0	3.1
High Lake	05/31/94	5.66	5.7	3.2	0.5	27.8	2.5	17.9	14.1	7.7	3.4	23.3	3.3
High Lake	06/01/94	5.74	5.7	2.9	0.0	29.1	2.2	20.7	14.6	8.7	4.0	24.5	3.2
High Lake	06/02/94	5.62	4.6	1.9	0.0	19.1	1.9	15.1	10.4	5.8	2.8	17.3	3.4
High Lake	06/03/94	5.70	5.5	4.0	0.0	28.9	2.2	18.6	13.7	7.9	3.4	23.6	3.6
High Lake	06/04/94	5.67	5.5	8.3	0.0	29.2	2.2	13.9	14.1	7.8	3.4	24.0	3.4
High Lake	06/05/94	5.58	5.2	-1.1	0.0	25.1	1.7	20.8	11.5	5.9	2.9	20.4	2.8

Site	Date	pH	Conductivity µS	ANC µeq/L	NH4 µeq/L	SiO2 mg/L	Cl µeq/L	NO3 µeq/L	SO4 µeq/L	Na µeq/L	Mg µeq/L	Ca µeq/L	K µeq/L
High Lake	06/06/94	5.72	8.0	0.6	0.0	30.5	2.2	20.6	14.7	7.5	3.6	23.7	3.3
High Lake	06/07/94	5.71	5.7	1.0	0.0	28.6	2.0	21.7	13.9	7.0	3.4	24.9	3.3
High Lake	06/08/94	5.68	4.3	-0.4	0.0	17.8	2.5	16.7	9.3	5.3	2.4	17.5	2.6
High Lake	06/09/94	5.56	3.7	-2.1	0.0	12.7	2.0	15.7	8.3	4.0	2.0	13.4	2.4
High Lake	06/10/94	5.58	3.8	-3.0	0.0	11.6	2.0	15.3	9.4	4.1	2.0	12.3	2.4
High Lake	06/11/94	5.62	3.6	-3.0	0.0	11.1	1.6	15.2	8.7	3.7	1.8	11.9	2.2
High Lake	06/12/94	5.54	3.5	-2.9	0.0	11.0	2.4	14.5	7.8	3.6	1.8	11.6	2.0
High Lake	06/13/94	5.69	3.2	-4.0	0.0	10.2	1.2	15.2	7.1	2.5	1.5	9.9	1.6
High Lake	06/14/94	5.59	3.9	-4.1	0.0	11.5	5.5	15.1	7.7	6.4	1.7	10.5	1.7
High Lake	06/15/94	5.76	3.7	-1.8	0.0	14.9	2.1	13.5	9.3	4.9	1.8	12.7	2.0
High Lake	06/16/94	5.70	3.7	-3.1	0.0	15.8	1.6	16.4	9.3	4.2	1.9	13.1	2.0
High Lake	06/17/94	5.71	4.0	-3.0	0.0	16.3	1.2	16.8	9.5	4.2	2.0	13.3	2.1
High Lake	06/18/94	5.75	3.8	-2.2	0.0	15.9	1.7	14.1	9.6	4.2	1.9	13.1	2.0
High Lake	06/19/94	5.64	3.9	-1.3	0.0	16.5	1.4	12.6	10.4	4.5	1.9	13.3	2.2
High Lake	06/20/94	5.92	4.2	-3.0	0.0	18.3	1.5	18.0	12.2	5.4	2.2	15.5	2.6
High Lake	06/21/94	5.82	4.0	-1.0	0.0	17.9	1.4	13.0	11.9	5.0	2.1	14.8	2.5
High Lake	06/22/94	5.79	4.1	-0.2	0.0	18.0	1.4	11.8	11.8	5.5	2.1	14.4	2.7
High Lake	06/23/94	5.80	4.0	1.6	0.0	18.6	1.3	9.4	11.6	5.0	2.0	14.7	2.3
High Lake	06/24/94	5.77	3.9	0.6	0.0	18.2	1.4	10.5	11.5	5.1	1.9	14.5	2.4
High Lake	06/25/94	5.86	3.7	0.7	0.0	18.2	1.8	7.7	12.3	5.3	2.0	12.8	2.5
High Lake	06/26/94	5.79	3.8	1.1	0.0	18.6	2.2	6.9	12.8	5.6	2.1	12.7	2.6
High Lake	06/27/94	5.80	3.8	0.1	0.0	18.1	1.8	8.3	11.9	5.4	1.9	12.3	2.5
High Lake	06/28/94	5.80	3.8	2.9	0.0	18.4	1.7	4.2	12.1	5.0	1.9	11.7	2.4
High Lake	06/29/94	5.77	3.8	2.8	0.0	18.6	1.7	5.0	12.2	5.3	1.9	12.1	2.5
High Lake	06/30/94	5.92	3.9	1.2	0.0	18.8	1.5	7.5	12.3	5.3	1.9	12.7	2.6
High Lake	07/01/94	5.91	3.8	-0.3	0.0	19.2	1.5	10.5	12.5	5.8	2.0	13.2	2.9
High Lake	07/02/94	5.87	3.9	-0.5	0.0	19.7	1.7	10.9	11.9	5.9	2.0	13.1	2.6
High Lake	07/03/94	5.89	3.9	2.4	0.0	20.3	1.4	7.4	12.7	5.7	2.1	13.5	2.7
High Lake	07/04/94	5.87	4.1	2.8	0.0	20.5	1.4	7.4	12.7	5.9	2.0	13.6	2.8
High Lake	07/05/94	5.88	4.1	2.0	0.0	21.8	1.4	9.8	13.3	7.0	2.2	14.1	3.2
High Lake	07/06/94	5.84	5.7	1.7	0.0	22.3	1.5	8.4	13.4	6.2	2.0	13.9	3.0
High Lake	07/08/94	5.92	4.2	-0.3	0.0	23.0	1.7	12.2	13.6	6.7	2.0	15.2	3.1
High Lake	07/10/94	5.88	4.3	-0.7	0.0	24.5	2.6	13.6	13.8	7.9	2.1	15.4	3.3
High Lake	07/13/94	6.04	4.6	0.6	0.0	27.0	2.7	14.4	14.1	7.9	2.3	18.1	3.6
High Lake	07/16/94	5.93	4.5	-0.4	0.0	28.3	2.2	14.9	14.9	8.0	2.3	17.2	3.7
High Lake	07/19/94	6.03	4.3	4.0	0.0	29.7	1.3	8.5	15.1	7.1	2.4	16.3	3.2
High Lake	07/22/94	6.00	4.3	6.0	0.0	30.1	1.4	7.5	15.0	7.4	2.5	16.7	3.4
High Lake	07/25/94	5.99	4.3	5.3	0.0	30.7	1.7	7.6	15.6	7.4	2.4	17.0	3.5
High Lake	07/28/94	5.87	4.7	5.5	0.0	32.0	2.6	7.2	15.2	7.5	2.5	17.0	3.6
High Lake	07/31/94	6.63	4.3	16.6	0.0	34.1	1.3	6.0	15.8	7.6	2.3	16.3	3.5
High Lake	08/03/94	6.11		9.5	0.0		1.5	5.4	15.7	8.3	2.4	17.6	3.9
Low Lake	04/17/94	6.48	9.9	51.7	4.7	62.9	4.5	15.4	13.0	14.7	6.0	58.1	5.8
Low Lake	04/18/94	6.58	9.4	60.8	2.3	64.9	4.2	7.4	11.8	14.6	5.6	58.2	5.8
Low Lake	04/19/94	6.52	9.0	59.0	1.5	64.4	4.2	7.7	11.4	14.5	5.3	56.8	5.7
Low Lake	04/20/94	6.41	9.9	61.9	1.3	71.7	3.5	12.5	12.7	15.9	5.6	63.0	6.3
Low Lake	04/21/94	6.41	8.3	50.9	2.9	51.0	3.9	12.0	12.7	14.2	5.2	53.7	6.4
Low Lake	04/22/94	6.48	8.1	46.9	2.6	49.2	3.8	16.7	11.7	12.9	4.9	55.1	6.2
Low Lake	04/23/94	6.62	9.4	62.4	1.7	53.5	4.1	21.3	11.0	13.7	4.7	74.8	5.7
Low Lake	04/24/94	6.62	8.5	55.6	0.8	59.2	3.9	24.3	11.0	14.7	4.0	69.7	6.4
Low Lake	04/26/94	6.61	9.2	62.7	0.4	60.4	3.9	18.8	11.5	15.5	4.9	69.7	6.8

Site	Date	pH	Conductivity µS	ANC µeq/L	NH4 µeq/L	SiO2 mg/L	Cl µeq/L	NO3 µeq/L	SO4 µeq/L	Na µeq/L	Mg µeq/L	Ca µeq/L	K µeq/L
Low Lake	04/27/94	6.56	9.7	52.4	1.9	58.2	3.7	19.5	14.6	14.2	5.2	64.0	6.9
Low Lake	04/28/94	6.43	9.2	39.4	2.1	57.8	3.1	15.0	25.6	14.7	6.3	54.7	7.5
Low Lake	04/29/94	6.45	9.8	37.6	1.0	58.5	2.1	11.0	31.2	14.4	6.5	53.9	7.1
Low Lake	04/30/94	6.39	9.7	37.6	0.5	58.5	2.3	10.1	31.6	14.7	6.9	53.0	7.0
Low Lake	05/01/94	6.47	9.5	35.9	0.3	59.0	1.9	12.5	30.7	14.6	6.7	53.1	6.7
Low Lake	05/02/94	6.40	9.7	37.4	0.3	56.2	2.7	12.8	28.9	14.9	6.6	53.4	6.9
Low Lake	05/03/94	6.50	9.4	35.6	0.6	53.4	2.8	14.2	27.0	14.3	6.3	52.5	6.6
Low Lake	05/04/94	6.46	9.2	36.3	1.0	50.2	3.1	14.2	24.1	13.7	6.1	51.1	6.7
Low Lake	05/05/94	6.46	8.9	35.8	1.4	47.5	3.3	12.6	21.1	12.9	5.6	47.7	6.6
Low Lake	05/06/94	6.47	9.1	39.2	0.9	52.7	3.3	12.6	22.3	14.1	5.9	50.8	6.7
Low Lake	05/07/94	6.40	9.3	40.2	0.8	55.6	3.4	12.1	23.3	14.6	6.0	51.4	7.0
Low Lake	05/08/94	6.53	9.4	40.4	0.7	57.1	3.1	12.1	23.7	14.6	6.1	51.6	7.1
Low Lake	05/09/94	6.53	9.3	40.0	0.4	57.1	3.2	13.5	23.3	14.8	6.1	51.9	7.2
Low Lake	05/09/94	6.55	9.5	38.6	0.7	56.4	2.6	16.8	21.9	13.9	6.1	53.1	6.8
Low Lake	05/11/94	6.60	8.9	40.2	1.4	51.6	2.5	10.9	21.2	12.6	5.9	49.8	6.5
Low Lake	05/12/94	6.45	8.4	34.8	2.5	46.5	2.9	8.8	19.8	11.6	5.3	42.7	6.7
Low Lake	05/13/94	6.40	7.8	35.2	2.3	47.1	2.5	9.8	21.0	12.3	6.0	43.3	6.9
Low Lake	05/14/94	6.43	7.5	33.1	2.1	48.2	2.2	7.8	23.1	12.2	6.0	41.2	6.9
Low Lake	05/15/94	6.35	6.7	27.4	1.9	42.6	2.0	7.6	21.2	10.8	5.5	35.7	6.3
Low Lake	05/16/94	6.31	6.5	24.7	1.6	37.7	2.1	8.4	17.9	9.2	4.8	33.5	5.6
Low Lake	05/17/94	6.20	6.5	22.2	1.2	36.9	2.1	11.1	16.6	9.1	4.6	32.6	5.6
Low Lake	05/18/94	6.26	6.4	22.5	0.9	40.5	2.0	13.1	15.4	10.1	4.7	32.7	5.6
Low Lake	05/18/94	6.30	6.3	21.8	1.0	40.9	2.2	13.5	15.5	9.8	4.7	33.1	5.5
Low Lake	05/19/94	6.39	6.5	26.4	1.1	43.2	2.1	12.5	13.9	10.5	4.7	34.3	5.5
Low Lake	05/20/94	6.44	6.7	25.7	1.1	45.1	1.9	13.1	14.6	10.3	4.8	34.9	5.4
Low Lake	05/21/94	6.46	6.9	26.2	0.3	48.0	2.0	13.6	15.0	10.7	4.9	35.8	5.4
Low Lake	05/22/94	6.46	7.0	29.2	0.4	50.5	1.9	12.3	14.4	10.6	4.8	37.0	5.3
Low Lake	05/23/94	6.40	7.2	28.3	0.5	48.0	2.4	13.4	15.1	11.1	4.9	37.7	5.7
Low Lake	05/24/94	6.47	7.1	29.2	0.2	48.2	1.9	12.0	15.1	10.4	5.0	37.6	5.2
Low Lake	05/25/94	6.32	6.9	23.7	0.1	48.5	2.4	14.0	15.5	10.2	4.6	35.7	5.0
Low Lake	05/26/94	6.32	6.5	20.9	0.3	45.8	2.2	14.9	16.1	10.0	4.7	34.6	4.9
Low Lake	05/27/94	6.17	6.1	20.2	0.6	42.1	2.3	12.8	15.5	9.3	4.5	32.5	4.6
Low Lake	05/28/94	6.28	6.0	17.9	0.4	41.1	2.2	14.9	15.1	9.3	4.4	31.9	4.6
Low Lake	05/29/94	6.26	6.1	17.9	0.2	38.3	2.4	14.2	14.4	9.2	4.2	31.0	4.5
Low Lake	05/30/94	6.21	6.0	20.0	0.9	37.1	2.1	9.4	14.3	8.6	4.1	29.0	4.1
Low Lake	05/31/94	6.21	5.9	20.0	0.5	36.5	2.2	7.1	13.8	8.4	3.9	26.9	4.0
Low Lake	06/01/94	6.17	5.8	20.5	0.0	36.9	1.8	11.5	12.2	8.4	3.6	30.2	3.9
Low Lake	06/02/94	6.55	5.8	20.2	0.0	37.9	1.8	11.4	12.9	8.2	3.8	30.6	3.8
Low Lake	06/03/94	6.64	5.9	17.7	0.0	38.4	1.9	15.0	13.1	8.6	3.8	31.4	4.0
Low Lake	06/04/94	6.46	5.7	19.8	0.0	36.9	2.0	11.6	12.4	8.3	3.6	30.2	3.8
Low Lake	06/05/94	6.50	5.6	17.1	0.0	35.3	2.1	14.7	11.5	8.4	3.5	29.8	3.7
Low Lake	06/06/94	6.25	5.7	15.1	0.0	35.4	1.9	18.8	10.6	7.7	3.4	31.7	3.7
Low Lake	06/07/94	6.28	5.8	17.3	0.0	36.6	1.8	17.6	10.1	7.7	3.3	32.2	3.6
Low Lake	06/08/94	6.32	5.4	20.0	0.0	36.5	1.5	16.0	10.0	8.2	3.3	32.5	3.5
Low Lake	06/09/94	6.33	5.1	17.0	0.0	33.7	1.4	16.2	9.9	7.6	3.1	30.6	3.3
Low Lake	06/10/94	6.29	4.9	13.6	0.0	31.7	1.4	17.1	9.6	7.3	3.0	28.2	3.2
Low Lake	06/11/94	6.27	4.7	14.5	0.0	29.9	1.4	15.3	9.0	6.9	2.8	27.4	3.1
Low Lake	06/12/94	6.34	4.5	12.5	0.0	29.6	1.2	16.2	9.0	6.8	2.7	26.4	3.0
Low Lake	06/13/94	6.39	4.4	11.6	0.0	30.6	1.7	17.5	8.7	7.1	2.7	26.6	3.1
Low Lake	06/14/94	6.38	4.8	16.3	0.0	31.4	2.2	12.2	9.1	6.3	2.7	28.0	2.9

Site	Date	pH	Conductivity µS	ANC µeq/L	NH4 µeq/L	SiO2 mg/L	Cl µeq/L	NO3 µeq/L	SO4 µeq/L	Na µeq/L	Mg µeq/L	Ca µeq/L	K µeq/L
Low Lake	06/15/94	6.31	4.7	17.1	0.0	31.4	1.3	11.3	8.6	6.0	2.5	27.1	2.7
Low Lake	06/16/94	6.55	5.0	16.9	0.0	34.3	1.3	11.9	8.9	6.3	2.6	27.4	2.8
Low Lake	06/17/94	6.52	5.3	22.6	0.0	36.6	1.5	9.4	9.6	7.2	3.0	29.9	3.1
Low Lake	06/18/94	6.53	5.6	23.2	0.0	38.1	1.7	7.9	11.9	7.5	3.2	30.8	3.2
Low Lake	06/19/94	6.47	5.7	23.9	0.0	38.3	1.5	8.7	12.1	8.6	3.3	31.0	3.4
Low Lake	06/20/94	6.44	6.0	19.7	0.0	35.8	4.3	10.2	12.9	10.5	3.3	30.1	3.3
Low Lake	06/21/94	6.54	5.5	21.6	0.0	34.2	1.5	11.5	11.7	8.6	3.3	31.0	3.4
Low Lake	06/22/94	6.49	5.6	20.8	0.0	33.6	1.5	9.9	13.4	8.3	3.3	30.8	3.3
Low Lake	06/23/94	6.58	5.3	21.0	0.0	36.1	1.4	9.0	12.2	7.8	3.2	29.5	3.1
Low Lake	06/24/94	6.51	5.3	21.7	0.0	36.9	1.7	8.1	12.6	8.0	3.2	29.9	3.1
Low Lake	06/25/94	6.43	5.4	20.1	0.0	35.8	1.8	8.7	12.1	7.8	3.0	29.0	3.0
Low Lake	06/27/94	6.57	5.1	23.0	0.0	36.8	1.5	8.3	11.0	8.3	3.0	29.3	3.2
Low Lake	06/28/94	6.52	5.1	21.8	0.0	35.6	5.2	7.8	10.5	11.6	2.9	28.0	3.0
Low Lake	06/29/94	6.47	4.9	19.8	0.0	34.1	1.6	7.8	10.5	7.9	2.7	26.1	3.0
Low Lake	06/30/94	6.42	5.1	23.1	0.0	35.2	2.4	6.4	10.9	8.9	2.8	28.1	3.1
Low Lake	07/01/94	6.60	4.7	20.7	0.0	32.8	2.2	6.9	10.0	7.7	2.5	26.7	2.9
Low Lake	07/02/94	6.65	4.8	20.8	0.0	33.7	1.5	8.9	9.8	7.9	2.6	27.6	3.0
Low Lake	07/03/94	6.66	4.7	21.5	0.0	34.2	1.6	9.9	9.9	8.1	2.7	29.1	3.0
Low Lake	07/04/94	6.63	4.9	21.3	0.0	34.1	1.2	9.9	9.9	8.0	2.6	28.7	3.0
Low Lake	07/05/94	6.59	4.9	22.6	0.0	34.9	1.7	7.8	10.7	8.1	2.6	29.0	3.0
Low Lake	07/06/94	6.51	5.1	23.3	0.0	35.3	1.7	9.3	10.4	8.6	2.8	30.1	3.2
Low Lake	07/07/94	6.56	5.2	22.0	0.0	35.4	1.6	9.8	10.7	8.9	2.7	29.1	3.4
Low Lake	07/09/94	6.64	5.3	23.3	0.0	36.3	1.9	10.2	10.2	9.3	2.8	30.2	3.3
Low Lake	07/11/94	6.50	5.3	22.1	0.0	35.4	1.2	11.4	9.9	9.6	2.7	29.1	3.2
Low Lake	07/14/94	6.59	5.3	22.6	0.0	35.5	1.2	11.6	9.4	8.2	2.8	30.7	3.1
Low Lake	07/18/94	6.40	5.2	22.9	0.0	34.9	1.1	10.8	9.2	8.0	2.8	30.3	3.0
Low Lake	07/28/94	6.49	4.7	22.8	0.0	33.1	1.2	5.8	9.6	8.0	2.6	25.7	3.1
Low Lake	08/01/94	6.69	4.8	27.2	0.0	35.3	1.0	1.4	9.2	7.9	2.3	25.6	3.0
Low Lake	08/05/94	6.75	5.3	27.3	0.0	36.0	1.5	1.2	9.8	8.3	2.5	25.5	3.5
Low Lake	08/09/94	6.68	5.1	24.4	0.0	36.9	1.4	7.7	10.2	8.5	2.8	29.1	3.3
Low Lake	08/13/94	6.76		27.8	0.0		1.1	1.3	12.1	8.8	2.6	27.2	3.6
Low Lake	08/17/94	6.76	5.7	25.6	0.0		0.9	5.4	11.5	9.0	2.8	28.2	3.5
Low Lake	08/21/94	6.68	5.7	24.2	0.0		1.0	6.6	10.4	8.5	2.7	27.8	3.2
Low Lake	09/05/94	6.53	6.5	26.9	0.0		1.2	3.0	14.7	10.4	3.3	28.1	4.0
Mills Lake	04/26/94	6.21	8.7	32.5	1.3	52.5	1.9	5.3	37.4	13.6	7.2	50.6	5.8
Mills Lake	04/27/94	6.35	8.8	31.9	1.1	53.0	2.2	7.1	35.9	13.9	7.0	50.4	5.8
Mills Lake	05/12/94	6.27	9.2	31.3	2.5	50.9	2.5	13.7	27.1	12.9	6.9	47.2	7.6
Mills Lake	05/13/94	6.42	8.4	32.5	3.0	50.4	2.7	8.5	28.2	13.6	7.0	43.9	7.4
Mills Lake	05/14/94	6.25	7.4	28.9	2.0	45.8	2.3	7.1	25.9	12.3	6.4	38.8	6.8
Mills Lake	05/15/94	6.11	6.8	23.3	2.4	38.6	2.1	7.8	21.6	10.3	5.6	32.8	6.2
Mills Lake	05/16/94	6.10	6.2	22.9	2.2	35.4	2.1	5.4	17.9	8.7	4.8	29.3	5.6
Mills Lake	05/17/94	6.05	6.3	17.4	2.2	35.2	2.1	12.0	17.8	8.9	4.9	30.0	5.5
Mills Lake	05/18/94	6.08	6.1	18.3	1.8	34.5	1.9	12.0	15.2	8.7	4.6	28.6	5.4
Mills Lake	05/18/94	6.07	6.0	18.7	1.9	36.2	1.9	11.5	15.1	8.7	4.5	28.6	5.4
Mills Lake	05/23/94	6.14	7.6	22.4	2.9	46.0	2.1	12.2	20.0	10.7	5.7	34.4	5.8
Mills Lake	05/25/94	6.38	7.0	27.3	0.9	46.4	2.2	7.4	18.9	10.2	5.1	35.2	5.3
Mills Lake	05/26/94	6.25	6.6	19.1	0.9	42.2	2.2	13.2	19.7	10.1	5.1	33.7	5.3
Mills Lake	05/27/94	6.20	6.5	14.4	1.3	39.4	2.3	15.7	19.7	9.1	4.8	33.6	4.6
Mills Lake	05/28/94	6.20	6.5	20.1	2.5	39.5	2.4	10.2	16.7	9.0	4.6	31.2	4.6
Mills Lake	05/29/94	6.17	6.3	13.9	1.0	38.4	2.4	14.8	17.0	8.6	4.4	30.8	4.3

Site	Date	pH	Conductivity µS	ANC µeq/L	NH4 µeq/L	SiO2 mg/L	Cl µeq/L	NO3 µeq/L	SO4 µeq/L	Na µeq/L	Mg µeq/L	Ca µeq/L	K µeq/L
Mills Lake	05/30/94	5.98	6.0	14.4	0.9	35.1	2.1	13.7	17.0	8.7	4.4	29.8	4.2
Mills Lake	05/31/94	5.94	5.8	14.8	0.9	33.9	2.1	12.5	14.4	8.1	3.9	28.0	3.9
Mills Lake	06/01/94	6.54	5.7	15.6	0.0	35.2	1.8	14.0	13.6	8.2	3.9	29.2	3.9
Mills Lake	06/02/94	6.26	6.2	18.2	0.0	38.0	2.0	15.7	14.8	8.9	4.3	33.6	4.0
Mills Lake	06/03/94	6.25	6.0	16.9	0.0	36.7	2.0	16.4	14.3	8.7	4.2	32.8	3.9
Mills Lake	06/04/94	6.26	5.7	18.9	0.0	33.6	2.0	11.1	14.2	8.0	3.9	30.8	3.7
Mills Lake	06/05/94	6.23	5.5	16.3	0.0	32.7	2.1	14.2	12.2	7.8	3.6	29.8	3.6
Mills Lake	06/06/94	6.13	5.6	14.7	0.0	32.7	2.0	15.9	11.4	7.2	3.3	30.0	3.5
Mills Lake	06/07/94	6.19	5.8	15.6	0.0	34.0	1.9	16.9	11.3	7.3	3.3	31.6	3.6
Mills Lake	06/08/94	6.40	5.4	15.0	0.0	34.8	1.6	19.4	10.4	7.7	3.3	32.1	3.4
Mills Lake	06/09/94	6.16	5.0	13.7	0.0	31.4	1.5	17.3	10.2	7.2	3.1	29.4	3.1
Mills Lake	06/10/94	6.22	4.7	13.3	0.0	29.4	3.5	15.1	10.3	8.3	2.9	27.9	3.1
Mills Lake	06/11/94	6.20	4.6	11.8	0.0	28.5	2.0	16.0	9.9	7.0	2.8	27.0	3.0
Mills Lake	06/12/94	6.12	4.6	11.9	0.0	27.3	3.9	15.4	9.4	8.7	2.7	26.5	2.9
Mills Lake	06/13/94	6.15	4.6	14.6	0.0	27.5	1.7	13.5	8.9	6.6	3.0	26.3	2.9
Mills Lake	06/15/94	6.32	4.5	12.4	0.0	28.3	1.2	12.9	8.6	5.6	2.4	24.6	2.5
Mills Lake	06/16/94	6.46	4.9	18.3	0.0	31.6	1.4	9.5	9.6	6.5	2.6	27.0	2.8
Mills Lake	06/17/94	6.43	5.4	16.8	0.0	33.6	1.1	12.5	12.3	7.2	3.0	29.4	3.1
Mills Lake	06/18/94	6.39	6.3	21.8	0.0	37.6	1.1	10.0	18.9	8.9	4.3	34.9	3.8
Mills Lake	06/19/94	6.40	5.9	20.3	0.0	35.6	1.4	9.8	16.5	8.4	3.9	32.2	3.6
Mills Lake	06/20/94	6.48	6.0	18.5	0.0	32.5	1.3	12.3	16.8	8.6	3.8	33.0	3.6
Mills Lake	06/21/94	6.33	5.5	15.5	0.0	29.8	1.2	14.4	13.4	7.6	3.2	30.4	3.3
Mills Lake	06/22/94	6.32	5.5	11.3	0.0	32.1	1.2	17.4	14.0	7.6	3.3	29.9	3.2
Mills Lake	06/23/94	6.50	5.4	16.8	0.0	31.5	1.5	9.9	13.2	7.0	3.0	28.5	2.9
Mills Lake	06/24/94	6.40	5.2	15.8	0.0	30.6	1.7	8.3	14.3	6.7	2.9	27.8	2.8
Mills Lake	06/25/94	6.48	4.8	19.1	0.0	29.3	1.8	5.0	11.7	7.2	2.7	25.0	2.8
Mills Lake	06/26/94	6.46	4.7	17.4	0.0	29.1	1.5	7.8	10.9	6.9	2.6	25.2	2.9
Mills Lake	06/27/94	6.47	4.7	16.8	0.0	29.1	2.1	8.6	9.9	7.4	2.6	24.2	3.2
Mills Lake	06/28/94	6.42	4.7	16.9	0.0	29.1	1.7	7.2	10.6	6.8	2.5	24.3	2.8
Mills Lake	06/29/94	6.43	4.6	16.4	0.0	28.3	1.6	7.7	10.2	6.6	2.4	24.3	2.7
Mills Lake	06/30/94	6.52	4.7	17.7	0.0	27.7	1.0	9.0	8.9	6.2	2.3	25.6	2.5
Mills Lake	07/01/94	6.47	4.6	17.3	0.0	27.2	1.2	9.3	9.0	6.2	2.5	25.6	2.6
Mills Lake	07/02/94	6.44	4.4	11.1	0.0	27.4	1.2	15.9	8.9	6.2	2.6	25.9	2.5
Mills Lake	07/03/94	6.47	4.5	16.6	0.0	28.2	1.4	10.0	9.1	6.2	2.6	25.7	2.5
Mills Lake	07/04/94	6.45	4.5	16.9	0.0	28.1	1.2	9.9	9.0	6.3	2.6	25.6	2.6
Mills Lake	07/05/94	6.54	4.5	17.0	0.0	28.2	1.3	9.0	9.2	6.4	2.6	24.9	2.6
Mills Lake	07/06/94	6.44	4.7	17.5	0.0	28.1	1.6	9.8	8.8	6.6	2.6	25.9	2.7
Mills Lake	07/07/94	6.53	4.7	16.5	0.0	28.3	1.3	10.1	9.0	6.5	2.6	25.3	2.6
Mills Lake	07/09/94	6.56	4.6	16.4	0.0	28.8	1.5	11.0	9.4	6.8	2.4	26.4	2.8
Mills Lake	07/11/94	6.54	4.4	17.7	0.0	28.2	1.0	10.0	9.1	6.7	2.4	26.0	2.7
Mills Lake	07/18/94	6.55	4.6	19.6	0.0	26.8	1.1	9.7	7.8	6.5	2.3	26.7	2.8
Mills Lake	07/22/94	6.60	4.4	21.4	0.0	28.0	1.5	4.2	8.8	7.1	2.4	23.6	2.8
Mills Lake	07/26/94	6.56	4.5	22.0	0.0	27.9	1.3	3.7	8.6	6.7	2.3	23.8	2.8
Mills Lake	07/30/94	6.61	4.2	22.4	0.0	28.4	1.3	4.0	8.3	7.1	2.3	23.7	2.9
Mills Lake	08/04/94	6.66	4.3	28.7	0.0	28.9	1.0	5.0	8.2	6.7	2.2	22.9	2.7
Mills Lake	08/08/94	6.65	4.7	22.0	0.0	30.1	1.2	7.6	8.6	7.0	2.5	27.2	2.8
Mills Lake	08/12/94	6.71	5.2	23.1	0.0		1.2	3.3	10.3	7.5	2.5	25.0	3.0
Mills Lake	08/16/94	6.53	5.4	24.2	0.0		1.2	0.2	11.0	7.2	2.4	24.1	3.0
Mills Lake	08/20/94	6.62	5.1	26.2	0.0		1.0	0.0	10.7	7.5	2.4	25.1	2.7
Mills Lake	08/24/94	6.58	5.5	25.0	0.0		1.2	1.2	10.8	7.8	2.4	24.9	3.1

Site	Date	pH	Conductivity µS	ANC µeq/L	NH4 µeq/L	SiO2 mg/L	Cl µeq/L	NO3 µeq/L	SO4 µeq/L	Na µeq/L	Mg µeq/L	Ca µeq/L	K µeq/L
Mills Lake	09/06/94	6.55	6.2	25.6	0.0		1.2	8.9	14.2	10.6	3.3	32.6	3.5
Ruby Lake	04/11/94	6.60	10.1	69.8	0.0	55.0	2.6	11.8	11.9	20.4	4.8	65.2	5.7
Ruby Lake	04/12/94	6.72	10.1	66.8	0.0	55.3	2.5	15.4	12.2	20.5	4.9	65.9	5.6
Ruby Lake	04/13/94	6.63	10.0	71.7	0.1	55.0	2.6	11.1	11.8	20.6	5.0	65.8	5.8
Ruby Lake	04/14/94	6.65	10.1	72.2	0.4	55.3	2.5	10.4	11.7	20.4	4.8	66.0	5.8
Ruby Lake	04/15/94	6.55	10.2	72.8	0.4	54.8	2.7	9.2	11.7	20.2	4.9	65.3	6.0
Ruby Lake	04/16/94	6.75	10.2	77.4	0.0	52.0	3.4	1.8	11.7	18.1	5.0	65.7	5.5
Ruby Lake	04/17/94	6.67	9.9	72.3	0.0	52.1	3.2	6.7	11.4	17.8	5.0	65.2	5.7
Ruby Lake	04/18/94	6.73	9.9	71.9	0.4	54.1	3.6	6.3	11.2	17.8	5.2	64.2	5.8
Ruby Lake	04/19/94	6.52	9.9	74.7	0.0	52.6	3.6	4.1	11.2	17.8	5.2	64.8	5.8
Ruby Lake	04/20/94	6.56	10.0	70.5	0.0	56.6	3.8	9.3	11.1	18.1	5.3	65.5	5.9
Ruby Lake	04/21/94	6.58	9.1	69.1	0.0	58.7	4.4	10.1	11.3	19.8	5.4	63.6	6.2
Ruby Lake	04/22/94	6.75	8.7	70.8	0.2	15.8	4.4	12.6	10.8	18.5	5.4	68.8	6.0
Ruby Lake	04/24/94	6.72	9.1	74.5	0.1	58.0	4.3	8.8	11.3	19.1	5.2	68.5	6.1
Ruby Lake	04/26/94	6.67	9.4	74.3	0.2	60.0	3.7	8.3	11.5	18.4	5.1	68.7	5.7
Ruby Lake	04/27/94	6.65	9.1	79.2	0.0	58.5	3.2	6.0	11.4	19.1	5.1	64.2	5.7
Ruby Lake	04/28/94	6.71	9.2	77.5	0.0	60.4	3.2	4.6	11.5	19.4	5.2	66.3	5.9
Ruby Lake	04/29/94	6.72	10.5	77.7	0.2	59.5	3.2	5.5	11.6	18.2	5.1	69.1	5.7
Ruby Lake	04/30/94	6.73	10.5	79.6	0.2	62.4	3.4	4.9	11.8	18.7	5.0	70.1	5.8
Ruby Lake	05/01/94	6.70	10.3	75.1	0.2	60.9	3.4	9.3	11.8	18.6	5.0	70.1	5.8
Ruby Lake	05/02/94	6.65	10.4	77.9	0.2	62.2	3.3	6.5	11.7	18.4	5.0	70.3	5.8
Ruby Lake	05/03/94	6.70	10.6	70.5	2.0	60.0	3.2	11.8	11.5	18.9	4.9	67.2	6.1
Ruby Lake	05/04/94	6.83	10.5	76.4	0.6	59.2	3.3	5.3	11.5	18.7	5.2	66.7	5.9
Ruby Lake	05/05/94	6.75	10.6	79.5	0.3	60.4	3.4	3.5	11.8	19.0	5.2	66.0	6.0
Ruby Lake	05/06/94	6.76	10.7	79.2	0.3	60.1	3.8	2.5	11.7	19.0	5.1	67.2	6.0
Ruby Lake	05/07/94	6.79	10.6	76.9	0.2	60.2	3.5	4.9	11.7	19.0	5.1	67.1	5.9
Ruby Lake	05/08/94	6.82	10.6	79.9	0.3	58.6	3.4	2.5	11.9	19.2	5.1	67.3	6.1
Ruby Lake	05/09/94	6.80	10.5	75.4	0.3	61.2	4.2	6.5	12.0	19.5	5.0	67.3	6.2
Ruby Lake	05/10/94	6.80	10.2	76.3	0.4	59.2	2.7	0.3	12.1	17.9	4.9	62.4	6.3
Ruby Lake	05/11/94	5.55	9.7	74.5	0.5	57.2	2.7	2.8	12.1	17.4	5.2	63.6	5.9
Ruby Lake	05/12/94	6.66	9.5	69.6	0.5	56.3	4.2	3.4	12.0	17.0	5.0	61.3	6.0
Ruby Lake	05/13/94	6.75	9.0	71.9	0.4	55.2	2.8	0.1	11.3	17.9	5.1	56.8	6.4
Ruby Lake	05/14/94	6.77	8.7	72.3	0.5	53.6	2.5	1.5	11.4	16.9	4.9	60.0	6.0
Ruby Lake	05/15/94	6.79	8.7	70.8	0.9	52.2	2.3	4.2	11.2	16.9	4.8	61.0	5.8
Ruby Lake	05/16/94	6.80	8.8	65.3	0.8	51.1	2.3	8.4	12.1	16.5	4.9	61.0	5.8
Ruby Lake	05/17/94	6.67	8.4	58.2	1.0	45.0	2.5	6.6	12.4	14.2	4.8	54.3	6.5
Ruby Lake	05/18/94	6.69	8.4	56.6	0.7	48.3	2.5	8.3	11.8	13.9	4.7	54.3	6.4
Ruby Lake	05/18/94	6.58	8.6	57.3	0.7	48.4	2.5	7.7	12.0	14.0	4.7	54.5	6.3
Ruby Lake	05/19/94	6.70	9.1	57.2	1.0	48.1	2.5	8.4	12.2	14.5	4.9	54.6	6.3
Ruby Lake	05/20/94	6.75	8.8	55.2	0.6	48.9	2.4	8.8	12.5	14.4	4.9	53.6	6.2
Ruby Lake	05/21/94	6.78	8.7	54.7	0.6	48.8	2.4	9.1	12.5	14.5	4.9	53.3	6.1
Ruby Lake	05/22/94	6.74	8.7	57.0	1.0	48.7	2.3	8.4	11.9	14.7	4.9	53.9	6.2
Ruby Lake	05/23/94	6.78	8.5	54.3	0.7	47.2	2.3	9.0	11.9	14.3	4.9	52.3	6.1
Ruby Lake	05/24/94	6.73	8.3	48.7	0.6	44.3	2.3	8.2	12.2	12.9	4.9	47.7	6.0
Ruby Lake	05/25/94	6.65	7.8	43.1	0.5	44.4	2.3	9.0	12.6	12.2	4.8	44.2	5.7
Ruby Lake	05/26/94	6.42	7.1	38.0	0.4	44.1	2.6	12.0	12.3	11.9	4.5	43.3	5.3
Ruby Lake	05/27/94	6.42	7.3	43.5	0.2	43.8	2.7	8.6	11.2	12.1	4.2	44.9	5.0
Ruby Lake	05/28/94	6.49	7.1	41.1	0.0	45.1	2.7	12.0	9.8	11.9	3.9	44.9	4.9
Ruby Lake	05/29/94	6.59	7.2	47.2	0.0	44.1	2.4	4.5	10.2	12.0	4.0	43.4	5.0
Ruby Lake	05/30/94	6.63	7.5	45.5	0.3	45.4	2.5	8.7	9.7	12.5	3.9	45.2	4.9

Site	Date	pH	Conductivity µS	ANC µeq/L	NH4 µeq/L	SiO2 mg/L	Cl µeq/L	NO3 µeq/L	SO4 µeq/L	Na µeq/L	Mg µeq/L	Ca µeq/L	K µeq/L
Ruby Lake	05/31/94	6.65	7.4	45.0	0.0	43.5	2.4	12.9	9.8	13.0	4.0	48.3	4.9
Ruby Lake	06/01/94	6.67	7.2	43.2	0.0	42.2	2.5	11.8	9.3	12.4	3.8	45.9	4.8
Ruby Lake	06/02/94	6.63	6.8	38.0	0.0	41.0	2.1	11.5	9.7	11.4	3.8	41.9	4.3
Ruby Lake	06/03/94	6.79	6.4	36.5	0.0	38.4	2.0	9.8	9.1	10.4	3.5	39.6	4.0
Ruby Lake	06/04/94	6.82	6.5	41.0	0.0	38.8	2.0	5.9	9.2	10.7	3.4	40.0	4.0
Ruby Lake	06/05/94	6.92	6.5	38.2	0.0	39.3	2.1	9.5	8.7	10.7	3.4	40.5	4.0
Ruby Lake	06/06/94	6.68	6.6	35.1	0.0	39.7	1.9	14.5	8.6	10.0	3.4	42.9	4.0
Ruby Lake	06/07/94	6.62	6.7	38.2	0.0	39.6	2.0	11.1	8.9	10.0	3.4	42.7	4.0
Ruby Lake	06/08/94	6.54	6.8	28.4	0.0	38.9	1.7	21.8	9.6	10.4	3.5	43.6	4.1
Ruby Lake	06/09/94	6.59	6.7	36.3	0.0	40.1	2.8	15.8	9.6	12.2	3.5	44.9	4.0
Ruby Lake	06/10/94	6.79	6.9	43.6	0.0	40.8	1.7	12.9	9.7	11.9	3.6	48.2	4.2
Ruby Lake	06/11/94	6.71	7.3	44.5	0.0	41.7	2.2	10.5	9.5	12.8	3.6	46.1	4.2
Ruby Lake	06/12/94	6.63	6.7	45.3	0.0	39.6	1.5	9.7	9.1	12.0	3.6	45.9	4.2
Ruby Lake	06/13/94	6.71	6.9	49.5	0.0	40.7	1.7	8.0	9.7	12.4	3.8	48.3	4.3
Ruby Lake	06/14/94	6.74	8.0	56.5	0.0	44.7	2.2	5.0	10.3	13.3	3.9	52.5	4.3
Ruby Lake	06/15/94	6.92	8.1	56.1	0.0	45.2	2.0	8.1	10.5	13.8	4.0	54.5	4.5
Ruby Lake	06/16/94	6.79	8.2	55.4	0.0	45.1	2.6	3.7	10.2	12.7	3.9	50.8	4.5
Ruby Lake	06/17/94	6.83	8.3	55.0	0.0	45.2	1.9	4.8	10.3	12.1	3.9	51.6	4.4
Ruby Lake	06/18/94	6.81	8.1	57.5	0.0	45.0	1.8	3.6	10.2	12.2	3.9	52.6	4.4
Ruby Lake	06/19/94	6.88	8.0	57.4	0.0	44.7	1.9	2.4	10.0	12.1	3.8	51.3	4.6
Ruby Lake	06/20/94	6.89	7.9	53.4	0.0	44.5	1.5	6.5	10.1	12.1	3.8	51.1	4.5
Ruby Lake	06/21/94	6.74	8.0	51.5	0.0	40.4	1.9	6.6	10.4	12.9	3.8	49.4	4.4
Ruby Lake	06/22/94	6.87	7.6	51.9	0.0	40.0	1.9	6.2	10.4	13.4	3.9	48.5	4.6
Ruby Lake	06/23/94	6.88	7.7	52.3	0.0	39.7	2.0	5.9	10.2	13.5	3.8	48.6	4.5
Ruby Lake	06/24/94	6.83	7.7	50.5	0.0	43.7	1.8	7.8	10.6	13.2	3.7	49.3	4.6
Ruby Lake	06/25/94	6.86	7.9	50.5	0.0	43.5	2.2	6.4	11.0	12.8	3.7	49.0	4.5
Ruby Lake	06/26/94	6.74	7.1	49.4	0.0	42.7	1.9	6.5	10.5	12.6	3.7	47.8	4.2
Ruby Lake	06/27/94	6.74	7.1	48.4	0.0	42.3	1.8	6.5	10.7	12.4	3.7	47.2	4.1
Ruby Lake	06/28/94	6.72	7.0	48.5	0.0	42.2	1.8	5.7	10.6	12.3	3.7	46.5	4.2
Ruby Lake	06/29/94	6.80	7.0	49.1	0.0	42.5	2.0	4.4	10.5	12.3	3.6	45.9	4.3
Ruby Lake	06/30/94	6.84	6.9	48.2	0.0	42.2	2.0	5.0	10.3	12.2	3.6	45.5	4.2
Ruby Lake	07/01/94	6.75	7.5	49.3	0.0	40.8	2.3	1.8	11.0	12.2	3.6	44.5	4.1
Ruby Lake	07/02/94	6.73	7.4	48.1	0.0	42.2	2.2	3.4	10.9	12.2	3.6	44.7	4.2
Ruby Lake	07/03/94	6.79	7.4	47.6	0.0	41.4	2.3	4.9	11.4	13.4	3.7	44.9	4.3
Ruby Lake	07/04/94	6.77	7.4	48.1	0.0	40.8	2.1	2.8	10.5	12.2	3.6	43.6	4.1
Ruby Lake	07/05/94	6.82	7.4	48.6	0.0	40.8	2.1	2.2	10.6	12.3	3.6	43.5	4.2
Ruby Lake	07/06/94	6.72	7.3	50.5	0.0	40.3	1.8	1.0	11.4	12.7	3.3	42.6	4.4
Ruby Lake	07/07/94	6.77	7.4	49.6	0.0	40.8	2.6	1.7	10.1	12.7	3.6	42.6	4.9
Ruby Lake	07/09/94	6.78	7.1	47.4	0.0	40.6	1.8	6.9	9.7	12.8	3.4	45.2	4.4
Ruby Lake	07/11/94	6.92	7.0	47.4	0.0	41.8	1.7	8.3	9.7	13.0	3.5	46.2	4.4
Ruby Lake	07/14/94	6.74	7.3	46.0	0.0	43.6	1.7	8.7	9.3	11.9	3.6	46.2	4.1
Ruby Lake	07/18/94	6.75	7.2	43.8	0.0	40.0	1.6	10.2	9.6	11.8	3.5	45.8	4.2
Ruby Lake	07/18/94	6.76	7.2	43.6	0.0	37.6	1.7	8.6	10.2	12.6	3.4	44.0	4.0
Ruby Lake	07/23/94	6.73	6.8	43.0	0.0	40.4	1.7	7.4	9.4	12.4	3.5	41.2	4.4
Ruby Lake	07/27/94	6.78	6.3	41.5	0.0	40.2	2.2	5.5	9.8	12.0	3.4	39.5	4.2
Ruby Lake	07/30/94	6.79	6.1	43.3	0.0	40.1	1.4	5.5	9.3	11.3	3.2	41.2	3.9
Ruby Lake	08/03/94	6.82	6.0	46.9	0.0	40.7	1.6	4.3	8.9	11.6	3.3	42.9	4.0
Ruby Lake	08/07/94	6.79	7.0	47.6	0.0	42.0	3.2	0.0	10.4	11.5	3.2	37.4	4.6
Ruby Lake	08/11/94	6.95	6.7	45.5	0.0	41.3	1.8	0.0	9.8	11.7	3.1	37.0	4.1
Ruby Lake	08/15/94	6.86	7.5	45.1	0.0		1.9	6.3	9.5	12.4	3.6	42.6	4.3

Site	Date	pH	Conductivity µS	ANC µeq/L	NH4 µeq/L	SiO2 mg/L	Cl µeq/L	NO3 µeq/L	SO4 µeq/L	Na µeq/L	Mg µeq/L	Ca µeq/L	K µeq/L
Ruby Lake	08/19/94	6.93	7.3	45.5	0.0		1.6	6.3	9.8	12.1	3.5	43.5	4.1
Ruby Lake	08/23/94	6.99	6.9	49.1	0.0		1.6	3.4	9.5	12.4	3.5	43.5	4.3
Spuller Lake	04/22/94	6.41	11.6	57.7	1.5	34.2	4.8	20.2	18.7	15.0	7.9	71.0	7.5
Spuller Lake	04/25/94	6.35	12.1	63.8	0.9	40.1	4.8	17.5	20.3	16.6	8.4	75.2	6.2
Spuller Lake	05/04/94	6.37	13.9	83.7	1.4	49.9	4.2	12.3	21.9	18.9	9.1	88.7	5.6
Spuller Lake	05/07/94	6.80	12.1	65.9	0.4	42.6	3.7	16.3	19.0	16.1	8.5	75.3	5.1
Spuller Lake	05/10/94	6.79	13.5	78.2	0.4	48.0	3.1	15.7	21.7	18.3	9.9	85.9	4.7
Spuller Lake	05/13/94	6.43	8.2	36.5	1.7	25.8	3.2	12.8	15.0	10.8	6.0	45.3	5.3
Spuller Lake	05/16/94	6.56	6.6	39.0	1.1	24.4	1.8	5.3	11.8	9.4	5.2	39.1	4.2
Spuller Lake	05/19/94	6.64	7.9	41.9	0.6	35.0	2.1	14.7	14.0	12.2	6.2	50.1	4.2
Spuller Lake	05/22/94	6.70	9.5	59.7	0.9	41.9	2.6	9.7	17.9	15.0	7.5	63.4	4.1
Spuller Lake	05/25/94	6.47	7.5	42.2	0.8	29.8	1.9	12.3	13.2	10.5	5.5	49.8	3.8
Spuller Lake	05/28/94	6.37	6.1	27.8	0.0	24.1	2.0	11.9	10.2	8.1	4.2	36.3	3.3
Spuller Lake	05/31/94	6.39	5.2	21.3	0.0	21.7	1.7	11.4	8.4	6.9	3.5	29.4	3.0
Spuller Lake	06/03/94	6.16	5.0	25.2	0.0	18.9	1.5	4.6	8.2	6.1	3.1	27.7	2.7
Spuller Lake	06/06/94	6.18	5.1	15.2	0.0	18.4	1.4	18.1	7.1	6.0	3.4	29.6	2.7
Spuller Lake	06/09/94	6.28	4.6	16.5	0.0	21.3	1.4	16.9	7.4	6.8	3.3	29.4	2.7
Spuller Lake	06/17/94	6.60	6.1	33.5	0.0	23.8	1.7	6.2	8.6	8.5	4.0	35.2	2.4
Spuller Lake	06/20/94	6.62	5.0	30.4	0.0	24.7	1.7	7.6	8.1	8.7	3.8	32.8	2.5
Spuller Lake	06/23/94	6.56	4.5	30.9	0.0	24.5	1.7	1.6	6.9	7.9	3.3	27.7	2.3
Spuller Lake	06/26/94	6.58	4.5	25.9	0.0	27.3	1.7	5.9	6.6	8.2	3.2	26.5	2.2
Spuller Lake	06/29/94	6.56	4.3	23.6	0.0	27.2	1.6	6.4	6.1	8.3	3.0	24.2	2.2
Spuller Lake	07/02/94	6.67	4.9	29.5	0.0	32.1	1.4	3.1	6.1	9.6	3.0	25.1	2.4
Spuller Lake	07/05/94	6.71	5.0	32.4	0.0	35.4	1.3	0.9	6.1	10.1	3.1	25.1	2.4
Spuller Lake	07/08/94	6.67	5.7	31.1	0.0	37.7	1.6	5.5	6.5	11.5	3.2	27.2	2.7
Spuller Lake	07/11/94	6.57	5.6	32.4	0.0	39.5	1.8	4.9	6.6	11.9	3.2	27.7	2.8
Spuller Lake	07/14/94	6.67	5.7	31.3	0.0	40.7	1.9	7.2	6.4	12.9	3.3	27.6	3.1
Spuller Lake	07/17/94	6.65	5.6	32.0	0.0	43.0	2.0	5.9	6.4	13.0	3.2	27.3	2.9
Spuller Lake	07/20/94	6.55	5.6	33.9	0.0	43.3	1.5	4.4	6.5	12.5	3.4	27.3	3.2
Spuller Lake	07/23/94	6.60	5.6	35.6	0.0	44.6	1.7	4.1	7.1	13.3	3.5	28.5	3.3
Spuller Lake	07/26/94	6.65	5.5	35.0	0.0	44.9	1.6	5.2	6.9	13.8	3.5	28.4	3.0
Spuller Lake	07/29/94	6.70	5.7	41.8	0.0	47.3	1.8	0.0	6.9	14.1	3.1	26.8	3.1
Spuller Lake	08/01/94	6.74	5.5	39.8	0.0	49.1	1.4	0.3	6.9	13.7	3.4	28.0	3.3
Spuller Lake	08/04/94	6.73	5.6	39.4	0.0	50.5	1.4	0.3	7.0	13.9	3.3	28.0	3.0
Spuller Lake	08/07/94	6.70	5.7	41.2	0.0	51.8	1.6	0.0	7.5	14.1	3.4	28.2	3.0
Spuller Lake	08/10/94	6.89	5.5	42.3	0.0	54.2	3.0	5.0	8.0	16.9	4.0	34.1	3.4
Spuller Lake	08/13/94	6.89	5.6	43.0	0.0	54.9	1.6	5.0	8.1	16.2	4.2	34.0	3.4
Spuller Lake	08/16/94	6.90	5.7	41.2	0.0	55.2	1.4	7.4	8.0	15.6	4.1	35.3	3.2
Spuller Lake	08/19/94	6.86	5.9	44.6	0.0	56.7	2.1	5.6	8.3	16.1	4.1	36.0	4.4
Spuller Lake	08/22/94	6.89	5.8	43.6	0.0	57.1	1.4	7.0	8.4	16.0	4.3	36.7	3.4
Treasure Lake	01/06/94	6.27	6.4	50.8	0.0	34.0	2.2		6.2				
Treasure Lake	04/07/94	6.46	6.0	36.9	0.0	21.2	2.0	11.1	7.8	12.0	3.9	37.3	4.6
Treasure Lake	04/13/94	6.34	5.8	37.5	0.7	37.1	1.7	7.4	7.3	11.1	3.3	35.2	4.4
Treasure Lake	04/14/94	6.52	5.9	39.8	0.8	37.0	1.7	5.3	7.1	11.2	3.2	35.0	4.5
Treasure Lake	04/15/94	6.46	5.8	42.9	1.0	36.7	1.7	1.1	7.3	10.8	3.2	34.8	4.3
Treasure Lake	04/16/94	6.41	6.0	39.6	1.2	36.4	2.0	4.4	7.4	10.8	3.2	35.1	4.4
Treasure Lake	04/17/94	6.44	5.9	41.4	1.2	36.3	1.8	2.1	7.4	10.7	3.2	34.5	4.3
Treasure Lake	04/18/94	6.31	5.1	37.9	1.5	36.8	1.9	5.8	7.4	11.0	3.2	34.5	4.4
Treasure Lake	04/19/94	6.34	6.3	38.2	1.0	37.8	1.8	4.5	7.2	10.4	3.3	33.8	4.3
Treasure Lake	04/20/94	6.38	5.4	36.8	1.3	36.7	2.5	5.6	8.2	10.6	3.4	34.6	4.6

Site	Date	pH	Conductivity	ANC	NH4	SiO2	Cl	NO3	SO4	Na	Mg	Ca	K
			µS	µeq/L	µeq/L	mg/L	µeq/L	µeq/L	µeq/L	µeq/L	µeq/L	µeq/L	µeq/L
Treasure Lake	04/21/94	6.33	6.1	32.9	1.6	35.6	3.4	9.8	9.4	10.7	3.7	36.0	5.2
Treasure Lake	04/22/94	6.33	6.0	28.7	2.2	32.3	3.6	11.1	9.3	9.8	3.7	34.0	5.3
Treasure Lake	04/23/94	6.30	5.6	29.6	1.4	33.9	3.3	9.0	9.1	9.7	3.6	32.6	5.1
Treasure Lake	04/24/94	6.29	5.6	24.7	1.5	31.9	3.4	13.3	9.2	9.7	3.6	32.4	5.0
Treasure Lake	04/26/94	6.30	5.6	24.9	1.3	34.9	2.9	12.0	8.6	9.6	3.4	30.7	4.7
Treasure Lake	04/26/94	6.31	5.4	26.8	1.2	35.6	3.2	10.3	7.8	8.5	3.3	31.7	4.6
Treasure Lake	04/27/94	6.30	5.3	27.9	1.0	36.9	3.2	10.4	7.4	9.4	3.3	31.7	4.6
Treasure Lake	04/28/94	6.25	5.2	27.8	0.9	39.7	3.2	9.9	7.4	9.5	3.5	30.7	4.5
Treasure Lake	04/29/94	6.30	5.7	26.6	1.0	38.3	3.1	12.7	7.4	9.3	3.3	32.8	4.4
Treasure Lake	04/30/94	6.30	5.8	27.6	1.0	39.3	3.1	11.8	7.3	9.3	3.4	32.6	4.4
Treasure Lake	05/01/94	6.26	5.7	30.0	0.9	39.3	3.0	9.2	7.4	9.5	3.5	32.0	4.6
Treasure Lake	05/03/94	6.18	5.4	27.3	0.6	40.0	3.1	11.6	7.5	9.9	3.5	31.7	4.3
Treasure Lake	05/04/94	6.27	5.4	27.1	0.8	38.2	3.1	11.9	7.2	9.5	3.3	32.4	4.1
Treasure Lake	05/05/94	6.30	5.4	31.2	0.7	37.5	3.0	8.5	7.1	9.4	3.5	32.7	4.2
Treasure Lake	05/06/94	6.22	5.6	29.1	0.6	38.5	3.3	11.4	6.9	9.9	3.5	32.9	4.4
Treasure Lake	05/07/94	6.33	5.9	31.5	1.2	39.5	2.5	8.2	7.2	10.3	3.6	30.6	4.9
Treasure Lake	05/08/94	6.35	5.9	29.9	0.9	40.2	2.3	10.1	7.5	10.4	3.7	30.9	4.9
Treasure Lake	05/09/94	6.37	5.8	31.0	0.8	39.4	2.6	8.6	7.5	10.0	3.7	31.2	4.8
Treasure Lake	05/10/94	6.38	6.0	34.8	0.8	39.7	2.5	5.7	7.5	10.2	3.8	31.7	4.9
Treasure Lake	05/11/94	6.43	6.4	31.0	0.9	39.1	2.8	9.8	8.1	9.9	3.6	33.4	4.8
Treasure Lake	05/12/94	6.34	6.6	31.1	1.4	37.4	2.5	9.4	8.7	9.4	3.7	34.0	4.7
Treasure Lake	05/13/94	6.30	6.3	26.4	1.6	31.6	2.4	9.2	8.7	8.3	3.4	30.9	4.1
Treasure Lake	05/14/94	6.24	5.4	29.3	1.2	34.3	2.3	9.4	6.9	9.1	3.4	31.2	4.3
Treasure Lake	05/15/94	6.20	5.1	25.0	1.3	30.5	2.0	9.2	6.9	8.3	3.2	27.6	4.1
Treasure Lake	05/16/94	6.25	5.3	24.1	1.2	33.7	2.2	12.5	7.1	8.8	3.4	29.6	4.2
Treasure Lake	05/17/94	6.22	5.3	24.7	1.1	34.9	2.3	11.3	7.3	8.8	3.2	29.4	4.2
Treasure Lake	05/18/94	6.20	5.3	21.9	1.2	35.7	1.9	15.2	6.8	9.1	3.4	29.2	4.1
Treasure Lake	05/19/94	6.25	5.3	22.5	1.3	35.9	1.9	14.1	6.7	8.8	3.3	29.1	4.0
Treasure Lake	05/19/94	6.28	5.3	22.9	1.2	37.3	1.9	13.5	6.6	8.7	3.4	28.9	3.9
Treasure Lake	05/20/94	6.29	5.4	24.1	0.9	37.2	1.7	14.9	7.7	8.9	3.2	32.3	4.1
Treasure Lake	05/21/94	6.31	5.4	23.0	0.8	39.0	2.7	14.4	8.2	9.0	3.2	32.1	4.1
Treasure Lake	05/22/94	6.36	5.5	25.3	0.7	39.0	1.7	14.8	7.6	9.2	3.2	32.9	4.1
Treasure Lake	05/23/94	6.38	5.7	25.5	0.7	40.3	1.5	14.5	7.7	9.4	3.2	32.5	4.1
Treasure Lake	05/24/94	6.35	5.8	26.6	0.9	37.9	1.5	14.8	7.6	9.4	3.2	33.8	4.2
Treasure Lake	05/25/94	6.32	5.7	28.0	1.3	33.5	1.7	11.6	7.3	8.7	3.2	32.6	4.1
Treasure Lake	05/26/94	6.39	5.6	24.7	1.0	32.8	2.7	12.4	7.0	8.4	2.9	31.6	3.9
Treasure Lake	05/27/94	6.19	5.5	20.4	0.9	31.9	2.8	13.4	7.1	8.2	2.9	28.9	3.7
Treasure Lake	05/28/94	6.14	5.4	22.5	0.9	32.3	2.9	10.2	7.3	8.3	2.9	28.1	3.6
Treasure Lake	05/29/94	6.15	5.3	17.1	0.6	31.2	2.4	16.3	7.6	8.1	2.9	28.8	3.6
Treasure Lake	05/30/94	6.13	5.0	19.3	1.1	29.4	2.5	12.8	6.6	7.6	2.7	27.6	3.4
Treasure Lake	05/31/94	6.23	5.1	19.5	0.6	29.6	2.5	13.9	6.2	7.5	2.8	28.4	3.4
Treasure Lake	06/01/94	6.07	5.3	16.8	0.0	30.2	2.6	17.7	6.6	7.8	2.9	29.4	3.6
Treasure Lake	06/02/94	6.21	5.2	22.0	0.0	31.1	2.9	10.3	6.7	7.7	2.8	28.0	3.5
Treasure Lake	06/03/94	6.38	5.9	21.7	0.0	28.6	2.6	14.1	7.5	6.9	2.3	33.8	3.0
Treasure Lake	06/04/94	6.24	4.9	14.5	0.0	27.4	1.9	14.3	7.1	6.6	2.5	25.7	3.1
Treasure Lake	06/05/94	6.32	4.8	11.8	0.0	27.9	2.0	18.0	6.4	6.9	2.5	25.7	3.2
Treasure Lake	06/06/94	6.30	4.9	13.0	0.0	28.6	4.3	16.2	5.8	8.9	2.5	24.8	3.1
Treasure Lake	06/07/94	6.29	4.9	14.8	0.0	29.2	2.0	16.5	6.2	6.7	2.6	27.0	3.3
Treasure Lake	06/08/94	6.21	4.8	14.8	0.0	29.9	2.0	17.6	6.0	6.8	2.5	27.9	3.2
Treasure Lake	06/09/94	6.23	4.5	14.3	0.0	27.9	2.3	15.8	5.9	7.1	2.5	25.6	3.2

Site	Date	pH	Conductivity µS	ANC µeq/L	NH4 µeq/L	SiO2 mg/L	Cl µeq/L	NO3 µeq/L	SO4 µeq/L	Na µeq/L	Mg µeq/L	Ca µeq/L	K µeq/L
Treasure Lake	06/10/94	6.23	4.4	32.1	0.0	26.0	2.6	13.0	5.4	7.2	2.4	24.7	3.4
Treasure Lake	06/11/94	6.28	4.4	16.5	0.0	26.1	2.1	12.6	5.7	6.3	2.5	25.3	2.9
Treasure Lake	06/12/94	6.35	4.3	15.4	0.0	25.6	2.1	14.2	5.6	6.6	2.4	25.4	2.9
Treasure Lake	06/13/94	6.40	4.3	20.6	0.0	24.9	2.2	7.9	5.3	6.4	2.3	24.6	2.8
Treasure Lake	06/14/94	6.31	4.2	20.3	0.0	25.4	2.1	8.5	5.0	6.6	2.2	24.2	3.0
Treasure Lake	06/15/94	6.38	4.2	17.0	0.0	24.9	1.1	11.8	5.0	6.2	2.3	23.6	2.9
Treasure Lake	06/16/94	6.37	4.2	17.0	0.0	25.2	1.4	11.3	5.1	6.2	2.3	23.5	2.9
Treasure Lake	06/17/94	6.45	4.3	16.6	0.0	25.8	1.5	12.5	5.1	6.3	2.3	24.1	3.0
Treasure Lake	06/18/94	6.45	4.3	16.8	0.0	26.6	1.6	11.2	5.1	5.8	2.3	23.9	2.7
Treasure Lake	06/19/94	6.48	4.3	17.4	0.0	26.6	1.7	12.0	4.9	6.7	2.3	24.3	2.9
Treasure Lake	06/20/94	6.48	4.2	17.0	0.0	26.6	1.5	11.3	5.0	5.9	2.3	24.0	2.7
Treasure Lake	06/21/94	6.46	4.2	17.2	0.0	25.8	1.5	12.0	5.0	6.4	2.3	24.1	2.9
Treasure Lake	06/22/94	6.50	4.1	16.6	0.0	26.4	1.4	11.8	5.1	6.3	2.2	23.6	2.9
Treasure Lake	06/23/94	6.48	4.0	17.8	0.0	26.5	1.4	10.2	5.0	5.9	2.2	23.5	2.7
Treasure Lake	06/24/94	6.44	4.1	18.7	0.0	26.7	1.3	10.0	4.8	6.5	2.1	23.2	3.0
Treasure Lake	06/25/94	6.37	3.9	18.6	0.0	26.7	1.4	7.2	5.2	5.9	2.1	21.9	2.6
Treasure Lake	06/26/94	6.45	4.0	16.3	0.0	27.0	2.2	9.7	4.9	6.6	2.1	21.9	2.6
Treasure Lake	06/27/94	6.42	3.7	16.5	0.0	26.7	1.6	9.1	4.6	5.9	2.1	21.4	2.5
Treasure Lake	06/28/94	6.45	3.7	16.8	0.0	26.0	1.5	8.5	4.8	5.7	2.0	21.5	2.5
Treasure Lake	06/29/94	6.48	4.2	14.0	0.0	25.9	2.8	9.1	5.0	6.3	2.0	20.1	2.6
Treasure Lake	06/30/94	6.40	4.1	15.4	0.0	25.5	2.0	9.6	4.5	6.2	2.0	20.9	2.5
Treasure Lake	07/01/94	6.46	3.9	16.4	0.0	25.4	1.8	8.2	4.3	5.8	1.9	20.6	2.6
Treasure Lake	07/02/94	6.53	4.0	10.6	0.0	26.2	1.3	15.1	4.2	5.9	2.0	20.5	2.7
Treasure Lake	07/03/94	6.48	3.8	10.0	0.0	26.5	1.3	16.3	4.4	6.1	2.1	21.0	2.8
Treasure Lake	07/04/94	6.49	3.9	16.3	0.0	26.7	1.3	10.3	4.3	6.3	2.1	21.1	2.8
Treasure Lake	07/05/94	6.56	3.9	18.3	0.0	27.1	1.4	9.6	4.2	6.6	2.1	21.9	2.9
Treasure Lake	07/06/94	6.65	3.9	15.4	0.0	27.2	1.4	11.9	4.2	6.7	2.2	21.1	3.1
Treasure Lake	07/07/94	6.64	3.9	16.1	0.0	25.9	1.2	11.3	4.1	6.5	1.9	21.4	2.9
Treasure Lake	07/08/94	6.64	4.0	17.5	0.0	27.4	1.2	10.1	4.2	6.6	2.0	21.6	2.9
Treasure Lake	07/09/94	6.57	4.0	18.6	0.0	27.6	1.5	9.9	4.1	6.6	2.1	22.6	2.9
Treasure Lake	07/13/94	6.53	4.4	19.6	0.0	28.0	2.1	10.3	4.2	7.0	2.2	24.2	2.9
Treasure Lake	07/17/94	6.49	4.3	21.0	0.0	28.8	1.3	10.2	3.9	6.8	2.2	24.1	3.3
Treasure Lake	07/21/94	6.62	4.2	27.6	0.0	29.1	1.2	5.5	4.0	7.0	2.2	25.9	3.2
Treasure Lake	07/22/94	6.60	4.2	22.1	0.0	29.1	1.6	9.6	3.9	6.6	2.3	25.5	2.9
Treasure Lake	07/25/94	6.59	4.1	25.2	0.0	29.4	2.1	4.3	4.0	6.7	2.3	23.7	3.0
Treasure Lake	07/29/94	6.65	3.9	29.4	0.0	29.6	1.2	0.0	3.7	7.0	2.0	21.4	3.3
Treasure Lake	08/02/94	6.64	3.9	28.5	0.0	28.7	1.0	0.1	3.7	6.6	1.9	21.9	3.0
Treasure Lake	08/06/94	6.68	4.5	23.9	0.0	28.1	1.4	5.0	4.0	6.7	2.1	22.6	3.0
Treasure Lake	08/10/94	6.69	4.1	25.8	0.0	28.3	1.2	2.6	4.0	6.7	2.2	21.9	2.9
Treasure Lake	08/14/94	6.42	5.4	25.3	0.0		1.0	1.3	4.1	6.7	1.9	20.1	3.0
Treasure Lake	08/18/94	6.44	5.3	24.4	0.0		2.5	3.5	4.2	8.3	2.0	21.2	3.1
Treasure Lake	08/22/94	6.44	5.1	26.0	0.0		1.1	2.7	3.7	7.1	2.0	21.3	3.2
Treasure Lake	09/03/94	6.45	4.8	28.3	0.0		1.0	4.3	4.2	7.3	2.3	24.9	3.3
M1	03/08/94	6.51	7.1	42.0	1.4	31.5	2.2	9.2	6.3	15.6	4.1	36.0	3.9
M1	03/09/94	6.55	6.6	42.7	0.6	32.2	2.1	9.3	5.9	15.7	4.3	36.7	4.0
M1	03/10/94	6.31	7.4	43.0	1.1	31.5	1.9	8.2	5.9	15.5	4.3	36.7	4.0
M1	03/12/94	6.53	8.4	44.0	0.0	35.0	2.3	7.6	5.5	15.8	4.2	35.7	3.8
M1	03/13/94	6.49	8.5	41.7	0.0	35.9	2.3	4.6	5.8	15.0	4.1	34.4	3.7
M1	03/14/94	6.44	7.6	39.7	0.0	36.3	2.5	7.5	5.8	14.1	4.2	34.4	3.8
M1	03/15/94	6.29	7.0	34.9	1.2	24.0	2.6	12.8	5.6	14.1	4.3	33.7	4.2

Site	Date	pH	Conductivity µS	ANC µeq/L	NH4 µeq/L	SiO2 mg/L	Cl µeq/L	NO3 µeq/L	SO4 µeq/L	Na µeq/L	Mg µeq/L	Ca µeq/L	K µeq/L
M1	03/16/94	6.24	8.9	35.1	0.5	35.9	2.6	12.2	5.7	13.5	4.2	34.5	4.0
M1	03/17/94	6.28	10.3	33.7	0.0	36.4	2.8	12.4	5.4	13.5	4.3	33.9	3.9
M1	03/18/94	6.15	6.7	34.2	0.0	24.1	3.0	11.8	5.9	13.9	4.3	34.0	4.0
M1	03/19/94	6.16	7.0	35.8	0.2	26.4	3.1	10.0	6.0	13.6	4.3	34.0	3.9
M1	03/20/94	6.15	7.0	36.7	0.5	26.1	2.5	11.9	5.3	13.9	4.4	34.5	4.5
M1	03/21/94	6.10	6.9	35.6	0.7	38.8	2.5	12.5	5.0	13.6	4.2	33.5	3.7
M1	03/22/94	6.10	6.8	35.1	0.0	29.2	2.8	11.3	5.9	14.0	4.2	33.9	3.8
M1	03/23/94	6.12	6.8	34.9	0.0	38.6	2.5	9.3	5.4	13.6	4.1	32.2	3.7
M1	03/24/94	6.15	6.9	35.7	0.0	38.6	2.5	10.7	5.9	14.3	4.2	33.4	4.2
M1	03/30/94	6.09	7.0	38.6	0.0	38.6	2.5	8.7	6.0	14.1	4.2	34.8	4.2
M1	03/31/94	6.24	6.7	34.3	0.5	35.9	2.6	9.3	5.7	14.2	3.8	30.8	3.7
M1	04/01/94	6.13	6.8	35.8	0.5	36.4	2.5	9.0	6.1	14.7	3.7	30.8	4.0
M1	04/02/94	6.13	6.8	35.4	0.2	33.2	2.7	9.1	5.1	14.3	3.8	31.1	4.2
M1	04/03/94	6.11	6.6	32.5	0.0	35.6	3.4	9.5	6.0	14.5	3.9	31.1	4.3
M1	04/04/94	6.15	6.7	31.2	0.0	36.2	3.0	11.1	5.7	14.1	3.8	29.7	4.1
M1	04/05/94	6.04	6.7	35.2	0.2	38.4	2.8	7.7	6.0	14.9	4.0	30.3	4.3
M1	04/06/94	6.19	6.6	34.1	0.0	38.2	2.8	5.0	6.1	13.7	3.8	28.9	3.7
M1	04/07/94	6.35	6.5	31.8	0.0	38.6	2.5	9.8	5.4	13.6	3.7	29.5	3.5
M1	04/09/94	6.23	6.5	33.7	0.3	38.0	3.5	7.7	5.9	14.0	3.8	30.2	3.5
M1	04/12/94	6.20	6.6	34.8	0.0	39.0	2.7	8.2	6.0	14.3	3.8	30.1	3.5
M1	04/13/94	6.14	6.4	33.0	0.0	37.4	2.4	9.4	5.9	13.3	3.9	31.3	3.3
M1	04/14/94	6.12	6.5	32.4	0.0	39.4	2.4	12.9	6.0	13.9	4.1	33.0	3.8
M1	04/15/94	6.12	6.6	32.8	0.0	33.9	2.7	10.9	6.3	13.4	4.0	32.2	4.1
M1	04/16/94	6.19	7.1	30.4	0.9	30.9	3.3	5.2	5.8	9.2	3.7	28.1	4.9
M1	04/17/94	6.24	6.6	29.6	1.0	32.1	3.3	11.4	6.1	12.6	3.8	29.5	4.2
M1	04/18/94	6.12	6.6	27.5	1.9	32.3	3.5	12.5	6.3	12.6	3.8	29.6	4.1
M1	04/19/94	6.14	6.7	29.4	0.0	31.2	3.5	11.7	6.2	12.4	4.0	31.3	4.2
M1	04/20/94	6.09	6.8	28.2	0.6	28.4	4.6	12.5	6.1	12.7	3.9	31.0	4.6
M1	04/21/94	6.01	6.9	27.6	0.0	26.6	4.1	13.1	6.0	12.7	4.1	30.3	5.3
M1	04/22/94	6.04	6.5	25.7	0.0	26.4	4.4	14.8	6.1	11.6	4.0	31.7	5.1
M1	04/23/94	6.20	6.1	21.7	0.0	25.8	4.1	17.5	5.6	11.3	3.9	29.0	4.8
M1	04/24/94	6.15	6.2	25.0	0.0	27.0	4.9	13.3	5.5	10.1	3.9	30.6	4.2
M1	04/25/94	6.06	6.4	25.3	0.6	27.5	5.8	12.0	4.3	11.8	3.7	27.2	4.6
M1	04/26/94	6.02	6.0	25.6	0.0	30.1	4.3	14.0	5.3	12.9	3.7	30.3	4.2
M1	04/28/94	6.09	6.2	27.6	0.0	31.0	4.2	11.8	4.8	10.2	3.8	31.5	3.7
M1	04/29/94	6.43	5.8	27.9	0.0	32.0	3.4	9.5	5.1	10.3	3.8	29.3	3.6
M1	04/30/94	6.16	6.1	30.4	0.0	31.7	3.3	3.2	5.4	10.3	3.6	26.9	3.4
M1	05/01/94	6.19	6.0	30.8	0.8	32.8	3.3	4.4	5.5	10.6	3.7	26.5	3.4
M1	05/02/94	6.15	6.1	27.8	0.0	32.8	3.3	10.9	6.0	10.7	3.8	30.7	3.4
M1	05/03/94	6.20	6.0	26.9	0.1	30.3	3.3	10.1	6.4	10.3	3.8	29.3	3.4
M1	05/04/94	6.07	6.1	25.2	0.0	27.6	3.0	7.9	6.2	9.4	3.6	27.6	3.1
M1	05/05/94	6.03	5.8	23.3	0.0	27.4	2.8	10.7	6.1	9.8	3.6	27.8	3.6
M1	05/06/94	6.41	6.7	19.9	0.0	26.7	2.1	10.7	5.8	9.2	3.2	24.5	2.8
M1	05/07/94	6.43	6.3	19.5	0.0	28.0	2.3	12.8	6.0	9.7	3.4	25.4	3.1
M1	05/08/94	6.47	6.4	22.4	0.0	31.0	2.3	9.9	5.9	9.6	3.2	25.8	2.8
M1	05/09/94	6.43	5.4	21.6	0.0	30.0	2.4	10.5	5.9	9.9	3.2	25.8	2.7
M1	05/10/94	6.39	5.2	21.6	0.0	28.9		20.3		11.2	3.3	24.9	3.7
M1	05/11/94	6.34	5.0	18.0	0.0	28.0	2.2	13.2	5.6	9.1	3.3	25.4	2.7
M1	05/12/94	6.26	5.1	17.8	0.5	25.1	2.0	14.0	5.5	8.6	3.2	24.3	2.9
M1	05/13/94	6.16	4.7	17.1	0.0	20.7	2.4	12.3	5.5	7.9	3.2	23.3	3.3

Site	Date	pH	Conductivity µS	ANC µeq/L	NH4 µeq/L	SiO2 mg/L	Cl µeq/L	NO3 µeq/L	SO4 µeq/L	Na µeq/L	Mg µeq/L	Ca µeq/L	K µeq/L
M1	05/14/94	6.14	4.4	15.3	1.6	19.1	2.3	11.8	5.2	6.7	3.0	21.3	2.8
M1	05/15/94	6.19	4.0	14.7	0.0	15.8	1.9	8.7	4.2	6.1	2.7	19.6	2.5
M1	05/16/94	6.15	4.0	13.7	0.0	17.4	1.8	11.1	4.1	6.4	2.8	19.5	2.4
M1	05/17/94	6.17	4.0	14.7	0.0	19.6	2.0	11.5	4.2	6.5	2.8	20.8	2.3
M1	05/18/94	6.27	4.0	16.7	0.0	21.0	1.5	9.0	4.1	6.6	2.8	20.8	2.3
M1	05/19/94	6.23	4.3	17.0	0.0	16.3	1.6	9.5	4.4	7.1	2.9	21.0	2.4
M1	05/20/94	6.22	4.4	17.9	0.0	18.1	1.5	7.8	5.1	7.3	2.8	21.5	2.2
M1	05/21/94	6.21	4.2	18.3	0.0	19.8	1.6	9.8	4.3	7.4	2.8	22.0	2.2
M1	05/22/94	6.25	4.7	14.0	0.0	22.5	1.5	10.1	4.4	7.3	2.5	19.0	2.1
M1	05/23/94	6.20	4.4	17.6	0.2	22.2	1.7	6.1	4.6	7.1	2.6	19.3	2.2
M1	05/24/94	6.17	4.3	15.0	0.0	18.6	1.7	7.0	4.3	6.6	2.4	18.0	2.2
M1	05/25/94	6.21	4.5	14.1	0.2	18.0	1.8	7.3	4.2	6.3	2.4	17.3	2.1
M1	05/25/94	6.19	4.8	13.7	0.9	18.3	1.8	9.5	4.3	6.4	2.6	18.0	2.0
M1	05/26/94	6.21	5.4	14.3	0.4	17.8	1.7	7.7	3.7	5.9	2.4	17.6	1.8
M1	05/27/94	6.16	4.5	14.8	0.6	17.2	2.2	7.9	4.0	6.2	2.5	17.7	2.0
M1	05/28/94	6.13	3.6	19.0	0.0	15.3	1.9	0.0	3.8	5.8	1.8	14.7	2.0
M1	05/29/94	6.23	3.6	14.2	0.0	14.6	1.7	4.3	3.5	5.8	1.7	14.4	2.0
M1	05/30/94	6.18	3.4	17.4	0.0	14.4	1.4	0.0	3.4	5.2	1.7	14.2	1.9
M1	05/31/94	6.11	3.1	13.4	0.0	15.1	1.6	4.8	3.6	5.8	1.7	14.3	2.0
M1	05/31/94	6.14	3.3	14.3	0.0	15.3	1.6	4.1	3.6	5.8	1.6	14.3	2.0
M1	06/01/94	6.14	3.3	13.9	0.0	14.7	1.2	4.2	3.8	5.3	2.1	14.6	1.9
M1	06/02/94	6.11	3.3	17.3	0.0	14.8	1.2	2.2	3.7	5.4	2.2	15.2	1.9
M1	06/03/94	6.24	3.2	13.9	0.0	13.6	1.1	5.3	3.2	4.9	2.1	15.1	1.9
M1	06/04/94	6.17	3.2	14.9	0.0	13.9	1.3	4.7	3.2	5.2	2.1	15.1	1.9
M1	06/05/94	6.21	3.1	16.6	0.0	13.8	1.0	2.4	3.5	5.1	2.0	15.3	1.8
M1	06/06/94	6.25	3.2	18.2	0.0	14.5	0.9	1.2	2.9	5.2	2.0	15.3	1.7
M1	06/07/94	6.21	3.3	18.6	0.0	15.6	1.7	3.0	3.6	6.6	2.2	16.0	2.1
M1	06/08/94	6.19	3.3	21.5	0.0	15.4	1.0	0.2	4.0	6.0	2.1	17.0	2.0
M1	06/09/94	6.06	4.5	24.2	0.0	16.1	1.1	0.0	4.2	6.2	2.3	17.1	2.3
M1	06/10/94	6.16	3.5	20.0	0.0	15.1	0.8	0.8	3.0	5.4	2.0	15.6	1.8
M1	06/11/94	6.11	6.0	16.4	0.0	14.0	1.3	0.5	3.2	5.1	1.7	12.9	1.7
M1	06/12/94	6.19	5.5	15.3	0.0	12.8	1.3	1.0	4.5	5.2	1.9	13.4	1.9
M1	06/13/94	6.22	7.0	13.2	0.0	12.9	1.1	5.2	3.0	4.9	2.3	13.9	1.8
M1	06/14/94	6.24	3.2	14.7	0.0	13.9	0.6	3.5	2.7	4.7	2.0	13.7	1.6
M1	06/15/94	6.29	2.8	14.7	0.0	12.9	0.5	2.9	2.7	4.7	1.9	13.1	1.7
M1	06/16/94	6.25	3.0	16.3	0.0	13.0	0.8	2.0	4.0	5.1	2.0	14.5	1.7
M1	06/17/94	6.11	4.2	15.0	0.0	13.7	1.2	1.7	3.2	5.1	1.7	13.4	1.6
M1	06/23/94	6.42	3.5	20.1	0.3	16.8	1.0	0.0	3.6	5.6	1.8	14.9	1.9
M1	06/25/94	6.38	3.5	22.6	0.5	16.6	0.8	0.0	3.0	6.3	1.8	15.7	2.1
M1	06/27/94	6.39	3.9	25.2	0.1	16.6	1.0	0.0	3.2	6.4	1.9	16.3	1.8
M1	06/29/94	6.31	3.9	25.5	0.0	18.2	0.9	0.0	3.2	6.8	1.9	17.3	1.7
M2	03/30/94	6.05	7.1	40.1	0.0	45.8	2.4	5.5	5.2	13.0	4.5	34.4	3.7
M2	03/31/94	6.44	6.7	31.9	0.0	39.0	3.8	14.2	5.1	11.8	5.0	33.9	4.3
M2	04/01/94	6.08	7.3	33.0	0.0	40.2	3.3	16.0	5.4	12.0	5.2	36.2	4.8
M2	04/02/94	6.03	7.2	30.0	0.5	26.4	3.6	17.9	5.6	11.9	5.2	35.9	4.7
M2	04/03/94	6.08	6.7	28.9	0.0	40.3	2.8	18.6	5.1	11.5	4.9	35.7	4.0
M2	04/04/94	6.10	6.8	33.0	0.0	42.3	3.0	13.4	5.4	11.9	4.8	36.2	3.8
M2	04/05/94	6.06	6.7	31.6	0.0	23.9	2.6	13.5	4.8	11.3	4.6	34.5	3.7
M2	04/06/94	6.22	7.0	34.3	0.2	43.6	2.8	13.1	5.1	12.2	4.7	35.9	3.7
M2	04/07/94	6.13	7.0	34.9	0.0	43.9	3.4	13.6	5.1	13.2	4.7	36.1	4.0

Site	Date	pH	Conductivity	ANC	NH4	SiO2	Cl	NO3	SO4	Na	Mg	Ca	K
			µS	µeq/L	µeq/L	mg/L	µeq/L	µeq/L	µeq/L	µeq/L	µeq/L	µeq/L	µeq/L
M2	04/08/94	6.13	6.7	34.7	0.0	41.5	3.0	13.5	4.9	12.4	4.6	35.9	3.6
M2	04/28/94	6.01	6.4	25.6	0.0	29.3	3.2	10.9	5.3	8.9	4.1	29.4	4.0
M2	05/02/94	6.08	6.3	24.3	0.5	31.9	3.0	11.8	6.2	9.0	4.1	29.7	3.3
M2	05/03/94	6.03	6.3	24.1	0.0	30.0	3.4	11.0	5.3	9.3	4.0	28.9	3.7
M2	05/04/94	6.15	6.2	19.4	0.0	27.1	3.3	12.8	5.7	8.5	3.8	27.3	3.5
M2	05/05/94	6.03	5.9	17.8	0.0	27.6	3.4	11.6	5.7	8.5	3.5	23.8	3.8
M2	05/14/94	6.12	4.6	16.6	0.0	19.6	1.3	9.3	4.3	6.3	3.0	21.7	2.0
M2	05/16/94	6.09	4.1	9.9	0.0	22.9	1.4	10.8	4.5	4.6	2.7	18.3	2.1
M2	05/27/94	6.11	3.9	10.3	0.2	16.0	2.2	9.9	4.0	5.3	2.5	17.3	1.8
M2	06/02/94	6.01	3.3	8.0	0.0	11.1	1.2	5.7	3.6	3.3	1.8	12.9	1.3
M2	06/11/94	6.10	2.4	0.0	0.0	10.2	0.9	11.8	2.8	2.7	1.4	10.5	1.0
M2	06/12/94	6.11	2.9	9.0	0.0	9.9	1.4	2.6	2.4	3.4	1.3	9.8	1.6
M2	06/13/94	6.04	2.5	6.9	0.0	9.5	0.6	5.3	2.4	2.9	1.3	10.2	1.5
M2	06/14/94	6.05	3.0	10.3	0.0	10.3	1.7	0.9	3.4	3.7	1.4	10.4	1.6
M2	06/15/94	6.02	2.4	7.6	0.0	10.1	1.0	4.2	2.8	2.8	1.2	10.3	1.5
M2	06/16/94	6.13	2.5	10.4	0.1	10.6	1.3	1.1	4.0	3.3	1.3	10.9	1.5
M2	06/17/94	6.23	2.5	11.9	0.0	10.7	0.6	1.7	2.8	3.3	1.4	11.2	1.5
M2	06/19/94	6.23	5.5	15.7	0.0	11.6	1.5	0.0	3.3	3.7	1.8	12.1	1.7
M2	06/21/94	6.11	6.2	16.5	0.0	11.4	2.2	0.0	3.0	4.2	1.4	10.2	1.6
M2	06/23/94	6.29	6.1	17.0	0.8	12.5	1.5	0.0	3.2	4.1	1.4	11.3	2.0
M2	06/30/94	6.31	3.3	23.2	0.4	13.4	1.0	0.0	3.1	4.0	1.7	13.8	1.7
M2	07/04/94	6.44	3.7	24.4	0.9	17.5	1.3	0.5	2.6	6.5	2.5	17.1	2.5
M2	07/06/94	6.38	2.9	28.2	1.2	19.3	1.6	0.0	3.1	6.5	2.3	14.8	2.6
M2	07/08/94	6.40	3.9	19.4	1.2	19.3	1.8	5.4	3.4	7.1	2.4	17.6	2.8
M3	03/30/94	6.14	6.4	31.2	0.0	31.2	2.2	9.9	4.9	10.3	3.8	31.5	3.5
M3	04/02/94	6.11	6.6	25.6	0.0	32.5	2.9	17.2	4.8	10.4	4.5	33.7	4.5
M3	04/03/94	6.03	6.6	23.0	0.0	25.3	3.0	19.3	4.8	10.9	4.5	33.0	4.1
M3	04/04/94	6.22	6.1	21.2	0.0	25.6	2.7	20.8	4.8	10.1	4.3	32.9	4.7
M3	04/05/94	6.14	6.1	23.3	0.0	31.1	2.6	14.7	4.5	9.9	3.6	28.3	4.1
M3	04/06/94	6.25	6.0	28.8	0.0	30.8	2.5	8.8	4.3	10.0	3.6	28.1	3.8
M3	04/07/94	6.15	5.9	23.1	0.0	31.9	2.5	13.1	4.6	9.5	3.6	28.6	3.3
M3	04/08/94	6.25	5.8	26.3	0.0	30.9	2.3	10.7	4.3	10.0	3.6	28.6	3.4
M3	04/15/94	6.15	6.3	22.8	0.0	31.0	3.1	15.3	5.1	10.1	4.1	29.1	3.4
M3	04/16/94	6.06	7.1	24.6	0.0	28.5	3.5	17.2	5.3	9.1	4.4	30.2	7.3
M3	04/17/94	6.01	6.5	21.8	0.0	26.6	3.1	15.3	5.0	8.5	4.0	28.1	5.3
M3	04/18/94	6.25	6.6	21.7	1.7	26.6	3.4	17.4	5.6	8.8	4.1	28.8	4.9
M3	04/28/94	6.01	6.4	22.5	0.0	23.9	3.4	13.0	5.9	8.0	4.2	29.4	4.3
M3	04/29/94	6.15	6.2	17.5	0.0	28.6	3.1	15.4	5.8	8.1	3.7	27.7	4.1
M3	05/01/94	6.20	6.2	16.1	0.0	27.8	3.1	18.7	5.5	8.8	3.7	28.5	4.1
M3	05/02/94	6.13	6.2	19.6	0.0	27.9	2.9	14.6	6.1	8.6	3.7	27.8	3.8
M3	05/03/94	6.23	5.9	19.5	0.0	28.2	3.0	12.3	6.7	8.0	3.6	27.5	3.6
M3	05/05/94	6.11	6.0	17.2	0.0	26.9	2.8	13.5	6.3	7.5	3.5	25.6	3.8
M3	05/06/94	6.17	6.0	14.0	0.0	23.2	2.6	20.3	6.2	7.8	4.0	29.2	3.6
M3	05/07/94	6.13	6.1	12.6	0.2	23.1	2.5	21.6	6.2	7.7	4.0	29.5	3.6
M3	05/08/94	6.15	6.0	13.1	0.5	23.8	2.6	20.1	6.4	7.7	3.5	27.5	3.5
M3	05/09/94	6.09	5.9	14.2	0.3	25.4	2.5	16.5	6.1	8.0	3.5	24.8	3.4
M3	05/10/94	6.12	5.6	15.1	2.5	25.3	2.0	19.4	5.5	7.8	3.3	25.7	3.1
M3	05/11/94	6.06	5.5	13.4	0.8	23.3	2.5	18.5	5.6	7.3	3.3	25.9	3.3
M3	05/12/94	6.02	5.2	11.7	0.0	19.7	1.9	15.9	5.4	6.8	3.0	23.1	3.1
M3	05/13/94	5.97	4.9	9.7	0.1	17.6	1.9	15.4	5.4	5.9	2.8	20.4	3.3

Site	Date	pH	Conductivity	ANC	NH4	SiO2	Cl	NO3	SO4	Na	Mg	Ca	K
			µS	µeq/L	µeq/L	mg/L	µeq/L	µeq/L	µeq/L	µeq/L	µeq/L	µeq/L	µeq/L
M3	05/14/94	5.95	4.5	7.7	0.1	15.5	1.7	14.8	5.3	5.3	2.6	18.8	2.9
M3	05/15/94	5.88	4.6	6.6	0.0	13.3	1.7	13.2	4.9	4.9	2.4	16.9	2.6
M3	05/16/94	6.00	4.0	8.6	4.1	13.4	1.6	14.5	4.7	4.5	2.3	16.6	2.2
M3	05/20/94	6.06	4.2	11.0	0.1	17.7	1.6	9.7	4.7	5.2	2.4	18.4	2.1
M3	05/21/94	6.09	4.9	10.1	0.1	19.2	1.7	11.8	4.6	5.1	2.4	19.1	2.1
M3	05/22/94	6.26	4.3	14.3	0.9	21.7	1.7	11.3	4.6	6.4	2.8	20.9	2.3
M3	05/23/94	6.06	4.2	10.5	1.3	19.1	1.9	13.8	4.4	5.6	2.6	19.8	2.3
M3	05/24/94	6.01	4.1	10.3	0.0	17.1	1.7	9.3	4.7	5.2	2.5	17.4	2.1
M3	05/25/94	6.04	4.0	10.5	0.0	15.9	1.6	7.0	4.6	4.8	2.2	15.1	2.0
M3	05/26/94	6.03	4.1	10.0	0.0	15.7	3.2	1.2	4.7	5.5	2.1	9.9	1.9
M3	05/27/94	6.02	3.8	10.3	0.3	14.3	1.6	9.3	4.5	4.8	2.1	17.2	2.0
M3	05/29/94	6.03	3.5	12.2	0.0	11.9	1.6	4.9	6.7	5.8	2.3	15.5	2.8
M3	05/29/94	5.98	3.4	11.0	0.2	11.5	2.7	5.6	6.3	6.0	2.2	15.3	2.3
M3	05/29/94	5.91	3.5	9.5	0.0	11.6	1.5	7.9	4.9	4.4	2.1	15.4	1.9
M3	05/29/94	5.95	3.6	7.4	0.0	12.6	1.6	9.1	4.5	4.5	2.0	15.2	1.9
M3	05/29/94	5.93	3.5	9.1	0.0	12.3	1.5	7.3	4.6	4.2	2.0	15.1	1.8
M3	05/29/94	5.89	3.4	9.2	0.0	11.9	1.6	7.3	4.6	4.3	2.0	15.2	1.8
M3	05/29/94	5.98	3.4	12.9	0.0	12.2	1.8	3.1	4.4	4.4	1.9	14.6	1.8
M3	05/29/94	5.94	3.3	8.5	0.0	12.2	3.6	5.9	4.3	5.4	1.8	14.0	2.2
M3	05/29/94	5.95	3.2	8.8	0.0	11.7	2.1	4.6	3.9	3.7	1.7	13.0	1.7
M3	05/30/94	5.90	3.9	13.4	0.0	11.4	2.0	0.6	3.6	3.8	1.7	13.1	1.7
M3	05/30/94	5.98	3.2	9.1	0.0	11.6	1.5	4.3	4.1	3.6	1.6	12.2	1.7
M3	05/30/94	5.91	3.8	10.8	0.0	11.6	1.5	4.4	4.3	3.6	1.8	14.1	1.7
M3	05/30/94	5.89	3.2	7.0	0.0	11.6	1.7	5.1	4.2	3.7	1.3	12.1	1.7
M3	05/30/94	5.91	3.3	6.7	0.0	12.0	1.7	7.1	4.2	4.0	1.4	12.7	1.8
M3	05/30/94	5.99	3.3	14.4	0.0	12.1	1.6	0.0	4.4	4.1	1.4	13.4	1.8
M3	05/30/94	5.96	3.9	9.9	0.0	12.4	3.8	4.9	4.2	6.3	1.5	13.5	2.3
M3	05/30/94	5.95	3.3	9.9	0.0	12.6	1.8	2.8	4.2	4.0	1.4	12.3	1.7
M3	05/30/94	5.92	3.2	9.9	0.0	12.6	1.5	3.6	3.9	3.8	1.3	12.5	1.6
M3	05/30/94	5.98	3.2	9.9	0.0	12.7	1.5	3.4	4.1	3.8	1.3	12.6	1.6
M3	05/30/94	5.91	3.2	12.3	0.0	11.7	1.2	1.4	3.9	3.7	1.3	12.4	1.6
M3	05/30/94	5.85	3.2	9.9	0.0	12.6	1.3	3.9	4.0	3.9	1.4	12.5	1.7
M3	06/03/94	6.02	3.0	3.2	0.0	10.8	1.6	9.8	3.5	3.6	1.6	12.3	1.4
M3	06/04/94	6.03	2.8	4.8	0.0	10.2	1.3	8.5	3.0	3.4	1.6	11.9	1.3
M3	06/05/94	5.97	2.9	2.0	0.0	10.5	2.1	12.3	3.0	4.3	1.6	12.3	1.4
M3	06/06/94	6.00	2.6	6.5	0.0	10.1	1.0	4.9	2.9	3.0	1.6	9.9	1.2
M3	06/07/94	6.00	3.7	6.6	0.0	10.5	0.9	3.9	3.0	2.8	1.3	9.5	1.1
M3	06/08/94	6.01	2.7	7.6	0.0	10.2	0.9	3.1	3.1	2.7	1.2	9.8	1.1
M3	06/09/94	5.98	2.5	6.8	0.0	9.4	0.8	4.0	2.8	2.8	1.3	9.7	1.1
M3	06/10/94	5.99	3.5	5.0	0.0	9.4	1.7	6.0	2.8	4.0	1.3	9.5	1.4
M3	06/11/94	5.64	3.5	3.9	0.0	9.4	1.5	7.0	2.5	3.5	1.3	9.0	1.4
M3	06/12/94	6.06	2.3	5.4	0.0	8.1	0.5	5.2	2.8	2.2	1.1	9.4	1.3
M3	06/13/94	6.02	2.2	6.6	0.0	8.4	0.5	3.7	2.7	2.1	1.1	9.6	1.3
M3	06/14/94	6.02	2.4	6.0	0.0	12.9	0.8	2.8	4.3	2.3	1.2	9.6	1.4
M3	06/15/94	6.03	2.3	5.9	0.0	8.4	0.7	5.4	2.5	2.3	1.2	10.1	1.4
M3	06/16/94	6.08	2.4	9.5	0.0	13.8	0.7	3.4	3.3	2.7	1.4	11.3	1.5
M3	06/17/94	6.17	2.4	10.7	0.0	17.4	0.9	0.4	6.0	3.3	1.5	11.5	1.7
M3	06/19/94	6.23	2.8	15.3	0.0	11.0	1.0	0.0	3.1	3.5	1.3	10.7	1.6
M3	06/23/94	6.23	3.4	15.5	0.0	10.5	1.0	0.0	3.1	3.4	1.4	11.0	1.7
M3	06/25/94	6.18	3.3	16.4	0.3	10.0	1.2	0.0	3.5	3.2	1.5	12.5	1.7

Site	Date	pH	Conductivity µS	ANC µeq/L	NH4 µeq/L	SiO2 mg/L	Cl µeq/L	NO3 µeq/L	SO4 µeq/L	Na µeq/L	Mg µeq/L	Ca µeq/L	K µeq/L
M3	06/27/94	6.18	3.2	25.4	0.0	10.8	0.9	0.0	3.4	3.3	1.5	12.1	1.7
M3	06/29/94	6.18	3.3	22.9	0.2	11.0	1.0	0.0	3.3	3.5	1.5	12.7	1.8
M3	07/01/94	6.85	3.3	18.0	0.9	20.0	1.0	2.2	3.6	4.4	2.2	15.8	2.2
M3	07/05/94	6.52	4.0	29.1	1.2	16.1	1.0	0.0	3.6	4.9	2.3	17.0	2.4
M3	07/09/94	6.61	5.4	36.8	0.0	13.5	1.0	0.0	5.5	4.8	5.2	25.2	2.8
M3	07/13/94	6.58	4.1	24.7	0.3	13.8	1.3	0.6	4.4	6.4	2.5	19.4	2.8