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Whole-catchment Application of Dolomite to an Acidified Forest Ecosystem in Gjerstad, Southern Norway

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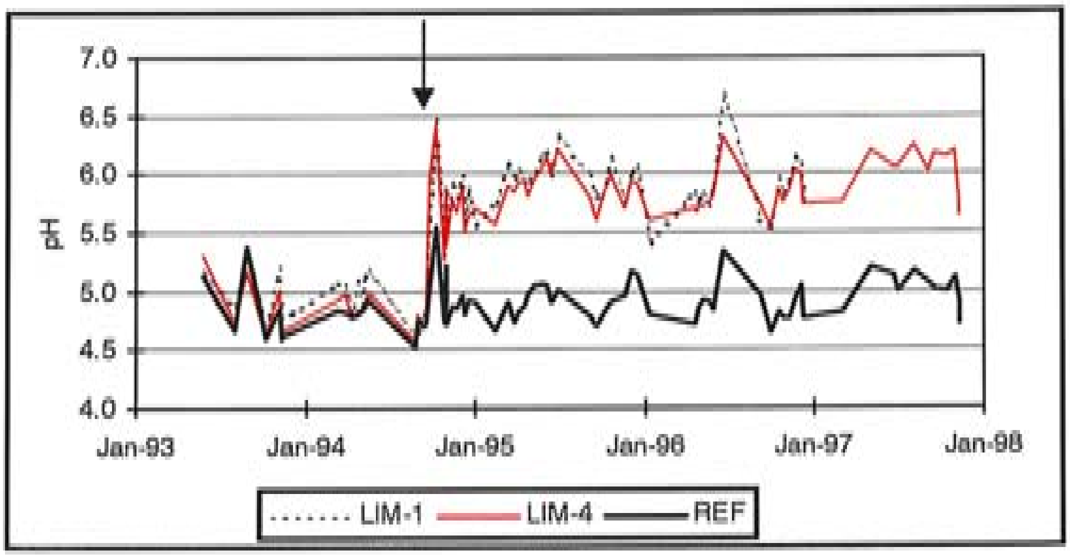

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Abstract

As part of the research programme "Countermeasures Against Acidification in Forest Ecosystems" (Miljøtiltak i skog), a coniferous-forested catchment was limed with dolomite in September 1996. 3 t ha^{-1} of coarse dolomite powder were spread on 0.8 km^2 by helicopter. The liming resulted in an immediate improvement in runoff water quality relative to an adjacent reference catchment. pH, Ca, Mg and ANC (acid neutralizing capacity) increased and inorganic Al decreased. Favourable water quality was maintained for 3 years. NO_3-concentrations increased the second year after liming, whereas concentrations of total N and TOC were not significantly changed. Liming did not affect concentrations of 7 trace metals (As, Cd, Cu, Fe, Ni, Pb, Zn) whereas concentrations of Mn, Co, and Zn decreased. Only minor changes in soil solution, and only in some of the lysimeters were detected. Steep slopes, thin soils, high amounts of precipitation and thus dominance of surface and subsurface flow in the catchment may explain the rapid response in runoff. During the first three years after liming there have been no significant effects on tree growth and vitality (crown density and crown colour). This experiment shows that liming of forested catchments is a viable method to obtain long-term improvement in water quality and positive effects for acid-sensitive aquatic organisms.

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Counteractions Against Acidification

in Forest Ecosystems

Whole-catchment Application of Dolomite to an Acidified Forested Ecosystem in Gjerstad, Southern Norway

Preface

The research program "Counteractions against acidification in forest ecosystems" (Miljøtiltak i skog) was initiated in 1991 as a Norwegian Forest Research Institute (NISK) program with funding from the Ministry of Agriculture. In 1993 the program was reorganised and a five-year research program led by NISK was started. Three co-operating institutes, NISK, the Norwegian Institute for Water Research (NIVA) and the Norwegian Institute for Nature Research (NINA), were main actors. Later on the Agricultural University participated.

The program was divided into an initial literature study and five separate research activities thereafter. This report gives background information and summarises the results from sub-project IV, the whole catchment application of dolomite to an acidified forested ecosystem in Gjerstad, southern Norway.

We would like to thank the forest owner Olav Fjærbu for careful sampling and maintenance of monitoring stations during the project period and for offering his forest as a research site in an early phase of the program.

This work has been financed by the Ministry of Agriculture, the Ministry of Environment, the four counties Rogaland, Vest-Agder, Aust-Agder and Telemark and NIVA.

Grimstad, September 16, 1999

Atle Hindar

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Summary

As part of the research programme "Counteractions Against Acidification in Forest Ecosystems", a forested catchment dominated by pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*) was limed with dolomite in September 1994. 3 t ha^{-1} of coarse dolomite powder were spread on 80 ha by helicopter. Mean pre-liming stream water qualities (n = 16 to 18) at four independent stations were in the range: pH 4.6 - 4.9; 0.85 - 1.28 mg L^{-1} Ca; 0.30 - 0.41 mg L^{-1} Mg, 194 - 275 µg L^{-1} reactive Al (Alr) and 34 - 103 µg L^{-1} inorganic monomeric Al (Ali). Dolomite application resulted in an immediate increase in runoff water quality relative to an adjacent reference catchment. For the period September 1994-December 1996 mean values at the main outlet of the limed catchment were: pH 5.86; 1.51 mg L^{-1} Ca; 0.81 mg L^{-1} Mg; 15 µg L^{-1} Ali. A small increase in NO_3 was found at the main outlet of the limed catchment the second winter after liming. Total N and TOC were not changed. Mn, Co and Zn showed significantly decreasing trends when compared to the reference stream, whereas Fe, Pb, Cd, Cu As and Ni remained relatively unaffected by the dolomite application. Cr was mostly below detection limits. Only minor changes in soil solution, most clearly for Mg, could be detected after liming. Steep slopes, thin soils, high amounts of precipitation and thus dominance of surface and subsurface flow in this catchment may explain the rapid response in runoff. During the first three years after liming there have been no significant effects on tree growth and vitality (crown density and crown colour). This experiment shows that liming of forested catchments is a viable method to obtain long-term improvement in water quality and positive effects for acid-sensitive aquatic organisms.

1. Introduction

1.1 Background

In areas in southern Norway characterised by widespread fish-death due to acidification of surface waters, so far no negative effects of acid rain on forest health can be documented (Aamlid *et al.* 1998). Forests tend to remove base cations, scavenge air pollutants and concentrate pollutants due to increased evapotranspiration (Jenkins *et al.* 1990). In the long run, acidification of forest soils may therefore be expected in vulnerable areas if the soil has a limited base cation supply. The supply of nitrogen from atmospheric deposition may stimulate forest growth and thereby also the loss of base cations from the soil. Although atmospheric deposition of sulphur in Norway has decreased during the last decade, the situation for the forest ecosystems is still uncertain, and the need to examine various counteractions against acidification of the soils has been recognised.

Episodic acidification, enhanced by sea salts, may be particularly important for sensitive aquatic organisms in forested areas (Hindar *et al.* 1994, 1995a). Afforestation may have undesired impacts on aquatic ecosystems, and the question of whether afforestation should be augmented with measures to prevent this extra acidification has been raised.

Several countermeasures against forest soil acidification are available for forest management practices, including both silvicultural measures and application of chemicals. The first group involves use of broadleaved trees, both in pure stands or mixed within conifer stands (Frank 1994).

Changes in forestry management may reduce the removal of base cations but will not prevent strong acid anions from entering soil solution and runoff. Strong acid anions, especially SO_4, are the driving force in soil acidification when balanced by base cations (BC, mainly Ca and Mg). Poorly buffered soils have a very limited capacity of base cation production because of the low weathering rate. In such soils strong acid anions may also be balanced by acid cations, especially H^+ and $Al(OH)_x^{(3-x)+}$.

A second group of countermeasures includes application of carbonates (liming), ash and various commercial fertilisers. The addition of carbonates as calcitic and dolomitic limestone increase the base saturation of the soils and thereby prevent leaching of H^+ and toxic Al species. Liming may thus be regarded as desirable for both forest soils and aquatic systems in acidified areas, and has been practised for a long time as a compensatory or ameliorating measure in forest soils (Hüttl and Zöttl 1993; Kreutzer 1995) and in acidified lakes and rivers (Olem 1991; Henrikson *et al.* 1995). Fertilisation with the goal of revitalisation of forest stands suffering from nutrient deficiencies has also proved successful (Hüttl 1991).

The question of whether liming should be launched on a practical scale in Norwegian forestry has been raised several times during the last decade (Nilsen *et al.* 1998). The inter-institutional research program "Counteractions against acidification in forest ecosystems" (Miljøtiltak i skog) was initiated in 1991. Main goals for the program were to:

- Give a status and evaluate potential and practical measures, such as liming, vitality fertilisation, use of broad-leaved trees and other silvicultural methods, that may counteract negative effects of acid deposition in forests.
- Perform research on the effects of selected measures on trees, ground vegetation, animal life, forest soils, soil solution and the runoff water quality.
- Give necessary basis for making decisions about future activities on a practical scale.

1.2 Definitions and targets

Liming is the addition of carbonates, oxides and hydroxides of calcium and magnesium to terrestrial and aquatic ecosystems to neutralise soil or surface water. This is consistent with the definition of Olem (1991), although he included all bases. Operational liming of forest soil has gradually changed towards dolomitic materials in Germany (Feger *et al.* 1995) due to the anticipated positive effect of Mg supply to prevent Mg deficiency. Dolomite and calcite mixture was also recommended for operational liming in Sweden (Lindström *et al.* 1993). However, some of the Swedish experiments were carried out using calcitic limestone, i.e. products composed of $CaCO_3$ with only a few percent Mg.

The targets for terrestrial liming operations may be many, e.g. the soil pH, the soil (Ca+Mg)/Al ratio, tree growth, forest health, stream water pH, stream water inorganic Al, a trout population and so on. Various application strategies may be used to achieve one or more of these goals (Henriksen *et al.* 1995), and lime quality, lime dosages, and application strategies may vary. If the goals are clarified, reasonable liming strategies may be recommended, if the potential effects are adequate and acceptable.

The main targets for forest soil liming should be to avoid the negative effects on forest soils of strong acid inputs and to avoid unwanted effects on the terrestrial and aquatic ecosystems. Another target may be improved living conditions for fish in the stream water draining the limed forest. If all the potential positive effects of forest liming are achieved all the negative effects may also occur, see section 1.3. If no undesired effects can be accepted, no positive effects may occur either. The real challenge is to maximise the positive and minimise the negative effects.

1.3 Potential effects of application of dolomite

Moderate addition of dolomitic limestone to the topsoil of forest ecosystems may be intermediate in both positive and negative effects. In this report the main focus is on reduced toxicity towards aquatic organisms.

1.3.1 Soil solution and stream water

The added dolomite gradually dissolves and releases Ca and Mg that can be adsorbed in the organic layer of the top soil. Vertical movement of these base cations to deeper soils then takes place, but this is a slow process, and may occur in the range of 1 cm $year^{-1}$ (Brahmer 1990). Fast changes in the chemical composition of soil solution are therefore not likely. The first change may be increased concentration of Mg in the soil solution due to the more mobile nature of this element relative to Ca (Brahmer 1990). On the other hand dolomite often contains almost four times as much Ca on a weight basis, thereby counteracting the dominance of Mg-increase over Ca-increase in the soil solution.

Although the change in soil solution may be slow, increased amounts of base cations in the topsoil may be important for runoff water quality when hydrological events are characterised by overland or subsurface flow. Overland and subsurface flow is promoted by thin soils and steep slopes, typical of acidified areas in Norway. High amounts of precipitation increase the likelihood for a high water table and saturated soils. Dominance of a more lateral movement of the runoff and reduced residence time of rainwater in the soil may be the result. Under such circumstances runoff acidity may be exchanged with the added base cations in the top soils, thus increasing the concentration of Ca and Mg and also increasing pH.

Dolomite addition thus may result in several positive effects. Increased base saturation of the topsoil, eventually also at greater depths in the soil, and increased pH will reduce Al mobilisation. This in turn decreases the leaching of toxic Al to soil solution and surface water. Also, increased concentrations of base cations should be expected. If no significant changes in SO_4 and NO_3 occur, liming with dolomite will therefore result in increased ANC[1] (acid neutralising capacity).

In acidified regions low pH and high Al concentrations in runoff may occur during episodes caused by sea salt inputs (Hindar *et al.* 1994; 1995a), snowmelt and other hydrological events. Increased base saturation in the forest soil and increased pH of the runoff after liming may reduce this Al transport, both by decreasing the preferential ion exchange with H^+ and Al in acid soils and by polymerising and precipitating ion exchanged Al in the overland flow. If forest liming in such areas reduces the Al transport and promotes terrestrial polymerisation of Al, the magnitude and frequency of episodes with toxic water will be reduced and mixing zones in streams and rivers characterised by unstable Al chemistry (Rosseland *et al.* 1992) may be avoided.

Undesirable chemical effects of terrestrial liming include increased NO_3-leaching and mobilisation of trace metals (Matzner *et al.* 1985; Persson *et al.* 1989; Hüttl and Zöttl 1993; Kreutzer 1995). This may partly be due to increased mineralisation of the surface organic (humus) matter, and may effect soil solution and surface water.

The liming-mediated change in the top soil pH may stimulate the bacterial degradation of organically bound N in the humic material to NH_4 due to a more favourable environment for these organisms (Kreutzer 1994). Nitrification, the bacterial mediated conversion of NH_4 to NO_3, may be stimulated and lead to decreased pH. If the supply of NO_3 is already in excess due to atmospheric deposition, the result may be increased leaching of NO_3 to the soil solution (Kreutzer 1995) and probably to runoff, with subsequent increased acidification and possibilities for increased supply of N to coastal areas. N leaching may thus reduce the deacidification effect of the dolomite in runoff. In less N polluted areas, NO_3 released will probably be stored in the soil and consumed by microorganisms and terrestrial vegetation.

Mineralisation may result in increased mobilisation of organically-complexed trace metals (especially Cu, Pb and Fe) and result in elevated concentrations in the soil solution. This may be especially so if the deposition rate of the metals is high, and they have accumulated in the surface soils, as in the Höglwald experimental area in Germany (Kreutzer 1995). Solubility of Cd and Zn (and Cu) is pH dependent and these metals will probably not be transported out after liming. On the contrary, increased pH may result in increased retention. Dissolved inorganic Mn and Cd may be oxidised and precipitated at increased pH and decrease in the soil solution after liming (Kreutzer 1995).

The deposition of Cu in Norway is mainly due to local sources and is generally low (Berg *et al.* 1996). Deposition of Zn and Pb in 1996 was an order of magnitude higher than other long-range transported metals but has decreased by 60-80 % in the period 1978-1996 (Tørseth and Manø 1997). This reduction is also true for Cd. Compared to the situation in Germany deposition of trace metals in Norway is low.

1.3.2 Aquatic organisms

Forest liming, according to the Swedish concept (Lindström *et al.* 1995) tends to result in a relatively moderate water quality change in the runoff. Exceptions may be found in areas heavily polluted with nitrogen or trace metals, as referred to above. An important question is: will these changes in any way affect aquatic organisms?

Several investigations have documented that even small water quality changes or differences may be of significance for the survival of fish (Staurnes *et al.* 1993; Dalziel *et al.* 1995; Kroglund and Staurnes 1997) and invertebrates (Raddum and Fjellheim 1984). Decreased concentration of the toxic inorganic Al-species is probably most important for sensitive aquatic organisms and increased concentration of Ca may ameliorate Al toxicity (reviewed by Wood and McDonald 1987; Rosseland *et al.* 1990). Increased concentration of dissolved organic matter will detoxify a larger fraction of Al at low pH due to complex binding. Forest soil liming may therefore represent an effective liming strategy for aquatic systems if significant changes in these parameters occur.

1.4 The whole-catchment liming project in Gjerstad

The question whether liming should be launched on a practical scale in Norwegian forestry may be answered if adequate results exist. Due to lack of integrated studies on soil, water and vegetation under Norwegian conditions, a catchment study with dolomite application was initiated in 1993. The project in Gjerstad, which is presented in this report, is one of five projects under the research program.

The purpose of the experiment was to study the effects of dolomite application to a forested area on soil solution chemistry, runoff water chemistry, soil chemistry, vegetation, tree growth and vitality. Few research programmes have focused on the effects of forest liming on both soil solution, stream water and the significance of water quality changes for aquatic organisms. One of the main purposes of the activities in the Gjerstad-project is to link these topics.

Results from this experiment have been published as part of the Acid Reign'95 Conference in Gothenburg (Hindar *et al.* 1995b) and in annual and final reports in Norwegian from the research programme. This report presents the results in more detail and covers the pre-liming and post-liming periods (until end of 1997).

2. Site description and liming

2.1 Site selection

Several possible areas were visited prior to the establishment of the project sites. The catchment was chosen to satisfy the following criteria:

- acidified due to long-range transported air-pollutants; pH in runoff in the range 4.5-5.5 and markedly elevated Al-concentrations
- mixed forest stands, typical for the moderately productive forests of the area
- mixed, but not too poor, growing conditions (nutrient and water availability) for ground vegetation
- not too close to the sea, due to possible special effects related to sea-salts
- two defined catchments with brooks suited for sampling and monitoring of runoff, one for liming operation and one as reference.

A mixed forest in Gjerstad, Aust Agder County, southern Norway (58° 53' N, 9° 00' E) was chosen for investigations of the effects of forest soil liming. Fugleliåsen (denoted LIM and FU; 84 ha) was selected as liming area and Spjotåsen (denoted REF and SP; 41 ha) as reference. The limed catchment was further divided in 3 by the sampling stations LIM-1 (40 ha), LIM-2 and LIM-3, whereas LIM-4 is the main sampling station (**Figure 1**).

2.2 Forest cover

The catchments are forested with a mixture of mainly Norway spruce (*Picea abies*) and Scots pine (*Pinus sylvestris*) stands. A relatively small amount of broad-leaved trees are mixed within the conifer stands. The forest consists of old mature stands and with a certain amount of newly regenerated areas (less than 15 years).

Table 1. Catchment areas (ha), standing volume (m^3), mean age (yr) and area distribution according to tree age classes and impediment.

	Size (ha)	Standing volume (m^3) Total	Spruce	Pine	Mean age (yr)	Middle aged + old forest	Regenerated areas	Imped.
LIM	84.3	9900	5400	4500	67	70 %	17 %	13 %
REF	40.8	6000	1600	3600	77	84 %	9 %	7 %

2.3 Precipitation and deposition

Mean annual precipitation is about 1200 mm and mean annual discharge about 900 mm (29 L s^{-1} km^{-2}). Mean total wet + dry deposition of S and N in the project period 1994-1996 at the Birkenes monitoring station 70 km SW of Gjerstad was 0.90 g m^{-2} and 1.52 g m^{-2}, respectively. At the Solhomfjell monitoring station 20 km NW of Gjerstad the mean wet deposition of S and N was 0.61 g m^{-2} and 0.91 g m^{-2}, respectively, in the same period. Deposition of trace metals at Solhomfjell in 1996 was as follows (numbers in mg m^{-2} yr^{-1}): 4.95 Zn; 2.01 Pb; 0.82 Cu, 0.26 Ni; 0.18 As; 0.16 Cr; 0.042 Cd; 0.02 Co (all deposition data from Forseth and Manø 1997).

2.4 Liming

In September 1994 a total of 240 tonnes of coarse grained dolomite was spread over the Fugleliasen catchment, except for two small (about 1000 m^2) ponds, by helicopter. This gives a mean dose of approximately 2.9 t ha^{-1}. The grain-size distribution of the dolomite was 10 % > 1.7 mm; 90 % > 0.18 mm. The Ca, Mg and water content were 23, 12 and 1 % by weight, respectively.

3. Methods

3.1 Hydrology and water chemistry

3.1.1 Discharge

The limed catchment was divided into three sub-catchments (**Figure 1**), of which two (sampling stations LIM-1 of one of the sub-catchments and LIM-4 at the outlet of the limed catchment) have been included in the water chemistry monitoring in the whole project period. Monitoring in LIM-2 and LIM-3 of the two other sub catchments were terminated in the summer of 1995.

Water flow was recorded beginning 26 May 1993 at 15-minute intervals at calibrated 90° (at LIM-1) and 120° (at LIM-4 and REF) V-notch weirs.

3.1.2 Runoff water sampling

Volume weighted stream water samples were collected biweekly beginning 26 May 1993 at LIM-1, LIM-4 and REF. Point samples were collected biweekly at the other two stations in the limed catchment. Water samples were sent to NIVA by post and were analysed 2-3 days after sampling.

Samples for analysis of trace metals were taken directly in 100-ml polyethylene bottles. Before sampling the bottles were washed in 3% HNO_3 for at least 24 hours and thereafter rinsed with demineralised water. After the washing procedure the PE-bottles were refilled with demineralised water until sampling. Before sampling the PE-bottles were emptied for demineralised water and immediately filled with the sample.

3.1.3 Chemical analyses – water and soil solution

Chemical analyses of all major ions and Al-fractions were carried out at NIVA according to standard procedures (**Table 2**). Trace metal analyses were performed with ICP-MS at the Norwegian Institute for Air Research (NILU). In the event that concentrations were reported below the detection limit, these were set at ½ the detection limit.

3.1.4 Calculations and statistical analyses

Ali (inorganic monomeric Al) is defined as the difference between Alr (reactive Al) and Alo (organic monomeric Al). Organic N is defined as the difference: total N - (NO_3-N + NH_4-N).

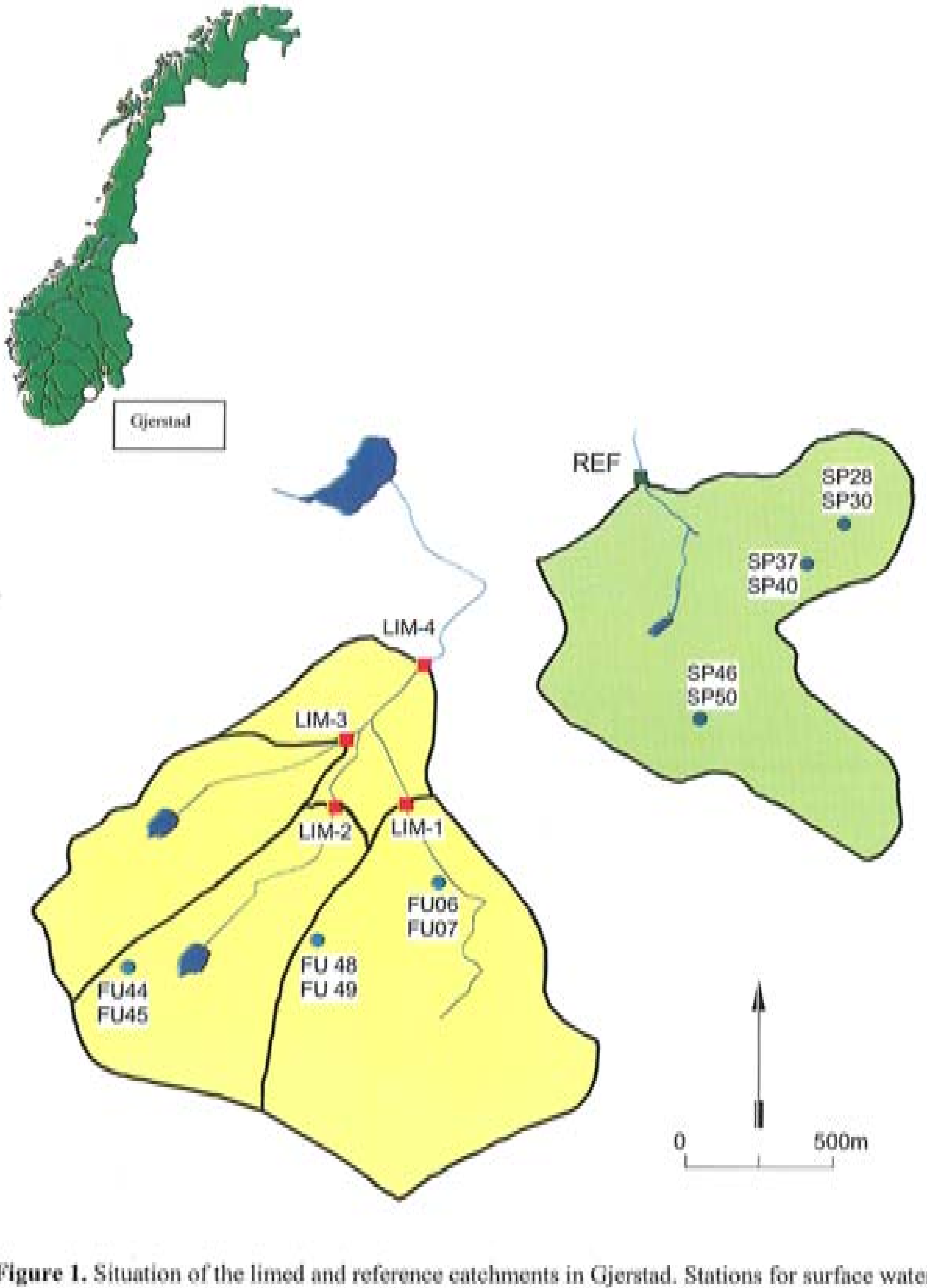

Figure 1. Situation of the limed and reference catchments in Gjerstad. Stations for surface water sampling (LIM-1, LIM-2, LIM-3, LIM-4 and REF), soil chemistry and soil solution sampling (FU and SP stations) are shown. Runoff is registered continuously at LIM-1, LIM-4 and REF.

Table 2. Chemical analysis methods used at NIVA (major components) and NILU (trace metals) ICP= Inductive coupled plasma emission spectrometry, ICP-MS= Inductive coupled plasma emission spectrometry combined with mass spectrometry; FIA= flow injection analysis.

Parameter	Parameter name	Unit	Analytical method
pH	pH	- log [H^+]	Potentiometric
Cond	Conductivity	mS m^{-1} at 25 °C	Electrometric
Ca	Calcium	mg L^{-1}	ICP
Mg	Magnesium	mg L^{-1}	ICP
Na	Sodium	mg L^{-1}	ICP
K	Potassium	mg L^{-1}	ICP
Cl	Chloride	mg L^{-1}	Ion chromatography
SO_4	Sulphate	mg L^{-1}	Ion chromatography
NO_3	Nitrate	µg N L^{-1}	Automatic colorimetry
NH_4	Ammonium	µg N L^{-1}	Automatic colorimetry
Alk	Alkalinity	µeq L^{-1}	Potentiometric titration to pH 4.5
TOC	Total organic carbon	mg L^{-1}	Oxidation to CO_2 and then IR detector
Alr	Reactive aluminium	µg L^{-1}	Automatic colorimetry
Alo	Non-labile aluminium	µg L^{-1}	Automatic colorimetry after ion exchange
SiO_2	Silica	mg L^{-1}	Photometry (FIA)
Tot N	Total nitrogen	µg L^{-1}	Automatic colorimetry
Tot P	Total phosphorus	µg L^{-1}	Automatic colorimetry
As	Arsenic	µg L^{-1}	ICP-MS
Cd	Cadmium	µg L^{-1}	ICP-MS
Co	Cobalt	µg L^{-1}	ICP-MS
Cu	Copper	µg L^{-1}	ICP-MS
Fe	Iron	µg L^{-1}	ICP-MS
Mn	Manganese	µg L^{-1}	ICP-MS
Ni	Nickel	µg L^{-1}	ICP-MS
Pb	Lead	µg L^{-1}	ICP-MS
Zn	Zinc	µg L^{-1}	ICP-MS

ANC (Acid neutralising capacity), in µeq L^{-1}, is defined as:
ANC = (Ca^{2+} + Mg^{2+} + Na^+ + K^+) - (Cl^- + SO_4^{2-} + NO_3^-) if NH_4^+ ≈ 0. All concentrations are in µeq L^{-1}.

Non-marine Na (Na*) in µeq L^{-1} is calculated as:
Na* = Na^+ - 0.859 * [Cl^-], assuming that Cl is entirely derived from sea salts. If the Na/Cl ratio departs from the ratio in the sea (0.859), this indicates sources or sinks of Na in the catchment.

Net change in transport of Ca and Mg from the limed catchment is calculated from water flow and the difference between simultaneously taken samples from LIM 4 and REF. This difference was then corrected for the mean pre-liming difference between the two catchments. This correction was +0.14 mg L^{-1} for Ca and -0.01 mg L^{-1} for Mg.

The data material was tested statistically by different methods:

Runoff water samples;

1. Systematic pre liming variability between sub catchments was tested with simple ANOVA. The tests were performed on the means of calculated differences of simultaneously taken samples at independent (no autocorrelation) LIM stations and the REF station. This difference, which reduces the contribution of variance from seasonal variability, is referred to as e.g. Ca diff.
2. Changes due to liming were also tested by use of this dataset and ANOVA.
3. Trends after, and due to, liming were tested by use of simple regression on the differences. General trends, as reflected in the reference catchment, were thereby eliminated.
4. Changes in water chemistry in the limed catchment (LIM4) relative to the reference catchment (REF) at the point of time of liming (September 1994) were tested by Random Intervention Analysis (RIA) (Carpenter *et al.* 1989). RIA compares differences in concentrations in paired, chronologically-ordered samples for the pre- and post-liming periods with the change obtained from 1000 randomly-ordered sets of differences.

3.2 Soil and soil solution chemistry

3.2.1 Soil sampling

Soil were sampled in summer 1994 before liming at the 6 plots (3 each in the limed and reference catchments) used for analysis of ground vegetation (**Figure 1**). At each plot 1 sample was collected from the humus horizon and 2-3 samples from the mineral soil horizon.

3.2.2 Chemical analyses – soils

Soils were extracted in water for measurement of pH and in 1 M NH_4NO_3 for determination of exchangeable cations. Bulk density, loss on ignition, and Kjeldahl N were measured on bulk soil. Contents of 31 elements was determined by ICP (Inductive coupled plasma emission spectrometry) on acid digests of the bulk soil. Analyses were performed at NISK using standard procedures.

Cation exchange capacity (CEC; NH_4NO_3 extract) was calculated as the equivalent sum of H^+, Al, Ca, Mg, Na, and K. Base saturation (%) is defined as the sum of (Ca+Mg+Na+K)/CEC.

3.2.3 Soil solution sampling

60 Prenart lysimeters were installed prior to liming (August 1994) in the 6 locations selected for vegetation analyses (**Figure 1**), at 3 sites in Fuglehåsen (FU) and 3 in Sjøpåsen (SP), two lysimeters for each sampling depth. The samples were collected following a 24-hour evacuation period. The soil solution was collected from 5 and 15 cm depth and stored in 2 litre Prenart bottles, which were covered to minimise reaction catalysed by sun light or alga growth. The soil solution samples were filtered through 2 µm membranes and stored for less than 48 hours prior to analysis at NIVA. Sampling began in September 1994. There are no pre-liming samples of soil solution.

3.3 Forest inventory

Forest inventories were carried out during summer 1994 in both limed and reference areas. The inventory was made as a systematic sample plot inventory. Lines were laid out with individual distances of 100 m in the forest and along each line sample plots were placed with 50-m distances (**Figure 2**). The plots were circular with an area of 200 m^2. Plots on mineral soil were permanently marked with a wooden pole in the centre. Plots that fell on peat-land, roads, water or barren rocks were classified as non-productive land. Plots that fell in boarder areas between stands were systematically moved 10 meters in one direction. A total of 122 (limed area) and 56 (reference area) plots were measured.

3.3.1 Tree measurement

In each sample plot all trees more than 5 cm in diameter at breast height were measured by diameter and permanently marked with tree number. Tree species were noted.

Sample trees were picked out with relascope. Relascope factor 2 was used and each third of the trees falling within the relascope were picked out for further measurements. These sample trees were measured for height above ground, height to living crown and different kinds of damages were noted according to a manual. Sample cores were taken from all sample trees and annual ring width was measured for the latest 40 years. From each sample plot, where possible, the two largest trees (by diameter) without damages were picked out for site index estimation. In addition to the variables already mentioned, bark thickness was measured and annual height growth visually estimated on these trees. All annual rings were measured for breast height age determination on these trees. The annual rings were measured in laboratory.

3.3.2 Site index, volume- and cutting class calculations

Site index for each sampling plot was estimated from age at breast height and height of the two largest trees (Tveite 1977). Curves for diameter to height relationship for each tree species were constructed for the two areas together. Tree height was then estimated for all trees. Volume was calculated using functions for spruce, pine and birch (all broad leaved trees are treated as birch in this connection) (Braastad 1966, Vestjordet 1967, Brantseg 1967) with diameter and height as independent variables. Cutting class (for definition see text in **Figure 24**) is dependent on site index, species and age and the area distribution of cutting classes have been calculated from the sample plot data for the two areas.

3.4 Intensive monitoring plots

In each of the two areas, 10 sample plots (25 x 30 m) were subjectively laid out (**Figure 3**). The criteria for placing the different plots were to cover the vegetation gradient in the limed catchment, and a comparable gradient in the reference catchment. The gradient varied from dry to wet and from fertile to infertile soils. Within each sample plot an area of 5 x 10 m was used for intensive registration of vegetation (Eilertsen *et al.* 1994). On each plot steepness and exposition were measured.

3.4.1 Registration in the plots

All trees more than 5 cm in breast height were measured by diameter and permanently marked with a number. Height and crown height was measured on about half of the trees in 1994. Height increment was visually estimated on the trees and bark thickness was measured. In 1998 height was just measured on ⅓ of the trees. Damages were also noted for these trees.

The 3 largest trees by diameter (spruce or pine) were cored to pith, and age and annual ring width were measured in the laboratory.

Each autumn, diameter was measured on all trees and tree vitality evaluated. The vitality evaluation is based on tree crown density and colour. The crown density (%) is defined as the amount of needles in tree crowns compared to what could be expected on a sound tree in that particular area. The crown colour is an overall impression of the colour based on a scale from 1 to 4: 1 is normal green, 2 slightly yellow, 3 average yellow and 4 strongly yellow. The result from the evaluation is based on the same trees each year and the work has been done by the same person and follows the same criteria as for the Norwegian forest monitoring programme (Groeggen 1997).

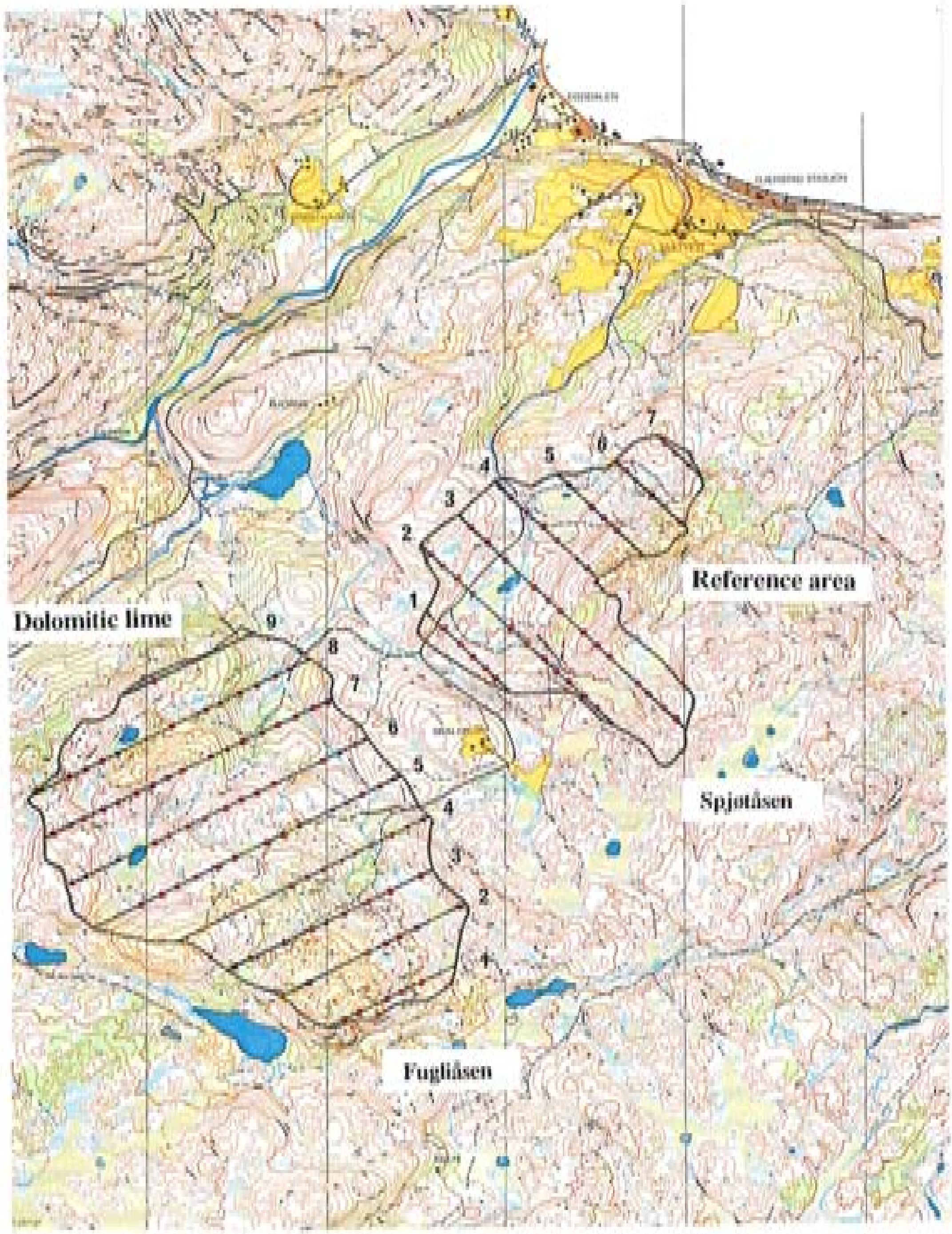

Figure 2. Map showing the two catchments and the sampling lines in each area. Red dots indicate plots where trees were measured. Scale approx. 1:20000.

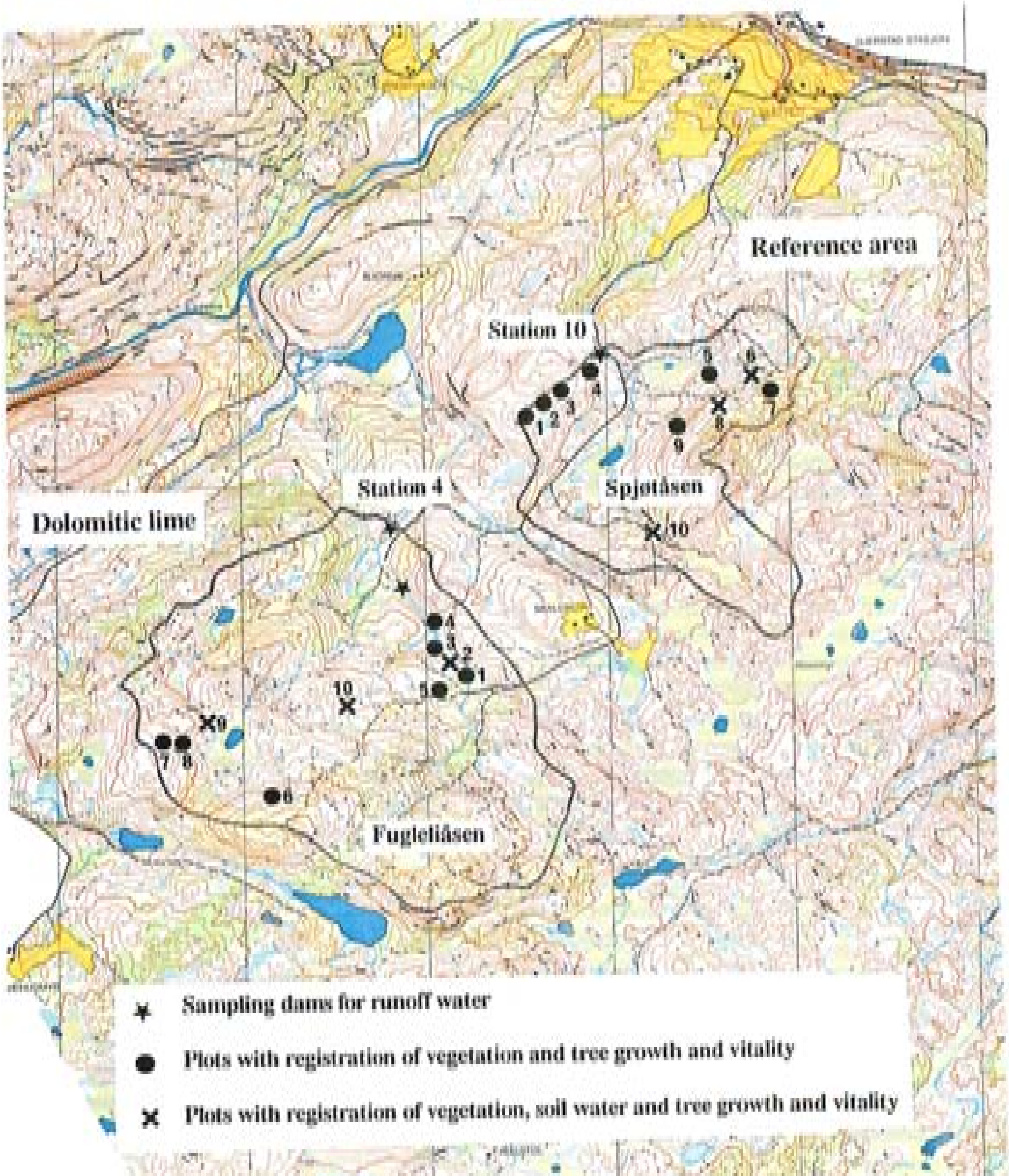

Figure 3. The location of the intensive monitoring plots. All plots were used for vegetation investigations and some for soil solution sampling. Scale approx. 1:20000.

3.4.2 Statistical analysis

Based upon height and diameter the volume of the sample trees was estimated using functions for different tree species (Braastad 1966, Vestjordet 1967, Brandseg 1967). A linear regression between diameter and volume on these trees was used to estimate volume for all trees. The function developed from the 1994 registration was also used for the 1998 data. Volume increment in the 4 year period was calculated as the difference in standing volume between the two years.

Site index (Tveite 1977) was estimated on the basis of age and height of the 3 trees per plot. Site index curves for the dominant tree species was used to determine the site index of the plots.

The increment in the 4-year period from 1994 to 1998 was compared to increment functions developed for Norwegian conditions based on increment investigations on permanent sample plots (Blingsmo 1988). The increment function has standing volume, stand age and site index as explanatory variables. Functions for pine, spruce and birch (used for all broad-leaves) were used and the increment was weighted with the tree species share of total volume.

4. Results

4.1 Precipitation and hydrology

Monthly precipitation amount at the nearby meteorological station Åsbø in Gjerstad and water discharge at the three monitoring stations are shown in **Figure 4** and **Figure 5**.

According to the runoff map of Norway average discharge in the area is 900 mm yr^{-1} (29 L s^{-1} km^{-2}). Based on the measured runoff and the subcatchment areas of stations LIM 1, LIM 4 and RFF specific discharge for the four years 1994-1997 were calculated (**Table 3**).

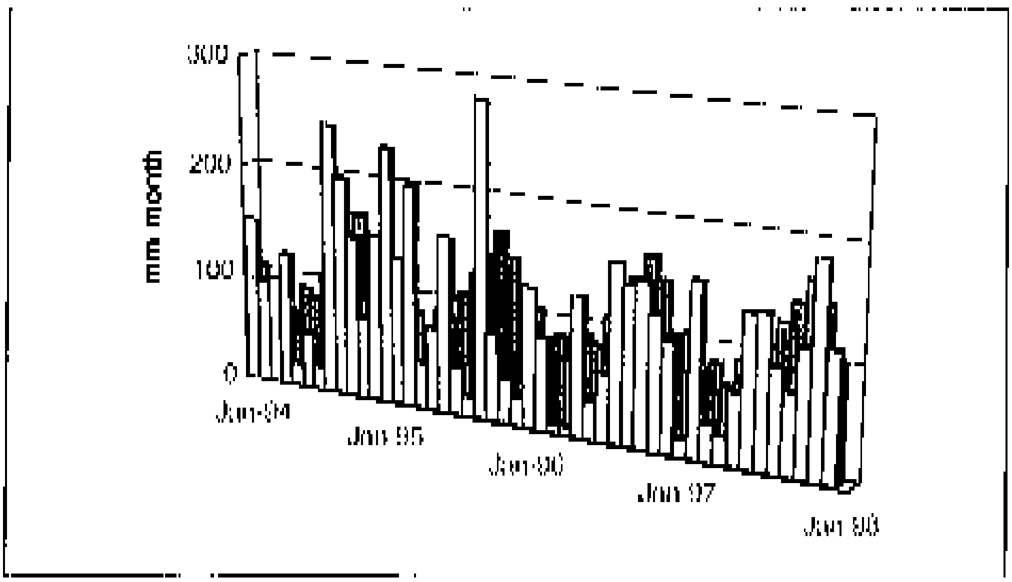

Figure 4. Monthly precipitation amount at the meteorological station (3520 Åsbø) in the monitoring period (in the front) and the 30-year monthly normal precipitation (in the back). Data from the Norwegian Meteorological Institute.

1994 and the hydrological year from summer 1994 to summer 1995 was very wet compared to the following years. Only the year 1995 was close to normal. 1996, 1997 and especially the hydrological year 1995-1996 were dry. Lower discharge in 1996 and 1997 compared with the initial period after liming is also evident when accumulated discharge is calculated (**Figure 6**).

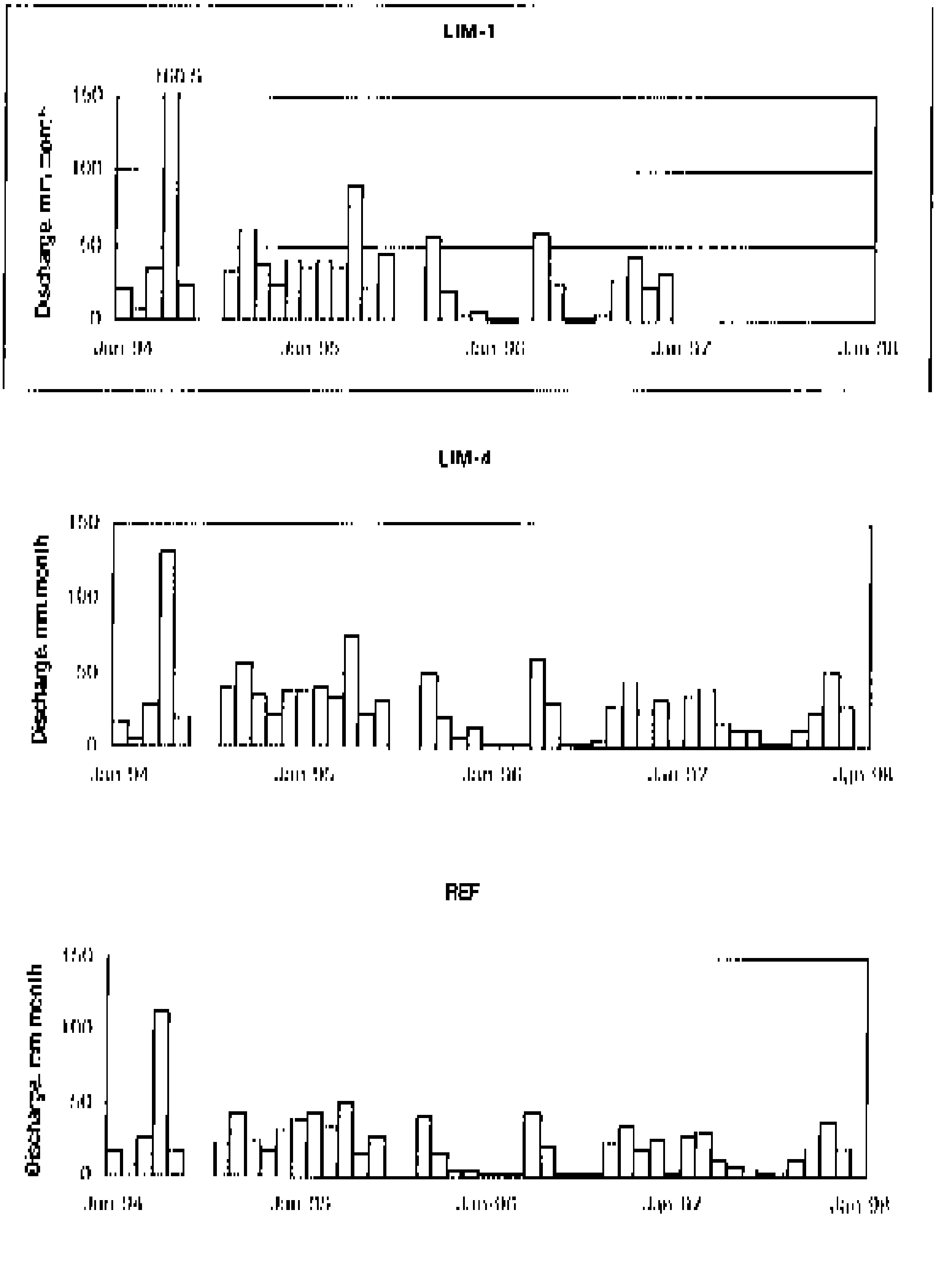

Figure 5. Monthly discharge at LIM 1, LIM 4 and REF. Discharge in 1997 was not measured at LIM-1.

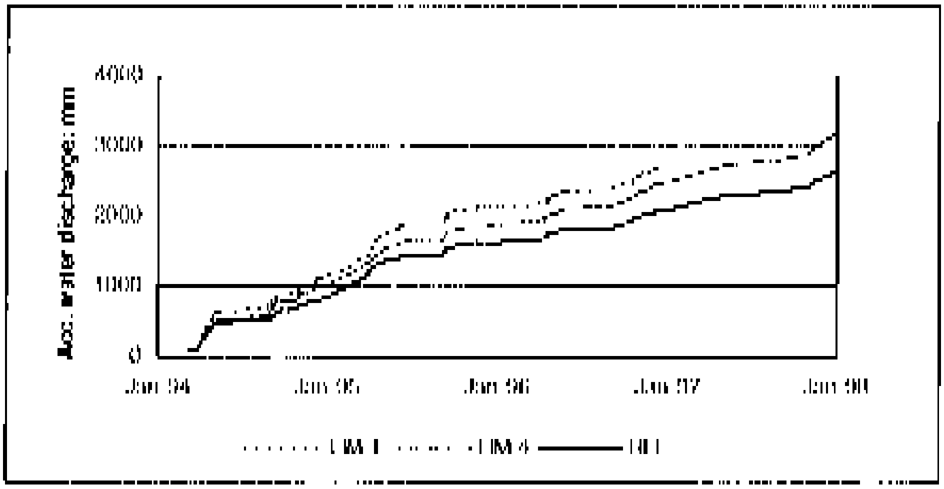

Figure 6. Accumulated water discharge (in mm) at monitoring stations LIM 1, LIM 4 and REF for the period 1994-1997.

Table 3. Calculated specific discharge (mm yr^{-1}) for catchments LIM-1, LIM-4 and REF. Results are given for calendar years and for hydrologic years (1 July to 30 June).

Calendar year		1994	1995	1996	1997
	LIM 1	1057	839	517	612
	LIM 4	1034	855	602	609
	REF	1082	918	599	
Hydrologic year		1994-1995	1995-1996	1996-1997	
	LIM-1	1104	410	653	
	LIM-4	1126	486	640	
	REF	1170	464		

4.2 Runoff water quality

4.2.1 Preliming characteristics

Significant pre-liming variability between subcatchments is reflected in pH, Ca, Mg, ANC, Al-fractions and TOC but not in SO_4 and NO_3 (**Table 4**). This reflects the relatively uniform response of S and N deposition on SO_4 and NO_3 in runoff within the catchment and the more non uniform geochemical characteristics. The areas draining to LIM-2 and LIM-3 are more acid sensitive that the LIM 1 catchment. These two areas also had the most toxic water before liming, as seen in lower pH and ANC and higher Ali.

Prior to liming the stream water in both catchments was chronically acidified (**Table 4** and **Table 5**). pH was generally between 4.5 and 5.5 (**Figure 7**), and mean concentrations of reactive aluminium (Alr) were 248 µg L^{-1} and 191 µg L^{-1} in the two catchments (**Table 5**). About 70 % of the Al was organically bound. The relatively high organic Al fraction can be related to the generally high contents of total organic matter (TOC) in the streams (6.8 mg TOC L^{-1}).

4.2.2 Post-liming characteristics

After liming significant increases in pH, Ca, Mg and ANC were found for all LIM stations relative to the REF-station. **Table 5** summarises this effect for LIM 4. The immediate response in pH, which increased to 5.5-6.0, is clearly seen in **Figure 7**. At the main outlet of the limed catchment (at LIM-4) the mean concentration of Ca and Mg increased by 0.35 and 0.44 mg L^{-1}, respectively. Acid

Table 4. Pre-liming mean values and st. dev. (in brackets) of 4 independent sampling stations (n=17 for LIM-2; n=19 for LIM-1, LIM-3 and REF) and of LIM-4 (n=19). Letters a-d denote significant differences (p<0.05) between columns based on multiple range tests.

		LIM-1	LIM-2	LIM-3	REF	LIM-4
SO_4	mg L^{-1}	4.5 (0.8)	4.2 (0.5)	4.4 (0.4)	4.3 (0.7)	4.4 (0.6)
NO_3-N	µg L^{-1}	74 (88)	67 (73)	50 (57)	50 (57)	70 (71)
H^+*	µeq L^{-1}	13 (6) a	24 (5) c	17 (6) ab	17 (5) b	15 (6) ab
pH*		4.94 (0.23) c	4.63 (0.10) a	4.82 (0.20) bc	4.79 (0.20) b	4.84 (0.19) bc
Ca*	mg L^{-1}	1.22 (0.37) b	0.85 (0.19) a	1.09 (0.23) b	1.26 (0.33) b	1.13 (0.29) b
Mg*	mg L^{-1}	0.41 (0.11) c	0.30 (0.06) a	0.32 (0.05) ab	0.36 (0.05) b	0.36 (0.05) b
ANC*	µeq L^{-1}	17 (14) cd	-6 (19) a	5 (19) b	23 (17) d	11 (11) bc
Alr*	µg L^{-1}	233 (72) ab	273 (63) b	268 (74) b	191 (56) a	248 (69) b
Alo	µg L^{-1}	175 (60)	184 (51)	164 (52)	157 (49)	176 (59)
Ali*	µg L^{-1}	58 (20) b	89 (27) c	103 (35) c	34 (14) a	72 (19) b
TOC*	mg L^{-1}	8.1 (3.4) b	6.8 (2.4) ab	5.1 (2.4) a	8.5 (2.9) b	7.0 (2.6) ab

neutralising capacity (ANC) increased from 11 to 49 µeq L^{-1}, whereas a decrease was seen in the unlimed catchment (**Table 5**. Liming did not result in significant changes in Na, K, NH_4, SO_4, Cl, Alo, tot N, organic N, TOC or organic C/N.

After the initial increase during the first 10 months after liming, no significant trends were detected for base cations, pH, ANC or aluminium species at LIM-4. There were thus no signs of re-acidification.

A significant decrease in Alr ($p \leq 0.001$) due to liming was found for LIM-1 and LIM-4 (**Table 6** and **Figure 9**). The decrease in Alr-concentration was rather modest, however, from 42 and 47 µg L^{-1} preliming to -10 and -9 µg L^{-1} post-liming for LIM-1 and LIM-4, respectively, relative to REF. This means that the Alr-concentration in the limed catchment was only slightly lower than in the reference catchment after liming. A corresponding decrease from 34 and 38 to -22 and -21 µg L^{-1} was found for the difference in the inorganic monomeric fraction (Ali-diff). Ali is supposed to include the toxic Al-species, and the mean concentration of this fraction was 17 µeq L^{-1} after liming (**Table 5**). No significant liming related change in Alo or TOC was found.

The Random Intervention Analysis also shows that pH, Ca, Mg, and ANC concentrations increased and Alr and Ali decreased significantly in LIM-4 relative to REF in September 1994, the point of time of liming (**Table 6**). RIA indicates no significant changes in TOC or NO_3.

A significant ($p \leq 0.05$) increasing trend was found for TOC at LIM-1, but not at LIM-4. For sulphate and the organic C/N-ratio this was reversed, a significant increasing trend at LIM-4, but not at LIM-1.

Table 5. Mean stream water values and std. deviation (in brackets) for different variables in the limed (LIM-4) and reference (REF) catchments before and after treatment in September 1994. n=17-19 pre-liming and n=55-57 post-liming for all variables. * denotes significant change (p<0.05) of mean or median at LIM-4 due to liming and at REF after the time of liming. Significance of change at LIM-4 is based on differences of simultaneously taken samples according to ANOVA or the non-parametric Kruskall-Wallis test, see also Table 6.

		LIM-4		REF	
		Before	After	Before	After
H^+	µeq L^{-1}	15.9 (6.2)	1.6 (0.88)*	17.3 (6.4)	12.7 (4.5)*
pH	units	4.84 (0.19)	5.86 (0.23)*	4.79 (0.20)	4.93 (0.18)*
Ca	mg L^{-1}	1.13 (0.29)	1.51 (0.25)*	1.26 (0.33)	1.29 (0.28)
Mg	mg L^{-1}	0.36 (0.08)	0.81 (0.17)*	0.36 (0.08)	0.38 (0.08)
Na	mg L^{-1}	1.81 (0.35)	1.73 (0.26)	1.81 (0.39)	1.74 (0.25)
K	mg L^{-1}	0.21 (0.11)	0.21 (0.09)	0.17 (0.08)	0.20(0.12)
NH_4-N	µg L^{-1}	23 (31)	40 (56)	19 (14)	52 (58)
SO_4	mg L^{-1}	4.4 (0.6)	4.3 (0.9)	4.3 (0.7)	4.0 (0.9)
Cl	mg L^{-1}	2.2 (0.8)	2.6 (0.7)	2.2 (0.8)	2.5 (0.7)*
NO_3-N	µg L^{-1}	70 (71)	98 (98)**	50 (57)	59 (58)
ANC	µeq L^{-1}	11 (11)	54 (19)*	23 (17)	17 (14)
Alr	µg L^{-1}	248 (69)	167 (40)*	191 (56)	176 (38)
Alo	µg L^{-1}	175 (59)	152 (40)	157 (49)	140 (30)
Ali	µg L^{-1}	72 (19)	15 (12)*	34 (14)	37 (18)
Tot N	µg L^{-1}	314 (163)	355 (115)	328 (115)	358 (124)
Org N	µg L^{-1}	223 (116)	217 (80)	261 (106)	247 (100)
TOC	mg L^{-1}	7.0 (2.6)	7.4 (2.1)	8.5 (2.9)	8.4 (2.3)
Org C/N		34 (6)	35 (4)	34 (4)	35 (6)

Table 6. Results of random intervention analysis comparing difference in concentrations in paired samples collected from LIM-4 (limed) and REF (reference) for the periods pre- and post-liming.

			H^+ µeq L^{-1}	pH	Ca mg L^{-1}	Mg mg L^{-1}	Alr µg L^{-1}	Ali µg L^{-1}	TOC mg L^{-1}	ANC µeq L^{-1}	NO_3-N µg L^{-1}
pre-liming	average	LIM4	15.9	4.84	1.14	0.36	250	73	7.2	11	70
n=18	average	REF	17.3	4.80	1.28	0.37	194	34	8.7	24	50
	avg. diff-pre	LIM4-REF	-1.4	0.04	0.14	0.00	56	38	1.5	13	20
post-liming	average	LIM4	1.6	5.86	1.51	0.81	167	15	7.4	54	98
n=57	average	REF	12.7	4.93	1.29	0.38	176	36	8.4	17	59
	avg. diff-post	LIM4-REF	-11.1	0.93	0.22	0.42	-9	21	1.0	36	40
change in difference between LIM4 and REF at point of time of liming, Sept. 94											
	diff post - diff pre		-9.7	0.89	0.36	0.43	65	60	0.5	49	19
	RIA level of significance, p<		0.001	0.001	0.001	0.001	0.001	0.001	n.s.	0.001	n.s.

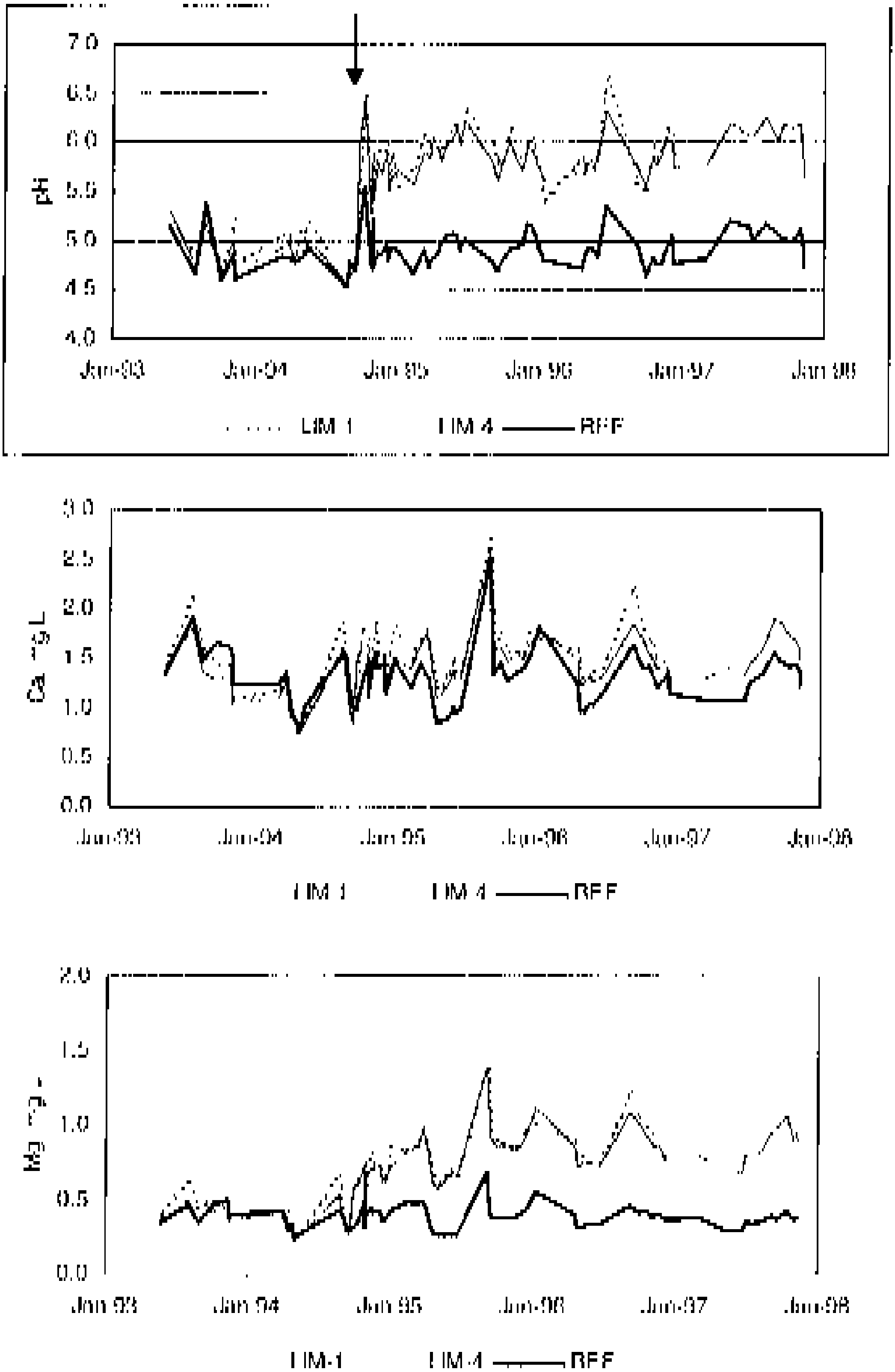

Figure 7. pH, Ca and Mg in streams of limed (LIM 1 and LIM 4) and reference (REF) catchment in the Gjerstad forest. Dolomite was spread in September 1994 (arrow).

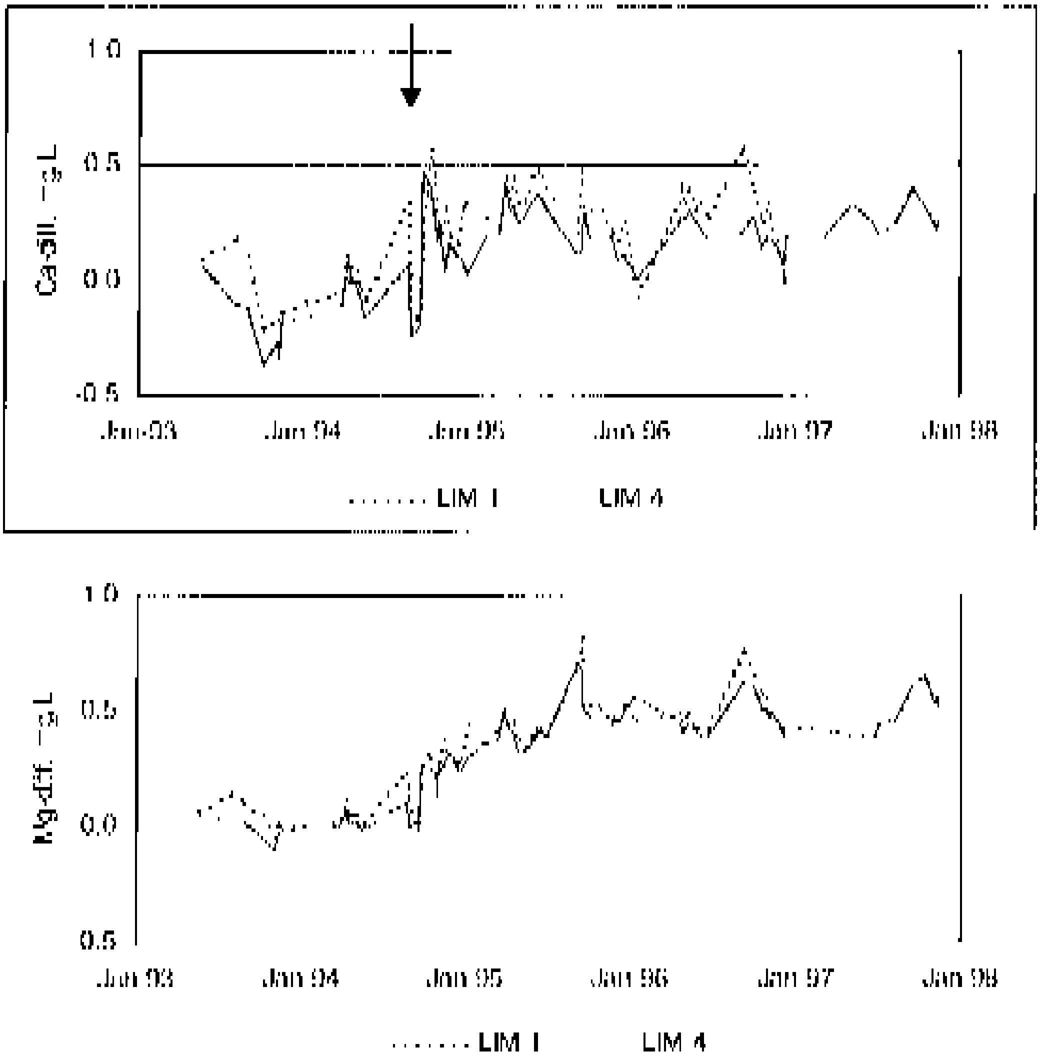

Figure 8. Differences in Ca and Mg concentrations between limed and reference streams in the Gjerstad forest. Dolomite was spread in September 1994 (arrow).

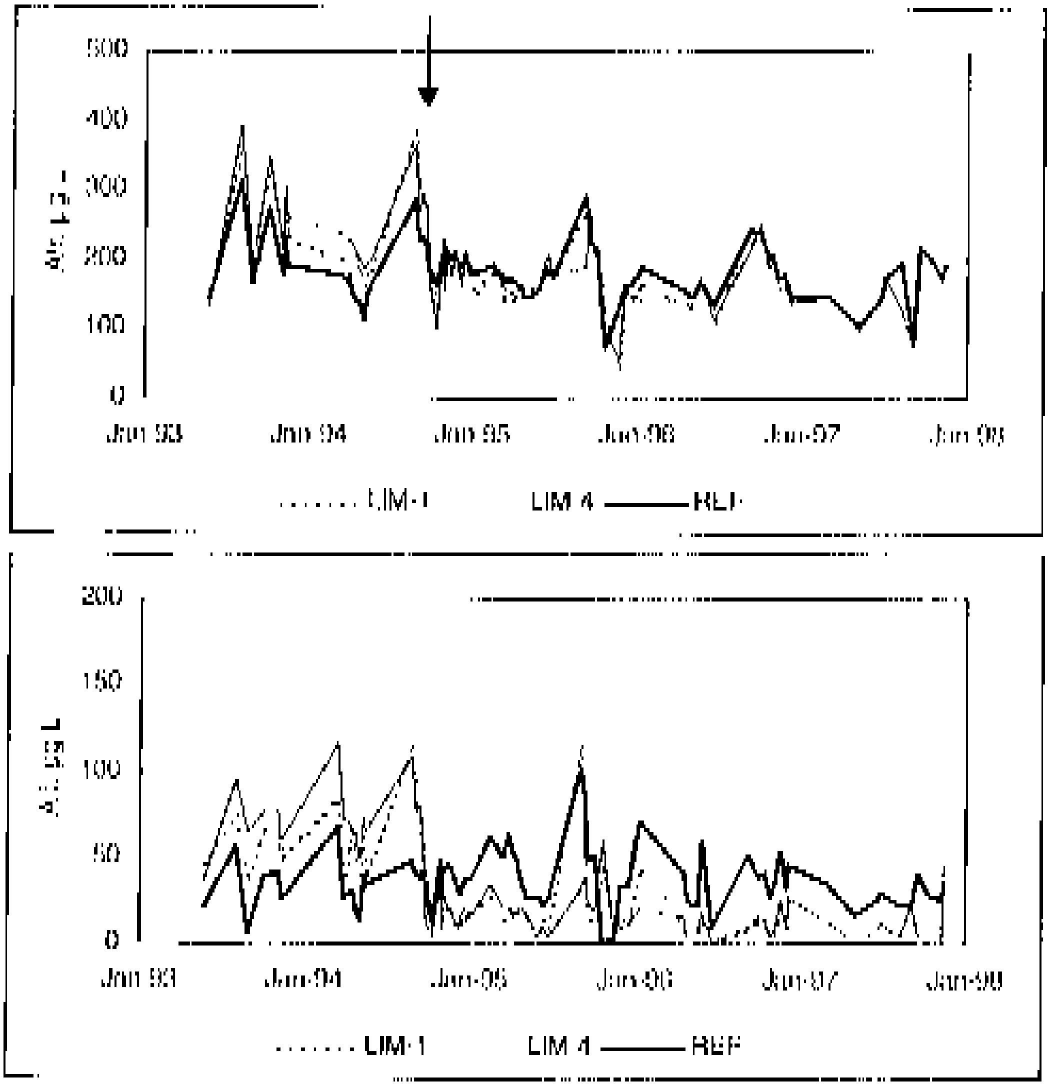

Figure 9. Reactive (Alr) and inorganic monomeric (Ali) aluminium in streams of limed (LIM-1 and LIM-4) and reference (REF) catchment in the Gjerstad forest. Dolomite was spread in September 1994 (arrow).

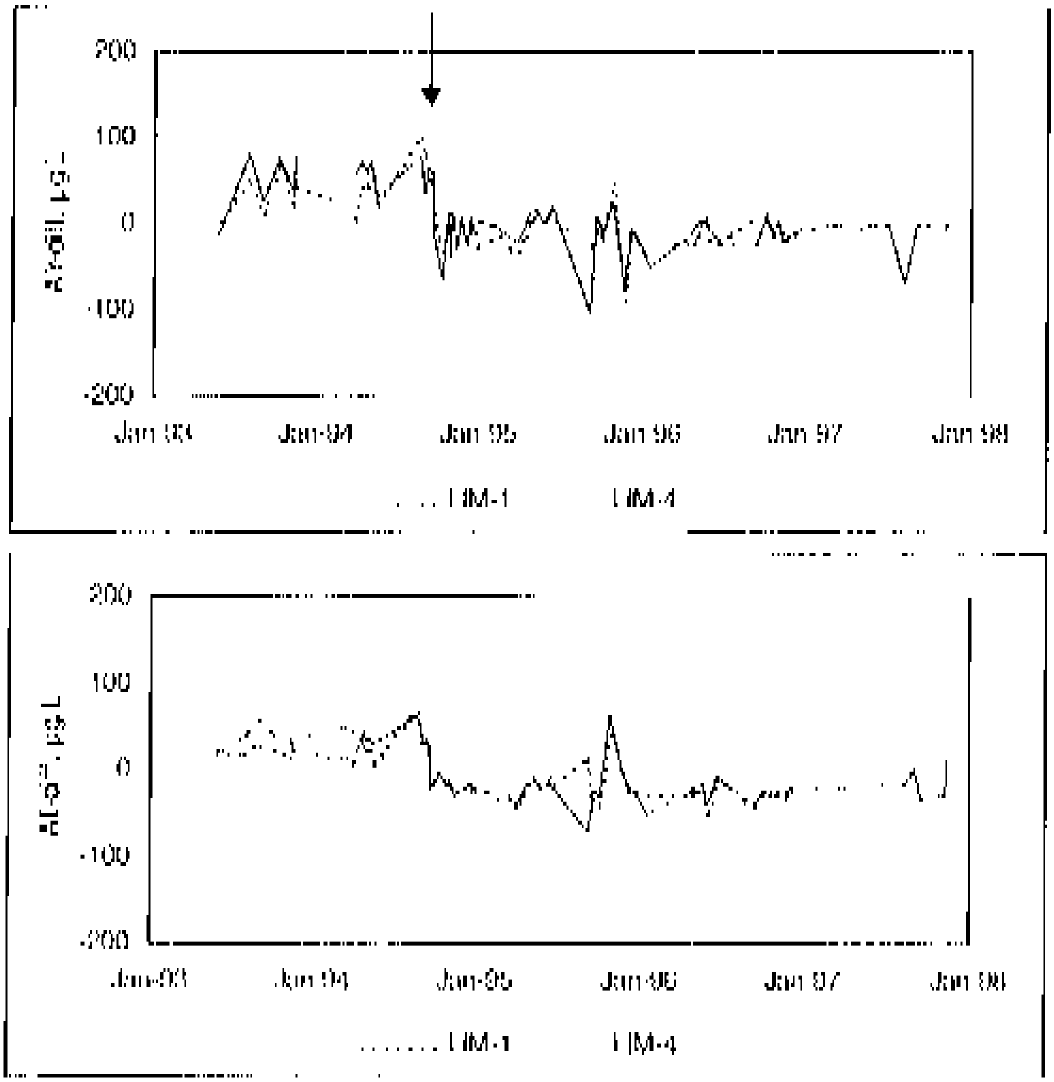

Figure 10. Differences in concentrations of reactive (Alr) and labile (Ali) aluminium between limed and reference streams in the Gjerstad forest. Dolomite was spread in September 1994 (arrow).

Sea salts were not supposed to have significant impacts on the water chemistry, in terms of episodic acidification and Mg supply to the forest soil, due to the distance from the coast. However, in January 1995 (four months after liming) a strong increase in stream Cl concentrations indicated relatively large inputs of salts, and this resulted in negative values for non marine Na and the lowest estimated ANC in the unlimed catchment in the project period **Figure 11**. The limed catchment also showed a drop in ANC, but not to negative values.

The seasonal variability was relatively large for concentrations of NO_3 (**Figure 12**). Some of the problems this might have on the statistical tests were eliminated by use of the differences between data-pairs of limed and reference samples. But also the differences were characterised by seasonal variability (**Figure 12**). This was found for both the preliming and post liming period. The streams do not appear to differ until the second winter following liming. The result of the ANOVA test of the pre-liming and post-liming NO_3-diff for LIM-1 and LIM-4 was a small but significant increase in the medians at the $p<0.05$ level in LIM-4, but not in LIM-1. Random intervention analysis showed no significant difference (**Table 6**).

The organic N fraction, the C/N-relationship of the dissolved organic matter and total phosphorus concentration did not change significantly after liming (**Table 5** and **Figure 13**).

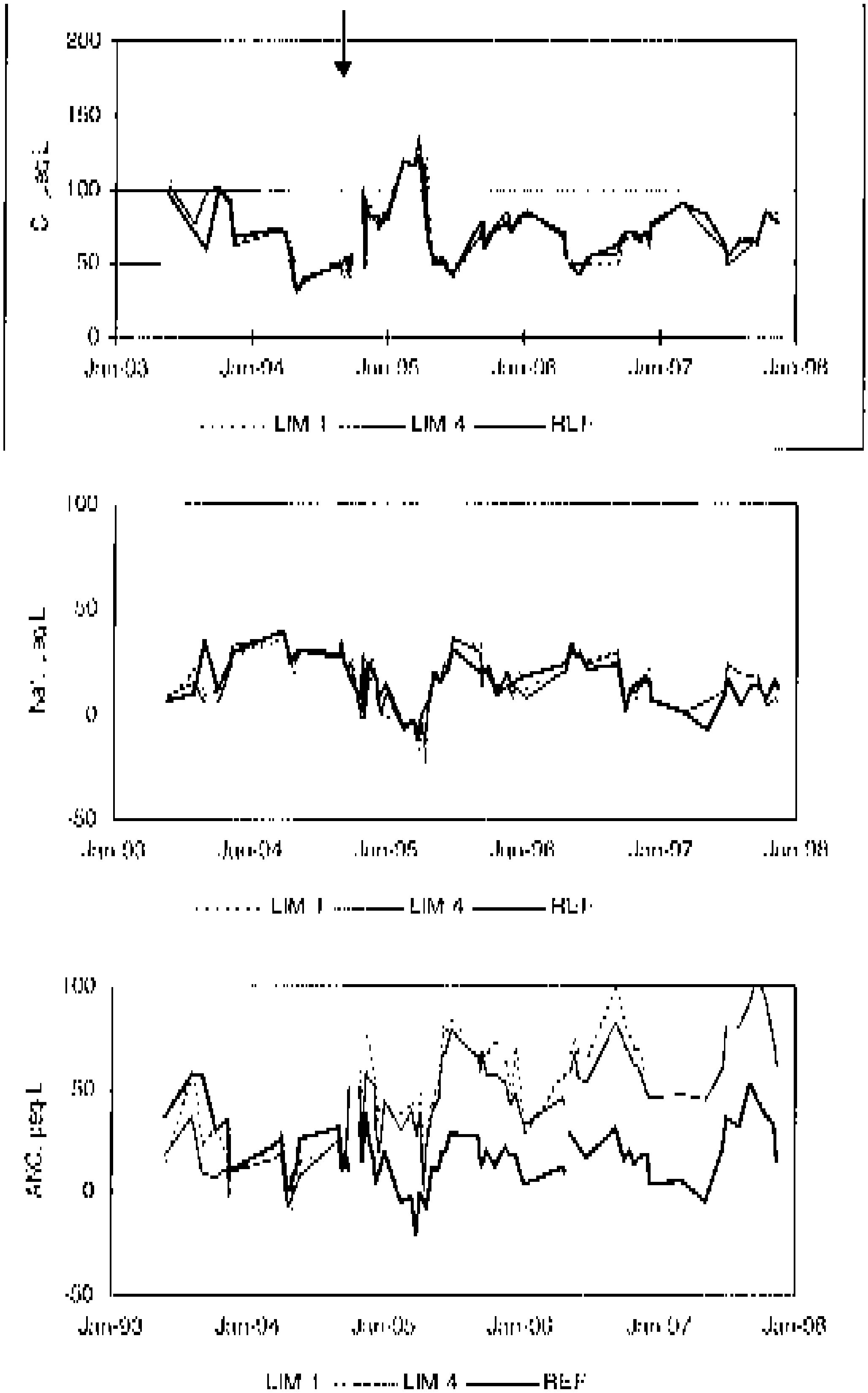

Figure 11. Chloride, non-marine Na (Na*) and ANC in streams of limed (LIM-1 and LIM-4) and reference (REF) catchment in the Gjerstad forest. Dolomite was spread in September 1994 (arrow).

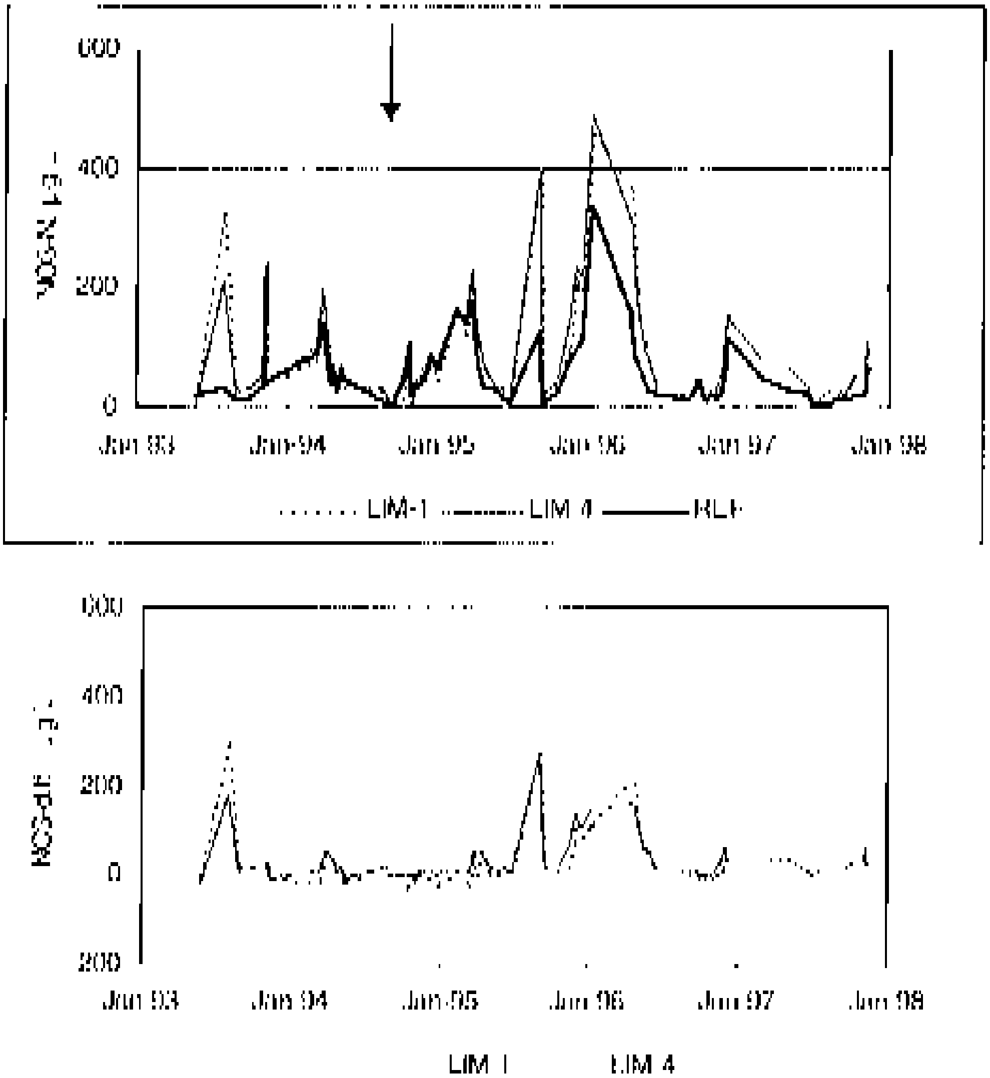

Figure 12. NO_3-N in streams of limed (LIM-1 and LIM-4) and reference (REF) catchments in the Gjerstad forest. The NO_3-N-diff. is shown in the lower panel. Dolomite was spread in September 1994 (arrow).

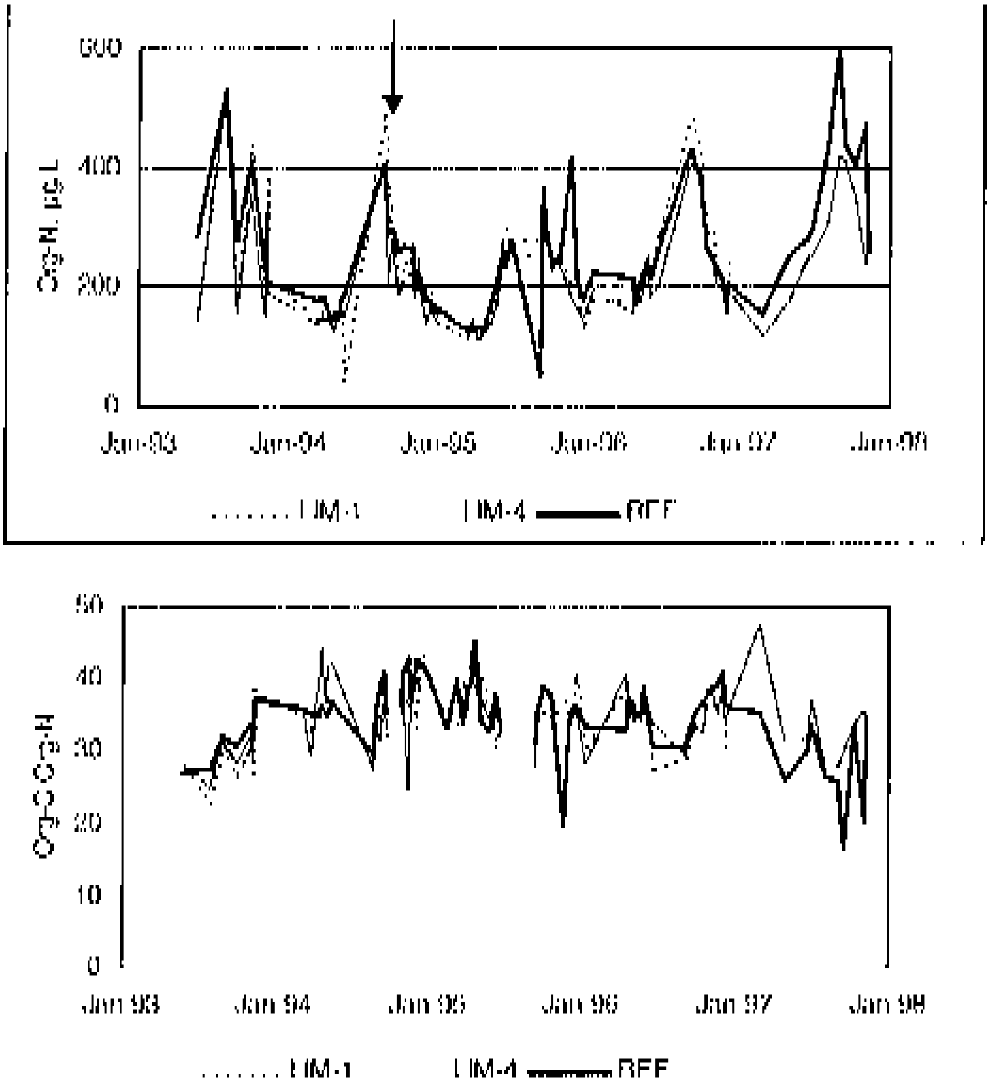

Figure 13. Dissolved organic N and the Org-C/Org-N ratio in streams of limed (LIM-1 and LIM-4) and reference (REF) catchment in the Gjerstad forest. Dolomite was spread in September 1994 (arrow).

4.2.3 Trace metals

No pre-liming data of trace metals are available and thus changes from pre liming to post liming period cannot be analysed. However, concentrations in the limed stream relative to the reference stream were analysed for differences and post-liming trends.

Relative to REF none of 10 trace metals in monthly point samples were significantly higher after liming (**Table 7**). In fact, Cd, Co, Fe, Mn, Ni, Pb and Zn were significantly lower in the stream of the limed catchment, which may be due to inherent differences between the streams or may be an effect of the liming. Only Mn, Co and Zn showed significantly decreasing trends in runoff from the limed catchment during the 3 year monitoring period (**Figure 14**). Fe, Pb, Cd, Cu, As and Ni remained relatively unaffected by the dolomite application. Cr was mostly below detection limits in both limed and unlimed catchments.

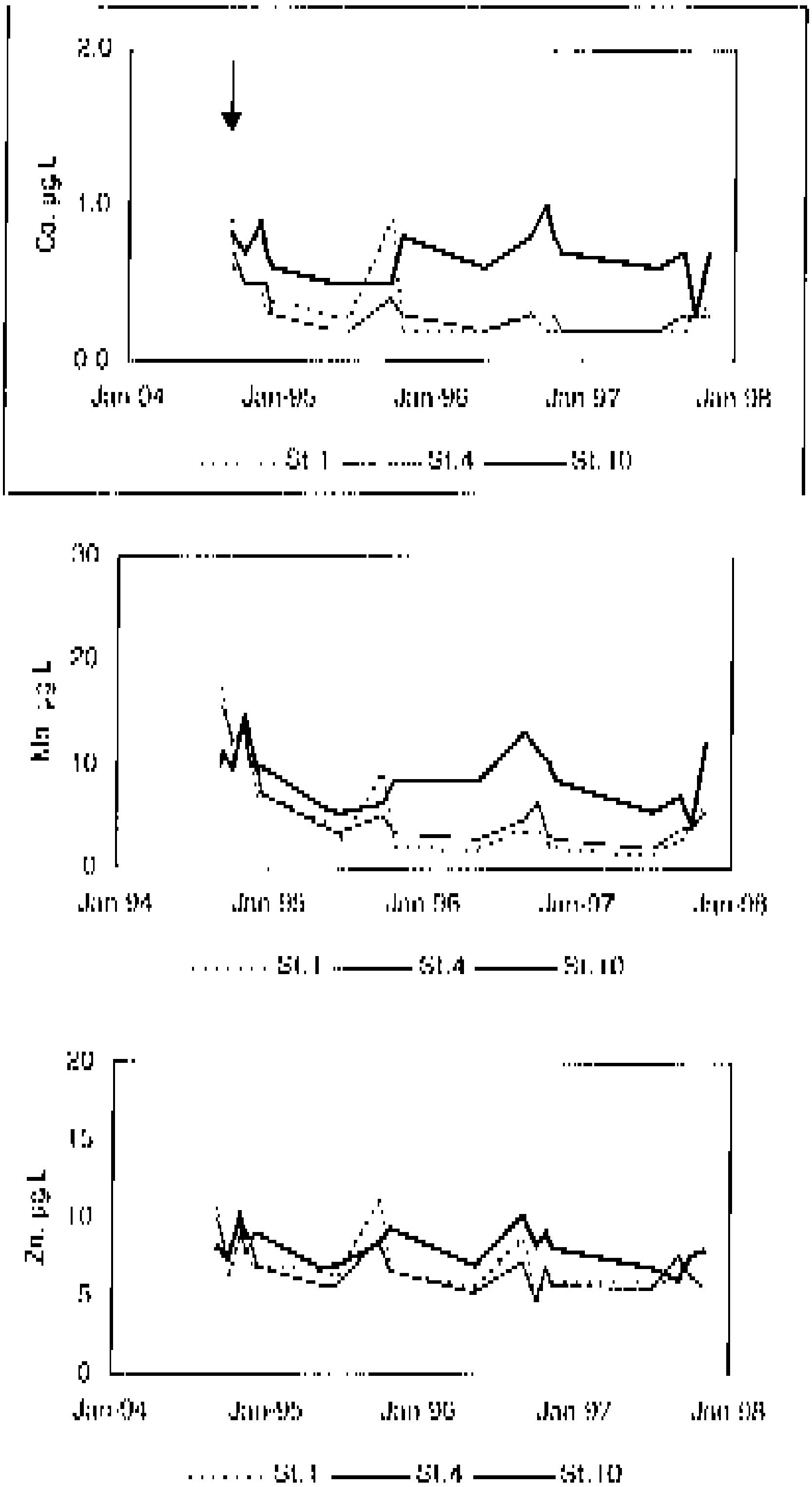

Figure 14. Cobalt (Co), manganese (Mn) and zinc (Zn) in streams of limed (LIM 1 and LIM 4) and reference (REF) catchment in the Gjerstad forest. Dolomite was spread in September 1994.

Table 7. Mean and st. dev. or median (in µg L^{-1}) of nine trace metals from point samples of streams in limed (LIM-4) and unlimed (REF) catchments. All samples (n=18) are from the post liming period. * denotes significantly (p≤0.05) lower mean or median values for LIM-4 than for REF. Other metals are not significantly different. Concentrations in the samples reported under the detection limit were set at ½ the detection limit.

	LIM-4		REF	
	Mean (st.dev.)	Median	Mean (st.dev.)	Median
As	0.27 (0.15)		0.36 (0.20)	
Cd*		0.03		0.05
Co*	0.32 (0.11)		0.68 (0.17)	
Cu	0.57 (0.17)		0.58 (0.21)	
Fe*		122		201
Mn*	5.7 (3.4)		9.0 (3.0)	
Ni*		0.8		1.05
Pb	0.64 (0.19)		0.72 (0.16)	
Zn*	6.8 (1.3)		8.2 (1.2)	

4.2.4 Ca and Mg transport

The total transport of Ca and Mg at LIM-4 during the first 3 years after liming was 2090 and 1150 kg, respectively (**Figure 15**; transport at LIM-1 is also shown). Based on the pre-liming and post-liming differences between samples from LIM-4 and REF a net transport of 518 kg Ca and 576 kg Mg from the applied dolomite was calculated for the first 3 years after liming (**Figure 16**). This corresponds to 0.9 % and 5.0 % of the added amounts of these elements. An annual transport of less than 1 % of the dose for both Ca and Mg was thus found in this experiment.

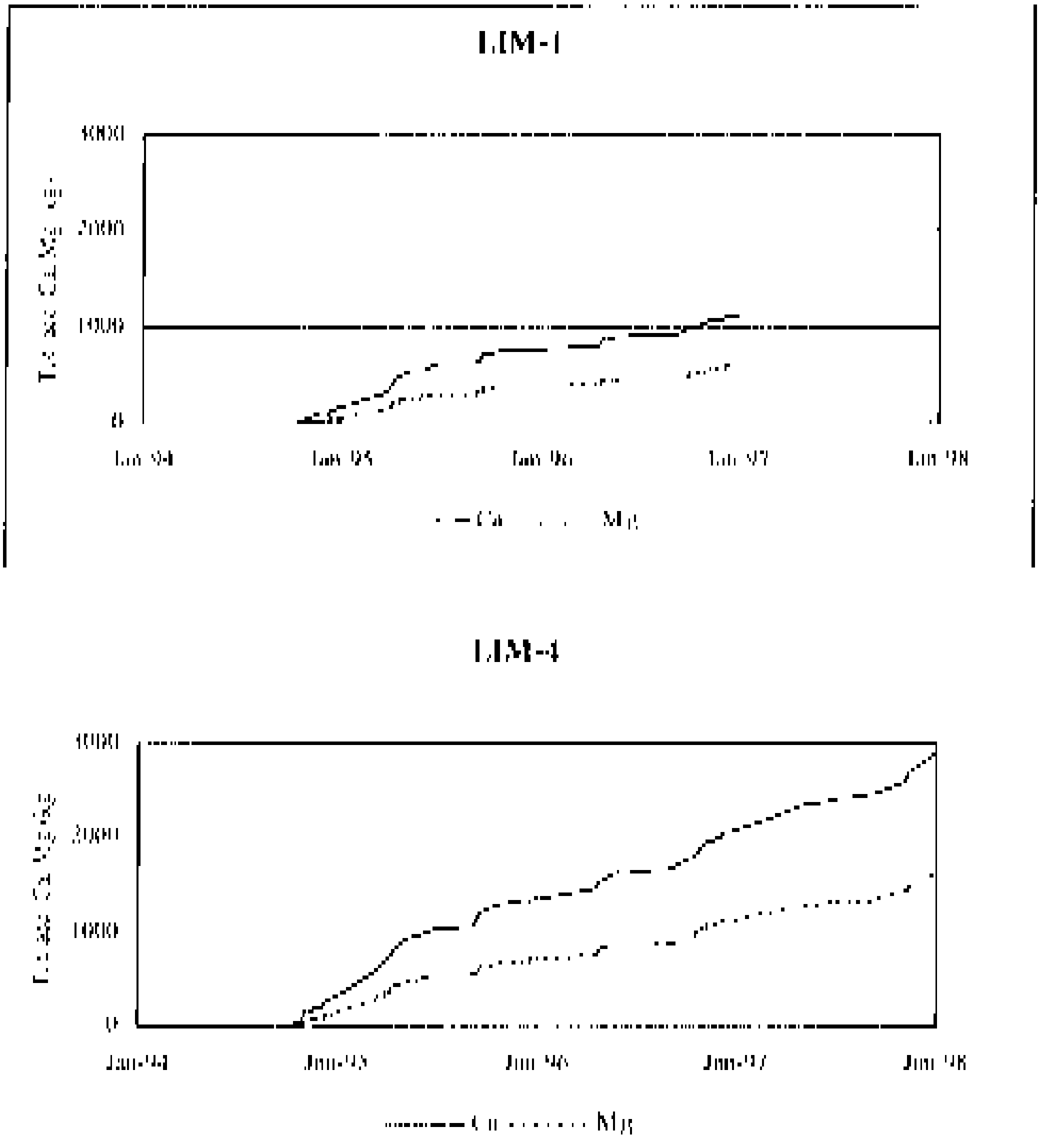

Figure 15. Accumulated total amount of Ca and Mg transported out at stations LIM-1 and LIM-4 of the limed catchment.

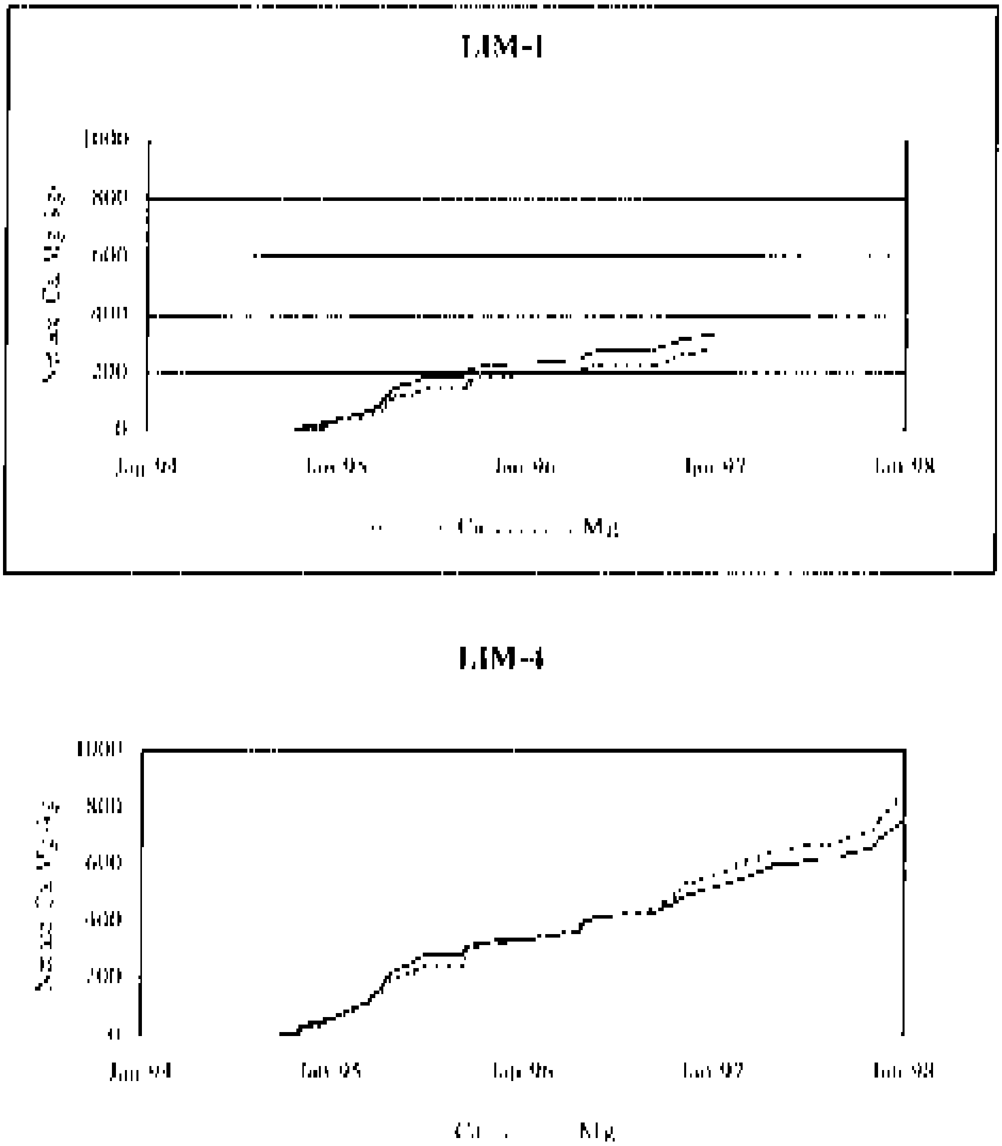

Figure 16. Accumulated net (due to liming) amount of Ca and Mg transported out at stations LIM-1 and LIM-4 of the limed catchment, relative to that expected based on transport from the reference catchment (REF).

4.3 Soil chemistry

The soil data at the lysimeter stations represent the composition of the organic (5 cm) and mineral (15 cm) soil layer before liming. Data for six locations, three located in the limed catchment and three located in the control catchment are given in **Table 8** and **Table 9**.

The results show that the soils vary widely in chemical composition. This reflects the wide range in site characteristics. The 3 sites in each catchment were intentionally chosen to cover a range in vegetation, soil and moisture conditions.

4.3.1 Soils of the control catchment

Stations SP 28 and SP 30.
This location is covered with ferns and deciduous trees. The ground water table is high, and there were never problems in filling the lysimeter bottles. The pH values in the water samples extracted from the organic and mineral soil were relatively high (4.82 and 4.9, respectively).

Stations SP 37 and SP 40
Station SP 37 is located in a hollow in the ridge hill, while SP 40 is located in a rather dry and poor slope just above SP 37. The dominating forest is coniferous. The soil solution samples normally had a vigorous yellow colour and the volume at SP 40 was usually low, especially at 15 cm.

Stations SP 46 and SP 50
These stations are located in a shady area beneath large spruce trees. The ground vegetation was poorly developed. The site is moderately dry.

4.3.2 Soils of the limed catchment

Stations FU 06 and FU 07
Stations FU 06 and FU 07 were located in poor soil in a pine forest. The soil solution samples from this location normally were low in volume and of yellow colour. The soil quality can be compared to soils at stations SP 30 and SP 40.

Stations FU 44 and FU 45
These stations are located in the bottom of a small valley with a mixed forest of coniferous and deciduous trees, among them a number of birches. The ground water level is high and the lysimeter bottles were filled up with water within a few hours.

Stations FU 48 and FU 49
Station FU 48 was placed in a boggy soil close to a stream, while FU 49 was located higher up on the ground in between the roots of a big alder. The lysimeter FU 49 seldom gave water samples at all.

Taken together the 6 soils at the 3 sites in the reference catchment are similar chemically to the 6 soils of the 3 sites in the limed catchment (**Figure 17**). The heterogeneity of the sites is reflected in the large standard deviations about the means. The soils are typical for coniferous forests in Norway, although they have rather low C/N ratios. This may reflect the long-term deposition and storage of N in the soil.

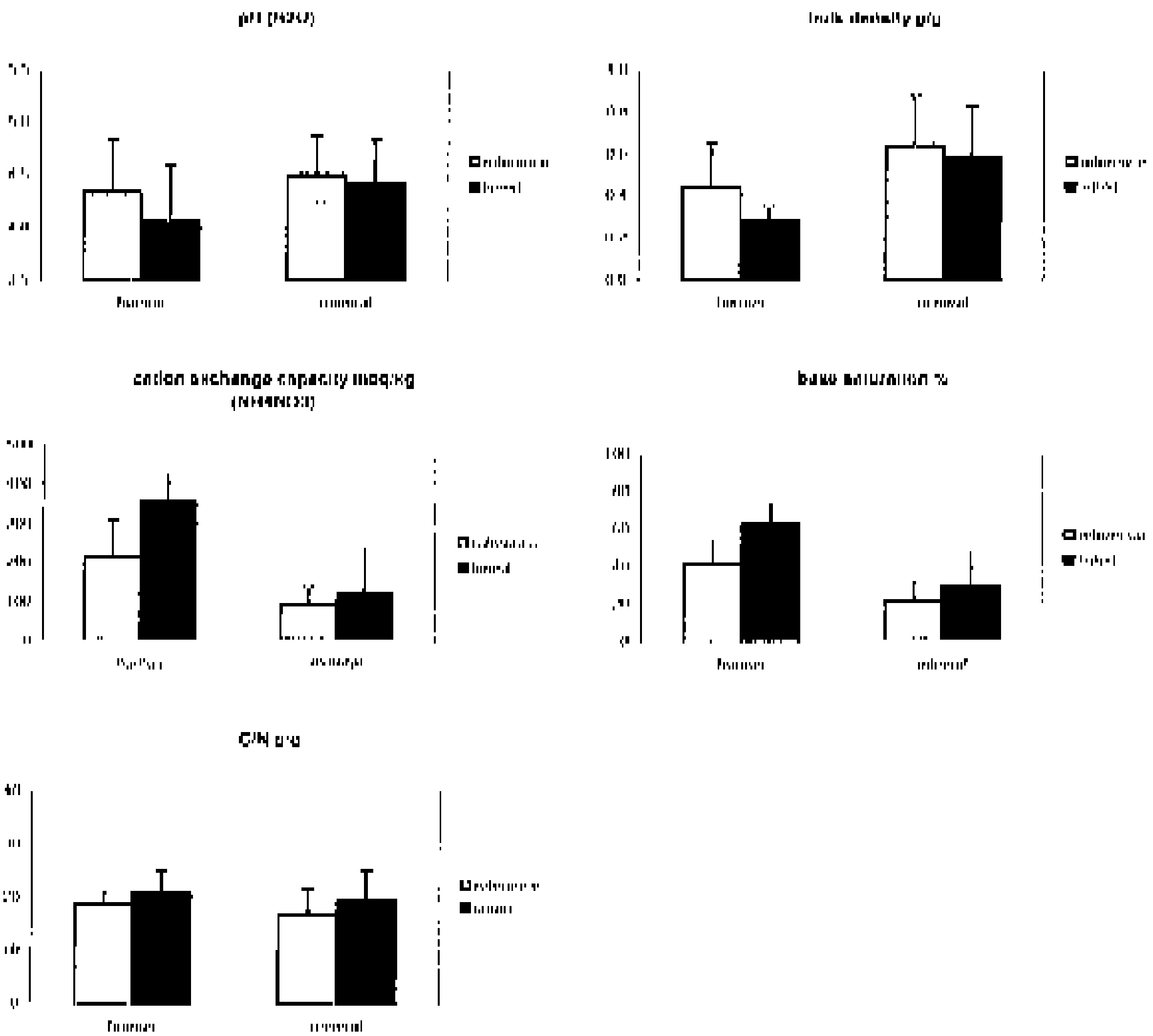

Figure 17. Soil chemistry at the 6 sites in the reference and limed catchments at Gjerstad, sampled in summer 1994 prior to liming. Mean and standard deviation of the samples (n=6 for humus; n=12-15 for mineral soil) are shown.

Table 8. a. Pre-liming composition of organic soil in three locations in the reference catchment (SP) and three locations in the limed catchment (FL). B.D. = bulk density; L.O.I. = loss on ignition; Kjel-N = Kjeldahl-N.

HUMUS GJERSTAD 1984

OBS	site		pH H_2O	B. D. g l^{-1}	Dry wt. %	L.O.I. %	Kjel-N mmol kg	calc C/N g g^{-1}	Al mmol kg	Ca mmol kg^{-1}	K mmol kg	Mg mmol kg^{-1}	Na mmol kg^{-1}	S mmol kg^{-1}
									total analyses, ICP					
35	SP25		4.56	0.526	90.4	32.76	1157	16.15	1255	25.6	19.2	104.3	6.29	53.62
36	SP30		4.52	0.23	95.3	91.53	1717	16.75	977	23.5	18.4	15.5	6.28	51.42
44	SP37		3.57	0.236	90.1	89.95	1454	21.45	260.2	33.3	25.9	16.9	8.25	78.26
45	SP40		3.6	0.263	92.7	74.05	1069	26.26	114.2	52.5	23.8	22.6	4.55	50.28
55	SP46		4.44	0.578	94.7	28.59	616	17.16	427.7	62.6	22.4	150.5	6.14	30.55
60	SP50		4.42	0.757	97.6	15.25	356	14.11	152.9	42.1	10.8	40.6	4.56	16.55
67	FL36		3.55	0.22	90.1	88.49	1051	29.57	50.66	53.3	25.7	22.1	8.62	55.54
68	FL37		3.56	0.231	90.8	56.38	1141	27.05	61.59	75.5	22.3	21.4	7.73	52.16
113	FL44		4.51	0.293	88.9	91.72	2091	15.59	403.2	134.2	25.8	23.5	13.51	121.6
114	FL45		4.58	0.255	88.1	54.54	1559	19.39	513.1	78.4	20.7	15.6	9.12	83.99
118	FL48		3.79	0.354	92.7	68.47	1410	17.34	1172	54.2	19.3	44.8	6.78	73.54
119	FL49		4.12	0.349	93.5	61.38	1328	16.57	912.4	111.8	15.2	49.7	7.4	55.34
count	SP	ref	6	6	6	6	6	6	6	6	6	6	6	6
average	SP	ref	4.24	0.44	92.30	57.25	1065.17	19.63	536.17	39.63	19.92	59.62	6.14	53.44
min	SP	ref	3.60	0.24	85.30	15.25	356.00	14.11	114.20	23.50	10.80	15.50	4.56	16.55
max	SP	ref	4.56	0.77	97.60	89.95	1777.00	26.26	1265.00	62.60	26.90	150.50	8.25	81.42
S.D.	SP	ref	0.51	0.22	3.42	29.52	518.34	4.46	455.31	15.29	5.76	56.10	1.24	20.08
count	FL	limed	6	6	6	6	6	6	6	6	6	6	6	6
average	FL	limed	4.05	0.29	90.55	60.36	1429.50	20.97	256.50	84.62	21.93	29.68	8.91	78.03
min	FL	limed	3.55	0.22	88.10	51.48	1051.00	15.59	50.66	53.20	19.30	16.60	6.78	55.34
max	FL	limed	4.58	0.35	93.50	91.72	2091.00	29.57	819.10	134.20	26.70	49.70	13.51	121.60
S.D.	FL	limed	0.54	0.06	2.11	12.27	393.49	5.66	303.37	29.31	3.54	13.39	2.54	25.17

Table 8. b. Pre-liming composition of organic soil extracts in NH_4NO_3 (1M) in three locations in the reference catchment (SP) and three locations in the limed catchment (FU). CEC = cation exchange capacity; BS = base saturation.

OBS	site		CEC	BS	Al	Ca	K	Mg	Na	P	S
					exchangeable ions						
			meq kg^{-1}	%	mmol kg^{-1}	mmol kg^{-1}	mmol kg^{-1}	mmol kg^{-1}	mmol kg^{-1}	mmol kg^{-1}	mmol kg^{-1}
34	SP29		150.5	31.6	34.55	13.79	8.09	4.29	3.48	0.1	4.1
39	SP30		219.3	24.7	62.94	35.64	14.27	10.45	5.47	0.1	5.03
44	SP37		356.4	30.3	55.5	29.45	24.31	12.29	7.45	2.89	6.29
48	SP40		291.5	48.7	14.12	46.21	17.53	13.99	4	2.89	3.72
55	SP46		180.5	51.4	21.12	35.05	7.41	5.55	1.56	0.15	4.14
60	SP50		96.2	57.1	9.33	20.95	3.55	4.07	0.95	0.15	1.24
67	FU06		427.6	54.7	7.18	75.6	21.55	17.53	8.54	1.58	3.51
68	FU07		353.3	52	10.7	72.99	17.51	17.43	7.26	2.12	4.07
112	FU44		446.4	73.4	38.78	127.5	22.58	15.55	12.97	3.48	6.64
114	FU45		302.5	58	47.54	47.54	14.07	5.47	3.76	0.1	5.23
118	FU48		265	57.6	15.4	40.62	15.29	15.3	5.4	1.09	5.14
119	FU49		316.5	79.4	4.19	90.25	12.25	25.75	5.2	1.35	3.55
count	SP	ref	5	6	6	6	6	5	6	5	6
average	SP	ref	215.92	40.57	34.67	30.20	12.55	8.65	3.82	0.77	4.09
min	SP	ref	96.21	24.70	9.33	13.79	3.55	4.07	0.95	0.10	1.24
max	SP	ref	356.40	57.10	65.90	46.21	24.31	13.99	7.45	2.89	6.29
S.D	SP	ref	95.19	13.09	24.85	11.52	7.39	4.15	2.42	1.06	1.67
count	FU	limed	5	6	5	6	6	5	6	5	6
average	FU	limed	355.65	62.52	22.25	79.63	17.30	19.61	8.62	2.15	4.74
min	FU	limed	265.00	52.00	4.19	40.62	12.25	8.47	5.20	0.12	3.55
max	FU	limed	446.40	79.40	47.54	127.50	22.55	25.75	12.97	3.11	6.55
S.D.	FU	limed	70.83	11.15	17.68	26.67	4.23	6.57	2.55	0.79	1.06

Table 9. a. Preliminary composition of mineral soils at three locations in the reference catchment (SP) and three locations in the limed catchment (FU). B.D. = bulk density; L.O.I. = loss on ignition; Kjel-N = Kjeldahl-N

MINERAL horizon GJERSTAD, 1994

OBS	site		pH H2O	B.D g/l	Dry wt %	L.O.I %	Kjel-N mmol/kg	calc. C/N g/g	Al	Ca	K	Mg	Na	P	S
									total analyses, ICP			mmol/kg			
1	FU36	1	3.92	0.69	65.2	13.79	231	24.366	49.24	19.5	7.6	9	2.93	4	11.75
2	FU36	2	4.32	0.995	58.8	5.94	84	24.288	157.2	12.1	8.8	21.2	2.22	2.8	4.57
3	FU07	1	3.75	0.518	67.2	22.95	434	20.288	95.24	28.3	11.2	13.8	2.55	6.7	22.71
4	FU07	2		0.533	96.8	28.02	409	24.457	97.35	27	9.6	13.4	2.91	5.8	20.52
5	FU07	3	4.44	0.543	97	2.11	159	24.935	291.2	18.8	12.1	34.2	2.42	7.6	10.27
6	FU44	1	4.79	0.208	90.1	90.35	1884	17.127	293.7	138.4	14.9	25.2	4.22	26.9	103.5
7	FU44	2	4.57	0.779	97.3	14.74	373	14.113	272.1	15.9	4.4	15.6	2.51	5.5	29.51
8	FU48	1	4.81	0.229	88	84.34	1545	15.521	1120	45.7	5.6	12.3	2.55	47.3	97.52
9	FU48	2	5.06	0.335	89.1	59.7	1152	15.035	1976	52.1	7.8	22.9	3.05	52	69.77
10	FU48	3		0.334	88.8	99.56	1128	15.699	1970	49.6	5.6	22.5	3.5	54.5	88.18
11	FU48	1	4.28	0.548	96.9	20.1	482	14.592	295.7	29	1.3	83.9	4.43	11.6	25.48
12	FU48	2	4.54	0.811	97.6	8.38	178	17.51	395.9	24.7	12.3	129	4.56	7.6	11.92
13	FU49	1	4.36	0.627	97.6	15.44	413	13.352	293.1	31.6	5.3	104	5.09	13.4	22.25
14	FU49	2	4.55	0.795	97.7	8.37	169	15.552	551.6	52.3	16.2	206.1	6.44	5.8	13.92
15	SP28	1	4.90	0.343	89.5	97.21	1432	14.268	1411	31.7	13.3	104.8	3.07	45.1	76.99
16	SP28	2		0.35	89	98.35	1436	14.507	1443	31.2	15.2	105.5	3.25	44.7	81.15
17	SP28	3	4.81	0.519	92.5	31.51	703	15.063	1367	29.3	13.3	121.9	3.75	29.1	34.66
18	SP32	1	4.55	0.272	87.3	73.05	1650	15.822	1306	24.1	9.3	35.4	2.59	52.3	67.22
19	SP32	2	4.58	0.623	94.8	20.63	478	15.414	1088	26.4	12.9	141.2	3.61	22.7	25.55
20	SP37	1	4.11	0.498	97.1	18.59	344	19.3	193.5	10.2	6.4	16.9	2.45	10	13.34
21	SP37	2	4.33	0.953	98.8	4.71	106	15.569	166.9	7.4	4.7	5.2	1.66	4	4.5
22	SP37	3		0.981	98.8	4.74	103	16.456	168.5	5.7	6.2	5.3	1.94	3.7	4.88
23	SP40	1	3.69	0.641	98.1	13.28	201	23.598	159.2	12.4	20.1	46.8	2.28	6.7	19.64
24	SP40	2	3.97	0.932	98.9	5.4	99	28.487	146.8	8.8	18	41.7	2.18	3.8	3.89
25	SP48	1	4.55	0.62	98.8	21.88	584	18.561	3477	50	15.4	135.6	2.76	40.9	26.95
26	SP48	2	4.73	0.686	96	13.13	249	18.661	648.5	47.9	20.1	148.3	3.89	37	18.13
27	SP50	1	4.47	0.611	95.1	10.98	252	15.567	146.4	28.7	7.8	31.7	4.65	16.4	12.19
28	SP50	2		0.715	95.2	10.62	246	15.482	150.1	31.9	8	32.7	4.28	17	12.58
29	SP50	3	4.49	0.83	95.2	8.08	181	15.949	222.2	25.1	6.8	50.9	4.3	14.7	10.29

MINERAL horizon GJERSTAD
1994

OBS	site		pH H_2O	B.D. g g⁻¹	Dry wt. %	L.O.I. %	Kjel-N mmol kg⁻¹	calc C/N g g⁻¹	Al	Ca	K	Mg	Na	P	S
									total analyses ICP			mmol/kg			
count	FU	limed	12	14	14	14	14	14	14	15	14	14	14	14	14
average	FU		4.43	0.55	95.1	31.7	816.2	19.4	566.6	37.4	9.6	52.5	3.6	15.0	35.7
min	FU		3.78	0.20	88.0	5.9	84.0	13.4	49.2	12.1	4.4	9.0	2.2	2.9	4.6
max	FU		5.16	1.00	99.6	90.4	1884.0	25.5	1975.0	135.4	14.8	209.1	6.4	54.3	103.5
S.D.			0.46	0.25	4.03	25.01	575.06	4.04	656.58	30.77	2.49	59.25	1.27	15.50	37.28
count	SP	ref	12	15	15	15	15	15	15	15	15	15	15	15	15
average	SP		4.51	0.64	95.4	23.3	524.9	17.1	539.8	24.9	11.6	68.6	3.5	23.3	25.0
min	SP		3.69	0.27	87.3	4.7	99.0	14.3	145.4	7.4	4.7	9.2	1.8	3.7	3.9
max	SP		4.91	0.98	99.9	75.1	1650.0	23.6	1506.0	55.0	27.1	145.3	6.0	52.8	87.2
S.D.			0.37	0.23	3.36	21.59	533.79	2.55	578.57	13.46	4.50	51.44	1.35	17.79	29.15

Table 9. b. Preliminary composition of mineral soils extracts in NH_4NO_3 (1M) at three locations in the reference catchment (SP) and three locations in the limed catchment (FU). CEC = cation exchange capacity; BS = base saturation.

OBS site	sample	CEC meq/kg	BS %	Al mmol/kg	Ca mmol/kg	K mmol/kg	Mg mmol/kg	Na mmol/kg	P mmol/kg	S mmol/kg
				exchangeable ions						
1 FU06	1	62.2	37.5	5.15	6.97	4.24	2.3	0.57	0.16	0.49
2 FU06	2	46.7	5.3	15.54	0.5	0.68	0.29	0.22	0.1	0.37
3 FU07	1	126.4	34.8	18.82	15.95	2.55	3.9	0.73	0.1	0.72
4 FU07	2	126.8	33.3	18.9	15.57	2.53	3.89	0.77	0.1	0.58
5 FU07	3	59.1	7.3	19.31	1.11	1.15	0.37	0.22	0.1	0.9
6 FU44	1	467.3	63	43.72	116	28.73	21.08	3.56	0.97	5.94
7 FU44	2	55.6	23.4	15.94	4.65	2.31	0.84	0.42	0.1	0.66
8 FU45	1	242.6	33.8	55	33.33	9.37	4.47	1.9	0.1	2.95
9 FU45	2	133.5	50	24.88	27.17	5.5	2.69	1.66	0.1	2.06
10 FU45	3	133.9	48.5	25.42	26.46	4.91	2.71	1.72	0.1	2.21
11 FU48	1	59.8	28.7	19.35	5.85	3.44	4.01	0.58	0.1	1.7
12 FU48	2	45.8	16.1	13.2	1.52	2.09	0.85	0.35	0.1	0.95
13 FU49	1	73.3	30.3	15.79	6.04	3.17	3.1	0.77	0.1	1.5
14 FU49	2	44.5	8.4	14.98	0.42	1.32	0.63	0.35	0.1	1.5
15 SP28	1	159.4	32.3	36.32	15.39	9.18	3.06	1.48	0.1	4.25
16 SP28	2	155.6	32.1	35.62	15.2	8.59	3.1	1.48	0.1	4.05
17 SP28	3	53.8	25.8	22.39	7.45	2.56	1.65	0.67	0.1	2.51
18 SP30	1	160.5	25.2	48.18	13.55	7.74	4.24	1.71	0.1	4.62
19 SP30	2	60.6	23.1	17.62	4.54	2.26	0.97	0.72	0.1	1.55
20 SP37	1	129.5	15.7	34.55	5.51	4.1	2.28	0.65	0.1	0.9
21 SP37	2	46.7	6.5	14.94	0.77	0.68	0.29	0.23	0.1	0.22
22 SP37	3	45.6	6.3	15.75	0.5	0.62	0.29	0.26	0.1	0.25
23 SP40	1	93.9	24.5	16.57	7.29	3.19	2.42	0.38	0.22	0.64
24 SP40	2	55	9.5	14.63	1.41	0.84	0.64	0.28	0.1	0.26
25 SP46	1	94.6	31.7	19.02	10.25	3.53	2.58	0.51	0.1	1.93
26 SP46	2	54.8	14.6	18.51	2.79	1.67	0.59	0.41	0.1	1.45
27 SP50	1	56.7	34.7	10.59	7.85	2.94	2.05	0.41	0.1	1.11
28 SP50	2	64.2	32.9	10.71	7.2	2.63	1.57	0.37	0.14	1.12
29 SP50	3	46.9	26	12.47	2.31	1.01	0.82	0.27	0.1	0.69

OBS	site		CEC µeq/kg	BS %	Al mmol/kg	Ca mmol/kg	K mmol/kg	Mg mmol/kg	Na mmol/kg	P mmol/kg	S mmol/kg
					exchangeable ions						
count	FU	limed	14	14	14	14	14	15	14	14	14
average	FU	limed	122.18	30.2	21.9	15.7	4.5	3.7	1.0	0.2	1.5
min	FU	limed	44.50	5.3	5.2	0.4	0.7	0.3	0.2	0.1	0.4
max	FU	limed	467.30	63.0	55.0	115.0	16.7	21.1	3.6	1.0	3.9
S.D.	FU	limed	113.18	17.06	12.54	30.07	4.19	5.25	0.93	0.22	1.04
count	SP	ref	15	15	15	15	15	15	15	15	15
average	SP	ref	90.28	22.1	21.9	6.8	3.5	2.1	0.7	0.1	1.7
min	SP	ref	46.70	6.5	10.7	0.8	0.6	0.3	0.2	0.1	0.2
max	SP	ref	180.90	34.7	48.2	15.4	9.2	5.1	1.7	0.2	4.6
S.D.	SP	ref	45.35	9.96	11.70	5.02	2.88	1.60	0.50	0.03	1.50

4.4 Soil solution

The lysimeters were installed in September 1994. Samples collected through 31 October 1994 were disregard here due to possible effects of disturbance caused by the installation.

The chemical composition of soil solution varies widely between the sites, in part reflecting the heterogeneity of soil and site properties. For example, pH in the humus layer was about 4 at site SP40, FU 06 and FU 07, but 5.5-6.0 at site SP28, FU 44 and FU 45 (**Figure 18** and **Figure 19**). There were no trends over time in pH at any of the lysimeters in either the limed or reference catchments.

Mg concentrations in soil solution also varied from site to site (**Figure 20** and **Figure 21**). At 5 of the lysimeters in the limed catchment the Mg concentrations show a statistically significant ($p<0.05$) increase during the 3 years following liming. There were no significant trends in Ca concentrations (**Figure 22** and **Figure 23**).

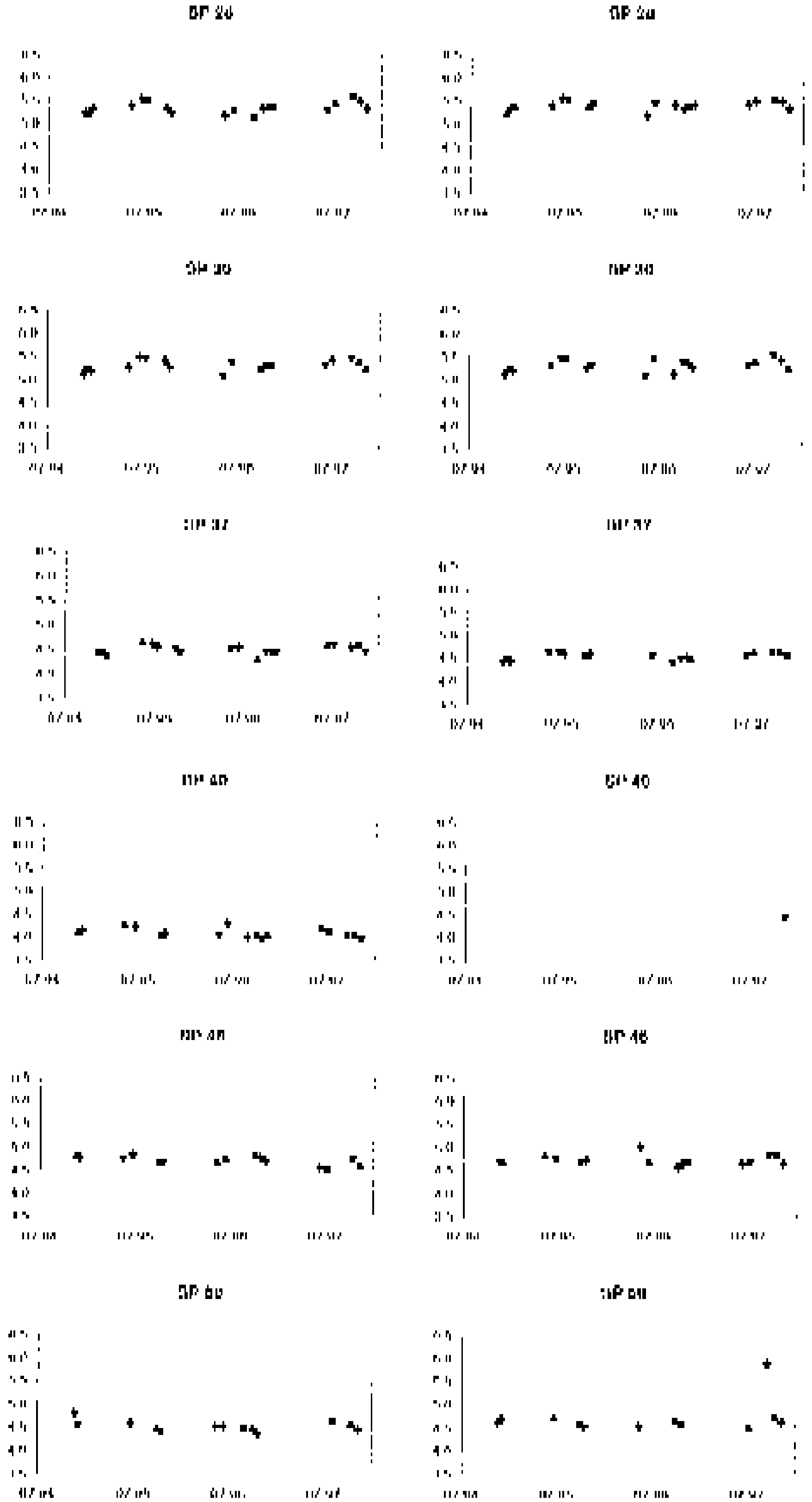

Figure 18. pH in soil solution in plots in the reference catchment.

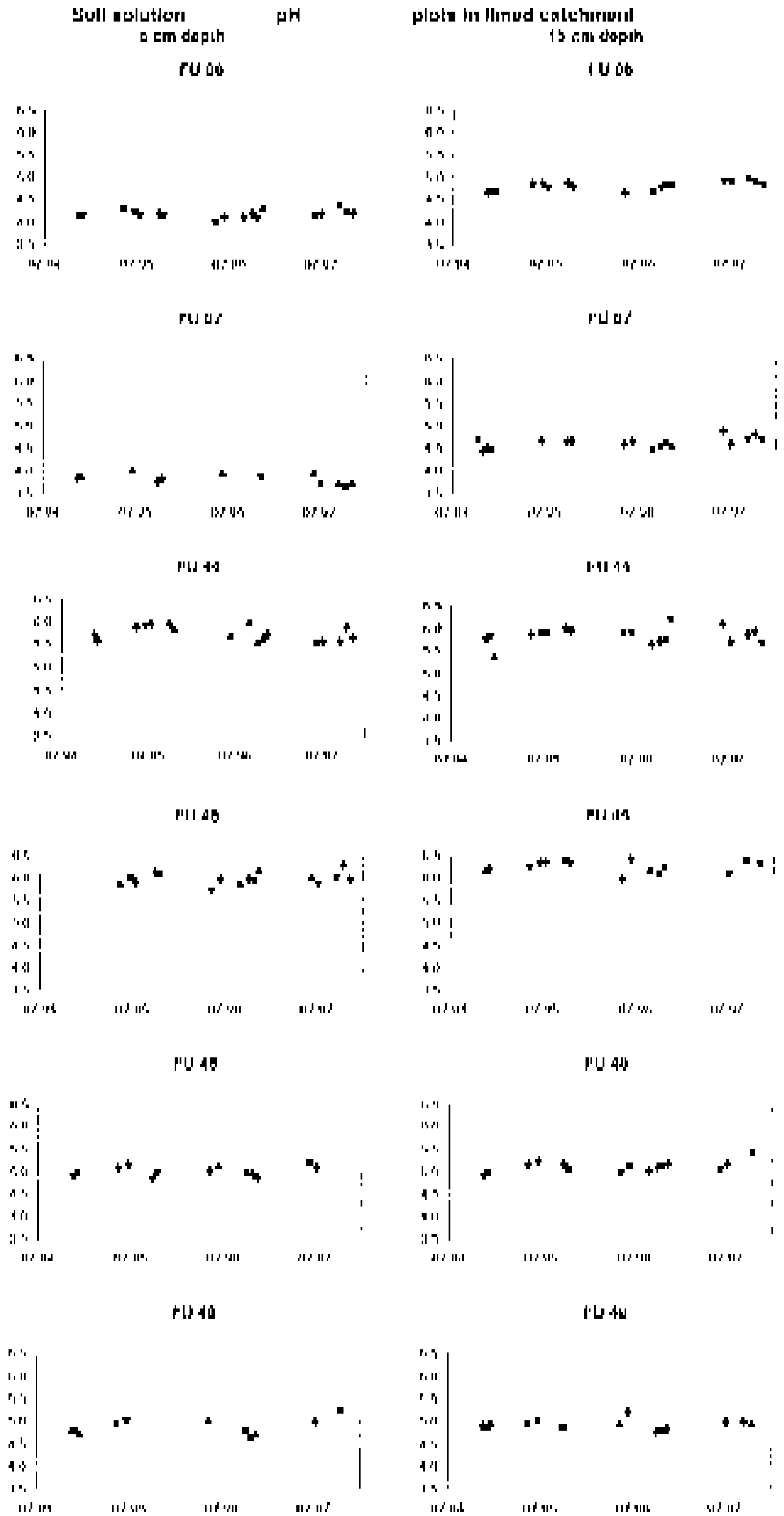

Figure 19. pH in soil solution in plots in the limed catchment.

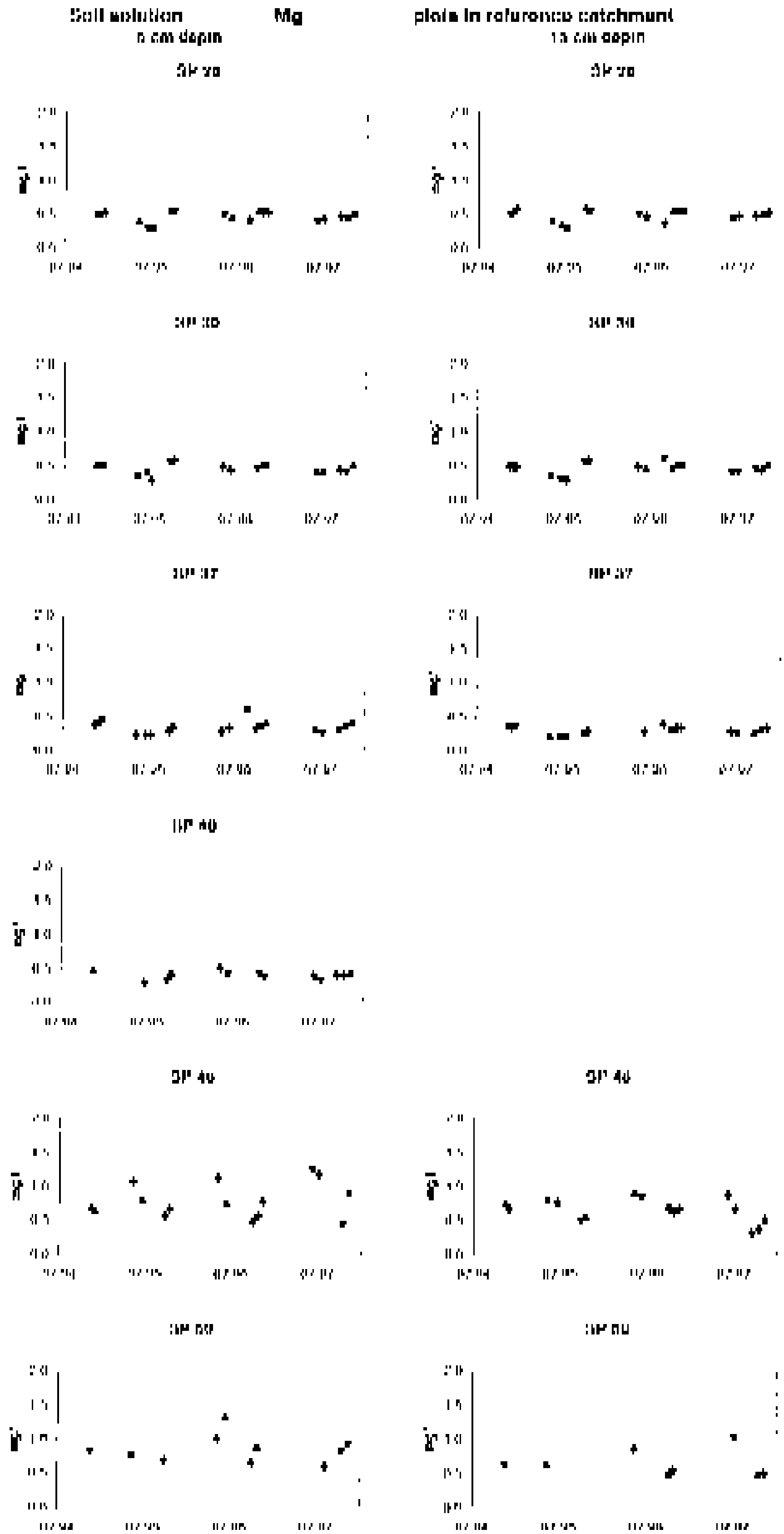

Figure 20. Mg concentrations in soil solution in plots in the reference catchment

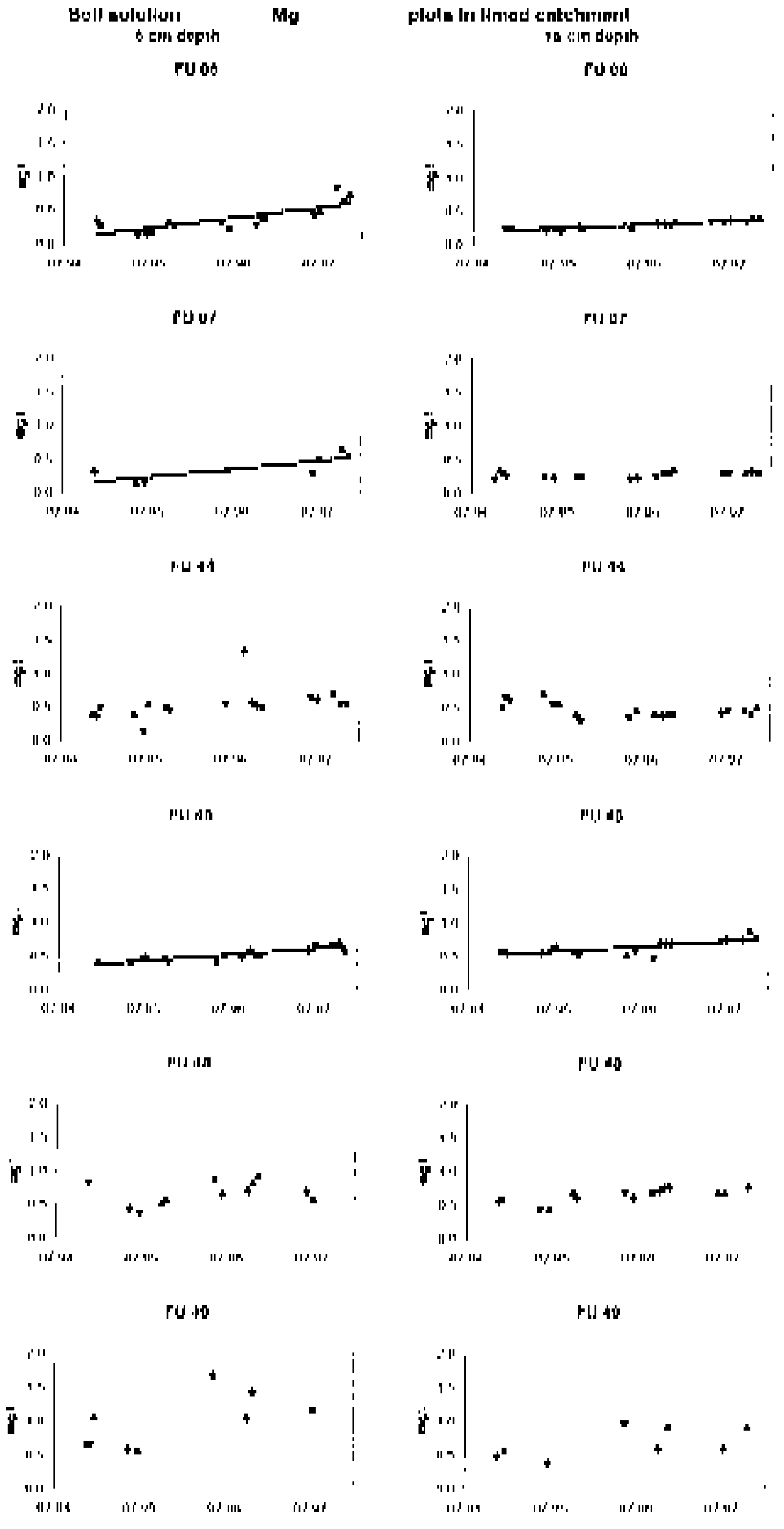

Figure 21. Mg concentrations in soil solution in plots in the limed catchment. Significant linear trends indicated by regression lines.

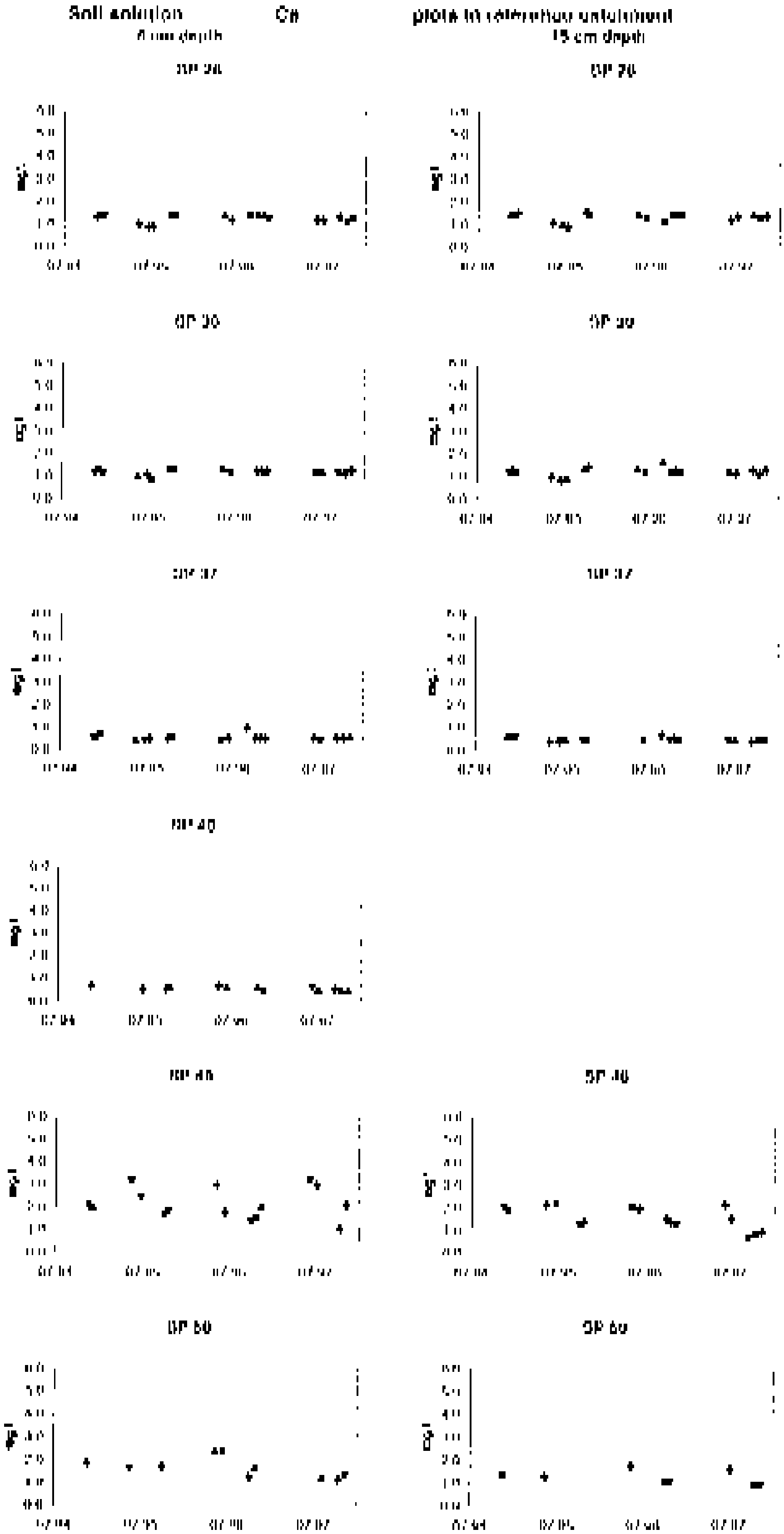

Figure 22. Ca concentrations in soil solution in plots in the reference catchment.

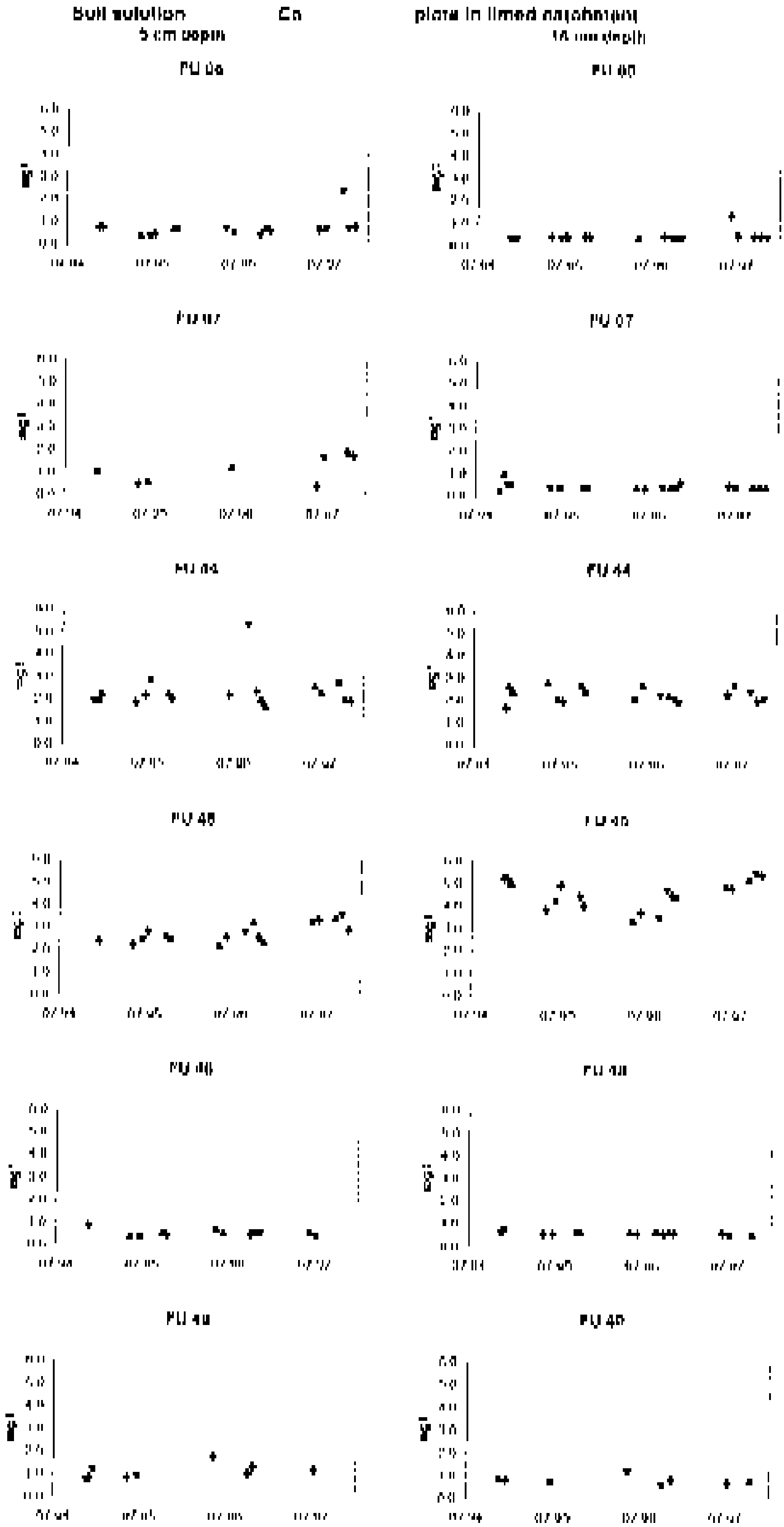

Figure 23. Ca concentrations in soil solution in plots in the limed catchment.

4.5 Forest investigations

4.5.1 Forest condition

In **Figure 24** the distribution of different cutting classes is shown in the two catchments. The sampling intensity is approximately 3% for both areas, and the stand composition is fairly alike. In the reference area there is less young and middle-aged forest. Here, about 70% of the forest area is classified as old production forest or old forest, while in the limed catchment this proportion is 50%.

Figure 24. Area distribution of different cutting classes in the two catchments. Cutting classes according to following definition: I- Forest under regeneration, II - Regenerated areas and young forest, III - Young production forest, IV - old production forest, V - old forest.

Table 10 and **Table 11** show aggregated figures for forest condition in the two catchments. The share of Scots pine to Norway spruce is higher in the reference area (70/30) compared to the limed area (56/44). A small fraction of broad-leaved trees in the middle aged and old stands is typical for this region. The clear-cut areas in the catchments are mainly dominated by birch or trembling aspen.

Table 10. Some key figures for the forest stands in the two catchments.

	Fuglehåsen - limed area	Spjotåsen - reference area
Area	84.4 ha	40.8 ha
Total standing volume	9920 m³	6027 m³
Mean diameter	140 mm	157 mm
Mean height	10.4 m	11.4 m
Average volume per tree	0.157 m³	0.187 m³
Mean age	67 yr	77 yr
Number of sample plots	122	56
Sample intensity	2.9%	2.7%
Site index (H_{40})	12.4	11.8

Table 11. Volume in different cutting classes and by tree species in the two catchments.

Fiplelåsen - limed catchment

	Volume (m^3)						
Cutting class	Spruce	Pine	Birch	Aspen	Oak	Other broadleaves	Sum
III	230	445	177	177	124	18	1171
IV	703	990	92	144	101	3	2033
V	2516	3025	192	502	306	51	6592
Sum	3449	4460	461	823	531	72	9796

Spjotåsen - reference catchment

	Volume (m^3)						
Cutting classes	Spruce	Pine	Birch	Aspen	Oak	Other broadleaves	Sum
III	48	231	8	108	16	2	413
IV	467	1015	36	114	1	1	1634
V	1050	2318	117	214	57	47	3803
Sum	1565	3564	161	433	74	50	5847

4.5.2 Intensive monitoring plots

The increment in the 4-year period 1994-1998 is compared to the estimated increment based on increment function (**Figure 25**) The overall level of estimated increment is 70% for the reference catchment and 77% for the limed catchment. This difference is not significant. As seen from **Figure 25** the variation in residuals is rather large. One plot, no 6 in the reference catchment, has a very low increment compared to that expected from the function. This is probably caused by low vitality and declining trees. The reason for this has not been investigated further.

The average crown density and crown colour are shown in **Figure 26** and **Figure 27**. The crown density is also relatively low, with many of the stands with less than 85% crown density for most of the period. The level varies little from year-to-year, no effect of liming can be extracted. The same holds for the crown colour. The year-to-year variation is more pronounced for crown colour. An increase in colour value (more yellow trees) was found in 1995. Then a steady decrease in value (more green trees) has been noted in both catchments.

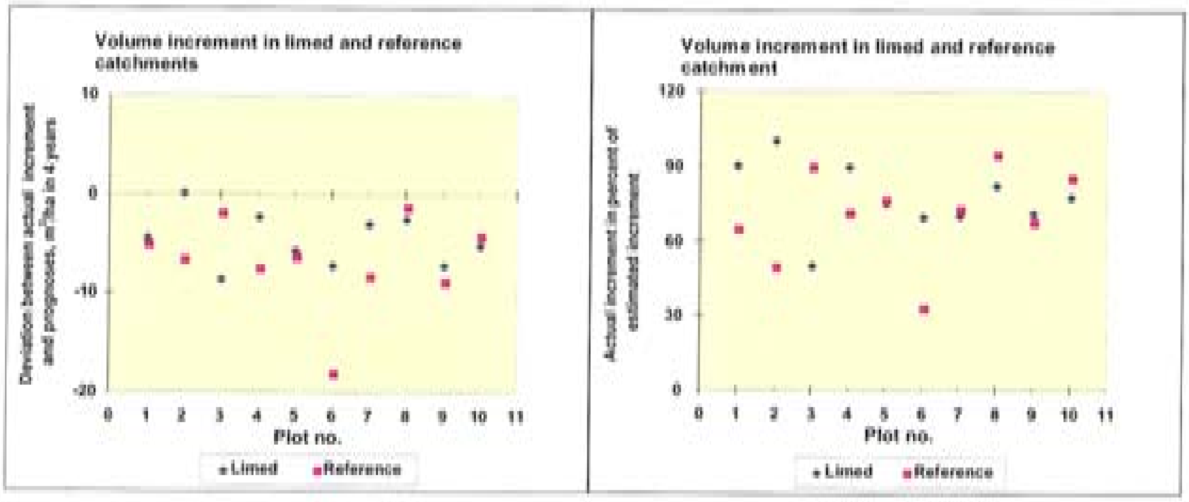

Figure 25. Differences between measured and estimated increment on the intensive monitoring plots. Residuals ($m^3 ha^{-1}$ in 4 years) (left) and measured increment in percent of estimated (right).

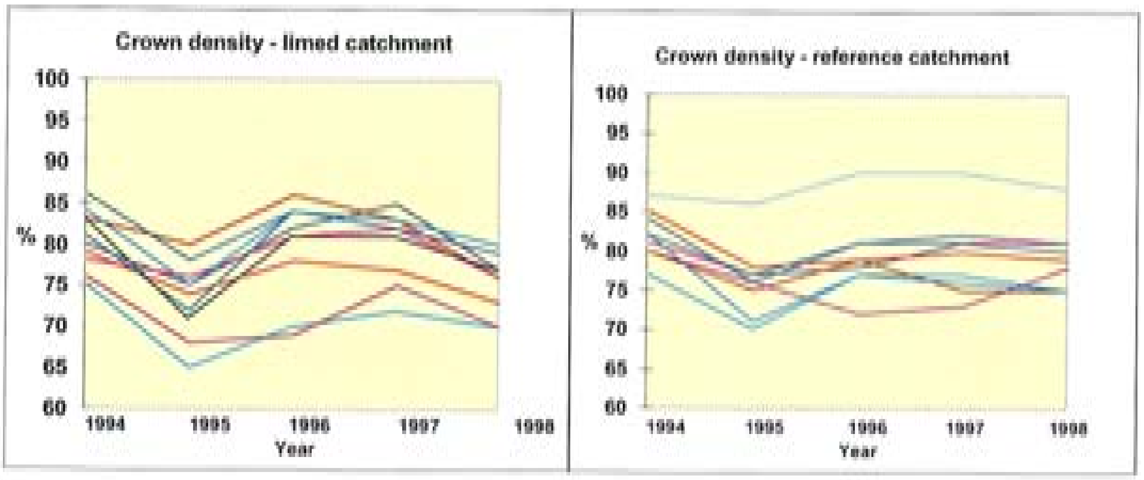

Figure 26. Average crown density on intensive monitoring plots in the period in the two areas.

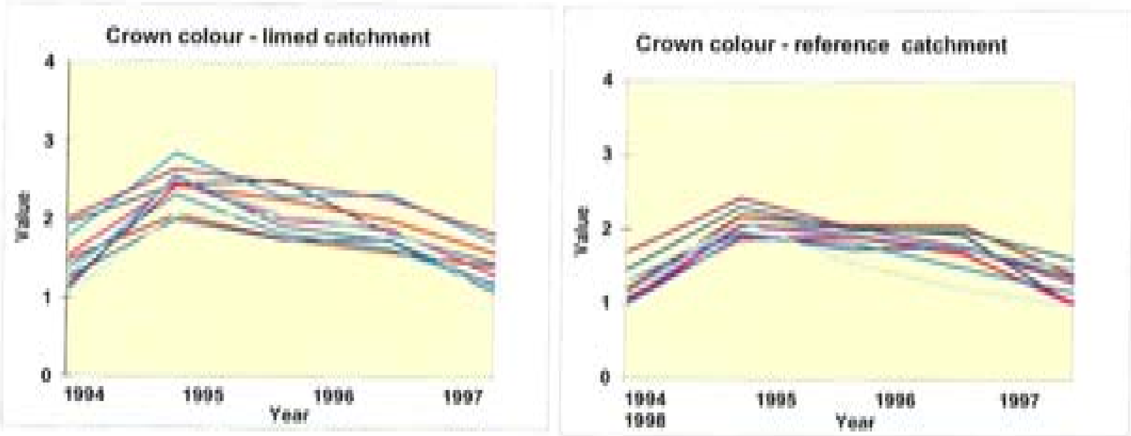

Figure 27. Average crown colour in the intensive monitoring plots during the period in the two catchments.

In **Figure 28** the percentage amount of green trees in each plot can be seen. For most of the plots an almost complete recovery in crown colour compared to 1994 has occurred. Still some stands have low proportions of green trees.

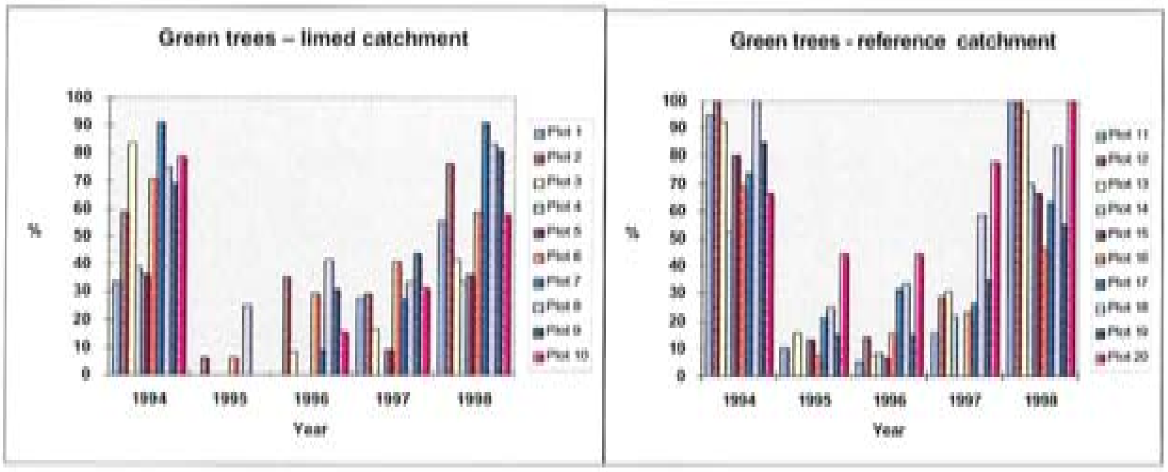

Figure 28. The amount of green trees on the intensive monitoring plots in the limed catchment and reference catchment in the different years.

5. Discussion

The choice of coarse dolomite and the dose of 3 t ha^{-1} for liming the 80 ha forested ecosystem in Gjerstad was partly based on recommendations for forest soil liming in Sweden, as summarised by Nihlgård *et al.* (1996). Results from the whole-catchment liming at Tjønnstrond (Traaen *et al.* 1997) with the same dose of more fine-powdered calcite indicated that significant improvement of the water quality was likely. Higher doses may change the soil pH too much, whereas ion exchange of accumulated Al and H^+ in the soil with the added Ca and Mg and production of organic acids from decomposition of organic matter may increase the acidity of the soil solution if lower doses are used.

Due to the anticipated variability of many important factors for acidity and liming effects within heterogeneous catchments, mixed forests and climatic regions, we chose a fixed dose and a paired catchment experiment in a forest ecosystem that might be regarded as typical for large acidified areas in Norway. An initial split in the limed catchment for stream water analyses and parallel sampling of soil solution at different stations were included to study in-catchment variability.

5.1 Soil chemistry

Sites for soil chemistry was selected mainly for vegetation purposes. Large gradients in nutrient status and water supply were two central criteria for this selection. As a result large variability in most of the soil chemical compounds was expected, and this is indeed what was found.

The chemistry of the soils at the two Gjerstad catchments is typical for soils in southern Norway in coniferous forests on nutrient-poor, siliceous moraine. Soils on well-drained sites are acidic and exhibit podsolic character, while those on adjacent wetter areas are typically organic-rich and humified. Both the cation exchange capacity (CEC) and the base saturation, two key parameters with respect to acidification of soil and mitigation by liming, are well within the ranges expected for coniferous forest soils of southern Norway.

Whether liming has resulted in changes in soil chemistry such as increase base saturation remains to be seen. A resampling of soils is scheduled for 1999. Liming at Tjønnstrond, for example, resulted in significant increase in base saturation (Traaen *et al.* 1997).

5.2 Soil solution chemistry

In principal one should expect a close relation between chemistry of soil and chemistry of soil solution at each individual site. The wide range in soil chemistry should be reflected in a corresponding wide range of soil solution chemistry. This is in part the case for pH in the humus layer. In both catchments soils with low pH (water) yield soil solution with low pH (**Figure 29**). This is the case for the humus layer. The mineral soil horizons do not show this relationship, however. Similarly for both Mg and Ca there is a tendency for the humus layers with higher contents of exchangeable base cations to have higher concentrations in soil solution (**Figure 30**). Again there is no such relationship for the mineral horizons.

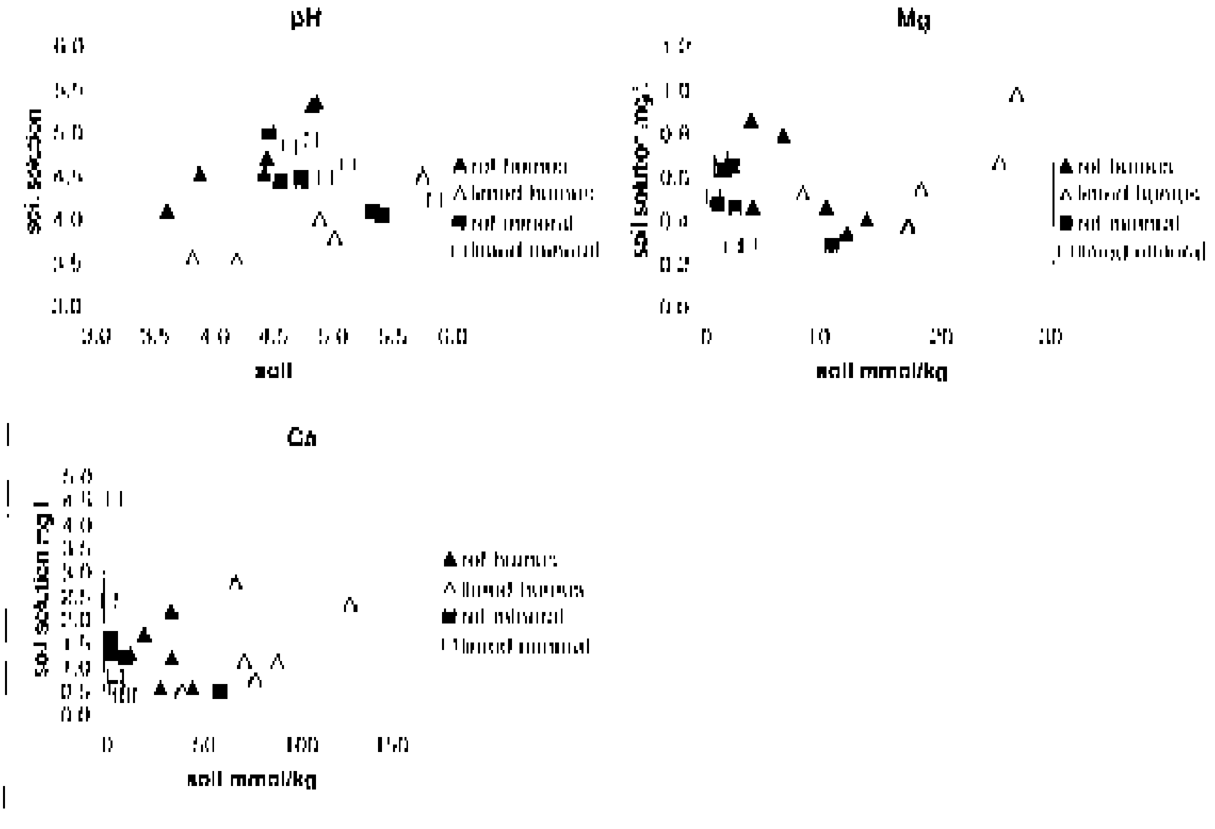

Figure 29. A comparison of soil and soil solution chemistry in the humus and mineral soil horizons in two catchments at Gjerstad. The soils were sampled in summer 1994. The soil solution data are means for samples from each lysimeter collected November 1994 through November 1997.

During the first 2.5 years following liming there have been very few indications of changes in soil solution chemistry. A small increase in Mg at only some of the locations has taken place. This was expected due to the slow movement of the dissolved base cations in other experiments (Brahmer 1994; Nohrstedt 1992). This contrasts with the rapid change of runoff water chemistry.

The most striking result from the Gjerstad experiment is the relatively uniform, acid and Al-rich runoff in the sub-catchments and the great variability in soil solution (**Figure 30**). This indicates that soil solution collected by the Prenart tension lysimeters is not representative of runoff. Similar observations on the lack of similarity between soil solution and runoff comes from other whole-catchment experiments such as the RAIN (Hauhs 1998) and CLIMEX (Jenkins *et al.* 1996) projects at Risdalsheia near Grimstad, about 60 km SW of Gjerstad and the NITREX project at Gårdsjön, near Gothenburg Sweden (Stuanes and Kjønaas 1998). In both these cases runoff responded more rapidly and consistently to changes in the chemical composition of deposition, while lysimeter data showed wide variations ranging from little or no response over many years, to immediate and persistent response. As at Gjerstad the lysimeter samples show great heterogeneity spatially.

There are several possible explanations for the lack of similarity between soil solution and runoff. First, the sampling technique for soil solution probably does not collect water in volumes proportional to that in runoff. Soil solution is comprised of water in pore spaces over a continuum of sizes, from macropores that have water only during saturated conditions, to micropores that retain water by capillary tension. The Prenart lysimeters under tension will collect water from a fraction of these pore sizes, but most probably some will be over-represented. The macropore flow will be underrepresented in volume. And since the lysimeters at Gjerstad were only evacuated 1 day each 14 days, the samples represent only a small time fraction as well.

Second, water movement varies greatly in time and space though heterogeneous uneven terrain such as is characteristic of the forested catchments at Gjerstad, and also Risdalsheia and Gårdsjön. The dominant pathway from soil surface to the stream is horizontal, not vertical. Incoming precipitation (or throughfall) percolates down through the soil undergoing chemical change underway until an impermeable surface is reached – either bedrock or a water-saturated zone. The water then moves horizontally towards the stream channel, and may alter chemical composition further, especially in the discharge regions near the stream. The runoff in the stream is a composite sample of water "packages" that have moved vertically and horizontally through the soil at a wide variety of distances and contact times.

Although lysimeter water is not representative for runoff, it may, however, give a good picture of the water quality available for uptake by roots. Thus the response of trees and ground vegetation to the liming treatment may first occur when the chemical composition of soil solution changes. At the NITREX experiment at Gårdsjön the runoff began to respond to N additions already during the first year of treatment, while the soil solution responded after 2-3 years and the vegetation yet later (Kjønaas *et al.* 1998).

5.3 Runoff chemistry

In runoff, the most striking effects of the dolomite treatment at Gjerstad were increased pH and concentrations of base cations, slightly reduced Al transport and change of Al species from highly toxic to non-toxic species. These effects are probably due to dissolution of dolomite in the topsoil and subsequent ion exchange of base cations in the humic layer. Lateral surface and sub-surface flow transport excess and non-exchanged Ca and Mg to the stream.

Rapid, almost immediate, improvements in the stream water quality were found. This occurred even though the finest fraction of the dolomite was removed before spreading, in contrast to the liming material used in e.g. the Gårdsjön liming experiment, where the particles were in the range 0-30 µm, a particle size fraction that was almost completely removed from the Gjerstad dolomite.

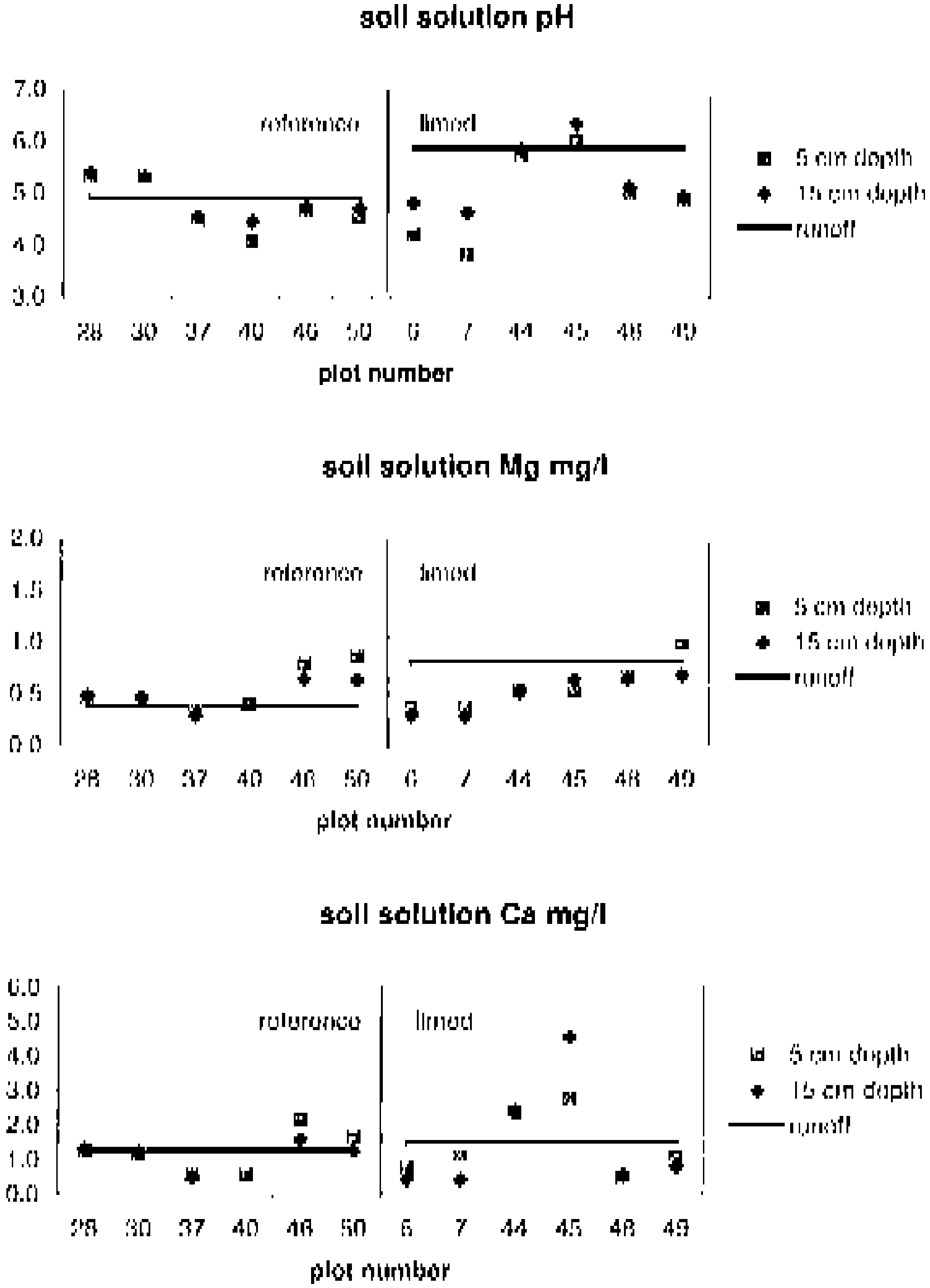

Figure 30. Comparison of mean concentrations in soil solution (6 sites at each catchment) and in runoff for samples collected during the post-liming period November 1994 through November 1997.

The post-liming increase in runoff concentrations of Ca and Mg was not significantly different in the Gjerstad experiment. Higher mobility of Mg relative to Ca was reflected in the relative increase. Whereas 0.5 % of the added Ca was transported out, 2.0 % of the added Mg was transported out of the limed catchment during the first 2.5 years.

Although the annual net transport of Ca and Mg was less than 1 % of the amount added, this was sufficient to cause a rapid response in runoff water quality after liming. The increase in water quality persisted throughout the period. No decreasing trends were documented after the initial increase in pH, base cations or ANC, and a longer monitoring period is needed to draw conclusions regarding duration and thereby mean annual liming costs.

These changes due to liming have turned the potentially toxic runoff into a water quality adequate for survival of acid sensitive organisms such as trout.

The results from Gjerstad generally agree with other comparable experiments with liming terrestrial areas. Hultberg *et al.* (1995) reported similar effects on runoff after application of 6 t ha^{-1} of extremely fine ground dolomite (particle size range: 0-30 µm) to a small catchment at the Gårdsjön research site, Sweden. A significant reduction of inorganic Al and Mn of 40-50 % was found. As in Gjerstad the mean annual flux of Mg was less than 1 % (7 % in 9 years). Fransman and Nihlgård (1995) also found increased pH, Ca and Mg and reduced Al, Fe and Mn after forest soil liming. Other experiments from Sweden with moderate lime doses (3-4 t ha^{-1}) showed only minor effects on pH and Al concentration in stream water during a 3-year period (Westling and Skärby 1993).

In Schluchsee, Black Forest in Germany a minor increase in stream-water Ca was registered one year after liming with 4 t ha^{-1} of pelleted dolomitic limestone, but the increase in Mg was as rapid as in Gjerstad (Brahmer 1994). Marked increases (after an initial peak) in both Ca and Mg in the soil solution at 30-cm depth were seen the year following liming. Increased Al-mobilisation at 30 cm was ascribed to the initial ion exchange processes after liming. Al did not increase in the stream water the first year after liming.

Kreutzer (1995) reported increased pH in the humic layer and in drainage water from this layer in the 6-year period after liming. No pH change in soil solution at 20 cm depth or drainage water from this layer was found. Drastic deprotonation of functional groups of the humic matrix was reported and both the cation exchange capacity and the base saturation increased. This stored buffer capacity in the topsoil. Six years after liming, dissolution of the added dolomite was regarded as 100 % and 70 % of the added Ca and 30 % of the Mg were still present in the humic layer. The low number for Mg reflects the more mobile nature of this element compared to Ca. Dissolution of lime was described by the equation, m (t) = A*e$^{[illegible]}$, where A is the mass of carbonate added in tonnes, m is mass of carbonates remaining in tonnes, and t is time in years. According to this equation 80 % of the added dolomite in Gjerstad should be dissolved at the end of 1996.

Liming of the heathland Tjønnstrond-catchment in Norway with a 3 t ha^{-1} dose of calcite powder resulted in a rapid and long-lasting increase in both pH and Ca and a more than 50 % reduction in reactive Al (Traaen *et al.* 1997). Liming of an upland, forested catchment (subcatchment IV) at Woods Lake, Adirondack Mountains, New York, USA, also resulted in improvement in water quality (Cirmo and Driscoll 1996). Liming of wetlands may increase the water quality of runoff, although the duration may be significantly shorter due to the more favourable dissolution properties of flushed bog surfaces and effective draining of dissolved liming material (Hindar *et al.* 1996).

Although the results from some of these experiments indicate only minor changes in pH, base cations and Al, even small water quality changes or differences may be of significance for the survival of acid-sensitive fish and invertebrates. The significance of minor water quality changes may also be important for the duration of adequate liming effects on streamwater, tending to increase duration and thereby reducing costs if being part of a liming programme for aquatic systems.

Potential undesirable effects, such as increased NO_3 leaching and mobility of organically-complexed trace metals (Fe, Cu and Pb), may be expected after forest soil liming. So far, a significant but minor increase in the median concentration of NO_3 due to liming was found after 2.5 years of liming in Gjerstad. The seasonal variability was large and concentrations in the limed catchment were within the concentration range in the reference most of the year. A clear increase in concentration was found the second winter after liming. This "winter/spring" trend was also found at Tjønnstrond (Traaen *et al.* 1997). A possible explanation may be that liming in general stimulates decomposition of organic matter and that the result of this change is insignificant or masked during the first period after liming due to a delay in the build up of the microflora and uptake of the produced NO_3 by the soil and vegetation during summer. Nitrification may still be significant in the snow-covered soil during winter, however, and the accumulated NO_3 from the dormant season may be flushed out with meltwater during spring melt, thus increasing the concentrations in late winter/spring. A longer data record is needed to draw any conclusion on the course of NO_3 in this experiment.

Warfvinge *et al.* (1996) summarised liming effects on runoff from several forested catchments in Sweden and found no increased N leaching during periods of 9-10 years. An alternative hypothesis to increased N leaching after liming was pointed out, increased N leaching due to shortage of base cations after several years of acidification was regarded as relevant for areas in Sweden that receive high amounts of atmospheric N. If liming would counteract this was not commented on, however.

At Schluchsee, increased NO_3 in soil seepage from the humus layer and both 30 and 80 cm soil depth were recorded (Brahmer 1994). As a consequence of the pH increase of two units in the O horizon a shift in the population of nitrifiers from heterotrophic to autotrophic organisms took place (Feger *et al.* 1995). All mineralised N was converted to NO_3 in the limed topsoil, whereas NH_4 dominated the inorganic N fraction in the reference. However, no change in streamwater was found the following 3 years after liming (Brahmer 1994; Feger *et al.* 1995).

Kreutzer (1995) reported loss of N from the humus layer after 7 years of liming and also an increase of about 1 meq L^{-1} in the NO_3 concentration in the drainage water leaving the root zone at 40-cm soil depth. The data record indicates a doubling of the NO_3 concentration at this depth due to liming already after one year. This is explained by a transformation of organically bound N from the humus layer to dissolved organic N which was translocated to deeper soil depth and converted to NO_3 by stimulated nitrification in the mineral soil. No data for streamwater was presented, but increased concentrations of drainage water NO_3 was calculated from soil solution data and a flux model. N deposition in Höglwald (12 kg N ha^{-1}) is of the same order of magnitude as in the Birkenes area but higher than at Solhomfjell closer to the Gjerstad site.

Increased mobility of potentially harmful trace metals complexed in the humic layer, especially Cu and Pb, may be expected after forest soil liming, if liming results in increased decomposition of organic matter (Kreutzer 1995). However, mobility of trace metals also depends on soil pH and increasing pH may stop leaching of metals related to accelerated soil acidification (Hüttl 1988). No increasing trends or elevated concentrations of the 10 trace metals relative to the reference stream were documented after the forest soil liming with dolomite in Gjerstad. This was probably due to the pH increase in runoff water, the moderate dose (3 t ha^{-1}) and low or moderate deposition of some of the trace metals in the area relative to e.g. German sites. Deposition of Cd, Cu and Pb in 1992-1993 at the Deuselbach monitoring station 200 km north of the Black Forest in Germany was higher than at Solhomfjell in Norway (Berg *et al.* 1996) by factors of 6.8, 4.6 and 1.5, respectively. Increased pH will increase the retention of some metals, whereas organically-complexed metals not will be mobilised if decomposition of organic matter is insignificant for this to occur. Hüttl (1988), in a review of forest soil liming, concluded that the risk of trace metal mobilisation for limed soils is probably not more pronounced than for acidified soils.

The decrease in Mn, Zn and Co may or may not be desirable, depending on the resulting concentrations. Both Mn and Co are elements of importance for flora and fauna and increased retention, e.g. as the result of oxidation of inorganic monomeric Mn to MnO_2 at pH>5 and subsequent precipitation, may result in shortage. Mn limitation in lime-rich soils has been reported and appears to be common (Pearson and Adams 1967). In some acidified areas in Sweden large concentrations of dissolved inorganic Mn (> 1 mg L^{-1}) have been reported and a reduction is probably desirable. In Gjerstad, however, the concentrations are very low (5-15 µg L^{-1}) and a reduction to < 5 µg L^{-1} after liming signals less availability of Mn for vegetation and forests and might be considered as a potential problem. For 985 Norwegian lakes the median Mn concentration was 2.5 µg L^{-1} (Skjelkvåle *et al.* 1999), about the same level as measured at LIM-1 and LIM-4 the last 1.5 years. Higher concentrations should be expected in streams with higher concentrations of organic matter such as is characteristic of forested ecosystems.

The liming effects on soil solution and stream water depend on hydrology, soil permeability and topography, i.e. the contact between runoff and limestone material. Steep slopes, thin soils and high precipitation, as in the Gjerstad area, was expected to promote rapid response in stream water due to anticipated dominance of overland and subsurface flow. Soil stratification in hillslope profiles is characterised by compact basal layers (Feger 1994), which also may promote lateral flow. Poorly mineralised humus, forming hydrophobic layers in the organic top layer of the coniferous forest may act in the same way. Less clear cut effects in stream water in other forested ecosystems may be due to different topography, soil properties and climatic conditions. Possibilities of undesirable effects, like increased leaching of N and trace metals, is dependent on the deposition history of these elements in the actual sites. As deposition may vary to a great extent, e.g. between German and Norwegian sites, different results should be expected and this is indeed also what has been found. This confirms the rationale in selecting Norwegian sites for research activities before drawing conclusions on possible effects of forest soil liming in Norway.

Terrestrial liming, as the forest soil liming in Gjerstad and the alternative strategies represented by whole catchment liming of non forested catchments (Traaen *et al.* 1997) and wetland liming (Hindar *et al.* 1996), has certain advantages compared to more traditional (in Norway) lake liming and lime dosing methods. The Al transport from the acidified catchment to watercourses will be reduced, and a more stable water quality is achieved throughout the year. Low doses of coarse-grained dolomite will probably minimise the undesirable effects on water quality. Terrestrial liming, also the forest soil liming concept, may therefore represent an interesting supplement to other liming methods for aquatic systems. A longer data record is needed, however, to draw conclusions on NO_3 leaching and costs.

5.4 Forest condition

An overall conclusion from the tree stand investigations is that the liming has so far shown no significant effects on tree growth and tree vitality (crown density and crown colour).

The causes for the general low level of increment could be several. In specific periods deviation from the function may occur due to e.g. climatic factors. The increment function can be said to represent the average climate for a long period. Another explanation could be that the function is based on forest stands that have been treated regularly with thinning and therefore represent high vitality and high selkasse stands.

From other investigations we know that increment in old pine and spruce forests will be little or even negatively effected for more than 20 years after liming (Staaf *et al.* 1996). To evaluate the forest growth more detailed increment analyses should be performed 10 years after liming. Then increment cores should be taken and a calibration to pre-liming increment could be done. Then more information on long-term effects of this low dose dolomite application can be extracted.

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Appendix A. Water and soil chemistry

Abbreviation and references for sampling stations

LIM 1: Stream outlet of catchment 1 in the limed catchment Fuglehåsen
LIM 2: Stream outlet of catchment 2 in the limed catchment Fuglehåsen
LIM 3: Stream outlet of catchment 3 in the limed catchment Fuglehåsen
LIM 4: Main stream outlet of the limed catchment Fuglehåsen
REF: Stream outlet of reference catchment Spjotåsen

Limed: 1 unlimed; 2 limed

FU-06 to FU-xx: Sampling stations for soil solution in the limed catchment Fuglehåsen
SP-28 to SP-xx: Sampling stations for soil solution in the limed catchment Spjotåsen

St.no	DATO	Limed	pH	Ca	Mg	Al	Alo	TOC	Na	K	Cl	SULF	ANC	NO3N	TOTN	NH4N	TOTP
			-log H	mg L-1	mg L-1	µg L-1	µg L-1	mg L-1	mg L-1	mg L-1	mg L-1	mg L-1	µeq L-1	µg L-1	µg L-1	µg L-1	µg L-1
LU1	26-May-99	[illegible]	5.2	1.4	0.4	155	110	4	2.2	0.2	3.7	4.1	15	18	155		2
LU3	26-May-99	[illegible]	5.4	1.5	0.4	120	48	3	2.3	0.2	3.4	4.3	22	5	127		2
LU4	26-May-99	[illegible]	5.0	1.4	0.4	130	54	4	3.2	0.2	3.5	4.0	18	1	143		2
REF	26-May-99	[illegible]	5.1	1.9	0.3	142	121	5	2.7	0.2	3.4	3.8	37	20	306		3
LU1	3-Aug-99	[illegible]	4.3	2.1	0.6	358	245	12	2.1	0.4	2.7	4.5	57	325	277	15	17
LU2	3-Aug-99	[illegible]	4.5	1.2	0.4	430	232	11	1.5	0.1	2.5	4.0	17	73	550	13	13
LU3	3-Aug-99	[illegible]	4.7	1.7	0.4	452	265	12	1.5	0.4	2.7	4.4	15	150	725	18	25
LU4	3-Aug-99	[illegible]	4.7	1.8	0.5	394	264	13	1.9	0.3	2.7	4.5	37	217	758	15	16
REF	3-Aug-99	[illegible]	4.7	1.9	0.5	312	266	14	1.8	0.2	2.5	3.8	52	32	575	18	17
LU1	31-Aug-99	[illegible]	5.4	1.6	0.4	150	143	5	2.2	0.1	2.5	4.2	24	30	215	5	3
LU2	31-Aug-99	[illegible]	4.7	1.2	0.3	250	156	5	2.1	0.1	3.4	4.0	-10	11	130	5	2
LU3	31-Aug-99	[illegible]	5.2	1.3	0.3	152	117	4	1.9	0.1	3.2	3.8	5	13	150	5	2
LU4	31-Aug-99	[illegible]	5.2	1.4	0.4	153	122	5	2.1	0.1	3.5	3.9	17	22	180	5	3
REF	31-Aug-99	[illegible]	5.4	1.6	0.5	168	142	5	2.0	0.1	2.1	3.6	56	13	286	5	4
LU1	5-Oct-99	[illegible]	4.7	1.4	0.5	307	272	12	2.2	0.5	3.4	4.4	30	34	480	11	15
LU2	5-Oct-99	[illegible]	4.5	1.1	0.4	355	256	13	2.0	0.3	2.7	4.0	4	12	370	3	5
LU3	5-Oct-99	[illegible]	4.7	1.0	0.5	305	230	9	1.9	0.4	2.0	3.5	3	25	325	3	2
LU4	5-Oct-99	[illegible]	4.8	1.3	0.4	345	272	13	2.1	0.5	3.5	4.4	-	25	395	10	11
REF	5-Oct-99	[illegible]	4.8	1.1	0.5	371	232	13	2.2	0.4	3.5	4.6	30	15	445	20	6
LU1	7-Nov-99	[illegible]	5.2	1.4	0.5	201	145	5	2.3	0.2	3.2	5.1	14	55	240	5	2
LU2	7-Nov-99	[illegible]	4.8	1.1	0.4	273	154	5	2.4	0.1	3.3	4.5	-7	50	240	5	2
LU3	7-Nov-99	[illegible]	5.0	1.2	0.4	227	115	4	2.3	0.1	3.2	4.3	-	50	205	4	2
LU4	7-Nov-99	[illegible]	5.0	1.3	0.4	217	141	5	2.3	0.1	3.2	4.6	12	50	215	4	2
REF	7-Nov-99	[illegible]	4.8	1.6	0.5	130	139	6	2.4	0.1	3.3	4.7	35	36	275	5	3
LU1	11-Nov-99	[illegible]	4.8	1.2	0.6	251	231	11	2.7	0.5	2.4	5.0	14	345	640	15	12
LU2	11-Nov-99	[illegible]	4.5	1.2	0.4	355	231	9	2.1	0.4	2.5	5.2	-12	203	565	27	-
LU3	11-Nov-99	[illegible]	4.8	1.1	0.4	325	212	9	2.1	0.4	2.7	5.0	-5	170	430	21	9
LU4	11-Nov-99	[illegible]	4.8	1.2	0.4	307	243	11	2.0	0.5	2.5	5.2	-2	230	530	18	10
REF	11-Nov-99	[illegible]	4.8	1.5	0.5	227	133	11	2.2	0.2	2.5	5.0	11	230	530	38	-
LU1	14-Nov-99	[illegible]	4.7	1.1	0.4	255	156	8	1.9	0.2	2.3	4.6	9	36	250	5	3
LU3	14-Nov-99	[illegible]	4.8	1.1	0.3	313	227	-	2.0	0.1	2.3	4.5	5	17	235	4	2
LU4	14-Nov-99	[illegible]	4.7	1.0	0.4	284	214	7	2.0	0.2	2.2	4.7	3	33	235	3	2
REF	14-Nov-99	[illegible]	4.8	1.2	0.4	130	165	3	2.0	0.2	2.4	5.0	17	44	225	12	3

St. no.	DATE	Limed	pH	Ca	Mg	Ar	Ac	TOC	Na	K	Cl	SULF	ANC1	NO3-N	Tot-N	NH4-N	Tot-P
			-log H+	mg L-1	mg L-1	µg L-1	µg L-1	mg L-1	mg L-1	mg L-1	mg L-1	mg L-1	µekv L-1	µg L-1	µg L-1	µg L-1	µg L-1
UM-1	13-Mar-94	•	5.1	1.2	0.4	157	115	4	2.2	0.3	2.5	4.7	22	91	255	6	2
UM-2	13-Mar-94	•	4.7	0.9	0.4	287	187	6	2.4	0.2	2.7	4.8	-2	160	320	15	2
UM-3	13-Mar-94	•	4.8	1.1	0.4	272	175	5	2.3	0.2	2.6	4.9	5	172	350	9	2
UM-4	13-Mar-94	•	4.8	1.1	0.4	237	121	5	2.3	0.2	2.5	4.7	15	193	350	9	2
REF	13-Mar-94	•	4.8	1.2	0.4	172	105	6	2.3	0.3	2.6	4.9	22	92	330	32	2
UM-1	29-Mar-94	•	5.1	1.3	0.5	175	143	4	2.2	0.3	2.5	4.6	25	185	370	42	3
UM-2	29-Mar-94	•	4.7	1.2	0.4	271	178	5	2.4	0.3	2.6	4.5	4	210	430	45	2
UM-3	29-Mar-94	•	4.8	1.1	0.4	280	158	5	2.5	0.2	2.5	4.5	21	175	360	42	2
UM-4	29-Mar-94	•	5.0	1.3	0.4	229	157	5	2.3	0.3	2.5	4.5	15	193	430	46	2
REF	29-Mar-94	•	4.8	1.4	0.4	171	142	7	2.3	0.3	2.5	5.0	25	139	385	59	3
UM-1	11-Apr-94	•	4.8	1.1	0.4	158	127	5	1.9	0.3	2.4	4.5	3	155	330	16	3
UM-2	11-Apr-94	•	4.8	0.9	0.3	239	153	4	1.9	0.3	2.5	5.1	-32	275	365	29	1
UM-3	11-Apr-94	•	4.7	1.0	0.3	271	162	5	1.9	0.2	2.4	5.0	-15	160	330	7	2
UM-4	11-Apr-94	•	4.8	1.0	0.4	214	145	5	1.9	0.3	2.4	4.9	-13	171	355	14	2
UM-1	15-Apr-94	•	4.8	0.9	0.4	158	132	6	1.7	0.3	2.1	4.6	-5	55	230	12	2
UM-2	15-Apr-94	•	4.7	0.7	0.3	224	151	5	1.5	0.2	1.9	4.6	-21	64	230	9	2
UM-3	15-Apr-94	•	4.8	0.8	0.3	255	156	4	1.7	0.2	1.9	4.7	-9	73	210	6	2
UM-4	15-Apr-94	•	4.8	0.9	0.3	225	143	6	1.7	0.2	2.0	4.5	-7	72	215	7	2
REF	15-Apr-94	•	4.8	0.8	0.3	142	113	4	1.6	0.2	1.8	4.4	1	33	195	12	2
UM-1	25-Apr-94	•	5.1	0.9	0.3	177	101	6	1.5	0.2	1.8	4.4	-5	73	240	13	2
UM-2	25-Apr-94	•	4.7	0.7	0.3	200	142	5	1.4	0.2	1.4	4.4	-18	73	220	13	2
UM-3	25-Apr-94	•	4.8	0.9	0.3	234	161	4	1.5	0.1	1.4	4.7	-11	72	215	5	2
UM-4	25-Apr-94	•	4.8	0.8	0.3	157	132	6	1.5	0.2	1.6	4.5	-5	74	210	10	2
REF	25-Apr-94	•	4.8	0.8	0.3	136	115	4	1.4	0.2	1.4	4.2	2	64	230	21	2
UM-1	2-May-94	•	4.8	0.8	0.3	152	122	6	1.3	0.2	1.2	3.9	5	43	220	9	3
UM-2	2-May-94	•	4.7	0.8	0.2	157	135	5	1.2	0.2	1.1	3.5	-7	41	162	6	2
UM-3	2-May-94	•	4.8	0.8	0.2	271	147	5	1.1	0.1	1.1	4.1	1	45	195	5	2
UM-4	2-May-94	•	4.8	0.7	0.3	158	135	6	1.3	0.2	1.2	4.1	1	51	215	7	2
REF	2-May-94	•	4.8	0.8	0.2	119	99	5	1.2	0.2	1.1	3.4	9	31	190	12	2
UM-1	12-May-94	•	5.1	0.8	0.3	153	122	7	1.3	0.2	1.2	4.0	9	48	245	14	5
UM-2	12-May-94	•	4.7	0.6	0.2	224	123	5	1.2	0.2	1.1	3.9	-11	67	231	5	2
UM-3	12-May-94	•	4.8	0.8	0.3	225	123	5	1.4	0.1	1.2	4.2	3	63	255	12	2
UM-4	12-May-94	•	4.9	0.8	0.3	153	120	6	1.4	0.2	1.2	4.1	2	74	245	25	2
REF	12-May-94	•	4.9	0.9	0.3	141	105	6	1.4	0.2	1.2	3.8	11	65	260	17	2

Site	DATE	Limed	pH	Ca	Mg	Al	Al	TOC	Na	K	Cl	SULF	ANC	NO3-N	Tot-N	NH4-N	Tot-P
			log H+	mg L-1	mg L-1	µg L-1	µg L-1	mg L-1	mg L-1	mg L-1	mg L-1	mg L-1	µeq L-1	µg L-1	µg L-1	µg L-1	µg L-1
UM-1	15-May-94	1	5.2	1.3	0.3	153	144	9	1.4	0.2	1.3	4.5	15	35	275	196	4
UM-2	15-May-94	1	4.7	0.7	0.2	222	145	6	1.4	0.1	1.5	4.5	6	35	180	5	2
UM-3	15-May-94	1	5.1	1.1	0.3	223	122	4	1.6	0.1	1.6	4.4	9	21	131	5	2
UM-4	15-May-94	1	5.1	1.3	0.3	136	131	6	1.4	0.2	1.3	4.1	5	41	265	95	2
REF	15-May-94	1	4.8	1.1	0.3	155	128	7	1.5	0.2	1.4	3.5	22	51	245	12	2
LM-1	25-Aug-94	1	4.6	1.9	0.7	365	265	17	1.7	0.2	1.9	7.3	20	23	347	127	17
LM-2	25-Aug-94	1	4.4	0.9	0.3	346	262	12	1.5	0.1	1.8	4.1	-1	7	270	13	1
LM-3	25-Aug-94	1	4.5	1.1	0.3	354	246	13	1.4	0.1	1.7	4.4	1	15	335	5	3
LM-4	25-Aug-94	1	4.5	1.2	0.5	352	254	11	1.7	0.2	1.3	5.5	24	32	542	122	12
REF	25-Aug-94	1	4.5	1.5	0.4	294	237	12	1.6	0.1	1.7	4.8	31	5	425	10	3
LM-1	31-Aug-94	1	4.5	1.3	0.5	327	231	12	1.5	0.1	1.4	5.1	22	6	370	11	1
LM-2	31-Aug-94	1	4.5	0.9	0.3	256	195	3	1.5	0.1	1.1	4.1	3	1	240	5	2
LM-3	31-Aug-94	1	4.3	1.2	0.3	256	144	6	1.7	0.1	1.6	4.5	21	9	225	5	3
LM-4	31-Aug-94	1	4.3	1.3	0.4	252	132	7	1.1	0.1	1.6	4.5	23	13	233	5	3
REF	31-Aug-94	1	4.3	1.5	0.4	225	156	10	1.8	0.1	1.8	4.8	32	6	337	5	4
LM-1	12-Sep-94	1	4.3	1.0	0.3	232	212	10	1.4	0.1	1.6	4.1	13	6	311	23	3
LM-2	12-Sep-94	1	4.6	2.7	0.2	273	138	7	1.5	0.1	1.9	4.3	-23	9	245	5	2
LM-3	12-Sep-94	1	4.3	1.0	0.3	231	174	6	1.5	0.1	1.9	4.5	-12	12	270	12	2
LM-4	12-Sep-94	1	4.7	1.3	0.3	295	217	9	1.5	0.1	1.6	3.9	11	9	300	12	3
REF	12-Sep-94	1	4.7	1.2	0.3	231	193	12	1.5	0.1	1.9	4.5	11	6	325	23	4
LM-1	19-Sep-94	1	4.3	0.9	0.2	258	275	10	1.3	0.2	1.4	5.4	22	3	270	15	4
LM-2	19-Sep-94	1	4.6	0.7	0.2	257	165	7	1.3	0.1	1.6	2.4	5	4	190	5	2
LM-3	19-Sep-94	1	4.9	0.9	0.3	287	167	7	1.4	0.1	1.6	3.9	4	15	155	5	2
LM-4	19-Sep-94	1	4.7	0.8	0.2	272	207	9	1.3	0.1	1.5	3.4	11	7	266	13	4
REF	19-Sep-94	1	4.7	1.0	0.5	213	176	12	1.4	0.1	1.6	3.5	21	6	325	12	4
LM-1	26-Sep-94	2	5.6	1.3	0.6	154	145	8	1.5	0.1	1.6	4.1	42	5	225	9	3
LM-2	26-Sep-94	2	5.3	0.9	0.5	223	152	7	1.3	0.0	2.0	3.5	3	6	215	9	3
LM-3	26-Sep-94	2	5.9	1.3	0.5	172	133	5	1.5	0.1	1.7	4.2	32	51	217	9	2
LM-4	26-Sep-94	2	6.1	1.6	0.6	172	161	6	1.5	0.1	1.7	4.7	51	25	223	11	4
REF	26-Sep-94	1	5.1	1.0	0.3	156	163	9	1.5	0.1	2.1	3.5	11	24	290	9	3
LM-2	29-Sep-94	2	5.4	1.1	0.5	213	173	7	1.4	0.1	1.6	3.6	21	10	225	14	2
LM-3	29-Sep-94	2	5.6	1.5	0.6	162	153	6	1.5	0.1	1.9	4.3	41	45	225	12	2

Site	DATE	Limed	pH	Ca	Mg	Ar	Ai	TOC	Na	K	Cl	SULF	ANC	NO3-N	Tot N	NH4-N	Tot P
			-log H+	mg L-1	mg L-1	µg L-1	µg L-1	mg L-1	mg L-1	mg L-1	mg L-1	mg L-1	µeq L-1	µg L-1	µg L-1	µg L-1	µg L-1
LM-1	12-Oct-94	2	6.3	1.8	0.6	125	123		1.5					13	475	214	
LM-2	12-Oct-94	2	5.5	1.1	0.6	134	173	6	1.5	0.1	2.1	4.4	13	27	200	12	2
LM-3	12-Oct-94	2	5.5	1.7	0.6	134	112	4	1.7	0.1	2.1	4.5	43	53	235	13	3
LM-4	12-Oct-94	2	6.4	1.6	0.6	98	92		1.5					36	580	332	
REF	12-Oct-94	1	5.6	1.2	0.3	161	150		1.5					43	557	256	
LM-1	27-Oct-94	2	5.3	1.7	0.5	222	194	9	2.0	0.5	3.6	3.7	59	97	370	21	5
LM-2	27-Oct-94	2	5.0	1.3	0.7	232	163	6	1.5	0.3	3.3	3.4	54	78	300	19	3
LM-3	27-Oct-94	2	5.2	1.6	0.7	251	206	8	1.5	0.3	3.3	3.8	45	65	255	21	4
LM-4	27-Oct-94	2	5.3	1.6	0.7	227	193	6	1.5	0.4	3.5	3.7	51	112	370	37	5
REF	27-Oct-94	1	4.7	1.5	0.5	212	164	10	2.1	0.4	3.4	3.7	93	106	395	23	4
LM-1	31-Oct-94	2	5.3	1.4	0.5	187	169	5	1.5	0.1	1.6	4.0	42	7	355	125	4
LM-2	31-Oct-94	2	5.4	1.1	0.5	215	173	7	1.4	0.1	1.3	3.8	27	10	215	14	2
LM-3	31-Oct-94	2	5.6	1.5	0.5	162	133	5	1.3	0.1	1.5	4.3	41	45	206	13	2
LM-4	31-Oct-94	2	5.9	1.4	0.5	154	146	7	1.5	0.1	1.7	4.0	39	25	370	137	3
REF	31-Oct-94	1	5.2	1.1	0.3	192	165	11	1.2	0.1	1.7	3.5	29	22	455	164	4
LM-1	3-Nov-94	2	5.5	1.5	0.7	208	182	5	1.3	0.3				19	230	5	3
LM-2	3-Nov-94	2	5.2	1.2	0.7	227	162	5	1.3	0.2	2.9	3.8	30	33	205	5	2
LM-3	3-Nov-94	2	5.4	1.4	0.8	224	177	5	1.3	0.1	2.5	3.3	23	52	200	5	3
LM-4	3-Nov-94	2	5.4	1.5	0.7	220	189	7	1.3	0.2	3.0	4.2	23	28	227	10	3
REF	3-Nov-94	1	4.7	1.3	0.4	206	164	8	1.3	0.2	3.1	3.8	15	30	250	12	3
LW-1	14-Nov-94	2	5.9	1.9	0.8	187	157	7	2.2	0.2	3.1	4.5	79	27	235	27	3
LW-2	14-Nov-94	2	5.2	1.3	0.7	226	184	5	1.8	0.1	2.7	3.7	47	100	255	5	2
LW-3	14-Nov-94	2	5.5	1.5	0.7	213	175	5	1.8	0.1	3.0	4.4	21	50	220	5	2
LW-4	14-Nov-94	2	5.8	1.6	0.7	172	154	5	1.9	0.2	2.5	4.0	58	49	215	13	2
REF	14-Nov-94	1	4.9	1.6	0.5	232	157	9	2.2	0.1	2.9	4.3	23	37	235	30	3
LU-1	21-Nov-94	2	5.3	1.6	0.7	193	175	7	2.1	0.2	2.5	4.0	70	41	250	19	3
LU-2	21-Nov-94	2	5.3	1.2	0.7	217	176	6	1.8	0.1	2.7	4.0	33	58	230	5	2
LU-3	21-Nov-94	2	5.5	1.4	0.8	210	156	5	1.8	0.1	2.7	4.0	23	59	205	5	1
LU-4	21-Nov-94	2	5.7	1.5	0.7	212	193	7	2.0	0.1	2.9	4.2	54	51	255	19	2
REF	21-Nov-94	1	4.9	1.4	0.4	213	151	5	2.1	0.1	2.9	4.2	25	37	275	19	2
LU-1	5-Dec-94	2	6.0	1.5	0.7	164	156	5	1.8	0.2	2.5	4.1	55	47	290	56	3
LU-2	5-Dec-94	2	5.5	1.2	0.7	212	157	5	1.8	0.1	2.5	3.9	31	120	255	5	2
LU-3	5-Dec-94	2	5.5	1.3	0.8	200	177	5	1.8	0.1	2.0	4.3	26	104	235	7	2
LU-4	5-Dec-94	2	5.9	1.6	0.7	166	153	6	1.8	0.1	2.0	4.3	53	53	255	49	2
REF	5-Dec-94	1	5.0	1.4	0.4	187	156	5	2.0	0.1	2.9	4.5	13	55	295	61	2

Site	DATE	Limed	pH	Ca	Mg	Al	Al	TOC	Na	K	Cl	SULF	ANC	NO3-N	Tot-N	NH4-N	Tot-P
			log H+	mg/L	mg/L	µg/L	µg/L	mg/L	mg/L	mg/L	mg/L	mg/L	µeq/L	µg/L	µg/L	µg/L	µg/L
UM-1	12-Dec-94	2	5.5	1.2	0.6	157	158	3	1.6	0.2	2.7	3.7	38	77	290	21	4
UM-2	12-Dec-94	2	5.3	1.2	0.6	216	191	5	1.7	0.1	2.6	4.0	25	73	225	5	1
UM-3	12-Dec-94	2	5.5	1.3	0.6	221	193	5	1.7	0.1	2.6	4.1	27	73	255	5	1
UM-4	12-Dec-94	2	5.5	1.3	0.6	211	197	7	1.6	0.2	2.6	3.7	30	87	280	21	2
REF	12-Dec-94	1	4.5	1.2	0.4	221	172	4	1.7	0.2	2.7	3.8	5	71	270	23	3
UM-1	21-Dec-94	2	5.5	1.4	0.7	174	160	7	1.8	0.2	2.8	3.5	43	91	260	19	3
UM-2	21-Dec-94	2	5.4	1.3	0.7	207	175	6	1.7	0.1	2.8	4.0	24	69	225	5	1
UM-3	21-Dec-94	2	5.5	1.4	0.6	215	175	5	1.7	0.1	2.8	4.1	22	77	310	5	1
UM-4	21-Dec-94	2	5.5	1.3	0.6	159	163	6	1.7	0.1	3.0	4.0	13	92	270	28	2
REF	21-Dec-94	1	4.5	1.3	0.4	153	146	4	1.7	0.2	2.7	3.9	3	65	296	41	3
UM-1	3-Jan-95	2	5.5	1.5	0.9	151	134	6	2.2	0.3				44	230	29	3
UM-2	3-Jan-95	2	5.3	1.3	0.7	229	165	6	1.5	0.1	3.0	4.5	21	109	245	5	1
UM-3	3-Jan-95	2	5.5	1.4	0.7	207	155	5	1.5	0.1	2.9	4.4	25	96	225	5	1
UM-4	3-Jan-95	2	5.7	1.5	0.7	153	162	5	1.5	0.2	2.9	4.2	44	73	250	32	1
REF	3-Jan-95	1	4.5	1.5	0.4	179	142	4	2.0	0.2	3.3	4.4	27	67	255	24	2
LM-1	15-Feb-95	2	5.5	1.5	0.6	177	151	5	2.2	0.3	4.2	3.5	38	163	315	14	2
LM-2	15-Feb-95	2	5.4	1.4	0.5	200	151	5	2.4	0.2	4.7	3.7	37	173	324	12	2
LM-3	15-Feb-95	2	5.4	1.4	0.8	213	151	5	2.2	0.2	4.1	3.5	29	160	296	12	2
LM-4	15-Feb-95	2	5.6	1.4	0.8	155	154	4	2.2	0.2	4.2	3.7	30	165	335	16	2
REF	15-Feb-95	1	4.7	1.2	0.5	133	131	5	2.2	0.2	4.2	3.7	-5	160	340	41	2
LM-1	14-Mar-95	2	5.1	1.7	0.9	144	131	4	2.1	0.2	4.2	4.1	43	119	245	7	2
LM-2	14-Mar-95	2	5.4	1.4	0.9	153	143	5	2.2	0.2	4.4	4.0	23	153	335	5	1
LM-3	14-Mar-95	2	5.6	1.5	0.5	151	138	4	2.2	0.1	4.1	4.3	22	170	255	12	1
LM-4	14-Mar-95	2	5.9	1.7	0.5	155	133	4	2.2	0.2	4.1	4.1	33	150	270	11	1
REF	14-Mar-95	1	4.9	1.5	0.5	171	121	5	2.2	0.2	4.1	4.3	-2	143	310	34	2
LM-1	27-Mar-95	2	6.0	1.8	1.0	138	113	6	2.3	0.3	4.8	4.5	25	220	415	52	2
LM-2	27-Mar-95	2	5.5	1.5	1.0	172	133	4	2.5	0.2	4.9	4.7	15	260	430	35	1
LM-3	27-Mar-95	2	5.5	1.6	0.5	130	138	4	2.3	0.1	4.5	4.5	13	153	335	5	1
LM-4	27-Mar-95	2	5.9	1.5	1.0	151	129	5	2.3	0.2	4.7	4.5	23	230	415	59	2
REF	27-Mar-95	1	4.7	1.3	0.5	171	113	5	2.2	0.3	4.3	4.5	-20	173	375	57	2
LM-1	5-Apr-95	2	6.0	1.6	0.9	145	127	4	2.2	0.4	4.1	4.2	45	130	220	5	1
LM-2	5-Apr-95	2	5.6	1.4	0.9	175	144	4	2.3	0.3	4.2	4.2	33	149	255	5	1
LM-3	5-Apr-95	2	5.5	1.5	0.5	130	144	4	2.2	0.2	3.9	4.3	30	153	270	5	1
LM-4	5-Apr-95	2	5.3	1.6	0.9	153	135	4	2.2	0.3	4.2	4.3	38	149	290	22	1
REF	5-Apr-95	1	4.3	1.3	0.5	163	113	5	2.2	0.3	3.9	4.2	-1	131	265	32	1

Site	DATO	Lmed	pH	Ca	Mg	Alr	Alo	TOC	Na	K	Cl	SO4	ANC	NO3-N	Tot-N	NH4-N	Tot-P
			log H+	mg L-1	mg L-1	µg L-1	µg L-1	mg L-1	mg L-1	mg L-1	mg L-1	mg L-1	µeq L-1	µg L-1	µg L-1	µg L-1	µg L-1
LM-1	16-Apr-96	2	6.3	1.5	0.9	145	128	5	1.3	0.3	4.3	4.8	[illegible]	124	235	12	2
LM-2	16-Apr-96	2	5.7	1.1	0.7	169	142	5	1.8	0.2	2.7	4.0	27	78	205	11	1
LM-3	16-Apr-96	2	5.5	1.2	0.8	156	127	5	1.3	0.2	2.5	4.2	21	53	210	8	1
LM-4	16-Apr-96	2	6.0	1.4	0.8	153	133	5	1.3	0.3	3.9	4.5	4	105	235	15	2
REF	16-Apr-96	1	4.9	1.0	0.4	159	111	5	1.0	0.3	2.9	3.8	-4	54	205	21	2
LM-1	25-Apr-96	2	5.9	1.2	0.7	147	123	5	1.3	0.3	2.8	3.3	31	56	225	11	3
LM-2	25-Apr-96	2	5.7	0.9	0.5	166	133	5	1.3	0.3	2.0	3.8	15	57	190	5	1
LM-3	25-Apr-96	2	5.5	1.0	0.8	203	171	5	1.5	0.2	2.2	4.1	12	54	200	5	2
LM-4	25-Apr-96	2	5.8	1.1	0.8	180	138	5	1.5	0.3	2.4	4.0	23	70	215	10	2
REF	25-Apr-96	1	5.0	0.9	0.3	143	103	5	1.4	0.5	2.0	3.2	-9	38	155	27	2
LM-1	8-May-96	2	6.0	1.2	0.8	150	133	5	1.3	0.3	1.9	4.0	43	44	230	25	3
LM-2	8-May-96	2	5.8	1.0	0.8	162	153	5	1.4	0.2	1.8	3.1	42	75	250	5	3
LM-3	8-May-96	2	5.7	1.2	0.8	155	157	5	1.6	0.1	1.9	3.7	45	51	220	5	3
LM-4	8-May-96	2	6.0	1.1	0.8	160	144	5	1.3	0.2	1.9	3.3	39	51	210	27	2
REF	8-May-96	1	5.1	0.9	0.3	144	117	5	1.4	0.2	1.5	3.0	10	34	255	33	2
LM-1	26-May-96	2	6.2	1.4	0.7	160	156	7	1.5	0.2	1.9	3.3	56	29	325	103	4
LM-2	26-May-96	2	5.6	1.1	0.8	167	150	5	1.5	0.1	2.0	4.2	37	54	215	5	3
LM-3	26-May-96	2	6.0	1.5	0.8	157	110	4	1.0	0.2	2.0	4.5	41	43	180	5	3
LM-4	26-May-96	2	6.1	1.2	0.8	160	152	5	1.4	0.2	1.9	3.8	45	38	250	32	3
REF	26-May-96	1	5.1	0.9	0.3	157	131	7	1.3	0.2	1.5	3.2	11	29	325	27	3
LM-1	5-Jun-96	2	6.2	1.5	0.7	152	151	10	1.6	0.2	1.8	3.4	60	33	335	40	4
LM-2	5-Jun-96	2	5.6	1.2	0.8	191	174	7	1.6	0.1	1.9	3.3	45	34	225	5	2
LM-3	5-Jun-96	2	5.9	1.3	0.8	175	155	5	1.7	0.1	2.1	4.2	43	19	175	6	3
LM-4	5-Jun-96	2	6.1	1.4	0.7	153	151	5	1.6	0.2	1.8	3.6	67	35	320	53	5
REF	5-Jun-96	1	5.1	1.0	0.3	175	149	5	1.4	0.1	1.7	3.3	19	19	375	91	6
LM-1	13-Jun-96	2	6.0	1.4	0.7	153	155	5	1.4	0.1	1.8	3.2	73	15	340	31	5
LM-2	13-Jun-96	2	5.8	1.1	0.7	196	153	5	1.4	0.1	1.7	3.4	52	30	225	5	3
LM-3	13-Jun-96	2	5.9	1.2	0.8	230	150	7	1.5	0.1	1.9	3.7	46	26	210	5	3
LM-4	13-Jun-96	2	6.0	1.3	0.7	236	187	5	1.3	0.1	1.7	3.0	58	26	290	23	3
REF	13-Jun-96	1	4.9	0.9	0.3	184	152	5	1.4	0.1	1.5	3.1	19	13	275	27	5
LM-1	27-Jun-96	2	6.3	1.4	0.7	178	170	5	1.6	0.1	1.4	3.4	53	14	325	54	7
LM-2	27-Jun-96	2	6.1	1.2	0.7	155	173	5	1.6	0.1	1.5	4.0	60	36	250	5	4
LM-3	27-Jun-96	2	6.0	1.5	0.7	162	145	5	1.3	0.1	1.5	4.3	72	24	215	5	4
LM-4	27-Jun-96	2	6.2	1.3	0.7	177	174	5	1.7	0.1	1.5	3.4	79	16	305	45	5
REF	27-Jun-96	1	5.0	1.0	0.3	174	147	5	1.6	0.1	1.5	3.3	23	10	355	65	5

Site	DATO	Limed	pH	Ca	Mg	Al	Alr	TOC	Na	K	Cl	SULF	ANC	NO3-N	Tot N	NH4-N	Tot P
			log H+	mg L-1	mg L-1	µg L-1	µg L-1	mg L-1	mg L-1	mg L-1	mg L-1	mg L-1	µeq L-1	µg L-1	µg L-1	µg L-1	µg L-1
LM-1	7-Sep-95	2	6.0	2.7	1.4	284	150	9	2.1	0.9	2.5	5.5	66	395	680	7	9
LM-2	7-Sep-95	2	5.4	2.3	1.5	231	152	10	1.9	0.8	2.2	5.4	39	340	670	9	8
LM-3	7-Sep-95	2	5.6	2.2	1.3	194	147	7	1.9	0.8	2.7	7.4	42	550	750	7	8
LM-4	7-Sep-95	2	5.8	2.6	1.4	137	152	8	2.0	0.8	2.4	5.5	64	400	600	10	8
REF	7-Sep-95	1	4.8	2.5	0.7	290	153	11	2.0	0.7	2.7	5.2	26	126	190	10	9
LM-1	14-Sep-95	2	5.3	2.5	1.4	239	273	11	1.8	0.4	2.7	5.5	60	57	425	10	6
LM-2	14-Sep-95	2	4.4	1.4	1.9	240	278	10	1.7	0.8	2.5	5.2	45	34	325	7	5
LM-3	14-Sep-95	2	5.5	1.6	1.0	225	191	5	1.7	0.2	2.5	5.7	42	51	300	8	5
LM-4	14-Sep-95	2	5.1	2.1	1.2	232	194	10	1.8	0.8	2.7	7.4	58	73	450	5	6
REF	14-Sep-95	1	4.7	2.1	0.5	253	175	11	1.8	0.4	2.5	7.0	17	21	410	31	6
LM-1	19-Sep-95	2	5.8	1.6	1.9	229	207	11	1.5	0.4	2.1	5.0	65	15	320	8	5
LM-2	19-Sep-95	2	5.6	1.2	0.5	225	211	9	1.7	0.8	2.1	4.5	54	16	255	5	3
LM-3	19-Sep-95	2	5.6	1.5	0.9	225	191	5	1.7	0.2	2.2	5.2	43	37	260	5	3
LM-4	19-Sep-95	2	5.6	1.6	0.9	226	210	10	1.7	0.5	2.2	5.1	66	21	321	7	4
REF	19-Sep-95	1	4.1	1.3	0.4	228	178	10	1.8	0.3	2.1	5.0	12	8	320	10	4
LM-1	4-Oct-95	2	5.5	1.7	0.8	196	163	9	1.5	0.3	2.5	5.0	68	21	270	19	4
LM-2	4-Oct-95	2	5.6	1.5	0.8	224	150	5	1.8	0.2	2.6	4.8	43	103	310	5	4
LM-3	4-Oct-95	2	5.6	1.5	0.5	184	162	6	1.5	0.2	2.5	4.5	44	97	255	7	3
LM-4	4-Oct-95	2	5.3	1.6	0.9	212	158	5	1.8	0.2	2.5	5.1	58	34	280	17	11
REF	4-Oct-95	1	4.9	1.4	0.4	212	162	10	1.2	0.2	2.4	4.5	20	17	290	25	4
LM-1	23-Oct-95	2	6.1	1.6	0.9	113	75	9	1.8	0.3	2.8	4.3	72	33	300	22	5
LM-4	23-Oct-95	2	6.0	1.5	0.9	97	27	8	1.7	0.3	2.7	4.2	57	46	325	21	6
REF	23-Oct-95	1	4.9	1.3	0.4	73	79	9	1.7	0.2	2.8	4.7	13	27	315	49	5
LM-1	20-Nov-95	2	5.8	1.6	0.5	42	45	7	1.5	0.5	2.9	4.7	62	100	375	72	4
LM-4	20-Nov-95	2	5.7	1.6	0.9	58	52	7	2.0	0.2	3.0	4.4	53	149	385	51	2
REF	20-Nov-95	1	5.0	1.4	0.4	131	129	6	2.0	0.2	2.7	4.0	22	65	640	144	7
LM-1	4-Dec-95	2	6.0	1.5	0.9	151	142	6	1.7	0.2	2.7	4.3	47	210	400	5	2
LM-4	4-Dec-95	2	5.8	1.5	0.8	154	139	6	1.7	0.2	2.6	4.3	42	233	405	5	2
REF	4-Dec-95	1	5.2	1.4	0.4	153	123	7	1.7	0.1	2.5	4.1	15	98	310	7	2
LM-1	19-Dec-95	2	6.1	1.3	0.1	141	129	6	2.0	0.2	2.7	4.7	70	195	355	5	1
LM-4	19-Dec-95	2	5.9	1.6	0.9	142	137	5	1.9	0.2	2.9	4.5	47	220	370	5	1
REF	19-Dec-95	1	5.1	1.5	0.4	153	129	6	1.9	0.1	2.8	4.6	15	110	330	10	2

Site	DATO	Limed	pH	Ca	Mg	Al	Alo	TOC	Na	K	Cl	SULF	ANC	NO3-N	Tot N	NH4-N	Tot P
			-log H+	mg L-1	mg L-1	µg L-1	µg L-1	mg L-1	mg L-1	mg L-1	mg L-1	mg L-1	µeq L-1	µg L-1	µg L-1	µg L-1	µg L-1
LM-1	12-Jan-96	2	5.4	1.7	1.1	165	123	6	1.3	1.5	2.9	5.3	23	455	560	24	4
LM-4	12-Jan-96	2	5.6	1.3	1.1	140	120	6	1.4	1.4	3.0	5.3	32	490	730	45	5
REF	12-Jan-96	1	4.6	1.3	0.6	155	119	5	2.1	1.4	3.0	5.0	4	340	630	25	4
LM-1	13-Apr-96	2	6.0	1.6	0.9	132	119	7	1.3	1.4	2.5	4.4	56	355	550	22	3
LM-4	13-Apr-96	2	5.7	1.5	0.9	141	128	6	1.3	1.4	2.5	4.5	46	320	500	22	3
REF	13-Apr-96	1	4.7	1.3	0.4	150	113	7	1.3	0.4	2.4	4.5	12	160	410	37	13
LM-1	22-Apr-96	2	5.6	1.4	0.5	129	126	6	1.0	0.4	2.0	4.0	57	325	520	15	7
LM-4	22-Apr-96	2	5.7	1.3	0.5	140	141	6	1.0	0.4	2.1	4.2	42	280	455	15	3
REF	22-Apr-96	1	4.9	1.0	0.3	149	117	7	1.3	0.3	1.9	4.1	10	121	320	24	3
LM-1	29-Apr-96	2	5.3	1.3	0.7	131	133	6	1.3	0.4				235	430	15	3
LM-4	29-Apr-96	2	5.7	1.2	0.7	142	135	6	1.3	0.5				220	425	15	3
REF	29-Apr-96	1	4.9	1.0	0.3	145	121	7	1.5	0.3				58	315	42	3
LM-1	7-May-96	2	5.8	1.4	0.5	148	152	7	1.0	0.4	1.6	4.0	60	149	355	12	3
LM-4	7-May-96	2	5.7	1.3	0.5	150	149	6	1.0	0.3	1.5	4.2	57	155	340	8	3
REF	7-May-96	1	4.9	1.0	0.3	142	126	7	1.0	0.3	1.7	3.8	29	70	315	38	3
LM-1	20-May-96	2	5.7	1.4	0.3	172	172	8	1.5	0.3	1.6	3.8	74	128	400	42	5
LM-4	20-May-96	2	5.6	1.3	0.3	160	161	8	1.2	0.3	1.0	4.0	63	100	350	38	4
REF	20-May-96	1	4.9	1.1	0.3	164	142	8	1.3	0.2	1.3	3.8	25	45	330	42	5
LM-1	29-May-96	2	5.9	1.4	0.3	145	135	8	1.6	0.3	1.6	4.2	68	77	310	32	3
LM-4	29-May-96	2	5.8	1.3	0.7	150	137	7	1.6	0.2	1.7	4.0	56	77	290	27	2
REF	29-May-96	1	4.8	1.0	0.3	161	121	8	1.3	0.2	1.5	3.8	23	26	275	33	3
LM-1	20-Jun-96	2	6.7	1.4	0.7	110	110	8	1.6	0.3	1.3	4.2	86	27	395	275	15
LM-4	20-Jun-96	2	6.5	1.2	0.7	112	111	7	1.6	0.2	1.9	4.2	83	36	405	163	5
REF	20-Jun-96	1	5.4	1.1	0.3	133	124	8	1.6	0.2	1.9	4.0	16	25	500	210	7
LM-1	7-Sep-96	2	5.6	2.2	1.2	240	245	14	1.0	0.2	1.5	5.6	93	24	655	160	11
LM-4	7-Sep-96	2	5.5	1.9	1.0	215	228	12	1.3	0.1	2.0	5.3	52	36	590	147	9
REF	7-Sep-96	1	5.0	1.6	0.5	241	197	10	1.3	0.1	2.2	5.1	30	12	700	252	10
LM-1	30-Sep-96	2	5.5	1.5	1.0	249	227	14	1.4	0.3	2.4	4.5	80	45	495	35	12
LM-4	30-Sep-96	2	5.6	1.7	1.0	245	230	12	1.4	0.2	2.4	4.4	72	49	465	10	11
REF	30-Sep-96	1	4.7	1.4	0.4	233	201	13	1.4	0.3	2.5	4.0	15	45	445	23	9
LM-1	16-Oct-96	2	6.0	1.7	1.0	183	175	10	1.6	0.1	2.4	4.5	76	9	320	25	4
LM-4	16-Oct-96	2	5.9	1.6	0.9	195	182	8	1.2	0.1	2.4	4.4	67	10	280	11	4
REF	16-Oct-96	1	4.8	1.4	0.4	204	158	10	1.7	0.1	2.5	4.4	20	12	290	12	3
LM-1	28-Oct-96	2	5.8	1.6	0.9	204	205	11	1.2	0.3	2.5	4.3	63	19	325	13	3
LM-4	28-Oct-96	2	5.8	1.5	0.9	207	202	9	1.2	0.2	2.5	4.3	60	23	230	7	4
REF	28-Oct-96	1	4.8	1.3	0.4	204	179	9	1.0	0.1	2.4	4.3	14	19	275	13	4

St.no	DATE	Lmed	pH	Ca	Mg	Al-R	Al-I	TOC	Na	K	Cl	SULF	ANC1	NO3-N	Tot-N	NH4-N	Tot-P
			log H+	mg L-1	mg L-1	µg L-1	µg L-1	mg L-1	mg L-1	mg L-1	mg L-1	mg L-1	µeq L-1	µg L-1	µg L-1	µg L-1	µg L-1
UH-1	7-Nov-96	2	5.5	1.4	0.9	156	153	9	1.6	0.2	2.9	3.9	70	14	250	12	3
UH-4	7-Nov-96	2	5.5	1.4	0.9	155	156	8	1.6	0.1	2.4	4.0	61	24	245	10	3
REF	7-Nov-96	1	4.8	1.2	0.4	174	141	9	1.7	0.1	2.4	4.0	15	13	250	12	3
UH-1	21-Nov-96	2	5.1	1.4	0.9	158	137	8	1.7	0.2	2.4	4.5	50	37	265	31	4
UH-4	21-Nov-96	2	5.0	1.4	0.9	152	135	7	1.7	0.1	2.5	4.4	54	57	270	20	3
REF	21-Nov-96	1	4.8	1.3	0.4	178	123	8	1.5	0.1	2.5	4.2	17	25	255	19	3
UH-1	4-Dec-96	2	5.7	1.3		136	127	5	1.7	0.2	3.1	4.1		95	260	5	2
UH-4	4-Dec-96	2	5.0	1.4	0.8	141	122	5	1.6	0.0	2.2	4.2	47	122	233	6	2
REF	4-Dec-96	1	5.0	1.0	0.4	151	115	7	1.7	0.3	2.3	4.0	12	81	222	15	2
UH-1	8-Dec-96	2	5.5	1.0	0.9	135	112	7	1.6	0.3	2.6	5.4	50	155	410	13	5
UH-4	8-Dec-96	2	5.7	1.0	0.8	137	110	7	1.6	0.2	2.6	3.6	48	150	360	15	4
REF	8-Dec-96	1	4.8	1.0	0.4	145	100	7	1.7	0.2	2.7	3.6	4	113	340	17	4
UH-4	3-Mar-97	2	5.5	1.0	0.8	144	131	6	1.8	0.2	3.2	3.3	47	62	255	56	4
REF	3-Mar-97	1	4.5	1.0	0.4	147	112	5	1.5	0.2	3.2	3.4	5	43	230	23	2
UH-4	5-May-97	2	5.2	1.4	0.7	89	99	5	1.5	0.2	2.3	3.8	45	68	323	84	4
REF	5-May-97	1	5.4	1.1	0.3	103	87	7	1.5	0.2	2.9	3.8	-5	50	373	22	12
UH-4	23-Jun-97	2	5.3	1.3	0.7	144	135	8	1.4	0.1	2.1	3.2	55	34	340	56	7
REF	23-Jun-97	1	5.0	1.0	0.3	143	115	8	1.4	0.2	2.2	2.9	41	25	330	73	4
UH-4	2-Jul-97	2	5.1	1.4	0.8	172	121	8	1.5	0.1	1.7	3.5	31	8	277	12	5
REF	2-Jul-97	1	5.0	1.2	0.4	174	148	10	1.4	0.1	1.3	3.1	36	8	322	22	7
UH-4	7-Aug-97	2	6.0	1.5	0.5	128	123	8	1.6	0.1	2.0	3.7	50	25	540	232	9
REF	7-Aug-97	1	5.2	1.3	0.4	125	170	12	1.4	0.1	2.0	2.8	32	8	510	156	11
UH-4	4-Sep-97	2	5.0	1.5	0.9	71	45	12	1.6	0.1	2.2	4.9	59	29	550	22	12
REF	4-Sep-97	1	5.1	1.5	0.4	74	51	15	1.6	0.1	2.0	3.0	52	10	715	132	30
UH-4	18-Sep-97	2	5.2	1.3	1.0	217	212	12	1.7	0.1	2.2	3.9	105	21	455	26	7
REF	18-Sep-97	1	5.0	1.5	0.4	215	172	7	1.6	0.1	2.3	3.1	48	13	490	42	16
LU-4	14-Oct-97	2	5.2	1.7	1.0	196	125	12	1.6	0.3	3.0	3.6	54	55	425	25	5
REF	14-Oct-97	1	5.0	1.4	0.4	203	172	13	1.8	0.3	3.0	3.5	37	21	450	25	12
LU-4	4-Nov-97	2	5.2	1.7	0.9	169	175	8	1.8	0.2	3.0	3.3	74	51	500	24	5
REF	4-Nov-97	1	5.1	1.4	0.4	173	145	10	1.9	0.1	2.3	3.6	33	25	510	20	7
LU-4	12-Nov-97	2	5.5	1.5	0.9	183	150	8	1.9	0.2	3.0	3.3	59	114	390	9	6
REF	12-Nov-97	1	4.9	1.1	0.4	182	158	10	1.9	0.1	2.8	3.7	26	57	330	18	9
LU-4	13-Nov-97	2	5.8	1.5	0.8	182	148	8	1.7	0.2	2.3	3.9	51	56	450	3	4
REF	13-Nov-97	1	4.7	1.2	0.4	191	156	8	1.9	0.1	2.7	3.7	14	58	340	14	6

Loc	no	Date	Depth cm	Limed	pH -log [H+]	Cond mS/m	ALK mmol/L	Cl mg/L	SO4 mg/L	Si mg/L	NH4-N µg/L	NO3-N µg/L	Tot-N µg/L	Ca mg/L	Mg mg/L	Na mg/L	K mg/L	Al µg/L	Ali µg/L	TOC mg/L
FL	96	2-Sep-94	5	1										1.35	0.35	[illegible]			[illegible]	
FL	96	11-Sep-94	5	1										1.37						
FL	96	13-Sep-94	5	1	4.6							4		1.56						
FL	96	11-Oct-94	5	1														292	271	
FL	96	31-Oct-94	5	1	4.13	4.58		4	4.4	4.2	25	12	250	1.79	0.35	1.75	0.13	294	229	12.2
FL	96	16-Nov-94	5	2	4.16	4.21		3.3	4.6	2.7	54	112	420	1.73	0.33	1.63	1.36	342	252	15.1
FL	96	30-Nov-94	5	2	4.17	4.31						3		1.75	0.28	1.74		431	474	
FL	96	17-May-95	5	2	4.32	3.38						66		1.38	0.15	1.65		395	387	25.4
FL	96	21-Jun-95	5	2	4.25	3.71								1.41	0.15	1.83		479	450	
FL	96	19-Jul-95	5	2	4.18									1.51	0.17					
FL	96	28-Sep-95	5	2	4.2							1.5		1.66	0.22	3.11		432	372	
FL	96	19-Oct-95	5	2	4.17									1.74	0.25	2.77		435	414	
FL	96	10-May-96	5	2	4.35									1.75	0.32			450	454	30.1
FL	96	12-Jun-96	5	2	4.12									1.52	0.23			624	566	
FL	96	29-Aug-96	5	2	4.12													722	712	
FL	96	9-Oct-96	5	2	4.19	4.52						1.15		1.49	0.3	2.05		432	350	20.1
FL	96	24-Oct-96	5	2	4.12									1.72	0.41			762	752	
FL	96	19-Nov-96	5	2	4.29									1.54	0.38	1.68				
FL	96	19-Jun-97	5	2	4.15									[illegible]	0.44			722	713	43.6
FL	96	8-Jul-97	5	2	4.19									1.79	0.47			650	512	
FL	96	17-Sep-97	5	2	4.32									2.46	0.55	2.75		615	550	
FL	96	16-Oct-97	5	2	4.24	5.02						2.75		[illegible]	0.58	2.55		497	483	40.4
FL	96	12-Nov-97	5	2	4.21									1.64	0.72			429	383	25.5
FL	96	2-Sep-94	15	1	4.59	2.96	0.012	1.8	4.6	5	5	1.3	116	1.49	1.25	1.66	0.18	411	185	3.6
FL	96	11-Sep-94	15	1	4.56	2.56	0.012	1.7	4.5	4.8	1	1.5	111	1.38	1.2	1.55	0.18	439	157	2.7
FL	96	13-Sep-94	15	1	4.62	2.2	0.015	1.4	4.2	4.5	3	2	103	1.37	[illegible]	1.3	0.27	444	135	3.2
FL	96	11-Oct-94	15	1	4.79	2.55	0.018	1.3	4.4	4.8	12	1.5	103	1.16	1.25	1.31	0.15	445	147	3.5
FL	96	31-Oct-94	15	1	4.58	2.92	[illegible]	3.5	4	4.8	3	5	89	1.4	1.27	1.3	0.18	396	136	3.2
FL	96	15-Nov-94	15	2	4.66	2.73	0.014	3.3	3.9	4.5	3	3	95	1.56	1.25	1.55	0.23	792	144	3.1
FL	96	30-Nov-94	15	2	4.49	2.5	0.014	3	4.1	4.5	3	4	78	1.37	1.24	1.56	0.22	552	127	2.7
FL	96	15-Dec-94	15	2	4.58	2.65	0.015	3	4.7	5.5	3	4	94	1.39	0.24	1.8	0.32	673	152	3.5
FL	96	11-May-95	15	2	4.56	2.26	0.025	1.4	5.3	4.4	6	3	52	1.33	0.22	1.56	0.43	451	138	3
FL	96	21-Jun-95	15	2	4.36	2.24	0.028	1.4	5	5.4	3	3	82	1.34	0.24	1.54	0.25	428	142	3
FL	96	19-Jul-95	15	2	4.73	2.36	0.019	1.7	5.5	5.4	3	5	115	1.4	0.22	1.59	0.24	415	127	3.4
FL	96	28-Sep-95	15	2	4.57	2.42	0.025	1.8	4.8	5.3	3	4	120	1.41	0.26	1.97	0.25	458	135	3.7
FL	96	19-Oct-95	15	2	4.79	2.53	0.024	2.5	4.6	5.1	3	4	99	1.36	0.24	1.2	0.25	426	142	3.4

Loc.	no.	Date	Depth	Lmed	pH	Kond	ALK	Cl	SO4	S	NH4-N	NO3-N	Tot-N	Ca	Mg	Na	K	Al	Al	TOC
			cm		-log H+	mS/m	mmol/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	mg/L
FU	96	10-May-96	15	2	4.56	3.45	0.029	1.5	5.4	7.3	3	2	138	0.54	0.24	1.77	0.48	443	152	3.3
FU	96	29-Aug-96	15	2	4.52	3.24	0.019	4.3	4.4	5	3	3	117	0.42	0.32	2.42	0.41	458	177	4
FU	96	3-Oct-96	15	2	4.75	2.56	0.024	2.3	4.6	[illegible]	3	3.5	96	0.37	0.27	1.92	0.11	456	152	3.7
FU	96	24-Oct-96	15	2	4.65	2.94	0.038	2.4	4.6	7.2	<1	3	78	0.36	0.27	1.57	0.15	434	173	3.5
FU	96	13-Nov-96	15	2	4.64	2.45	0.027					4		0.4	0.33	1.86		450	177	3.6
FU	96	10-Jun-97	15	2	4.94	2.4	0.028	2.2	5	6.1	4	5	90	0.37	0.34	2.92	0.13	475	115	3
FU	96	9-Jul-97	15	2	4.51	2.37	0.028	2.5	4.4	5.2	3	1.5	52	0.47	0.27	1.62	0.28	389	139	2.1
FU	96	17-Sep-97	15	2	4.39	2.31	0.038	1.1	4.2	7	4	2.5	135	0.42	0.35	1.56	0.72	354	155	3.9
FU	96	15-Oct-97	15	2	4.9	2.5	0.13	2.7	4.4	7.5	5	3.5	111	0.41	0.32	1.83	0.26	457	152	2.2
FU	96	12-Nov-97	15	2	4.84	2.47	0.023	2.9	4.5	6.5	3	12	117	0.4	0.32	2.14	0.76	443	153	3.4
FU	97	9-Sep-94	5	1								5		0.11	0.29	1.73				
FU	97	11-Sep-94	5	1								3		0.15						
FU	97	19-Sep-94	5	1	4.03															
FU	97	11-Oct-94	5	1														92	74	
FU	97	16-Nov-94	5	2	3.55									1.03	0.32	1.87		37	45	
FU	97	30-Nov-94	5	2	3.65															
FU	97	11-May-95	5	2								35		3.49	0.13	1.33				
FU	97	21-Jun-95	5	2	4.01									3.56	0.16	1.52				
FU	97	28-Sep-95	5	2	3.72															
FU	97	19-Oct-95	5	2	3.83															
FU	97	12-Jun-96	5	2	3.80	2.42								1.2	0.33	2.06	2.6			
FU	97	13-Nov-96	5	2	3.85															
FU	97	10-Jun-97	5	2	3.84									0.4	0.5	1.79				
FU	97	9-Jul-97	5	2	3.73									1.12	0.51					
FU	97	17-Sep-97	5	2	3.71															
FU	97	15-Oct-97	5	2	3.54									1.92	0.64	2.93		41	51	
FU	97	12-Nov-97	5	2	3.7									1.73	0.56			53	66	
FU	97	9-Sep-94	15	1	4.52							4		0.79	0.5	1.52				
FU	97	11-Sep-94	15	1	4.58							2		0.71				244	163	
FU	97	19-Sep-94	15	1	4.56							1		0.5				273	181	4.5
FU	97	31-Oct-94	15	1	4.53	3.12	0.013					4		0.55	0.29	1.02		274	197	
FU	97	21-Oct-94	15	1	4.44	3.42		4.2	3.7	5.3	6	5	160	0.56	0.34	1.94	0.43	460	213	5.5
FU	97	16-Nov-94	15	2	4.53									0.55	0.3	2.06		446	233	
FU	97	30-Nov-94	15	2	4.47							1.8		0.51	0.26	2.24		443	244	6.5
FU	97	11-May-95	15	2								5		0.38	0.25	1.45				5.7
FU	97	21-Jun-95	15	2	4.57	2.44	0.015							0.38	0.28	1.38		450	281	
FU	97	28-Sep-95	15	2	4.56	3.11	0.012							0.37	0.35	1.34		454	267	7.3
FU	97	19-Oct-95	15	2	4.57	2.83	0.013							0.33	0.28	2.54		465	256	

Loc.	no.	Date	Depth cm	Level	pH -log H+	cond. mS/m	ALK mmol/L	Cl mg/L	SO4 mg/L	Si mg/L	NH4-N µg/L	NO3-N µg/L	Tot-N µg/L	Ca mg/L	Mg mg/L	Na mg/L	K mg/L	Fe µg/L	Al µg/L	TOC mg/L
FL	17	12-May-96	15	2	4.6									2.35	0.28			413	254	5.5
FL	17	12-Jun-96	15	2	4.46									2.34	0.29			427	224	
FL	17	28-Aug-96	15	2	4.43									2.41	0.25			501	250	5.5
FL	17	3-Oct-96	15	2	4.55	2.83	0.005					1.5		2.36	0.3			544	248	5.6
FL	17	24-Oct-96	15	2	4.63	2.52	0.012					1.5		2.37	0.29			572	277	5.7
FL	17	13-Nov-96	15	2	4.59									2.6	0.34	1.73		578	247	
FL	17	10-Jun-97	15	2	4.39									2.45	0.3	2.14		409	225	
FL	17	8-Jul-97	15	2	4.6									2.39	0.27			479	184	
FL	17	17-Sep-97	15	2	4.73									2.36	0.29	1.92		418	220	
FL	17	16-Oct-97	15	2	4.41	2.69	0.026	2.3	4.3	8	38	1.5	230	2.36	0.32	1.91	0.17	446	320	5.5
FL	17	12-Nov-97	15	2	4.71	2.58	0.015	2.4	4.3	7.8	1	21	150	2.35	0.3	2.05	0.18	459	313	5.6
FL	44	8-Sep-94	5	1	5.32	3.1	0.086	2.5	5.1	4.3	3	1.5	210	2.64	0.42		0.13	162	151	7.2
FL	44	11-Sep-94	5	1	5.3	2.5	0.179	2.2	5.4	4.5	8	1.5	175	2.26	0.31	1.22	0.12	199	130	5.5
FL	44	14-Sep-94	5	1	5.34	2.30	0.08	1.4	4.2	4.4	3	1.5	122	1.92	0.32	1.41	0.16	82	74	5.1
FL	44	11-Oct-94	5	1	5.61	2.5	0.09	2.5	5.2	4	5	1.5	225	1.36	0.27	1.22	0.32	154	130	3.8
FL	44	31-Oct-94	5	1	5.46	2.5	0.106	3.5	4.2	4.1	3	1.5	121	2.32	0.42	1.73	0.25	113	126	3.4
FL	44	15-Nov-94	5	2	5.72	2.41	0.067	2.5	3.7	4.3	1	1.5	95	1.97	0.38	1.96	0.15	112	122	2.5
FL	44	30-Nov-94	5	2	5.57	2.41	0.051	2.7	4	4.4	3	1.5	138	1.91	0.37	1.96	0.11	155	134	4.2
FL	44	15-Dec-94	5	2										2.22	0.5	1.95				
FL	44	11-May-95	5	2	5.5	2.44	0.07	2	5.1	3.7	8	3	55	1.36	0.36	1.59	0.14	67	92	1.9
FL	44	21-Jun-95	5	2	5.95	2.30	0.087	1.7	5.2	4.3	1	2	80	2.19	0.14	1.65	0.13	1	88	2.4
FL	44	13-Jul-95	5	2	5.96	3.45	0.08	3.3	7.4	3.8	5	1.5	200	2.36	0.54	2.02	0.42	127	124	4.2
FL	44	26-Sep-95	5	2	5.96	3.02	0.073	2.7	5.5	3	8	1.5	135	2.24	0.3	2.1	0.54	174	174	3.1
FL	44	13-Oct-95	5	2	5.53	2.58	0.067	2.7	5.2	4.3	8	1.5	155	2.11	0.42	2.1	0.51	136	150	3.6
FL	44	12-Jun-96	5	2	5.89	2.54	0.15	2.3	7	4.1	14	1.5	155	2.21	0.56	1.41	0.24	127	130	4.5
FL	44	28-Aug-96	5	2	5.96	3.5	0.16					2		5.37	1.34			885	215	3.9
FL	44	3-Oct-96	5	2	5.53	2.56	0.056	2.4	5.1	4.8	2	1.5	125	2.34	0.57	1.34	0.25	161	128	4
FL	44	24-Oct-96	5	2	5.62	2.64	0.07	2.3	5.2	5.1	13	1.5	125	1.64	0.52	1.75	0.23	155	132	3.6
FL	44	13-Nov-96	5	2	5.73	2.44	0.052	2.4	5.3	5.2	2	1.5	138	1.57	0.5	1.65	0.23	127	87	3.5
FL	44	10-Jun-97	5	2	5.54	3.35	0.046	3.4	7	3.3	5	5	112	2.56	0.56	1.35	0.25	136	107	3.4
FL	44	8-Jul-97	5	2	5.57	3.3	0.056	2.3	5.7	4.7	5	3.5	125	2.29	0.52	1.54	0.22	142	118	3.8
FL	44	17-Sep-97	5	2	5.38	3.5	0.056	3.5	5.6	4.5	8	7.5	210	2.75	0.7	2.33	0.18	132	101	3.1
FL	44	15-Oct-97	5	2	5.6	3.83	0.073	2.5	5	5.3	6	1.5	135	2.12	0.56	1.73	0.17	143	113	3.7
FL	44	12-Nov-97	5	2	5.85	2.76	0.05	3.7	4.6	4.5	3	4	140	1.64	0.55	1.62	0.25	154	127	4

Loc	nr	Date	Depth	Limed	pH	Cond	ALK	Cl	SO4	Si	NH4-N	NO3-N	Tot-N	Ca	Mg	Na	K	Al	Mn	TOC
			cm		-log H+	mS/m	mmol/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	mg/L
FL	44	5-Sep-94	15	1	[illegible]	[illegible]	[illegible]	2.3	[illegible]	[illegible]	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	44	11-Sep-94	15	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	55	[illegible]	[illegible]
FL	44	11-Oct-94	15	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	44	31-Oct-94	15	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	44	15-Nov-94	15	2	[illegible]	[illegible]	[illegible]	2.9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	44	30-Nov-94	15	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	51	[illegible]	[illegible]
FL	44	15-Dec-94	15	2	[illegible]	[illegible]	[illegible]					4		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
FL	44	11-May-95	15	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	44	21-Jun-95	15	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	44	13-Jul-95	15	2	[illegible]	[illegible]	[illegible]	2.4	[illegible]	[illegible]	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	44	26-Sep-95	15	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	44	15-Oct-95	15	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	44	10-May-96	15	2	[illegible]	[illegible]	[illegible]	2	[illegible]	[illegible]	3	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	44	12-Jun-96	15	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	44	29-Aug-96	15	2	[illegible]	[illegible]	[illegible]	[illegible]	13.4	[illegible]	3	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	125	[illegible]	2.1
FL	44	3-Oct-96	15	2	[illegible]	[illegible]	[illegible]	2.3	[illegible]	5	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	115	[illegible]	[illegible]
FL	44	24-Oct-96	15	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	44	13-Nov-96	15	2	[illegible]									[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
FL	44	10-Jun-97	15	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	44	8-Jul-97	15	2	[illegible]	[illegible]	[illegible]	2.3	[illegible]	[illegible]	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	44	17-Sep-97	15	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	44	15-Oct-97	15	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	44	12-Nov-97	15	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	45	5-Sep-94	5	1	[illegible]	[illegible]	[illegible]	1.3	[illegible]	[illegible]	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	45	11-Sep-94	5	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2
FL	45	19-Sep-94	5	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	45	11-Oct-94	5	1	[illegible]	[illegible]	[illegible]					3		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	
FL	45	31-Oct-94	5	1	[illegible]	[illegible]	[illegible]	2.4	[illegible]	[illegible]	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	45	15-Dec-94	5	2	[illegible]	[illegible]	[illegible]					4		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
FL	45	11-May-95	5	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	45	21-Jun-95	5	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	45	13-Jul-95	5	2	[illegible]	[illegible]	[illegible]	2	[illegible]	[illegible]	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	45	26-Sep-95	5	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5	3	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	45	15-Oct-95	5	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Loc	no.	Date	Depth m	Limed	pH	Cond mS/m	ALK mmol/L	Cl mg/L	SO4 mg/L	Si mg/L	NH4-N µg/L	NO3-N µg/L	Tot-N µg/L	Ca mg/L	Mg mg/L	Na mg/L	K mg/L	Al µg/L	Alo µg/L	TOC mg/L
FJ	45	30-May-96	5	2	5.75	2.65	0.112	1.6	4.6	4.5	3	3	74	2.13	[illegible]	1.55	[illegible]	54	61	1.5
FJ	45	12-Jun-96	5	2	5.58	2.9	0.098	2	5.3	5	3	4	53	2.59	[illegible]	1.7	[illegible]	81	51	1.9
FJ	45	29-Aug-96	5	2	5.87	2.53	0.096	2.5	3.4	4.7	3	4	64	2.85	[illegible]	1.91	[illegible]	61	53	1.9
FJ	45	3-Oct-96	5	2	5.79	3.22	0.112	2.1	5.7	5	3	3.5	87	3.22	[illegible]	1.57	[illegible]	76	51	2
FJ	45	24-Oct-96	5	2	5.96	2.75	0.127	2	4.1	5.2	–	3.5	56	2.87	[illegible]	1.44	[illegible]	113	72	2.1
FJ	45	13-Nov-96	5	2	6.13	2.44	0.121	2.3	3.4	5.2	12	3.5	52	2.31	[illegible]	1.47	[illegible]	91	66	2.1
FJ	45	10-Jun-97	5	2	6.01	3.51	0.128	2.4	5.3	5.2	3	4	51	3.3	[illegible]	1.79	[illegible]	50	38	1.5
FJ	45	6-Jul-97	5	2	5.89	3.46	0.129	2.2	5.1	5.2	5	3.5	66	3.36	[illegible]	1.47	[illegible]	59	43	2.1
FJ	45	17-Sep-97	5	2	6.75	3.45	0.138	2.1	5.6	5.3	5	3.5	56	3.39	[illegible]	1.53	[illegible]	50	45	2.1
FJ	45	15-Oct-97	5	2	6.21	3.56	0.158	2.5	5.4	5.4	5	3.5	64	3.62	[illegible]	1.52	[illegible]	73	45	2.3
FJ	45	12-Nov-97	5	2	5.96	2.51	0.114	2.1	2.3	3.5	3	4	75	2.91	[illegible]	1.7	[illegible]	68	48	2.1
FJ	45	3-Sep-94	15	1	5.79	4	0.259	3	5	5.2	3	3.5	–	3.89	[illegible]	1.93	[illegible]	55	16	1.9
FJ	45	11-Sep-94	15	1	6.62	4.53	0.275	2.2	5	5.2	15	3.5	51	5.13	[illegible]	1.87	[illegible]	52	11	1.9
FJ	45	13-Sep-94	15	1	6.58	3.91	0.281	1.1	2.2	5.1	4	2	53	4.57	[illegible]	1.87	[illegible]	26	16	1.7
FJ	45	11-Oct-94	15	1	6.72	3.45	0.299	1.5	1.5	5	15	3	51	4.83	[illegible]	1.56	[illegible]	31	20	2.1
FJ	45	31-Oct-94	15	1	6.66	4.11	0.275	3.1	2.2	5.2	6	3.5	63	5.24	[illegible]	1.56	[illegible]	31	20	1.7
FJ	45	13-Nov-94	15	2	6.13	3.5	0.279	1.2	1	5.1	3	3.5	57	5.22	[illegible]	1.51	[illegible]	36	22	1.5
FJ	45	30-Nov-94	15	2	6.28	3.7	0.274	2.2	2.2	5	3	3.5	44	5.28	[illegible]	1.9	[illegible]	19	14	1.5
FJ	45	15-Dec-94	15	2	6.85	3	0.256					4		4.36	[illegible]	1.79	[illegible]	56	30	1.9
FJ	45	11-May-95	15	2	6.28	3.62	0.196	2.2	4.6	4.3	–	4	45	3.51	[illegible]	1.63	[illegible]	31	14	1.5
FJ	45	20-Jun-95	15	2	6.58	3.21	0.215	1.9	4.6	4.3	11	4	28	4.23	[illegible]	1.67	[illegible]	15		1.5
FJ	45	12-Jul-95	15	2	6.36	4.4	0.156	2.1	10.1	4.5	5	3.5	66	4.92	[illegible]	1.87	[illegible]	21	11	1.4
FJ	45	28-Sep-95	15	2	6.42	3.55	0.175	2.5	6.3	5.2	3	4	71	4.44	[illegible]	1.78	[illegible]	44	23	1.8
FJ	45	15-Oct-95	15	2	6.33	3.5	0.196	2.4	4.4	5.1	3	3.5	66	4	[illegible]	1.92	[illegible]	27	23	1.9
FJ	45	15-May-96	15	2	6.99	3.32	0.154	1.5	4.6	4.3	3	4	104	3.9	[illegible]	1.68	[illegible]	25	21	1.7
FJ	45	12-Jun-96	15	2	6.43	3.45	0.131	2	5.5	5.1	3	3.5	63	3.71	[illegible]	1.75	[illegible]	45	22	1.2
FJ	45	29-Aug-96	15	2	6.13	3.56	0.193	2	5.5	4	3	4	54	3.9	[illegible]	1.64	[illegible]	45	28	2.5
FJ	45	3-Oct-96	15	2	6.1	4.31	0.206	2.4	5.5	5.4	6	3.5	138	4.74	[illegible]	1.91	[illegible]	52	32	1.1
FJ	45	24-Oct-96	15	2	6.25	3.92	0.246	2.1	4.3	5.5	6	3.5	81	4.66	[illegible]	1.68	[illegible]	52	32	1.4
FJ	45	13-Nov-96	15	2	6.67	3.5	0.251	2.1	3.3	5.5	3	3.5	74	4.06	[illegible]	1.57	[illegible]	32	21	2
FJ	45	10-Jun-97	15	2	6.58	4.22	0.215	2.3	5	5.4	3	4	65	4.37	[illegible]	1.81	[illegible]	26	14	1.4
FJ	45	6-Jul-97	15	2	6.13	4.2	0.212	2	5.5	5.1	3	3.5	54	4.8	[illegible]	1.6	[illegible]	27	13	1.5
FJ	45	17-Sep-97	15	2	6.41	4.45	0.22	2.2	5.5	5.5	3	3.5	50	5.15	[illegible]	1.78	[illegible]	25	16	1.6
FJ	45	15-Oct-97	15	2	6.6	4.65	0.251	2.2	5	5	3	3.5	56	5.51	[illegible]	1.9	[illegible]	29	18	1.7
FJ	45	12-Nov-97	15	2	6.34	4.14	0.283	2.3	3.5	5.5	3	4	56	5.5	[illegible]	1.81	[illegible]	23	18	1.7

Loc	nr	Date	Depth m	Level	pH	Kond mS/m	ALK mmol/L	Cl mg/L	SO4 mg/L	Si mg/L	NH4-N µg/L	NO3-N µg/L	Tot-N µg/L	Ca mg/L	Mg mg/L	Na mg/L	K mg/L	Al µg/L	[illegible] µg/L	TOC mg/L
FL	48	6-Sep-94	5	1	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	3	5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	48	11-Sep-94	5	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]
FL	48	16-Nov-94	5	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	48	30-Nov-94	5	2	[illegible]															
FL	48	11-May-95	5	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	48	21-Jun-95	5	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	48	23-Sep-95	5	2	[illegible]							[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	
FL	48	15-Oct-95	5	2	5	[illegible]	[illegible]							[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	
FL	48	10-May-96	5	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	22	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	48	12-Jun-96	5	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	48	29-Aug-96	5	[illegible]																
FL	48	3-Oct-96	5	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	48	24-Oct-96	5	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	48	13-Nov-96	5	2	[illegible]									[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
FL	48	10-Jun-97	5	2	[illegible]	[illegible]	[illegible]					[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
FL	48	8-Jul-97	5	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	48	17-Sep-97	5	2																
FL	48	6-Sep-94	15	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	48	11-Sep-94	15	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	48	19-Sep-94	15	1	5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	48	1-Oct-94	15	1	5	[illegible]	[illegible]	[illegible]	[illegible]	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	48	31-Oct-94	15	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	48	16-Nov-94	15	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	48	30-Nov-94	15	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	48	11-May-95	15	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	48	21-Jun-95	15	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	48	23-Sep-95	15	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	48	15-Oct-95	15	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	48	10-May-96	15	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	48	12-Jun-96	15	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	48	29-Aug-96	15	2	[illegible]									[illegible]	[illegible]			[illegible]	[illegible]	
FL	48	3-Oct-96	15	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	48	24-Oct-96	15	2	[illegible]									[illegible]	[illegible]			[illegible]	[illegible]	
FL	48	13-Nov-96	15	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3
FL	48	10-Jun-97	15	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
FL	48	8-Jul-97	15	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3
FL	48	15-Oct-97	15	2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Loc.	no.	Date	Depth	Lysim.	pH	Cond.	ALK	Cl	SO4	S	NH4-N	NO3-N	Tot-N	Ca	Mg	Na	K	Al	Alo	TOC
			cm		log H+	mS/m	mmol/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	mg/L
FJ	49	5-Sep-94	5	1	4.96							415		1.02	0.59	1.55				
FJ	49	11-Sep-94	5	1	4.95							455		1.56						
FJ	49	13-Sep-94	5	1	5.07							106		0.53						
FJ	49	31-Oct-94	5	1	4.59	5.36		4.6	6.4	2.3	74	528	1300	1.30	1.13	3.66	1.3	350	257	11.2
FJ	49	15-Nov-94	5	2	4.75	3.47					[illegible]	127		0.81	0.55	1.62		390	345	10.5
FJ	49	30-Nov-94	5	2	4.52									0.81	0.56	1.53				
FJ	49	15-Dec-94	5	2	4.71	5.5	0.018							1.23	1.05	1.85		453	334	
FJ	49	11-May-95	5	2	4.96	3.79	0.031					555		1.57	0.56	1.90		501	427	17.5
FJ	49	21-Jun-95	5	2	5.08	2.79	0.042					124		0.98	0.56	1.54		538	425	17.4
FJ	49	10-May-96	5	2	5.21							2540		1.79	1.56			277	185	7.7
FJ	49	3-Oct-96	5	2	4.8									1.04	1.05	2.15		327	256	
FJ	49	24-Oct-96	5	2	4.89									1.35	1.43			434	314	
FJ	49	13-Nov-96	5	2	4.71															
FJ	49	8-Jul-97	5	2	5.01									1.22	1.15	1.9				
FJ	49	15-Oct-97	5	2	5.26															
FJ	49	5-Sep-94	15	1	5.03							53		1.07	0.53	1.57				
FJ	49	11-Sep-94	15	1								51		1.26						
FJ	49	13-Sep-94	15	1	5.02							13		1.57						
FJ	49	11-Oct-94	15	1										1.13						
FJ	49	31-Oct-94	15	1	4.58	3.26	0.014	5	3.4	8.1	4	120	305	1.02	0.42	1.98	0.34	145	92	4.4
FJ	49	15-Nov-94	15	2	4.81									0.99	0.45	1.33		153	151	
FJ	49	30-Nov-94	15	2	4.56															
FJ	49	15-Dec-94	15	2	4.73									0.52	0.57	1.40				
FJ	49	11-May-95	15	2	4.95	2.71	0.031											154	132	
FJ	49	21-Jun-95	15	2	5.03	2.27	0.034							0.71	0.36	1.58		202	133	
FJ	49	25-Sep-95	15	2	4.56															
FJ	49	10-May-96	15	2	4.92							1080		1.23	0.56			207	120	5.5
FJ	49	13-Jun-96	15	2	5.22															
FJ	49	3-Oct-96	15	2	4.73									0.54	0.6	1.6		238	134	
FJ	49	24-Oct-96	15	2	4.81															
FJ	49	13-Nov-96	15	2	4.54									0.83	0.91	1.83				
FJ	49	8-Jul-97	15	2	4.96									0.58	0.4	1.65		234	156	7.2
FJ	49	17-Sep-97	15	2	5															
FJ	49	15-Oct-97	15	2	4.93	2.12	0.028					51	380	0.75	0.31	1.31		309	184	6.3

Loc.	nr.	Date	Depth	Limed	pH	Kond.	Alk.	Cl	SO4	Si	NH4-N	NO3-N	Tot-N	Ca	Mg	Na	K	Al	Fe	TOC
			m		-log H+	mS/m	mmol/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	mg/L
SP	23	6-Sep-94	5	1	5.15	2.52	0.04	2	5.7	3.9	3	4	132	1.32	0.48	1.86	0.11	171	113	3.5
SP	23	11-Sep-94	5	1	5.11	2.44	0.041	1.8	5.4	3.9	3	4	145	1.17	0.42	1.51	0.19	150	122	3.5
SP	23	19-Sep-94	5	1	5.19	2.33	0.042	1.2	4.2	3.6	3	5	150	1	0.32	1.23	0.14	150	129	3.5
SP	23	11-Oct-94	5	1	5.24	2.23	0.036	1.7	5.3	2.6	11	111	270	1.06	0.35	1.46	0.14	220	121	4.5
SP	23	31-Oct-94	5	1	5.14	2.36	0.037	3.4	4.1	3.3	2	69	200	1.4	1.56	1.74	0.24	220	131	3.4
SP	23	16-Nov-94	5	1	5.24	2.54	0.034	3	4.1	3.9	3	68	188	1.32	0.49	1.86	0.22	222	138	3.2
SP	23	30-Nov-94	5	1	5.21	2.53	0.034	3	4.5	4.1	2	60	188	1.41	0.51	1.96	0.21	225	113	3.2
SP	23	15-Dec-94	5	1	5.33	2.11	0.036	5.3	5.6	4.3	3	65	205	1.43	0.53	1.86	0.27	250	150	3.9
SP	23	11-May-95	5	1	5.4	2.05	0.045	1.7	4.2	2.3	2	50	147	1.02	0.38	1.5	0.18	216	135	3.4
SP	23	21-Jun-95	5	1	5.56	1.83	0.051	1	3.9	3	3	9	138	0.9	0.31	1.33	0.27	212	148	4.5
SP	23	13-Jul-95	5	1	5.51	1.81	0.039	1.6	4.7	3	5	60	260	0.91	0.29	1.56	0.04	219	144	4.6
SP	23	28-Sep-95	5	1	5.32	2.56	0.044	2.4	5.6	4.4	3	72	188	1.41	0.55	2.01	0.2	225	133	3.6
SP	23	15-Oct-95	5	1	5.29	2.72	0.037	3.7	5.1	4.1	3	213	345	1.39	0.56	1.95	0.13	217	122	3.7
SP	23	10-May-96	5	1	5.13	2.58	0.041	1.5	4.7	4	3	415	490	1.39	0.5	1.83	0.32	191	125	3.2
SP	23	12-Jun-96	5	1	5.29	2.33	0.038	1.7	5.3	4	5	50	120	1.19	0.44	1.56	0.12	193	111	3.9
SP	23	28-Aug-96	5	1	5.15									1.41	0.47			248	132	
SP	23	3-Oct-96	5	1	5.34	2.5	0.042	2.5	5.2	3.5	3	5	145	1.4	0.54	1.81	0.06	228	154	3.7
SP	23	24-Oct-96	5	1	5.35	2.54	0.045	2.2	5.4	4.2	4	13	122	1.38	0.53	1.67	0.12	224	138	3.4
SP	23	13-Nov-96	5	1	5.36	2.4	0.043	2.5	4.6	4.2	3	58	161	1.31	0.53	1.55	0.15	211	127	3.5
SP	23	10-Jun-97	5	1	5.5	2.35	0.045	2.2	4.7	3.8	3	22	149	1.21	0.4	1.56	0.09	193	135	3.3
SP	23	8-Jul-97	5	1	5.43	2.28	0.045	3	4.4	3.9	3	15	125	1.2	0.43	1.51	0.03	158	111	3.4
SP	23	17-Sep-97	5	1	5.6	2.48	0.044	2.4	4.6	4.1	4	51	361	1.32	0.46	1.63	0.08	159	113	3.9
SP	23	15-Oct-97	5	1	5.49	2.34	0.047	2.4	4.1	4.4	3	15	175	1.11	0.44	1.52	0.1	134	115	5
SP	23	12-Nov-97	5	1	5.30	2.5	0.04	2.3	4	4.3	5	200	325	1.3	0.5	1.73	0.06	200	119	3
SP	23	6-Sep-94	15	1	5.13	2.66	0.043	1.7	5.1	3.8	3	5	135	1.42	0.5	1.73	0.11	132	115	3.9
SP	23	11-Sep-94	15	1	5.1	2.66	0.044	1.5	5.8	4.1	3	10	144	1.36	0.46	1.52	0.06	155	114	4
SP	23	19-Sep-94	15	1	5.14	2.38	0.042	1.5	4.5	3.8	3	7	140	1.06	0.36	1.20	0.14	155	131	4
SP	23	11-Oct-94	15	1	5.30	2.3	0.042	1.6	5.4	4	9	54	160	1.15	0.42	1.57	0.1	129	125	3.7
SP	23	31-Oct-94	15	1	5.11	2.79	0.038	3.4	4.3	3.8	3	30	220	1.43	0.53	1.84	0.2	225	117	3.2
SP	23	16-Nov-94	15	1	5.20	2.59	0.038	2.6	3.8	3.3	3	73	190	1.32	0.51	1.95	0.22	230	130	5.2
SP	23	30-Nov-94	15	1	5.30	2.57	0.043	3	4.8	4.1	3	56	136	1.48	0.53	1.95	0.22	222	121	3
SP	23	15-Dec-94	15	1	5.38	2.65	0.041	3.7	4.8	4.8		55		1.52	0.53	1.96	0.28	274	162	3.8
SP	23	11-May-95	15	1	5.4	2.15	0.043	1.7	4.5	3.7	3	54	156	1.38	0.39	1.56	0.21	213	158	3.3
SP	23	21-Jun-95	15	1	5.56	1.91	0.053	1	4.3	3	3	8	135	1.07	0.38	1.35	0.08	139	145	4.1
SP	23	13-Jul-95	15	1	5.55	1.83	0.048	2.7	3	2.7	3	38	150	0.9	0.3	1.32	0.09	155	132	4.1
SP	23	28-Sep-95	15	1	5.36	2.71	0.054	2.4	5.8	4.5	3	72	159	1.57	0.58	2.29	0.19	215	127	3.8
SP	23	15-Oct-95	15	1	5.45	2.72	0.047	2.6	5.4	4.1	3	121	250	1.42	0.56	2.28	0.19	224	131	3.8

Loc.	No.	Date	Depth	Limed	pH	Cond.	ALK	Cl	SO4	Si	NH4-N	NO3-N	Tot-N	Ca	Mg	Na	K	Al	Ac	TOC
			m		-log H+	mS/m	mmol/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	mg/L
SP	28	15-May-96	15	0	5.18	2.74	0.044	2	4.9	4	3	410	490	1.43	0.51	1.65	0.32	214	125	3.3
SP	28	12-Jun-96	15	0	5.43	2.43	0.042	1.8	5.4	4.1	1	45	155	1.23	0.46	1.6	0.17	201	125	3.5
SP	28	28-Aug-96	15	0	5.41	2.23	0.042	1.1	4.4	2.1	2	74	155	1.15	0.38	1.25	0.27	156	125	3.5
SP	28	9-Oct-96	15	0	5.38	2.54	0.045	2.2	5.3	3.9	3	15	138	1.44	0.54	1.61	0.24	217	114	3.4
SP	28	24-Oct-96	15	0	5.39	2.65	0.048	2.3	5.4	4.2	2	13	117	1.42	0.54	1.56	0.1	235	132	3.5
SP	28	19-Nov-96	15	0	5.42	2.88	0.045	2.5	5	4.2	3	24	133	1.45	0.55	1.65	0.18	232	124	3.3
SP	28	15-Jan-97	15	0	5.43	2.47	0.041	2.3	4.6	4	5	29	122	1.21	0.43	1.47	0.11	190	125	2.6
SP	28	6-Jun-97	15	0	5.51	2.37	0.059	2	4.5	3.5	3	2	205	1.36	0.47	1.55	0.24	195	125	3.2
SP	28	17-Sep-97	15	0	5.50	2.56	0.054	2.2	4.6	4.4	5	70	215	1.41	0.48	1.27	0.22	157	123	3.4
SP	28	15-Oct-97	15	0	5.51	2.36	0.049	2.4	4.8	4.3	3	12	155	1.28	0.45	1.62	0.26	199	117	3.7
SP	28	12-Nov-97	15	0	5.33	2.61	0.04	2.3	4.5	4.2	3	155	310	1.39	0.52	1.91	0.22	214	135	3
SP	30	9-Sep-94	5	1	5.06	2.45	0.036	1.5	5.3	3.7	3	4	121	1.15	0.48	1.53	0.12	175	135	2.5
SP	30	11-Sep-94	5	1	5.06	2.53	0.038	1.6	5.1	3.8	3	5	141	1.1	0.42	1.5	0.13	196	106	3.3
SP	30	19-Sep-94	5	1	5.17	3.06	0.038	1.1	4.7	3.4	3	4	129	0.96	0.36	1.14	0.14	193	110	2.6
SP	30	11-Oct-94	5	1	5.25	2.13	0.04	1.4	4.8	3.5	8	33	205	0.96	0.4	1.25	0.14	227	112	3.2
SP	30	31-Oct-94	5	1	5.04	2.73	0.033	2.7	3.5	3.8	3	72	190	1.30	0.57	1.61	0.16	255	95	2.2
SP	30	15-Nov-94	5	1	5.13	2.46	0.032	2.6	3.7	3.8	3	73	160	1.22	0.45	1.71	0.13	260	112	3.1
SP	30	30-Nov-94	5	1	5.23	2.39	0.038	2.7	4.3	3.5	3	56	147	1.25	0.49	1.72	0.18	221	150	2.5
SP	30	15-Dec-94	5	1	5.19	2.43	0.035	3	4.3	3.6	3	55	155	1.15	0.5	1.56	0.23	271	131	3.4
SP	30	11-May-95	5	1	5.29	2.1	0.042	1.7	4.5	2.6	3	44	147	0.87	0.38	1.51	0.26	229	126	3.3
SP	30	21-Jun-95	5	1	5.5	1.88	0.052	1.9	4.2	2.9	3	4	126	1.08	0.41	1.3	0.15	212	156	3.5
SP	30	13-Jul-95	5	1	5.45	1.73	0.042	1.6	4.8	2.9	3	56	191	0.88	0.39	1.48	0.15	205	127	3.3
SP	30	28-Sep-95	5	1	5.42	2.49	0.045	2.1	5.4	4.0	5	53	190	1.31	0.56	1.58	0.23	274	122	3.3
SP	30	15-Oct-95	5	1	5.27	2.54	0.045	2.4	5.1	3.8	3	125	255	1.35	0.52	1.67	0.22	244	116	3.3
SP	30	10-May-96	5	1	5.39	2.29	0.045	1.8	4.7	3.8	3	445	555	1.30	0.45	1.52	0.35	217	117	2
SP	30	12-Jun-96	5	1	5.4	2.29	0.048	1.8	5.2	3.9	5	51	155	1.13	0.44	1.4	0.22	209	120	3.4
SP	30	9-Oct-96	5	1	5.23	2.4	0.038	1.8	5	3.8	3	4	123	1.23	0.47	1.57	0.12	223	126	3.2
SP	30	24-Oct-96	5	1	5.32	2.4	0.041	2.1	5.2	4	3	5	101	1.23	0.5	1.44	0.1	236	123	3.4
SP	30	13-Nov-96	5	1	5.33	2.23	0.04					16		1.22	0.52	1.33		231	129	3.4
SP	30	15-Jan-97	5	1	5.34	2.32	0.038	2.1	4.5	3.7	3	41	175	1.19	0.40	1.54	0.1	189	135	3.7
SP	30	5-Jun-97	5	1	5.44	2.19	0.043	1.3	4.5	2.7	3	1	125	1.16	0.41	1.41	0.08	175	110	3.1
SP	30	17-Sep-97	5	1	5.49	2.31	0.05	1.8	4.5	4	11	52	225	1.21	0.44	1.62	0.17	200	108	3.4
SP	30	15-Oct-97	5	1	5.37	2.28	0.042	2.4	4.5	4	3	8	144	1.04	0.43	1.6	0.07	212	125	3.3
SP	30	12-Nov-97	5	1	5.22	2.43	0.036	2.7	4	4	3	215	330	1.27	0.5	1.64	0.14	242	135	3.9

Loc.	No.	Date	Depth	Limed	pH	Kond.	ALK	Cl	SO4	Si	NH4-N	NO3-N	Tot-N	Ca	Mg	Na	K	Fe	Al	TOC
			m		-log[H+]	mS/m	mmol/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	mg/L
SP	30	8-Sep-94	15	1	5.17	2.5	0.037	1.7	6.2	3.7	5	4	126	1.19	0.45	1.53	0.77	171	101	3.4
SP	30	11-Sep-94	15	1	5.15	2.45	0.039	1.5	5.5	4	2	5	135	1.12	0.45	1.49	0.77	156	112	2.5
SP	30	19-Sep-94	15	1	5.25	2.74	0.038	1.1	4.6	4.2	3	3	122	1	0.4	1.14	0.72	200	112	3.3
SP	30	11-Oct-94	15	1	5.34	2.15	0.049	1.4	4.5	3.7	5	75	273	1.15	0.51	1.43	1.1	222	118	3.4
SP	30	18-Nov-94	15	1	5.13	2.43	0.032	3	4.1	3.7	3	72	151	1.24	0.45	1.74	0.75	231	114	3
SP	30	30-Nov-94	15	1	5.24	2.4	0.04	2.7	4.2	3.8	3	53	146	1.3	0.42	1.74	0.15	228	136	3
SP	30	15-Dec-94	15	1	5.21	2.4	0.038	2.9	4.2	3.7	3	7	171	1.15	0.45	1.57	0.21	271	123	3.3
SP	30	11-May-95	15	1	5.32	2.39	0.04	1.7	4.4	2.6	3	44	141	1.36	0.36	1.44	0.25	224	129	3.2
SP	30	21-Jun-95	15	1	5.46	1.94	0.049	1.9	4.1	2.5	3	4	129	1.34	0.31	1.27	0.11	212	136	4.1
SP	30	13-Jul-95	15	1	5.45	1.6	0.043	1.8	4.5	2.3	3	17	162	0.87	0.25	1.54	0.16	226	151	3.5
SP	30	25-Sep-95	15	1	5.29	2.55	0.049	2.2	5.4	4.1	3	57	165	1.30	0.57	1.32	0.21	217	116	3.5
SP	30	15-Oct-95	15	1	5.34	2.5	0.052	2.4	5.1	4	3	130	247	1.42	0.58	1.51	0.19	217	139	3.2
SP	30	13-May-96	15	1	5.11	2.62	0.045	1.3	4.2	3.2	3	440	555	1.30	0.49	1.51	0.36	125	114	4.5
SP	30	12-Jun-96	15	1	5.47	2.33	0.044	1.7	5.1	3.9	6	51	193	1.21	0.45	1.48	0.221	212	106	3.4
SP	30	25-Aug-96	15	1	5.12	2.17	0.033	4.8	3.5	2.4	5	256	415	1.50	0.52	1.21	0.24	235	121	4.3
SP	30	3-Oct-96	15	1	5.41									1.13	0.49	1.43		135	106	
SP	30	24-Oct-96	15	1	5.36	2.57	0.04	2.1	5.2	4	3	7	117	1.26	0.5	1.45	0.19	213	129	3.5
SP	30	13-Nov-96	15	1	5.27	2.29	0.042	2.3	4.5	4	3	21	136	1.21	0.51	1.45	0.12	253	122	3.3
SP	30	13-Jan-97	15	1	5.27	2.33	0.036	2.4	4.3	3.3	3	4	124	1.13	0.41	1.54	0.09	225	105	2.8
SP	30	3-Jun-97	15	1	5.36	2.15	0.045	1.6	4.4	3.6	3	2	117	1.45	0.42	1.41	0.17	156	112	3.3
SP	30	17-Sep-97	15	1	5.57	2.4	0.055	1.9	4.5	4.2	3	11	135	1.25	0.47	1.62	0.16	157	112	3.3
SP	30	16-Oct-97	15	1	5.44	2.27	0.043	2.4	4.3	4.1	2	12	155	1.12	0.44	1.52	0.32	210	109	3.5
SP	30	12-Nov-97	15	1	5.26	2.46	0.036	2.3	4.7	4	3	232	345	1.25	0.51	1.54	0.24	236	109	3
SP	27	8-Sep-94	5	1	4.42	2.53		1.4	3.3	4.4	3	2	250	0.54	0.27	1.32	0.13	458	343	13.5
SP	27	12-Sep-94	5	1	4.44	2.54		1.2	3.1	4.2	1	1	250	0.44	0.22	1.32	0.15	451	358	11.4
SP	27	19-Sep-94	5	1	4.5	2.54		1.1	2.5	3.4	3	1	215	0.4	0.2	1.35	0.18	415	343	11.3
SP	27	10-Oct-94	5	1	4.47	2.3		1.5	3.4	4.5	3	2	215	0.57	0.31	1.27	0.25	425	315	11
SP	27	31-Oct-94	5	1	4.34	3.51		3.3	3.5	4.7	3	5	152	0.72	0.43	1.66	0.13	425	292	9.5
SP	27	16-Nov-94	5	1	4.4	2.58		1.3	2.3	2.6	1	1.6	135	0.61	0.33	1.51	0.13	336	300	3.4
SP	27	30-Nov-94	5	1	4.46	2.73		2.1	3.6	4.5	3	5	170	0.61	0.4	1.54	0.13	431	300	5.5
SP	27	15-Dec-94	5	1	4.32	3.52						1.5		0.73	0.47	1.7	1	496	321	
SP	27	11-May-95	5	1	4.65	2.23	0.014	1.3	2.5	3	1	2	208	0.41	0.22	1.12	0.15	357	273	9.2
SP	27	21-Jun-95	5	1	4.64	2.21	0.014	0.8	3.2	3.1	1	2	215	0.47	0.21	1.36	0.13	403	308	11.6
SP	27	13-Jul-95	5	1	4.57							1.3		0.6	0.21	1.49	1	399	250	10.3
SP	27	26-Sep-95	5	1	4.54	3.33		1.5	3.1		11	1.3	255	0.54	0.25	1.54	0.27	434	360	14.2
SP	27	16-Oct-95	5	1	4.46	3.73		2.5	3.4	5.2	1	4	250	0.59	0.34	1.82	0.24	427	330	11.2

Loc.	no.	Date	Depth	Limed	pH	Kond	ALK	Cl	SO4	Si	NH4-N	NO3-N	Tot-N	Ca	Mg	Na	K	Al	Mn	TOC
			cm		log (H)	mS/m	mmol/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	mg/L
SP	37	10-May-96	5	-	4.54	2.47	0.019	1	2.1	3.4	5	14	221	0.49	0.25	1.25	0.4	368	253	10.6
SP	37	12-Jun-96	5	-	4.53	2.56		1.2	2.5	4.8	11	4	250	0.59	0.32	1.3	0.38	422	30	12
SP	37	29-Aug-96	5	-	4.3	4.62		3.4	5.3	3.5	32	0.05	750	0.96	0.51	1.88	0.18	1100	564	15.3
SP	37	3-Oct-96	5	-	4.47	3.35		1.8	3.8	4.7	6	7.5	245	0.59	0.33	1.43	0.38	474	352	12.1
SP	37	24-Oct-96	5	-	4.45	3.18		1.8	3.7	4.8	1	5.5	193	0.53	0.32	1.36	0.38	451	353	10.6
SP	37	13-Nov-96	5	-	4.46									0.52	0.35	1.3		359	263	
SP	37	10-Jun-97	5	-	4.56	2.77	0.005	2.2	2.8	5.4	5	3.5	173	0.53	0.3	1.44	0.35	396	264	8.6
SP	37	6-Jul-97	5	-	4.62	2.87	0.005	1.3	2.5	5.2	10	1.8	250	0.48	0.27	1.51	0.75	435	345	14.4
SP	37	17-Sep-97	5	-	4.55	2.82	0.005	1.4	3.3	6.4	9	0.5	315	0.54	0.27	1.58	0.25	482	275	15.8
SP	37	15-Oct-97	5	-	4.5	2.87	0.005	2	3.2	5.4	10	1.8	257	0.64	0.35	1.42	0.26	432	351	13.4
SP	37	12-Nov-97	5	-	4.48	3.33		2.2	3.4	5	6	0.3	238	0.55	0.4	1.55	0.24	482	242	12.9
SP	37	8-Sep-94	15	-	4.45	2.8		1.4	2.3	4.5	3	0.5	225	0.51	0.29	1.5	0.11	446	372	13.9
SP	37	19-Sep-94	15	-	4.51	2.3		1.1	2.8	3.8	3	3	215	0.59	0.18	1.22	0.18	471	382	12.6
SP	37	11-Oct-94	15	-	4.5	2.42		1.2	2.3	4.5	12	2	155	0.43	0.25	1.14	0.15	411	272	12.6
SP	37	31-Oct-94	15	-	4.36	3.47		3.8	3.4	5	3	2	150	0.59	0.42	1.54	0.18	431	275	8.6
SP	37	15-Nov-94	15	-	4.45	3.75		1.7	2.5	4.1	3	1.5	175	0.5	0.37	1.43	0.13	416	326	8.1
SP	37	30-Nov-94	15	-	4.43	3.67		2	3.4	4.8	3	0.5	155	0.58	0.33	1.45	0.11	451	287	6
SP	37	15-Dec-94	15	-	4.44	3.11						1.5		0.64	0.37	1.4		490	270	10.4
SP	37	10-May-95	15	-	4.63	1.55	0.014	1.7	2.4	3.3	6	2	410	0.38	0.2	1.09	0.22	373	309	9.6
SP	37	20-Jun-95	15	-	4.45	2.2	0.015	1.8	2.9	3.1	1	2	315	0.4	0.2	1.34	0.13	452	248	12
SP	37	13-Jul-95	15	-	4.61	2.33	0.011					0.5		0.44	0.21	1.4		453	288	11
SP	37	28-Sep-95	15	-	4.56	2.5		1.6	2.5	5.1	1	1.5	225	0.48	0.29	1.42	0.22	455	275	13
SP	37	15-Oct-95	15	-	4.51	2.58	0.015	2.2	2.4	5.4	5	1.5	200	0.47	0.29	1.62	0.22	412	342	11.1
SP	37	12-Jun-96	15	-	4.56	2.5	0.005	1	3.4	5	11	0.5	205	0.44	0.29	1.35	0.2	422	318	11.2
SP	37	29-Aug-96	15	-	4.49	4.36		2.8	4	5.7	25	0.3	710	0.68	0.38	1.75	0.51	1290	567	28.9
SP	37	3-Oct-96	15	-	4.61	2.75		1.5	3.3	5	3	2.8	220	0.5	0.31	1.36	0.28	442	358	12
SP	37	24-Oct-96	15	-	4.53	2.86		1.5	3.5	4.8	1	5.5	175	0.52	0.33	1.33	0.15	458	382	10.7
SP	37	13-Nov-96	15	-	4.47									0.49	0.38	1.22		365	290	
SP	37	10-Jun-97	15	-	4.57	2.77	0.005	2	3.3	6.8	6	0.5	170	0.47	0.27	1.47	0.13	456	262	8.8
SP	37	6-Jul-97	15	-	4.59	2.45	0.005	1.3	2.6	5.7	10	0.8	235	0.45	0.29	1.31	0.15	459	345	14.8
SP	37	17-Sep-97	15	-	4.65	2.47	0.014	1.3	2.6	7.1	11	3.5	255	0.41	0.25	1.56	0.14	452	278	14.3
SP	37	15-Oct-97	15	-	4.45	2.75	0.011	2.1	3	6.8	10	1.5	250	0.44	0.28	1.64	0.15	452	345	13.3
SP	37	12-Nov-97	15	-	4.57	2.7	0.006	2.3	2.1	6.8	3	4	220	0.49	0.33	1.71	0.13	459	344	11.3

Loc.	No.	Date	Depth cm	Level	pH -log [H+]	Cond. mS/m	ACK mmol/L	Cl mg/L	SO4 mg/L	Si mg/L	NH4-N µg/L	NO3-N µg/L	Tot-N µg/L	Ca mg/L	Mg mg/L	Na mg/L	K mg/L	Fe µg/L	Al µg/L	TOC mg/L
SP	40	6-Sep-94	5	.	4.12							5		1.38	0.33	1.57	0.21			
SP	40	11-Sep-94	5	.													0.12			
SP	40	19-Sep-94	5	.	4.25							3		1.38						
SP	40	11-Oct-94	5	.								3		1.58	0.32	1.13		255	234	
SP	40	31-Oct-94	5	.	4.1			3.4	4.1	3.1	12	1	500	1.43	0.39	1.65		199	133	14.5
SP	40	15-Nov-94	5	.	4.1									1.7	0.45	1.5		256	225	
SP	40	30-Nov-94	5	.	4.15												0.18			
SP	40	11-May-95	5	.	4.26	3.88														
SP	40	21-Jun-95	5	.	4.22									1.54	0.25	1.54				
SP	40	26-Sep-95	5	.	4.24									1.53	0.35	1.26		257	217	
SP	40	16-Oct-95	5	.	4.29									1.6	0.45	1.39		323	272	
SP	40	10-May-96	5	.	4.07							3		1.58	0.51			321	309	25
SP	40	12-Jun-96	5	.	4.3									1.6	0.41					
SP	40	29-Aug-96	5	.	4.01															
SP	40	3-Oct-96	5	.	4.05															
SP	40	24-Oct-96	5	.	3.96									1.59	0.41			396	380	30.5
SP	40	13-Nov-96	5	.	4.04									1.49	0.33	1.36				
SP	40	10-Jun-97	5	.	4.13									1.62	0.4	1.56		442	380	
SP	40	8-Jul-97	5	.	4.12									1.48	0.34	1.45		337	367	
SP	40	17-Sep-97	5	.	4.06									1.54	0.41	2.16		436	430	
SP	40	15-Oct-97	5	.	4.04							2		1.42	0.41	1.53		334	396	40.6
SP	40	12-Nov-97	5	.	3.93									1.44	0.42			416	364	32.4
SP	40	6-Sep-94	15	.								1								
SP	40	11-Sep-94	15	.								6								
SP	40	19-Sep-94	15	.	4.6															
SP	40	12-Nov-97	15	.	4.45															
SP	46	6-Sep-94	5	.	4.57		0.044					4		2.34	0.58	3.67	0.13	595	458	22.6
SP	46	11-Sep-94	5	.	4.99							2	800	1.74			0.15	434	380	
SP	46	19-Sep-94	5	.	4.52	2.54		1.5	4	4.5	8	2	555	1.36	0.39	1.44		477	271	15.6
SP	46	11-Oct-94	5	.	4.66	2.27	0.027	3.8	3.4	3.4	54	6	350	1.3	0.45	1.43		545	212	8.8
SP	46	31-Oct-94	5	.	4.56	3.06		16.4	4.7	4.6	156	14	750	2.62	1.13	3.58	1.21	771	309	12.5
SP	46	16-Nov-94	5	.	4.6	3.93	0.021	4.5	4.9	4.2	33	10	500	2.14	0.58	2.43	0.7	528	329	12.6
SP	46	30-Nov-94	5	.	4.73	4.21	0.022	5.1	4.7	4.5	1	22	425	1.95	0.53	2.43	3.1	451	257	10.1
SP	46	11-May-95	5	.	4.77	5.81	0.023	12	5.7	4.9	3	6	400	3.24	1.07	4.6	1.1	566	294	11
SP	46	21-Jun-95	5	.	4.34	5.07	0.029	5.5	5.4	4.4	11	4	500	2.52	0.73	3.56	0.29	544	314	13.3
SP	46	26-Sep-95	5	.	4.66									1.56	0.57	2.52	1.34	394	213	8.5
SP	46	15-Oct-95	5	.	4.59	4.83	0.016					1.5		1.38	0.57	3.27	0.7	354	157	4

Loc.	no	Date	Depth m	Level	pH -log H+	cond. mS/m	ALK mmol/L	Cl mg/L	SO4 mg/L	Si mg/L	NH4-N µg/L	NO3-N µg/L	Tot-N µg/L	Ca mg/L	Mg mg/L	Na mg/L	K mg/L	Al µg/L	Mn µg/L	TOC mg/L
SP	46	10-May-96	5	1	4.58	5.4		[illegible]	3.4	[illegible]	[illegible]	[illegible]	[illegible]	2.39	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
SP	46	13-Jun-96	5	1	4.73	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]
SP	46	29-Aug-96	5	1													[illegible]			
SP	46	3-Oct-96	5	1	[illegible]	[illegible]					[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
SP	46	24-Oct-96	5	1	4.79	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SP	46	13-Nov-96	5	1	4.7									[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
SP	46	10-Jun-97	5	1	[illegible]	[illegible]	[illegible]					[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
SP	46	8-Jul-97	5	1	[illegible]	[illegible]						[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
SP	46	15-Oct-97	5	1	[illegible]									[illegible]	[illegible]	[illegible]				
SP	46	12-Nov-97	5	1	[illegible]									[illegible]	[illegible]			[illegible]	[illegible]	
SP	46	5-Sep-94	15	1	[illegible]		[illegible]	[illegible]	[illegible]	4.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
SP	46	11-Sep-94	15	1	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
SP	46	18-Sep-94	15	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SP	46	11-Oct-94	15	1	[illegible]	[illegible]	[illegible]	[illegible]	4.4	[illegible]	3	[illegible]	[illegible]	1.2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SP	46	21-Oct-94	15	1	[illegible]									[illegible]	[illegible]	[illegible]	[illegible]			
SP	46	15-Nov-94	15	1	4.7									[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
SP	46	30-Nov-94	15	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
SP	46	10-May-95	15	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
SP	46	21-Jun-95	15	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SP	46	28-Sep-95	15	1	[illegible]							[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SP	46	15-Oct-95	15	1	[illegible]	[illegible]	[illegible]					[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SP	46	10-May-96	15	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
SP	46	12-Jun-96	15	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12	4	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
SP	46	29-Aug-96	15	1													[illegible]			
SP	46	3-Oct-96	15	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SP	46	24-Oct-96	15	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SP	46	13-Nov-96	15	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SP	46	10-Jun-97	15	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SP	46	8-Jul-97	15	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SP	46	17-Sep-97	15	1	[illegible]									[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	
SP	46	15-Oct-97	15	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
SP	46	12-Nov-97	15	1	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Loc	No	Date	Depth	Limed	pH	Kond	ALK	Cl	SO4	Si	NH4-N	NO3-N	Tot-N	Ca	Mg	Na	K	Al	Fe	TOC
			m		log H+	mS/m	mmol/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	mg/L
SP	50	5-Sep-94	5	1	4.59							4		1.5	0.29	2.37				
SP	50	11-Sep-94	5	1	4.66							2		1.7						
SP	50	15-Sep-94	5	1	4.65															
SP	50	31-Oct-94	5	1	4.45															
SP	50	16-Nov-94	5	1	4.52									2.47	0.24	2.56				
SP	50	30-Nov-94	5	1	4.56									1.87	0.34	2.24		454	374	
SP	50	11-May-95	5	1								15		1.52	0.76	3.52				
SP	50	21-Jun-95	5	1	4.6															
SP	50	28-Sep-95	5	1	4.42									1.7	0.7	2.6				
SP	50	15-Oct-95	5	1	4.43															
SP	50	10-May-96	5	1	4.53									2.34	0.11			571	507	
SP	50	12-Jun-96	5	1	4.53									2.4	0.32					
SP	50	26-Aug-96	5	1	4.5															
SP	50	3-Oct-96	5	1	4.46									1.24	0.66	1.54		550	450	
SP	50	24-Oct-96	5	1	4.37									1.52	0.57					
SP	50	7-Aug-97	5	1	4.54									1.27	0.6	2.5				
SP	50	16-Oct-97	5	1	4.56									1.15	0.84	4.25		542	536	16.5
SP	50	13-Nov-97	5	1	4.47									1.27	0.94			505	338	
SP	50	5-Sep-94	15	1	4.58							1		1.27	0.51	2.05				
SP	50	11-Sep-94	15	1								2		1.24						
SP	50	15-Sep-94	15	1	4.73															
SP	50	31-Oct-94	15	1	4.61															
SP	50	15-Nov-94	15	1	4.52									1.38	0.64	2.8		154	86	
SP	50	30-Nov-94	15	1	4.7															
SP	50	11-May-95	15	1								4		1.25	0.62	2.77	0.41			
SP	50	21-Jun-95	15	1	4.72															
SP	50	28-Sep-95	15	1	4.59															
SP	50	15-Oct-95	15	1	4.54															
SP	50	12-May-96	15	1	4.64							1155		1.73	0.36			365	145	4.5
SP	50	3-Oct-96	15	1	4.55									1.34	0.47	1.53		258	136	
SP	50	24-Oct-96	15	1	4.56									1.12	0.54					
SP	50	6-Aug-97	15	1	4.51									1.52	0.63	3.73		524	352	
SP	50	17-Sep-97	15	1	4.35															
SP	50	16-Oct-97	15	1	4.74									0.90	0.46	2.71		275	149	7.4
SP	50	12-Nov-97	15	1	4.54									0.85	0.5			320	146	4.2
SP	50	11-Sep-94	15	1	4.7	2.54	0.022	1.6	4.5	4.5	3	1.5	265	1.12	0.34	1.75	0.25	352	342	11.1

Appendix B. Hydrology

Abbrevation and references for sampling stations:
LIM 1: Stream outlet of catchment 1 in the limed catchment Fuglebåsen
LIM 4: Main stream outlet of the limed catchment Fuglebåsen
REF: Stream outlet of reference catchment Spjotåsen

DATO	LIM 1 m3/period	LIM 4 m3/period	REF m3/period
1 Mar 94			
13 Mar 94	40409	71455	35718
29 Mar 94	12056	20082	14520
11 Apr 94	90137	156122	60815
18 Apr 94	27254	47206	23250
25 Apr 94	28191	48809	20565
2 May 94	38072	67329	28031
9 May 94	14058	24482	12153
16 May 94	5632	9755	3450
25 Aug 94	12747	30574	9079
31 Aug 94	22917	57695	16500
11 Sep 94	25815	58405	22729
19 Sep 94	30121	58337	25593
29 Sep 94	3180	5060	372
12 Oct 94	1789	2428	1338
26 Oct 94	8774	17119	12401
31 Oct 94	22534		7212
3 Nov 94	11524	93380	8300
14 Nov 94	5301	10642	4321
21 Nov 94	8675	18438	7314
6 Dec 94	6146	11686	4907
12 Dec 94	20230	39500	14988
21 Dec 94	14412	27807	11131
31 Dec 94	6506	13172	5316
3 Jan 95	1152	2449	1055
15 Feb 95	53055	112820	63605
14 Mar 95	31353	65867	30739
22 Mar 95	25161	48771	22201
5 Apr 95	42085	78331	38208
16 Apr 95	39339	68756	23391
25 Apr 95	30706	53875	15301
8 May 95	23320	45088	13540
26 May 95	9231	18022	7794
8 Jun 95	11330	18708	7054
13 Jun 95	10064	24167	10057
27 Jun 95	22061	31850	13372
7 Sep 95	1083	1762	1052
14 Sep 95	17515	29530	11148
18 Sep 95	27845	54604	22360
4 Oct 95	13909	20732	10049
23 Oct 95	16168	36174	13771
20 Nov 95	4779	11418	3737
4 Dec 95	2715	6021	1850
19 Dec 95	4400	10787	2907
31 Dec 95	858	2307	975

DATO	LIM 1 m3/period	LIM 4 m3/period	REF m3/period
12 Jan 96	600	2070	907
18 Apr 96	25894	60129	27005
22 Apr 96	10876	42038	13419
28 Apr 96	16009	39703	11703
7 May 96	6767	20570	7680
20 May 96	10797	24844	8553
29 May 96	7424	10413	6707
20 Jun 96	2810	9437	3157
7 Sep 96	7488	18105	5467
30 Sep 96	25441	51575	21310
16 Oct 96	11839	36823	10589
28 Oct 96	26720	55804	22506
7 Nov 96	17440	37884	15207
21 Nov 96	8094	19409	7497
4 Dec 96	8001	26174	6213
8 Dec 96	15230	39127	17310
31 Dec 96	7679	16610	7082
3 Mar 97		104885	41315
5 May 97		100724	30857
23 Jun 97		32745	9340
2 Jul 97		17348	5711
7 Aug 97		5320	2857
4 Sep 97		9252	5658
18 Sep 97		19720	10900
14 Oct 97		35088	14427
4 Nov 97		16359	7866
10 Nov 97		29766	9648
13 Nov 97		39454	14800
31 Dec 97		163500	61217

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