

Geochemical Baseline Studies and Relations Between Water Quality and Streamflow in the Upper Blackfoot Watershed, Montana: Data for July 1997 - December 1998

By Sonia A. Nagorski,^{1,2} Johnnie N. Moore,¹ and David B. Smith²

¹Murdock Environmental Biogeochemistry Laboratory,
Department of Geology, University of Montana, Missoula, MT 59812

²U.S. Geological Survey, Denver Federal Center, MS 973, Denver, CO 80225

U.S. Geological Survey Open File Report 01-0059

Geochemical Baseline Studies and Relations Between Water Quality and Streamflow in the Upper Blackfoot Watershed, Montana: Data for July 1997- December, 1998.

Authors: Sonia A. Nagorski^{1,2}, Johnnie N. Moore¹, and David B. Smith²

¹Murdock Environmental Biogeochemistry Laboratory, Department of Geology, University of Montana, Missoula, MT 59812

²U.S. Geological Survey, Denver Federal Center, MS 973, Denver, CO 80225

Abstract

We used ultraclean sampling techniques to study the solute (operationally defined as <0.2 µm) surface water geochemistry at five sites along the Upper Blackfoot River and four sites along the Landers Fork, some in more detail and more regularly than others. We collected samples also from Hogum Creek, a tributary to the Blackfoot, from Copper Creek, a tributary to the Landers Fork, and from ground water seeps contributing to the flow along the Landers Fork. To better define the physical dynamics of the hydrologic system and to determine geochemical loads, we measured streamflow at all the sites where we took samples for water quality analysis. The Upper Blackfoot River, which drains historic mines ca. 20 Km upstream of the study area, had higher trace metal concentrations than did the Landers Fork, which drains the pristine Scapegoat Wilderness area. In both rivers, many of the major elements were inversely related to streamflow, and at some sites, several show a hysteresis effect in which the concentrations were lower on the rising limb of the hydrograph than on the falling limb. However, many of the trace elements followed far more irregular trends, especially in the Blackfoot River. Elements such as As, Cu, Fe, Mn, S, and Zn exhibited complex and variable temporal patterns, which included almost no response to streamflow differences, increased concentrations following a summer storm and at the start of snowmelt in the spring, and/or increased concentrations throughout the course of spring runoff. In summary, complex interactions between the timing and magnitude of streamflow with physical and chemical processes within the watershed appeared to greatly influence the geochemistry at the sites, and streamflow values alone were not good predictors of solute concentrations in the rivers.

Table of Contents

<u>Introduction</u>	1
<u>Methods</u>	1
1. Sampling locations and frequencies	1
2. Streamflow measurement	2
3. Water sampling	2
4. Lab Methods	3
5. Quality Assurance/ Quality Control	4
<u>Results and Discussion</u>	5
1. Streamflow	5
a) Streamflow at Landers Fork (sites LA, LB, LC, LD) and Copper Creek (site C)	5
b) Streamflow at Blackfoot River (sites BH, BB, BC, and BD) and Hogum Creek (site HC)	6
2. Surface Water Geochemistry	7
a) Landers Fork and Copper Creek	8
1) Copper Creek	8
2) Landers Fork at LA	9
3) Landers Fork at LB	9
4) Landers Fork at LC	10
5) Landers Fork at LD	11
b) Blackfoot River and Hogum Creek	11
1) Blackfoot River at BH	11
2) Hogum Creek	12
3) Blackfoot River at BB	12
4) Blackfoot River at BC	13

<u>Summary</u>	14
<u>References</u>	16
<u>Tables:</u>	
1. Discharge measurements	18
2. pH meter and D.O. meter calibrations	20
3. Sample analysis dates	20
4. Detection limits of analytes	20
5. External and internal standards	21
6. Summary of USGS standards measured on ICAPES	22
7. Duplicates and spike recoveries	23
8. Laboratory and field blanks	24
9. All data for water samples collected April 1998-December 1998	25
<u>Figures:</u>	
1. Site location map	31
2. Streamflow vs. concentrations at Copper Creek	32
3. Trends over time at Copper Creek	34
4. Loads at Copper Creek	37
5. Streamflow vs. concentrations at Landers Fork site LA	39
6. Trends over time at Landers Fork site LA	41
7. Loads at Landers Fork site LA	44
8. Streamflow vs. concentrations at Landers Fork site LB	46
9. Trends over time at Landers Fork site LB	48
10. Loads at Landers Fork site LB	51
11. Streamflow vs. concentrations at Landers Fork site LC	53
12. Trends over time at Landers Fork site LC	55
13. Loads at Landers Fork site LC	58

14. Streamflow vs. concentrations at Landers Fork site LD	60
15. Trends over time at Landers Fork site LD	62
16. Loads at Landers Fork site LD	65
17. Streamflow vs. concentrations at Blackfoot River site BH	67
18. Trends over time at Blackfoot River site BH	69
19. Loads at Blackfoot River site BH	72
20. Streamflow vs. concentrations at Hogum Creek	74
21. Trends over time at Hogum Creek	76
22. Loads at Hogum Creek	79
23. Streamflow vs. concentrations at Blackfoot River site BB	81
24. Trends over time at Blackfoot River site BB	83
25. Loads at Blackfoot River site BB	86
26. Streamflow vs. concentrations at Blackfoot River site BC	88
27. Trends over time at Blackfoot River site BC	90
28. Loads at Blackfoot River site BC	93

Introduction

This report presents the results of a temporal and spatial investigation of the surface water geochemistry of the upper Blackfoot River and Landers Fork in western Montana. These two rivers come together at the site of a proposed large-scale open-pit gold mine, and it is for this reason that they were chosen for study by the Mineral Resources Program (MRP) of the U.S. Geological Survey (USGS). The characterization of water quality in mineralized basins, whether impacted by mining or not, has potentially strong regulatory implications. Only recently have researchers begun to examine detailed spatial and temporal trends in watersheds using clean sampling techniques, which have been shown to be critical in obtaining accurate dissolved trace metal data (Windom et al., 1991; Benoit, 1994; Taylor and Shiller, 1995)

The Blackfoot River watershed is located in west-central Montana, where it flows for 215 km before joining the Clark Fork, a major tributary to the Columbia River. Several historic mines, which have been linked to water and bed sediment contamination in the watershed, are located in the headwaters of the Blackfoot River, 20-30 Km upstream of this project's study area (Moore et al., 1991; Menges, 1997; Nagorski et al., 2000). In contrast, the Landers Fork largely drains a pristine area, a section of the rugged Scapegoat Wilderness area. The upper Blackfoot River and the Landers Fork flow adjacent to the undeveloped McDonald Gold Project area before joining together to the southwest of the ore deposit (Figure 1).

The first portion of this project is detailed in Nagorski et al. (1998) which describes the results of data collected from July, 1997 until March, 1998. Here we focus on data collected between April and December, 1998. Although many sections of this report include the July 1997- March 1998 data, the reader is referred to the 1998 OFR for details on the first portion of the project. In addition, Nagorski et al. (2000) place the study area in geochemical context to the rest of the Blackfoot basin by reporting on a one-time, basin-scale sampling event of the water and bed sediment of the Blackfoot River and its major tributaries.

Methods

1. Sampling locations and frequencies:

The sites sampled between April and December, 1998 were the same as those visited between July, 1997 and March, 1998, the time period that was the focus of the earlier report (Nagorski et al., 1998) (Figure 1). Between April and August, 1998, we sampled at four sites along the Landers Fork (LA, LB, LC, and LD), three sites along the Blackfoot River (BH, BB, and BC), one site at Copper Creek (C) and one at Hogum Creek (HC) four to six times per site. We continued sampling at two of the Landers Fork sites (LB and LC) and two of the Blackfoot River sites (BB and BC) approximately monthly through December, 1998 (although sites LB and BC could not be accessed in December, 1998). One site reported in the 1998 OFR (site BA) was not sampled later than September, 1998 and therefore is not included in this report. Site BD, below the confluence of the Landers Fork and Blackfoot River was sampled from July to September, 1997, and then only in August, 1998.

During the study period, we collected samples of seep water emerging from the streambanks at sites LB and LC when possible-- in April at LB, and in April, October, November, and December at site LC. During the other times, the seeps were submerged by channel flow.

2. Streamflow measurement:

We measured streamflow at each sampling site using a Price AA current meter connected to an Aqua Calc 5000 calculator (Rickly Hydrological Co.). We made the measurements by wading across transects at each sampling site, although two high flow events at site LC necessitated the use of a bridge crane from which we suspended the current meter.

Between 5 and 29 velocity measurement stations were used along each streamflow transect. Those channels where flow was measured using fewer than 10 stations were mostly less than 5 m in width. We spaced the stations so as to account for obvious changes in depth and velocity, and we attempted to set up each station to represent approximately equal flow sections of the channel. At each station, we set the current meter at 60% of the water depth. Because no station was deeper than 1 meter, it was not necessary to make a more detailed vertical profile.

During the majority of the sampling events, we measured streamflow twice at each site in order to define the measurement precision. We set up each replicate measurement along a separate transect, usually within 3 m of the original. Replicate measurements at sites with less than 5 ft³/s (142 L/s) of flow were within 14%; at sites with streamflow between 5 and 35 ft³/s (142-991 L/s), reproducibility was within 9%, and at sites where flows were greater than 35 ft³/s (991 L/s), the precision was better than 7%. At sites where we took only one streamflow measurement, the error given to the measurement is assumed to be the maximum precision error found in the appropriate streamflow bracket.

We report the streamflow measurements (as well as the mean velocity, number of stations, and channel width at each transect) in Table 1, with the English units (cubic feet per second) used by the Aquacalc. However, in subsequent figures and in the load calculations, the measurements are converted into metric units.

3. Water sampling

Two people were present for each sampling event. While one person measured streamflow, the other took measurements of pH, dissolved oxygen, conductivity, air temperature, and water temperature. We used an Orion model 230A pH meter, an Orion model 820 dissolved oxygen meter, a Hach Conductivity/TDS meter, and a Barnant 100 Thermocouple Thermometer for these purposes. The pH and dissolved oxygen meter were calibrated at least once a day, and their calibrations were checked and redone if necessary at each new sampling site (Table 2).

We followed the clean sampling techniques as generally recommended by Windom et al. (1991), Benoit (1994), and Taylor and Shiller (1995) in order to minimize the chances of contaminating the samples. We stored each sample bottle in double zip-close bags, from which we removed it only moments before sampling. The sampler contacted the bottles wearing new and clean latex or nitrile gloves. With the help of the other person, the sampler wearing the clean gloves contacted nothing but the sample bottle and the inner storage bag.

Generally, we took three 1-L samples per site. An exception to this was made in August, 1998, when we collected 10 samples from site LD in order to see if any more variability within a transect would be captured by taking more than the standard three samples. After rinsing the sample bottle with one volume of stream water, the sampler

filled each bottle by depth integrating in the area upstream of where the sampler stood. We obtained the samples upstream of the area where we had disturbed the site by measuring streamflow and the other in situ parameters. In addition, we always took samples upstream of bridges in order to limit additional sources of contamination. The sample bottles were immediately returned to their zipped double bags and stored on ice until return to the laboratory.

All collection materials (bottles, syringes, etc.) that could potentially ever come into contact with the water sample were extensively pre-cleaned. The cleaning procedure consisted of a regular wash with warm water and soap, several rinses in deionized water, soaking in 6N HCl for 2 hours, three rinses in Milli-Q deionized water, soaking in a 1 % (by volume) trace-metal grade HNO₃ bath for 24 hours, another three rinses in Milli-Q, and drying and storing into clean plastic bags under a Class 100 laminar flow hood.

4. Lab Methods

The laboratory methods for sample treatment and analysis did not differ for the samples collected in this second half of the project as reported for the first in Nagorski et al.(1998). Although the reader is again referred to the previous report for details, a summary of the methods is presented here.

We filtered samples upon return to the laboratory within 30 hours following collection. We kept the samples on ice until filtering, when we removed them from their double bags under a Class 100 Laminar Flow Hood at the University of Montana Murdock Environmental Biogeochemistry Laboratory. Again, we wore clean nitrile or latex gloves whenever handling the sample bottles and any other sample storage or processing materials (syringes, filters, etc.) We filtered the samples through 0.2 µm syringe filters with glass prefilters (Gelman Sciences Serum Acrodiscs). We used at least 50 mL of sample to rinse the syringe, filter, and bottle and to reduce the effective pore size (and as a result, the passage of colloidal material) of the filters (Taylor and Shiller, 1995). Following the purging by the 50 mL of sample, we filled a 60 mL amber glass bottle with filtered sample for the purposes of carbon and anion analysis. Finally, we filled a 125 mL plastic bottle with filtered sample material for cation and arsenic analysis. We stored the amber bottles in a 4 degrees Celcius refrigerator while awaiting carbon/anion analysis, whereas we acidified the samples in the plastic bottles to pH<2 with ultrapure, double distilled from quartz Optima (FisherScientific) HCl.

We measured trace element and major cation concentrations in the water samples using a Thermo Jarrel-Ash ICP (IRIS) with ultrasonic nebulization (Cetac, U-5000AT+) according to EPA Method 200.15 (Martin et al., 1994). This method was modified slightly in that we did not add nitric acid nor hydrogen peroxide to the samples. Nitric acid was previously determined by the laboratory to not improve analytical performance, and hydrogen peroxide was not necessary because arsenic was not being analyzed on the ICP.

We analyzed for dissolved anions by ion chromatography according to EPA Method 300.0 (Pfaff, 1993) within 48 hours of collection, although this analysis was done only for the July, 1997 through January, 1998, August, 1998 and October, 1998 samples. We did not analyze for anions in all samples because most anions consistently were below the detection limit and sulfate information could be inferred from the sulfur analysis done on the ICP.

We measured dissolved inorganic carbon with a Shimadzu Carbon analyzer within one week of sample collection according to Standard Method 505A (Franson, 1985a). Due

to technical problems with the Shimadzu Carbon analyzer in the summer and fall of 1998, we did not analyze inorganic carbon on all samples collected in that time period. However, we measured total alkalinity by titration with sulfuric acid on any samples that did not receive analysis for inorganic carbon, and both total alkalinity and dissolved inorganic carbon were measured on many of the fall, 1998 samples. As reported in Nagorski et al. (1998), the Shimadzu Carbon analyzer was also used to measure organic carbon according to Franson (1985). However, poor performance by the instrument during large portions of the rest of the study period precludes us from reporting organic carbon values.

Arsenic analysis was done using atomic absorption spectroscopy with hydride generation (HGAAS) according to Standard Method 303A (Franson, 1985b). This method was modified by the Murdock Environmental Biogeochemistry Laboratory to optimize analytical performance (Mickey, written communication, 1997). The modifications consisted of adding KI and HCl to the samples and standards to achieve final concentrations of 2% KI and 1 M HCl and of running solutions of 0.35% NaBH₄ (stabilized with 0.5% NaOH) and 6N HCl through the hydride generation during analysis.

Table 3 lists the dates on which analysis was performed on the various instruments for each set of samples.

5. Quality Assurance/ Quality Control

We conducted sample analysis at the Murdock Environmental Biogeochemistry Laboratory according to a strict quality assurance/ quality control program. Instrument calibrations were designed to linearly bracket the concentrations of analytes in the water samples. Each instrument used for sample analysis was calibrated at the start of each day and checked for accuracy and precision following the analysis of every 10 samples. Accuracy was measured through the analysis of laboratory fortified blanks (internal standards), external standards, laboratory fortified samples (spikes), and laboratory reagent blanks. Precision was evaluated by running replicate samples and standards during single and over multiple analytical events. The practical quantification limit (PQL) was determined as the threshold at which a sample can be reproduced within a maximum variability of 30% (Table 4). It should be noted that the PQLs for Cu and Zn have been modified since Nagorski et al. (1998). The PQL for Cu has been determined to be 0.8 µg/L instead of the previously reported 0.3 µg/L, and Zn has been set at 0.3 µg/L instead of 0.2 µg/L.

The following summary of the quality control results includes all analyses of samples collected for the project (from July, 1997 through December, 1998).

External standards: Six different external standards were analyzed on the HGAAS with the arsenic samples, and each measured within the reported acceptable range (Table 5.1). The external sample “QC Spex” analyzed on the Ion Chromatograph also fell within the reported range (Table 5.2). On the ICP, three USGS standards (USGS T-107, USGS T-143, and USGS T-145) were run with sample analyses, and the average measured concentrations of most elements fell within the reported acceptable range (Tables 6.1-6.3). Those elements whose average readbacks did not fall within the reported range were Sr, which measured low on all three standards, and Ag, which measured high on USGS T-143.

Internal standards: The mean percent difference between known and measured values of internal standards measured on the HGAAS, Carbon analyzer, and Ion Chromatograph was less than 7.1% (Table 5.3).

Duplicates: The mean percent difference of sample duplicates run on all instruments was less than 8% (Tables 7.1 and 7.2).

Spikes: Mean percent spike recoveries for all measurable elements were between 86 and 112% (Tables 7.3 and 7.4).

Blanks: Laboratory reagent blanks were all below the PQL on all instruments (Tables 8.1 and 8.3). Field collected blanks, which check for contamination rather than analytical quality control, were mostly below the PQL for all elements as well (Tables 8.2 and 8.4). Exceptions are for Ca, Mg, Na, S, Si, and Zn, which were detectable in 2 to 23 of the 31 field blanks. The concentrations of Ca, Mg, S, and Si found in the blanks were inconsequential, as they were at least an order of magnitude lower than concentrations found in environmental samples. However, the highest Na concentration (0.42 mg/L) detected in the field blanks could explain the noisiness of much of the Na data. The appearance of 3.7 µg/L of Zn in one of the field blanks unfortunately calls into question much of the Zn data. However, it should be noted that 24 of the 31 field blanks did not have quantifiable Zn (<0.3 µg/L), and the vast majority of samples from the Landers Fork did not have detectable Zn either. The value of the highest Zn in the blanks (3.7 µg/L) found is included in the plots of Zn concentrations.

Results and Discussion

1. Streamflow

As described in the Nagorski et al. (1998) streamflow at most of the sites decreased over the time period of the first half of the study, between July, 1997 and March, 1998. Between April and December, 1998, we found a more variable streamflow pattern, as would be expected due to the occurrence of spring runoff during this time period. At most sites we streamflow started to rise in April, with runoff lasting through the month of July.

a) Streamflow at Landers Fork (sites LA, LB, LC, LD) and Copper Creek (site C):

Streamflow patterns at C and LA were similar on the dates they were measured in 1998, in that the highest flows measured were in mid May and early June (Table 1 and Figures 3a and 6a). Although site LA had no streamflow on 4/7/98, we measured 878-935 L/s at the site less than three weeks later (on 4/26/98), and 4220 L/s in mid-May. We reported a similarly rapid increase in streamflow at site C, with streamflow at 396-425 L/s in early April to 2917-3002 L/s in mid-May. In late July (7/20/98), streamflow at both sites was between 1699 to 1813 L/s, still well above the low flow levels observed the previous fall and winter.

On five occasions between April and December, 1998, sites C, LA, and LB were all measured on the same day, allowing for an evaluation of whether the reach above LB was gaining, losing, or averaging at a constant flow level. Results of this evaluation show that on 4/7/98, 4/26/98, and 5/18/98, the reach was losing flow to the ground water

system. However, there was no measurable difference in the combined streamflow of C and LA and that at LB on 6/5/98 and 7/20/98.

At site LB, the highest flow measured over the study period was on 6/29/98, with 11,696 to 11,894 L/s. This is a drastic increase over the 28 to 340 L/s measured during all 5 events between November, 1997 and late April, 1998. Site LB was never observed to be frozen, even in the cold winter months. An explanation for this was found on 4/7/98, when we walked approximately 200 m upstream of the sampling site, and found where the surface flow was originating. An ice-free pool about 8-10 meters in diameter and up to approximately 1 m deep was observed on both 4/7/98 and 4/26/98, and a school of 10-20 cm long fish were seen inhabiting the pool. Downgradient of the pool, streamflow gradually increased, and more seeps were visible along the stream channel. The seeps downstream of the pool were those that were sampled on both 4/7/98 and 4/26/98, and are listed as "LB Seeps" in Table 9.

At site LC, the streamflow pattern was consistent with that reported in the first portion of the study, which is that streamflow at LC was higher than at LB on every sampling event. Because of this as well as the observance of complete absence of ice at the site during the 18 month study period, we conclude that ground water input is critical in maintaining streamflow at the site during low flow and winter conditions. Other studies in the area have attributed the gaining system to a structural bedrock feature in the area which constricts the local alluvium (Schafer and Associates, 1994). Again, as reported in Nagorski et al. (1998), numerous seeps were visible along the east bank of the river at LC, and when not submerged by channel flow, samples were taken from these areas and are reported as "LC Seeps" in Table 9.

Between April and December 1998, we measured site LD only three times (on 4/7/98, 7/20/98, and 8/17/98). On both occasions (on 4/7/98, 7/20/98) that both LC and LD were measured, the reach between the sites was losing streamflow.

b) Streamflow at Blackfoot River (sites BH, BB, BC, and BD) and Hogum Creek (site HC):

Surface water at the most upstream site (BH) on the Blackfoot River was not found to be frozen at any time when it was visited between July, 1997 and August, 1998. Streamflow was never measured as lower than 566 L/s, while the highest flow was 2917 - 3144 L/s during the study period. The streamflows measured in 1998 did not exceed the high flow measured at the site on 7/4/97. However, we did not visit site BH on 6/29/98, which is when we measured the highest streamflows of the entire study period at sites BB and BC downstream.

Hogum Creek's (HC) highest flow was measured on 6/5/98, with 396-425 L/s. The last time it was sampled, on 8/17/98, the flow level (57-85 L/s) was already close to that measured in November, 1997 and January, 1998 (28 L/s).

There were four events between April and August 1998 when sites BH, HC, and BB were all measured, allowing for an evaluation of gaining versus losing status of the stretch of river above site BB. The stretch is calculated to have been losing on 4/29/98, 6/5/98, and 7/20/98, but there was no measurable net gain nor loss on 5/19/98.

Between April and December, 1998, both BB and BC were measured and sampled 9 times. Results indicate that there was no measurable net gain or loss of streamflow along the reach between these two sites on 4/7/98, 5/19/98, 7/20/98, and 10/6/98. However,

streamflow at BC was higher than at BB on 4/29/98, 6/5/98, 6/29/98, 9/4/98, and 11/7/98. As reported in the 1998 OFR, the reach was gaining streamflow on 5 of the 6 measurement events between July 1997 and March, 1998. Overall, it appears that this stretch of river is not losing, and it is more often than not a gaining reach. The important role of ground water input along the reach is also implied by the observation that site BC was also never found to be frozen (unlike site BB); and flow did not drop below 396 L/s at any time that we studied the site.

As mentioned earlier, site BD, below the confluence of the Landers Fork and Blackfoot River, was sampled only once after September, 1997. On 8/17/98, streamflow at the site (3087 L/s) was similar to measurements made in the late summer of 1997 (4276 L/s in 8/7/97 and 2266 L/s in 9/14/97.)

2. Surface Water Geochemistry

The surface water solute chemistry of the Landers Fork was generally different from that of the Blackfoot River. Overall comparisons of dissolved concentrations show the Blackfoot samples had higher concentrations of organic carbon, sulfate, Cu, Fe, K, Mn, Na, S, Si, Sr, and Zn and lower concentrations of inorganic carbon, As, and Ca than the Landers Fork, (based on t-tests with p-values < 0.05) during the study period. The rivers had similar pH values, water temperatures, and dissolved oxygen, Ba, Li, and Mg concentrations. No samples had detectable concentrations of Ag (< 1 µg/L), Be (< 0.05 µg/L), Cd (< 0.5 µg/L), Co (< 0.5 µg/L), Mo (< 1 µg/L), Ni (< 2 µg/L), Pb (< 6 µg/L), Ti (< 2 µg/L), and V (< 2 µg/L).

Concentrations of most solutes were inversely related to streamflow in both the Landers Fork and the Blackfoot River sites through the summer and fall of 1997. However, in the 11/97, 1/98, and 3/98 samples, most solutes differed from this trend, as concentrations dropped while streamflow continued to decrease. Following the start of spring runoff in April, 1998, most of the major ions decreased in concentration through the rising limb of the runoff hydrograph, and subsequently rose throughout the rest of study period through summer and fall. Few generalizations can be made about the behavior of the trace elements in the Blackfoot River, although several increased in concentration during high flow events. On most events, the trace metal concentrations were below detection in the Landers Fork, indicating that more sensitive analysis (e.g. by ICP-Mass Spectrometer) is necessary to detect any ultra-low levels at this site. This result further justifies the use of clean sampling and handling techniques. Furthermore, the authors recognize that the operationally defined dissolved phase (< 0.2 µm) sampled in this project may in fact not reflect the truly dissolved phase because of the possibility that colloids passed through the filters. During high flow events, suspended solid concentrations are typically elevated in rivers, and hence the chances of obtaining suspended particles in the filtrate may have increased as well.

Hysteresis patterns were observed for some elements at most of the study sites, indicating that factors other than the amount of streamflow need to be considered when predicting the solute geochemistry in the rivers. Hysteresis describes a loop pattern in plots of concentration vs. discharge caused by elemental concentrations differing along the falling limb from the rising limb of a hydrograph. Hysteresis patterns have been reported by many authors studying storm-scale and seasonal hydrographs in a wide variety of streams and rivers (e.g. Bird, 1987; Hooper et al., 1990; Droppo and Jaskot, 1995; Bhangu and Whitfield, 1997, Evans and Davies, 1998). The direction of hysteresis rotation can be clockwise or counterclockwise, and it is thought to signify which geochemically distinct sources in the watershed are dominating streamflow at different times. In clockwise hysteresis, elemental concentrations are higher during the rising limb of the

hydrograph than along the falling limb. That is, water sources with higher solute concentrations are larger contributors to streamflow during early spring runoff than later in the year (considering a seasonal hydrograph). Counter-clockwise rotation indicates the opposite—that solutes are more dilute on the rising limb than on the falling limb. Seasonal counter-clockwise rotation would be expected in watersheds which contain snowpacks. When thawed in the spring, the snowpack would presumably produce overland surface flow of snowmelt, thereby dominating contributions to the stream channel and creating more dilute geochemical conditions (Bhangu and Whitfield, 1997). In other words, counter-clockwise hysteresis may be an indication of ground water and soil water (presumably dominant during late summer and fall) having higher elemental concentrations or longer residence times in the soils than the spring runoff water, or “surface event water”, as defined by Evans and Davies (1998). The differences in the widths of the loops are likely an indication of greater or lesser chemical differences among the various water sources supplying streamflow during different periods in the hydrocycle (Johnson and East, 1982).

Site-specific geochemical trends are described below.

a) Landers Fork and Copper Creek

1) Copper Creek:

As can be seen on Figure 2, a hysteresis effect is present for inorganic carbon, Ba, Ca, Li, Mg, and Sr. The effect is counter-clockwise in that the concentrations of these elements are higher on the falling limb of the hydrograph (Summer--Fall-Winter 1997, and late Summer 1998) than on the rising limb of the hydrograph (Spring 1998). The cyclical patterns of these elements have an overall negative relationship ($r < -0.85$, $p\text{-value} < 0.01$) with streamflow, meaning that elemental concentrations are higher with lower streamflow on each of the falling and rising limbs. Of the above mentioned elements, Ba, Ca, Mg, and Sr show a wider hysteresis loop, while inorganic carbon, K, and Li have much tighter loops.

Despite its name, Copper Creek did not have detectable ($>0.8 \mu\text{g/L}$) concentrations of filterable Cu (Figure 3h). Chromium was less than its PQL of $1 \mu\text{g/L}$ at all times except for January, 1998, when it was detected at levels near the quantifiable limit (Figure 3g). Iron was found in the 1997 samples only, when streamflow was in falling limb and baseflow conditions (Figure 3i). During spring runoff in 1998, Fe was not detected. Similarly, Mn was detected at or above above the PQL of $0.3 \mu\text{g/L}$ only during the first four sampling events, July to September, 1997 (Figure 3m). Zinc was mostly below the PQL as well, and it was always below the concentration found in the highest field blank (Figure 3r).

Arsenic did not correlate well with streamflow, although its slope was positive overall ($r = 0.68$, $p = 0.03$) (Figure 2c). Its concentration in Copper Creek stayed relatively constant over the course of the 13 month study, with the exception of a slight increase in As concentrations during the two highest streamflows measured, in July, 1997 (Figure 3d). Another anomaly in the dataset is S, which despite having a negative relationship with streamflow ($r = -0.79$, $p = 0.007$) did not have a clear hysteresis loop (Figure 2l). In addition, S concentrations were higher during runoff in 1998 than during the falling limb of the 1997 streamflow, an opposite trend to those seen for the major elements. Finally, pH at the site exhibited counter-clockwise hysteresis, with pH lower ($\text{pH} = 8.0$) at spring runoff compared to the previous fall and winter ($\text{pH} = 8.1\text{--}8.4$) and to the post-runoff sample in July 1998 ($\text{pH} = 8.4$) (Figure 2a).

Elemental loads in Copper Creek (calculated as streamflow multiplied by concentration) generally follow a pattern identical to streamflow (Figure 3a and 4). Hence, the amount of streamflow is the dominant factor in influencing the loading of dissolved elements in Copper Creek, and any variations in dissolved concentrations are largely insignificant.

2) Landers Fork at LA

Overall, a similar hysteresis effect is seen at site LA as at site C. Inorganic carbon, Ba, Ca, K, Li, Mg, Si, and Sr all have counter-clockwise hysteresis loops (Figures 5b, d, e, g, h, i, m, and n). Only Ba, K, and Sr had significantly ($p < 0.04$) negative ($r < -0.74$) relationships with streamflow. However, it should be noted that at this site there are far more falling limb datapoints than rising limb points, and fewer data points overall due to the lack of streamflow at the sites during many winter months.

Trace element relationships to streamflow were also similar at LA as at C (Figure 5). Copper was never detected, and Cr was just at the detection limit in only one of the three samples collected in July 1998 (Figures 6g and 6h). Iron was at a quantifiable level ($>5 \mu\text{g/L}$) only during the 1997 events, which were in the late summer and fall (Figure 6i). Rather than not showing up in 1998 as it did at site C, Mn at LA was at its highest concentration at the early portion of runoff in 1998 (Figure 6m). It was detectable also in July 1997, but otherwise below the PQL. Except for a couple of the 3 samples collected on July 3, 1997, all samples at LA had Zn concentrations at less than the $0.3 \mu\text{g/L}$ PQL (Figure 6r).

Arsenic at LA did not show a correlation ($r = 0.41$, $p = 0.31$) with streamflow (Figures 5c and 6d). Concentrations were relatively constant at about $0.4 \mu\text{g/L}$ in most of the samples, other than in the 7/3/97 samples, which had As levels of $0.6 \mu\text{g/L}$. Sulfur was anomalous in that it followed the counter-clockwise hysteresis loop similar to that of the other major elements, although its concentration did not rise with the decrease in streamflow at the last sampling event, in July, 1998 (Figures 5l and 6o). pH does not have a clear relationship with streamflow at LA either, although a slight decrease in pH was detected during spring runoff in 1998 (Figure 6b).

As at site C, elemental loads at site LA followed the same trend as did streamflow, again indicating that changes in streamflow levels are by far more important than elemental concentrations in influencing the loading of dissolved elements through the site (Figures 6a and 7).

3) Landers Fork at LB:

At site LB, the hysteresis patterns are not nearly as clear as those seen upstream at C and LA, despite the additional five months of sampling at the site (Figures 8 and 9). Overall, inorganic carbon, Ba, Ca, K, Li, Mg, S, Si, and Sr show an inverse relationship ($r < -0.64$, $p < 0.01$) to streamflow, and hysteresis cycling is either absent or only weakly apparent (Figure 8b, d, e, g, h, i, l, m). For many of these elements, a bottoming-out of the concentrations is visible at ca. 6000 L/s . That is, after streamflow levels reached ca. 6000 L/s , concentrations were maintained at a relatively uniform level compared with the large variability of concentrations during lower flows.

As discussed in the Streamflow Results section, site LB was spring fed for several months prior to runoff in the late spring and summer. In April, 1998, when streamflow was still very low (<113 L/s), concentrations of Ca and S rose before being diluted by snowmelt in May and June (Figures 9f and 9o). This rise could be explained by a flushing effect at the very start of runoff. This idea postulates that elements which have been accumulating in adjacent soil and ground water over the winter are suddenly released into the surface water creating a brief surge in concentrations (Edwards, 1973; Walling and Foster, 1975; Johnson and East, 1982).

Arsenic had a significantly positive relationship with ($r=0.66$, $p<0.01$) (Figure 8c). Its lowest concentrations were present during the low flow periods of the late winter months (Figure 9d). Copper was not detected above its PQL of 0.8 $\mu\text{g/L}$ (Figure 9h). Chromium showed up only occasionally above the PQL in some of the samples, but never in all three samples from a single site, indicating it may be primarily colloidal or that the Cr PQL was not well enough defined (Figure 9g). Similarly to site LA, Fe was at detectable levels only through January, 1998 (Figure 9i). It did not rise above the PQL in the fall of 1998 as it did in 1997. As at site LA, Mn was found in the late summer of 1997, and only at the highest flow event in 1998 (Figure 9m). Hence, the high flow appears to mobilize and not dilute Mn concentrations at both LA and LB. Zn concentrations at LB were all below the level found in the highest field blank, and so trends cannot be explained (Figure 9r). The pH at LB was generally higher in the summers of 1997 and 1998 than during other times of the year (Figure 9b).

Loads at LB are streamflow-dominated (Figure 10).

4) Landers Fork at LC:

The surface water geochemistry at site LC (Figures 11, 12, and 13) is generally similar to that of site LB, with some exceptions. A thaw flushing effect might explain a small rise in Ca and Mg in March and early April, 1998, just before spring runoff at the site (Figures 12f, and 12l). In general, inorganic carbon, Ba, Ca, K, Li, Mg, Si, and Sr exhibited similar trends over the course of the study period, with approximately negative relationships ($r>-0.77$, $p<0.01$) with streamflow (Figure 11 b, d, e, g, h, i, m, and n). As at site LB, the concentrations of many of these elements cease decreasing beyond a certain level of streamflow. At this site, this appears to occur at about 8000 L/s, which is approximately 10 times the baseflow level.

As at the upstream sites, Cu was always below the PQL at LC, and like at site LB, Mn was quantifiable only during the high flow events of both summers 1997 and 1998 (Figures 12h and 12m). Chromium was detected in all three site replicate samples on 11/16/97, 1/6/98, and then again during the highest flow in 1998, on 6/29/98 (Figure 12g). As at the upstream sites, Fe at LC was detected no later than January, 1998 (Figure 12i). Arsenic concentrations were approximately twice as high at LC than at LB, reaching a maximum of 1.0 $\mu\text{g/L}$ in early 1998 (Figure 12d). During this time, streamflow at site LC was dominated by ground water input, and the seeps measured near the site had As concentrations of 0.9-1.0 $\mu\text{g/L}$ (except for during November and December, 1998, when the seep concentrations were 0.5 $\mu\text{g/L}$) (Table 9). As can be seen on Figure 11c, a range of As concentrations (from 0.4 to 1.0 $\mu\text{g/L}$) was present during low flow conditions at the site. However, during the rest of the time, concentrations were mostly restricted to the 0.4 to 0.6 $\mu\text{g/L}$ range, and there was no significant correlation between As and streamflow ($r=-0.40$, $p=0.11$).

Dissolved S again behaved anomalously; and it did not correlate well with streamflow ($r=-0.48$, $p=0.05$). It maintained a relatively steady concentration over the

course of the dynamic streamflow conditions of 1998 (Figure 12o). Also not exhibiting a strong relationship to streamflow was pH, although pH was generally lower in the winter of 1997 to spring of 1998, when the site was ground water fed (Figure 12b). The seeps at the site had pH levels that were lower than the surface water (7.1 - 7.8 compared to 7.7 - 8.3), which could explain the lower winter pH levels at the site. The pH values remained relatively low at the start of runoff, and then rose in June (Figure 12b). Fall measurement of pH at the site were at levels similar to pre-runoff conditions.

The highest loading of dissolved elements at site LC again occurred during high streamflow levels, as evident on Figure 13 compared to Figure 12a.

5) Landers Fork at LD:

As mentioned in the streamflow section, site LD was not sampled during the rise of runoff in 1998, and not beyond August, 1998. For the most part, concentrations at LD were very similar to those upstream at site LC when both sites were measured (Table 9). Therefore, the apparently different trends seen on the plots of data from LC and LD are simply an artifact of the presence of fewer datapoints at site LD (Figures 11-16). As at LC, inorganic carbon, Ba, Ca, K, Li, Mg, Si, and Sr had negatively sloping correlations with streamflow ($r < -0.69$, $p < 0.04$) and counter-clockwise hysteresis loops (Figure 14b, d, e, g, h, i, m, and n).

b) Blackfoot River and Hogum Creek

1) Blackfoot River at BH:

At site BH, a counter-clockwise hysteresis with a negative slope ($r < -0.60$, $p < 0.05$) to streamflow is seen for inorganic carbon, Ba, Ca, Li, and Si, (Figure 17b,d,e,h, and m). Potassium and Mg also correlate inversely with streamflow ($r < -0.78$; $p < 0.01$), but the falling and rising limbs are not distinct from one another in this dataset (Figures 17g and 17i). Dissolved As shows a counter clockwise hysteresis as well, although the loop has neither a positive nor negative trend ($r = 0.12$, $p = 0.72$) with streamflow (Figure 17c). Hence, As concentrations could be better predicted using rising limb vs. falling limb information rather than the streamflow values alone.

The pH at the site always was well above neutral (between 7.8 and 8.4), and the lowest pH values occurred on the post-rain storm sampling day (7/20/97) and during spring runoff in 1998 (Figure 18b). Arsenic, Cu, Fe, and Mn exhibit a reaction to the storm in July, 1997 as well, by being the most highly concentrated on that sampling event than on any other over the 14 month study at the site (Figure 18d,h,i, and m). Although As was somewhat diluted by the high flows in the spring and summer of 1998, dissolved Fe, Mn, and Zn concentrations increased with the runoff. Copper was not detected other than on the post-storm date and in 1 of 3 samples on each sampling date in July and August 1998 (Figure 18h). Chromium concentrations appeared above the PQL during a few of the low flow events, but not during spring runoff (Figure 18g).

Zinc concentrations were highest in late April, 1998, at the early portion of spring runoff, and overall, Zn correlated positively with streamflow ($r = 0.79$, $p < 0.01$) (Figures 17o and 18r). Sulfur behaved similarly to Zn, in that its highest value was in late April, 1998 as well (Figure 18o). In late April and May, 1998, its value was 2-4 times the concentrations found during the rest of the study period. During the 6/5/98 and 7/20/98

sampling, when streamflow was still high due to runoff, S concentrations were relatively similar to pre-runoff conditions and Zn concentrations decreased. Hence, it appears that S and Zn were “flushed” from the system during the early part of the spring snowmelt.

Plots of solute loads at the site indicate that like elsewhere, the amount of streamflow is the strongest influence on load quantities (Figures 18 a and 19). However, variations in the chemical concentrations of elements also play a role. For example, the S load did not increase with the second runoff peak sampled on 6/5/98; because its concentration dropped so dramatically after the start of runoff, its load continued to drop as well despite the rise in streamflow (Figure 19e). This same phenomenon is visible for the Zn loads; although the second runoff peak is detectable via the rise in Zn loads, the second peak is not as high as the first one, even though the streamflow level had increased (Figure 19d).

2) *Hogum Creek:*

Hogum Creek was sampled less often than most other sites-- only seven times and only between November 1997 and August, 1998 (Figure 21a). Nonetheless, this time period captured at least one pre-, during- and post runoff event. Results show that most detectable elements (Ba, Ca, K, Li, Mg, Mn, and Sr) correlated negatively ($r < -0.82$, $p < 0.03$) with streamflow (Figures 20c,d,f,g,h,i, and m). Although a hysteresis pattern is difficult to discern from the data, there appears to be a slight counter clockwise rotation (falling limb has higher concentrations than rising limb) for the Ba, K, and Li concentrations, and a clockwise rotation (rising limb more highly concentrated than falling limb) for Ca, Mg, and Mn.

Elements that did not correlate negatively with streamflow were As, S, and Si ($p > 0.31$) (Figures 20b,k, and l). Arsenic was peculiar in that it went from being at the PQL of 0.2 $\mu\text{g/L}$ during November, 1997 and January, 1998, to increasing steadily through the end of the sampling period, when it measured 1.1 $\mu\text{g/L}$ on 8/17/98 (Figure 21d). This indicates that the physical and/or chemical sources to Hogum Creek in the winter months were more depleted in As than the sources that played increasingly larger roles in the summer. Sulfur exhibits a trend roughly opposite to that of As, in that its concentration dropped over the course of the study period (Figure 21o). It was close to 3 mg/L in November, 1997, January, 1998, and April, 1998. In May, 1998, it dropped to 2.5 mg/L, and in June, July, and August it was at 1.1- 1.4 mg/L. Thus, similarly to other sites, S at HC was low in the summer after the start of runoff, possibly indicating a flushing phenomenon again. Sulfur had clockwise rotation and Si had counterclockwise rotation at the site with no linear relationship to streamflow. Iron also did not follow the trends the other elements did; although it showed a slight negative relationship with discharge for most of the study period, the last sample collected (in August, 1998) was 3-4 times as high in Fe as all the other samples (Figure 21i). Zinc was below the PQL of 0.3 $\mu\text{g/L}$ for all but the November and January samples, but even those were lower than the measurement of the highest field blank (Figure 21r). The pH at HC was between 7.3 and 7.6, although it was higher (at 8.0 and 7.8) at the last two sampling events, in July and August, 1998, on the falling limb of the hydrograph (Figure 21b).

3) *Blackfoot River at BB:*

Many of the same geochemical trends discussed at site BH are apparent at site BB. Many elements correlate inversely with streamflow ($r < -0.64$, $p < 0.02$). However, the highest flow sample, taken when streamflow was at ca. 6000 L/s, was hardly different than the samples taken at ca. 2000 L/s. This may indicate that beyond a certain flow threshold,

meltwater overwhelms baseflow contributions. There was a wide amount of variation in dissolved concentrations during low flow conditions, and relatively little geochemical variation at higher flows. Inorganic carbon, Ba, Li, Si, and Sr appear to follow a counter-clockwise hysteresis pattern, while S follows in a clockwise direction (Figures 23 b,d,e,i,j,k,o, and p). Also similar to site BH, As at BB exhibits a counter clockwise hysteresis cycle with no positive or negative trend with streamflow ($r=0.29$, $p=0.29$) (Figure 23c). However, many of the hysteresis cycles for these and other solutes are unclear, with falling and rising limb points not always being distinct from one another. For example, Ca and Mg exhibit clockwise hysteresis when considering the 1998 data only, but when adding the fall 1997 data, the hysteresis loop is no longer valid because the 1997 falling limb points overlap with the 1998 rising limb points.

Site BB's reaction to the storm immediately before the 7/20/97 sample is seen as a drop in pH and an increase in Cu and Fe (Figures 24b,h, and i). However, while many trace elements were at higher concentrations following the storm in 7/97, only Fe was at its maximum on that event compared the whole study period. Generally, Fe correlated poorly with streamflow ($r=0.05$; $p=0.86$) although its lowest values were found in the 6/29/98 samples, when streamflow was the highest. Copper showed up above its PQL not only after the storm, but also in some of the late spring and summer samples of 1998 (Figure 24h). In fact, its maximum concentration was collected during the highest flows measured, in late June, 1998. Manganese typically changed little with streamflow, but overall there is a slightly positive relationship ($p=0.02$) between Mn and streamflow (Figure 23l). Arsenic was higher in the late summers of 1997 and 1998 than during other times of the study, when its concentrations followed no discernable pattern (Figure 24d). The pH values at BB were not clearly correlated with streamflow either, although they were lower at the start of 1998's spring runoff than they were before and after (Figure 24b).

As at site BH, S and Zn at BB peaked during the early stages of runoff (Figures 24o and r). However, while S returned to pre-runoff levels shortly after the start of high flow, Zn remained at relatively high levels during the course of runoff. Sulfur concentrations in April to May were approximately 3 times as high as during the rest of the study period. Dissolved Zn was relatively high not only during runoff in 1998, but also during the two July, 1997 sampling events. The early spring runoff mobilizations of dissolved Zn and S are evident in the load plots (Figure 25).

4) Blackfoot River at BC:

Dissolved inorganic carbon, Ba, K, Li, Si, and Sr at site BC exhibit counter-clockwise hysteresis similar to that seen upstream at BB and BH (Figures 26b,d, g, h, m, and n). Again, they (and Ca, and Mg) have a generally negative relationship ($r < -0.52$, $p < 0.05$) to streamflow, with high variability in concentrations during low flow periods. As at sites LB, LC, and BB, there appears to be a bottoming-out of solute concentrations during high flow periods (e.g. Figures 26e and h). This may again indicate that beyond a certain flow threshold, meltwater overwhelms the baseflow contributions.

Site BC was first sampled on 7/20/97, the event that immediately followed the summer storm referred to before. These first samples at BC are relatively low in pH and high in As, Fe, Mn, and Zn (Figures 27b,d,i, m, and r). Like at the other sites, dissolved As at BC was variable (0.2-0.5 $\mu\text{g/L}$) during low flow conditions and it did not have a negative or positive relationship to streamflow overall ($r=0.04$, $p=0.88$) (Figures 26c and 27d). The highest Fe found at the site over the study period was on the first sampling date, the post-storm event (Figure 27i). Copper was detected only during the highest flow level measured at BC, on 6/29/98 (Figure 27h). Cr was found barely above its PQL in the

November 1997 and January 1998 samples, as well as in one of the three from 6/29/98 (Figure 27g). Dissolved Mn at BC had a remarkably good positive correlation ($r=0.91$, $p<0.01$) with discharge (Figure 26j). Dissolved Zn appears to have been mobilized by spring runoff as well, with its highest concentrations occurring in the samples collected during the highest flows (Figure 26o and 27r). The pH levels at BC were variable within the 7.7 to 8.3 range, although pH was clearly lower at the start of runoff than at the end (Figure 27b).

Following along with the trends at BH and BB, concentrations of dissolved S and Zn were observed to rise during the early stages of spring runoff in 1998 (Figures 27o and 27r). Concentrations during the peak of runoff are lower than those during the start, indicating a flushing of these solutes into the river with the onset of snowmelt.

Summary

- Streamflow levels and surface water- ground water dynamics varied seasonally at the sites along the Landers Fork and Blackfoot River drainages studied in this project. We began this project towards the end of spring runoff in 1997, and we sampled the sites through the following winter and spring runoff.
- Streamflow data from the Copper Creek and Landers Fork sites (LA and LB) show that the stretch of river between the sites is disconnected during the low flow winter period. Although Copper Creek was free flowing at all times other than in early March, 1998, site LA was dry for much of the winter.
- Streamflow generated from ground water seeps sustained ice-free flow in the Landers Fork at sites LB and LC at all times of the year. The reach between LB and LC was gaining streamflow during all 17 times that both sites were gauged between July, 1997 and November, 1998.
- At the Blackfoot River sites, streamflow was present at all sites every time they were visited over the course of the study. The one exception to this is site BB, where the river was frozen over on 1/6/98. The ice-free streamflow at sites BH and BC during the cold winter months indicate an important role by the local or regional ground water system in sustaining streamflows in the area.
- The stretch between BH and BC was a losing reach most of time it was measured. However, the stretch of river between sites BB and BC was gaining streamflow the majority of the times the sites were gauged.
- The concentrations of dissolved ($<0.2 \mu\text{m}$) elements measured at the sites indicate that the Blackfoot River had higher mean concentrations of Cu, Fe, K, Mn, Na, S, Si, Sr, and Zn than the Landers Fork; lower concentrations of inorganic carbon, Ba, and Ca than the Landers Fork; and similar concentrations of As, Li, and Mg as the Landers Fork.
- A counter-clockwise, negatively trending hysteresis effect was present for many elements along Copper Creek, and for only a few in the Landers Fork. Although hysteresis cycles were unclear for most solutes at the Landers Fork sites, many solute concentrations correlated inversely with streamflow.

- The dissolved trace metals Cu, Cr, Fe, Mn, and Zn were usually or always below detection levels at Landers Fork sites. However, Mn was detected during the highest flow measured in 1998. Arsenic was not well correlated with streamflow at any of the sites.
- During the low flow winter months, the geochemistry at sites LB and LC was largely influenced by the chemistry of the seeps supplying much of the flows, and a small surge in concentrations of several elements was detected at an early stage of spring runoff.
- At the Blackfoot River sites, a counter-clockwise hysteresis with a negative relationship to streamflow was detected for many of the non-trace metals. At BB and BC, a leveling out of concentrations is seen at the higher flow levels.
- Unlike in the Landers Fork, many of the trace metals in the Blackfoot were well above their detection limits, allowing for characterization of their trends with time. Trace metals such as Cu, Fe, Mn, S, and Zn regularly were at higher concentrations during spring runoff in 1998, and they were also elevated following a rainstorm in July, 1997. Sulfur and Zn appeared to be mobilized during the early stages of runoff. Manganese correlated particularly well with streamflow at site BC. Like at the Landers Fork sites, a haphazard relationship between streamflow and As is seen along the Blackfoot.
- It is unknown whether the observed increases in some trace elements in both the Landers Fork and Blackfoot Rivers during high flow events were due to increased passage of colloids through the filters or due to geochemical and hydrologic source variations that increased concentrations of truly dissolved elements.
- Considerable hydrological and geochemical variation existed among sites within the relatively short river segments studied (<7 kms), indicating the importance of defining small-scale spatial and temporal variations in rivers subjected to baseline characterization studies.
- In summary, this report presents the results of up to 18 months of baseline geochemical studies in the upper Blackfoot and lower Landers Fork watersheds. Streamflow levels alone were poor predictors of solute geochemistry in the Landers Fork and upper Blackfoot River. The location on the side of the hydrograph peak(s) appears to be at least as important as knowing the streamflow level for many elements at the sites studied. Many trace metals were mobilized during high flow events in the Blackfoot River. A geochemical signal of the presence of the undeveloped McDonald ore body was not apparent in the water quality data for the Landers Fork.
- More detailed temporal studies would be helpful to better understand issues of early spring runoff flushing, storm geochemistry versus spring runoff geochemistry (especially for the trace metals), and the perplexing haphazardness of arsenic concentrations in both watersheds.

References

- Benoit, G., 1994, Clean technique measurement of Pb, Ag, and Cd in freshwater: a redefinition of metal pollution. *Environ. Sci. Tech.* 28(11): 1987, 1991.
- Bhangu, I. and P.H. Whitfield, 1997, Seasonal and long-term variations in water quality of the Skeena River at Usk, British Columbia. *Water Research* 31 (9): 2187-2194.
- Bird, S.C. The effect of hydrological factors on trace metal contamination in the river Tawe, South Wales. *Environmental Pollution*, 45, 87-124, 1987.
- Droppo, I. G. and C. Jaskot, Impact of river transport characteristics on contaminant sampling error and design, *Environ. Sci. Technol.* 29: 161-170, 1995.
- Edwards, A.M.C., 1973, The variation of dissolved constituents with discharge in some Norfolk rivers, *J. Hydrology*, 18: 219-242.
- Evans, C. and T.D. Davies, 1998, Causes of concentration/discharge hysteresis and its potential as a tool for analysis of episode hydrochemistry. *Water Resources Research* 34(1): 129-137.
- Franson, M.A. H. (ed.), 1985, American Public Health Association, American Water Works Association, and Water Pollution Control Federation, Standard methods for the examination of water and wastewater, a) Organic carbon (total), combustion-infrared method, p 507-511, b) Determination of arsenic and selenium by conversion to their hydrides by sodium borohydride reagent and aspiration into an Atomic Absorption Atomizer; p. 165-171.
- Johnson, R.A., and J.W. East, Cyclical relationships between river discharge and chemical concentration during flood events. *J. Hydrology*, 57: 93-106, 1982.
- Martin, T.D., C.A. Brockhoff, J.T. Creed, 1994, Determination of metals and trace metals in water by Ultrasonic Nebulization Inductively Coupled Plasma-Atomic Emission Spectrometry (200.15). Environmental Monitoring Systems Laboratory, Office of Research and Development, U.S. Environmental Protection Agency.
- Menges, J. L., 1997, Investigation of temporal changes of heavy metal concentrations in sediments and water of the Blackfoot River, Montana. Unpublished M.S. thesis, University of Montana, 163 p.
- Moore, J.N., S.N. Luoma, D. Peters, 1991, Downstream effects of mine effluent on an intermontane riparian system, *Can. J. Fish. Aquat. Sci.* 48: 222-232.
- Nagorski, S.A., J.A. Shifflett, J.N. Moore, and D.B. Smith, 1998, Geochemical baseline studies and relations between water quality and streamflow in the Upper Blackfoot River watershed, Montana: Progress report for July 1997- March 1998. U.S. Geological Survey Open-File Report 98-499, 133 p.
- Nagorski, S.A., T.E. McKinnon, J.N. Moore, and D.B. Smith, 2000, Geochemical characterization of surface water and streambed sediment of the Blackfoot River, Montana, during low flow conditions, August 16-20, 1998. U.S. Geological Survey Open-File Report 00-003, 59 p.

Pfaff, J.D., 1993, Determination of inorganic anions by Ion Chromatography (300.0). EPA methods for determination of inorganic substances in environmental samples. EPA/600/R-93/100.

Schafer and Assiates, Final surface water baseline characterization report for the Seven-Up Pete Joint Venture McDonald Project. Submitted to Seven-Up Pete Joint Venture, 1994.

Taylor, H.E. and A.M. Shiller, 1995. Mississippi River methods comparison study: Implications for water quality monitoring of dissolved trace elements. *Environ. Sci. Technol.* 29(5): 1313-1317.

Walling, D.E. and I.D.L. Foster, Variations in the natural chemical concentration of river water during flood flows, and the lag effect: Some further comments. *J. Hydrology* 26: 237-244, 1975.

Windom, H.L., J.T. Byrd, G. Smith, and F. Huan, 1991, Inadequacy of NASQAN data for assessing trace metal trends in the nation's rivers. *Environ. Sci. Technol.* 25(6): 1137-1142.

Summary: pH meter calibration standard checks			D.O. meter
	7.00 standard	10.00 standard	calibration slopes
Total number of standard checks	76	76	mean slope= 88.43
Mean reading	7.00	10.00	stdev =8.70
Standard Deviation	0.02	0.02	
Minimum reading	6.96	9.93	(reported acceptable
Maximum reading	7.09	10.09	slope range: 70-120)

Table 3: Sample analysis dates

Sample Date	Ion Chromatography Analysis date	Inorganic Carbon Analysis date	Alkalinity Analysis date	Arsenic by AAS Analysis date	ICAPES Analysis date
7/3/97, 7/4/97	7/6/1997	7/9/1997	(Not analyzed)	7/29/1997	8/13/97-8/15/97
7/20/97, 7/21/97	7/22/1997	7/22/1997	(Not analyzed)	7/29/1997	8/13/97-8/15/97
8/7/97, 8/8/97	8/9/1997	8/13/1997	(Not analyzed)	8/14/1997	8/13/97-8/15/97
9/13/97, 9/14/97	9/15/97-9/16/97	9/15/97-9/16/97	(Not analyzed)	10/31/1997	10/23/1997
10/19/1997	10/20/1997	10/20/1997	(Not analyzed)	10/31/1997	10/23/1997
10/25/1997	10/26/1997	10/27/1997	(Not analyzed)	10/31/1997	10/30/1997
11/16/1997	11/18/1997	11/17/1997	(Not analyzed)	12/30/1997	12/31/1997
11/18/1997	11/20/1997	11/20/1997	(Not analyzed)	12/30/1997	12/31/1997
1/6/1998	1/8/1998	1/7/1998	(Not analyzed)	1/12/1998	1/14/1998
3/8/1998	(Not analyzed)	3/18/1998	(Not analyzed)	6/15/1998	6/23/1998
4/7/1998	(Not analyzed)	4/8/1998	(Not analyzed)	6/15/1998-6/18/98	6/30/98, 7/10/98
4/26/1998	(Not analyzed)	4/27/1998	(Not analyzed)	6/15/1998-6/17/98	6/30/98, 7/10/98
4/29/1998	(Not analyzed)	4/30/1998	(Not analyzed)	6/15/1998-6/17/98	6/30/98, 7/10/98
5/18/98, 5/19/98	(Not analyzed)	5/21/1998	(Not analyzed)	6/18/1998	7/6/98, 7/13/98
6/5/1998	(Not analyzed)	(Not analyzed)	6/7/1998	6/18/1998	7/13/1998
6/29/1998	(Not analyzed)	(Not analyzed)	6/30/1998	7/30/1998	7/13/1998
7/20/1998	(Not analyzed)	(Not analyzed)	7/21/1998	7/30/1998	10/29/1998
8/98 basinwide	8/18/1998	(Not analyzed)	8/19/1998	9/16/98-9/21/98	1/13/99-1/16/99
9/4/1998	(Not analyzed)	9/9/1998	9/9/1998	9/14/1998	1/17/1999
10/6/1998	10/7/1998	10/7/1998	10/7/1998	11/11/1998	1/17/1999
11/7/1998	(Not analyzed)	(Not analyzed)	11/9/1998	3/1/1999	1/18/1999
12/5/1998	(Not analyzed)	12/8/1998	12/7/1998	3/1/1999	1/18/1999

Table 4:
Detection limits of analytes

<u>Practical Quantification Limits (PQLs)</u>	
Analyte	PQL
Inorganic carbon	1 mg/L
Organic carbon	1 mg/L
F	0.05 mg/L
Cl	2 mg/L
Nitrate-N	0.2 mg/L
Nitrite-N	0.02 mg/L
Phosphate-P	0.2 mg/L
Sulfate	1.00 mg/L
As	0.2 µg/L
Ag	1 µg/L
Al	5 µg/L
Ba	1 µg/L
Be	0.05 µg/L
Ca	0.01 mg/L
Cd	0.5 µg/L
Co	0.5 µg/L
Cr	1 µg/L
Cu	0.8 µg/L
Fe	5 µg/L
K	0.10 mg/L
Li	0.5 µg/L
Mg	0.01 mg/L
Mn	0.3 µg/L
Mo	1 µg/L
Na	0.15 mg/L
Ni	2 µg/L
Pb	6 µg/L
S	0.01 mg/L
Si	0.02 mg/L
Sr	2 µg/L
Ti	2 µg/L
V	2 µg/L
Zn	0.3 µg/L

Tables 5.1-5.3

External and Internal Standards Measurements

Table 5.1

Summary: External standards measured on AAS <i>Concentrations in μ g/L.</i>			
Standard	Reported value (Range)*	Measured values or mean (std. dev.)	Measured values within Report. Range?
USGS T-107 (n=1)	10.8 (4.2)	9.4	Yes
USGS T-119 (n=3)	4.2 (0.57)	4.0 (0.5)	Yes
USGS T-121 (n=2)	8 (2.2)	8.0, 8.0	Yes
USGS T-143 (n=16)	15.2 (2.4)	15.3 (1.5)	Yes
USGS T-145 (n=9)	9.88 (2.08)	9.2 (1.1)	Yes
USGS T-113 (n=16)	23.8 (3.0)	24.8 (0.7)	Yes

*Reported Range is 2 pseudosigmas from the mean

Note: USGS Standards T-121, T-143, and T-113 were diluted to 10%, and USGS Standards T107, T-119, and T-145 were diluted by 50% for analysis in order to fall within the range of calibration of the AAS.

Table 5.2

Summary: External standard "QC SPEX" measured on IC <i>(Concentrations in mg/L)</i>			
Analyte	Reported Mean (Range)*	Measured Mean (Stand. Dev.)	Measured Mean w/in Reported Range?
Fluoride (n=10)	3.0 (0.47)	2.8 (0.1)	Yes
Chloride (n=8)	30.0 (2.62)	28.8 (1.0)	Yes
Nitrate-N (n=10)	5.0 (0.84)	4.9 (0.2)	Yes
Nitrite-N (n=10)	2.0 (0.21)	1.9 (0.1)	Yes
Phosphate-P (n=10)	1.0 (0.29)	1.0 (0.1)	Yes
Sulfate (n=10)	30.0 (5.27)	29.6 (2.2)	Yes

*Reported Range is the 95% Confidence Interval

Table 5.3

Summary: Internal standards (fortified lab blanks) measured on AAS, Carbon Analyzer, and IC		
Standard	Mean % difference of fortified lab blank and measured concentration	Standard Deviation of mean % differences
Arsenic (n=276)	5.2	5.9
Inorganic C (n=176)	2.8	3.1
Organic C (n=94)	6.9	6.7
Fluoride (n=99)	3.6	4.4
Chloride (n=79)	7.0	10.6
Nitrate-N (n=82)	7.1	10.6
Nitrite-N (n=90)	3.5	4.7
Phosphate-P (n=83)	6.4	10.3
Sulfate (n=99)	3.1	4.1

Tables 6.1-6.3: Summary of USGS standards measured on ICAPES during sample analyses.

Table 6.1

Summary: USGS Standard T-107 measured on ICAPES (n=30)				
Element	Units	Reported	Measured	Measured Mean
		Mean (Range)*	Mean (Std. Dev.)	w/in Reported Range?
Ag	µg/L	12.3 (4.4)	13.4 (0.9)	Yes
Al	µg/L	220 (90)	203 (6)	Yes
Ba	µg/L	192 (22)	173 (8)	Yes
Be	µg/L	11 (2.2)	10.6 (0.3)	Yes
Ca	mg/L	11.7 (1.4)	10.45 (0.41)	Yes
Cd	µg/L	14.3 (4.2)	12.4 (0.5)	Yes
Co	µg/L	11 (2.8)	10.4 (0.8)	Yes
Cr	µg/L	13 (4.2)	11.0 (0.5)	Yes
Cu	µg/L	30 (4.6)	26.0 (0.84)	Yes
Fe	µg/L	52 (14)	54 (4)	Yes
K	mg/L	0.84 (0.3)	0.74 (0.02)	Yes
Li	µg/L	193 (28)	193.6 (3.8)	Yes
Mg	mg/L	2.1 (0.26)	1.95 (0.05)	Yes
Mn	µg/L	45 (12)	40.7 (1.3)	Yes
Mo	µg/L	15 (3.8)	12.1 (0.5)	Yes
Na	mg/L	20.7 (2.2)	20.54 (0.49)	Yes
Ni	µg/L	28.1 (7.8)	23 (1)	Yes
Pb	µg/L	26 (8)	25 (1)	Yes
S	mg/L	(Not reported)	-	-
Si	mg/L	3.6 (0.468)	3.27 (0.22)	Yes
Sr	µg/L	61 (8)	51 (2)	No
Ti	µg/L	(Not reported)	-	-
V	µg/L	14 (5.6)	13 (1)	Yes
Zn	µg/L	75.8 (19.8)	68.9 (3.3)	Yes

*Reported Range is 2 pseudosigmas from the mean

Table 6.2

Summary: USGS Standard T-143 measured on ICAPES (n=78)				
Element	Units	Reported	Measured	Measured Mean
		Mean (Range)*	Mean (Std. Dev.)	w/in Reported Range?
Ag	µg/L	19.6 (2.8)	25.4 (3.7)	No
Al	µg/L	22.1 (16.6)	21.8 (2.3)	Yes
Ba	µg/L	81.9 (9)	75.2 (3.1)	Yes
Be	µg/L	8.5 (1.32)	8.3 (0.4)	Yes
Ca	mg/L	53.7 (4.4)	53.6 (2.7)	Yes
Cd	µg/L	19.1 (3)	17.6 (0.7)	Yes
Co	µg/L	17 (2.4)	15.7 (0.5)	Yes
Cr	µg/L	37 (5.2)	33 (1)	Yes
Cu	µg/L	22.3 (3.8)	22.6 (0.9)	Yes
Fe	µg/L	222 (28)	225 (12)	Yes
K	mg/L	2.5 (0.42)	2.5 (0.11)	Yes
Li	µg/L	18 (4.2)	17.6 (0.8)	Yes
Mg	mg/L	10.4 (1)	10.7 (0.3)	Yes
Mn	µg/L	18.2 (3.8)	16.5 (0.5)	Yes
Mo	µg/L	36.1 (8.6)	32.5 (1.4)	Yes
Na	mg/L	34 (3.2)	35.0 (1.2)	Yes
Ni	µg/L	71 (10)	64.1 (3.2)	Yes
Pb	µg/L	83.4 (14.2)	82.9 (2.9)	Yes
S	mg/L	(Not reported)	-	-
Si	mg/L	10.94 (1.64)	11.54 (0.58)	Yes
Sr	µg/L	306 (30)	270 (12)	No
Ti	µg/L	(Not reported)	-	-
V	µg/L	30 (6)	28.5 (2.2)	Yes
Zn	µg/L	20 (4.4)	18.3 (0.9)	Yes

*Reported Range is 2 pseudosigmas from the mean

Table 6.3

Summary: USGS Standard T-145 measured on ICAPES (n=42)				
Element	Units	Reported	Measured	Measured Mean
		Mean (Range)*	Mean (Std. Dev.)	w/in Reported Range?
Ag	µg/L	7.55 (1.84)	8.8 (1.4)	Yes
Al	µg/L	67.6 (22)	66.9 (6.6)	Yes
Ba	µg/L	37.1 (3.8)	34.9 (1.78)	Yes
Be	µg/L	9.04 (1.4)	8.7 (0.4)	Yes
Ca	mg/L	30.7 (2.6)	29.6 (1.6)	Yes
Cd	µg/L	9.33 (1.64)	8.6 (0.4)	Yes
Co	µg/L	10 (1.8)	9.3 (0.4)	Yes
Cr	µg/L	15.3 (2.8)	13.3 (0.7)	Yes
Cu	µg/L	11 (2.8)	10.9 (0.4)	Yes
Fe	µg/L	101 (16)	102 (7)	Yes
K	mg/L	2.13 (0.32)	2.05 (0.08)	Yes
Li	µg/L	27.3 (5)	25.9 (1.7)	Yes
Mg	mg/L	8.68 (0.9)	8.52 (0.28)	Yes
Mn	µg/L	20.9 (3)	19.2 (0.8)	Yes
Mo	µg/L	9.23 (2.58)	7.9 (0.5)	Yes
Na	mg/L	41.2 (3.8)	42.4 (2.4)	Yes
Ni	µg/L	11 (2.6)	9.5 (0.7)	Yes
Pb	µg/L	12.7 (2.4)	12.3 (0.7)	Yes
S	mg/L	(Not reported)	-	-
Si	mg/L	5.28 (0.66)	5.82 (0.25)	Yes
Sr	µg/L	203 (18)	178 (7)	No
Ti	µg/L	(Not reported)	-	-
V	µg/L	11.7 (3.4)	10.3 (0.7)	Yes
Zn	µg/L	10 (4.8)	8.9 (0.6)	Yes

*Reported Range is 2 pseudosigmas from the mean

Tables 7.1-7.4: Duplicates and Spike Recoveries

Table 7.1

Summary: ICAPES duplicate comparisons of water samples			
Element	Number of dupl. pairs above PQL	Mean % difference of dupl. pairs	Stand. dev. of mean of % difference of dupl. pairs
Ag	0	-	-
Al	0	-	-
Ba	55	3.8	4.0
Be	0	-	-
Ca	55	3.6	4.7
Cd	0	-	-
Co	0	-	-
Cr	12	7.4	4.2
Cu	13	3.3	4.0
Fe	36	7.8	10.0
K	54	4.1	5.0
Li	55	3.4	4.3
Mg	55	2.9	4.3
Mn	31	3.8	4.8
Mo	0	-	-
Na	55	5.4	6.7
Ni	0	-	-
Pb	0	-	-
S	55	5.0	6.7
Si	55	3.3	4.4
Sr	55	4.0	5.2
Ti	0	-	-
V	0	-	-
Zn	28	7.8	13.3

Table 7.3

Summary: ICAPES Spike (fortified sample) recoveries					
Element	Unit	Spike values	Number of samples above PQL	Mean percent recovery	Stand. dev. of mean percent recovery
Ag	µg/L	20	0	-	-
Al	µg/L	10	0	-	-
Ba	µg/L	200	58	98.0	9.5
Be	µg/L	-	0	-	-
Ca	mg/L	10, 20, 30	40	102.5	10.3
Cd	µg/L	10	0	-	-
Co	µg/L	-	0	-	-
Cr	µg/L	10	18	100.7	7.6
Cu	µg/L	3, 10, 20	15	106.9	6.7
Fe	µg/L	20, 30, 50	43	106.0	16.3
K	mg/L	1, 2, 2.5	58	101.3	5.6
Li	µg/L	5, 10	56	103.0	6.0
Mg	mg/L	5, 10	59	103.8	6.4
Mn	µg/L	10	23	92.0	4.8
Mo	µg/L	-	0	-	-
Na	mg/L	2.5, 5, 10	58	102.6	7.5
Ni	µg/L	20	0	-	-
Pb	µg/L	80	0	-	-
S	mg/L	2, 5	55	111.8	8.5
Si	mg/L	2, 5	55	111.9	8.7
Sr	µg/L	50, 100	54	92.5	8.6
Ti	µg/L	-	0	-	-
V	µg/L	-	0	-	-
Zn	µg/L	10, 20	37	104.4	8.1

Table 7.2

Summary: AAS, Carbon Analyzer, and IC Replicate Comparisons			
Analyte	Number of replicate sets above PQL	Mean % difference or % RSD of replicate sets	Stand. dev. of mean of % diff./%RSD of replicate pairs
Arsenic =<0.5 ppb	63	7.0	6.1
Arsenic >0.5 ppb	39	3.6	3.5
Alkalinity	27	3.2	3.4
Inorganic C	71	2.0	2.7
Organic C	35	9.1	11.2
Fluoride	58	3.5	1.5
Chloride	0	-	-
Nitrate-N	0	-	-
Nitrite-N	0	-	-
Phosphate-P	0	-	-
Sulfate	69	1.5	2.1

PQL= Practical Quantifiable Limit

%RSD= Percent relative standard deviation

Table 7.4

Summary: AAS, Carbon Analyzer, and IC Spike (fortified sample) recoveries					
Analyte	Unit	Spike Value	Number of samples above PQL	Mean percent recovery	Stand. dev. of mean percent recovery
Arsenic	µg/L	1.0	44	109.8	7.0
Organic C	mg/L	0.5, 2.0	10	95.6	31.8
Fluoride	mg/L	0.1	26	85.9	14.8
Chloride	mg/L	0.2	-	-	-
Nitrate-N	mg/L	0.025	-	-	-
Nitrite-N	mg/L	0.025	-	-	-
Phosphate-P	mg/L	0.025	-	-	-
Sulfate	mg/L	0.5, 1.5, 3.0	32	109.2	19.4

Tables : Summary of duplicates and spike recoveries measured on all instruments used for analysis of water samples.

Tables 8.1 - 8.4: Laboratory and Field Blanks

Table 8.1

Summary: ICAPES measurement of Lab Blanks				
Element	Units	PQL	Total number of blanks	Number of blanks below PQL
Ag	µg/L	1	41	41
Al	µg/L	5	41	41
Ba	µg/L	1	41	41
Be	µg/L	0.05	41	41
Ca	mg/L	0.01	41	41
Cd	µg/L	0.5	41	41
Co	µg/L	0.5	41	41
Cr	µg/L	1	41	41
Cu	µg/L	0.8	41	41
Fe	µg/L	5	41	41
K	mg/L	0.10	41	41
Li	µg/L	0.5	41	41
Mg	mg/L	0.01	41	41
Mn	µg/L	0.3	41	41
Mo	µg/L	1	41	41
Na	mg/L	0.15	41	41
Ni	µg/L	2	41	41
Pb	µg/L	6	41	41
S	mg/L	0.01	41	41
Si	mg/L	0.02	41	41
Sr	µg/L	2	41	41
Ti	µg/L	2	41	41
V	µg/L	2	41	41
Zn	µg/L	0.3	41	41

PQL= Practical Quantifiable Limit
 BPQL= Below Practical Quantifiable Limit

Table 8.2

Summary: ICAPES measurement of Field Blanks					
Element	Units	PQL	Total number of blanks	Number of blanks below PQL	Highest Conc. found
Ag	µg/L	1	31	31	BPQL
Al	µg/L	5	31	31	BPQL
Ba	µg/L	1	31	31	BPQL
Be	µg/L	0.05	31	31	BPQL
Ca	mg/L	0.01	31	8	0.04
Cd	µg/L	0.5	31	31	BPQL
Co	µg/L	0.5	31	31	BPQL
Cr	µg/L	1	31	31	BPQL
Cu	µg/L	0.8	31	31	BPQL
Fe	µg/L	5	31	31	BPQL
K	mg/L	0.10	31	31	BPQL
Li	µg/L	0.5	31	31	BPQL
Mg	mg/L	0.01	31	19	0.02
Mn	µg/L	0.3	31	31	BPQL
Mo	µg/L	1	31	31	BPQL
Na	mg/L	0.15	31	20	0.42
Ni	µg/L	2	31	31	BPQL
Pb	µg/L	6	31	31	BPQL
S	mg/L	0.01	31	25	0.04
Si	mg/L	0.02	31	29	0.03
Sr	µg/L	2	31	31	BPQL
Ti	µg/L	2	31	31	BPQL
V	µg/L	2	31	31	BPQL
Zn	µg/L	0.3	31	24	3.7

Table 8.3

Summary: Laboratory blanks measured on AAS, Carbon Analyzer, and IC				
Analyte	Units	PQL	Total number of blanks	Number of blanks BPQL
Arsenic	µg/L	0.3	95	95
Inorganic C	mg/L	1.0	50	50
Organic C	mg/L	1.0	40	40
Fluoride	mg/L	0.05	27	27
Chloride	mg/L	2	27	27
Nitrate-N	mg/L	0.2	27	27
Nitrite-N	mg/L	0.02	27	27
Phosphate-P	mg/L	0.2	27	27
Sulfate	mg/L	1.00	27	27

Table 8.4

Summary: Field Blanks measured on AAS, Carbon Analyzer, and IC				
Analyte	Units	PQL	Total number of blanks	Number of blanks BPQL
Arsenic	µg/L	0.3	28	28
Alkalinity	mg/L	1	8	8
Inorganic C	mg/L	1.0	28	28
Organic C	mg/L	1.0	19	19
Fluoride	mg/L	0.05	15	15
Chloride	mg/L	2	15	15
Nitrate-N	mg/L	0.2	15	15
Nitrite-N	mg/L	0.02	15	15
Phosphate-P	mg/L	0.2	15	15
Sulfate	mg/L	1.00	15	15

Table 9: All data for water samples collected April 1998-December 1998

All elements BPLQ for: Al (<5), Cd, (<0.5), Co (<0.5), Ni (<2), Pb (<6), Ti(<2), and V (<2) (in µg/L)

SAMPLE NAME	SAMPLE DATE	STREAM-FLOW (cfs)	STREAM-FLOW (L/s)	pH (units)	D.O. (mg/L)	Con-ductivity (mS/cm)	Water Temp (Cel.)	Air Temp (Cel.)	Inorganic Carbon (mg/L)	Total Alkalinity (mg/L CaCO ₃)	Sulfate (µg/L)	As (µg/L)	Ba (µg/L)	Ca (mg/L)	Cr (µg/L)	Cu (µg/L)	Fe (µg/L)	K (mg/L)	Li (µg/L)	Mg (mg/L)	Mn (µg/L)	Na (mg/L)	S (mg/L)	Si (mg/L)	Sr (µg/L)	Zn (µg/L)	
Copper Creek																											
C-1	4/7/1998	13.86	393	8.26	NA	0.21	2.7	6.0	27.8	NA	NA	0.5	257	30.9	<1	<0.8	<5	0.4	1.4	10.9	<0.3	1.6	1.04	4.1	45	<0.3	
C-2	4/7/1998	14.58	413	8.23	NA	0.21	2.8		28.0	NA	NA	0.5	250	30.2	<1	<0.8	<5	0.4	1.4	10.8	<0.3	1.5	1.01	4.0	44	1.4	
C-3	4/7/1998			8.26	NA	0.21	2.8		27.8	NA	NA	0.6	237	28.6	<1	<0.8	<5	0.4	1.3	10.4	<0.3	1.5	0.95	3.8	41	<0.3	
C-1	4/26/1998	28.22	799	8.10	NA	0.21	6.2	15.2	26.2	NA	NA	0.5	217	26.7	<1	<0.8	<5	0.3	1.1	9.6	<0.3	1.3	0.87	3.5	38	<0.3	
C-2	4/26/1998	28.25	800	8.08	NA	0.21			26.2	NA	NA	0.5	214	25.7	<1	<0.8	<5	0.3	1.1	9.2	<0.3	1.4	0.88	3.5	38	<0.3	
C-3	4/26/1998			8.08	NA	0.21			25.8	NA	NA	0.6	213	26.5	<1	<0.8	<5	0.3	1.1	9.5	<0.3	1.5	0.88	3.4	39	<0.3	
C-1	5/18/1998	105.59	2990	7.97	11.1	0.18	4.8	2.5	22.0	NA	NA	0.5	193	24.6	<1	<0.8	<5	0.2	0.8	8.7	<0.3	1.2	0.83	2.7	35	<0.3	
C-2	5/18/1998	103.32	2926	8.00	11.3	0.18			21.9	NA	NA	0.5	194	24.8	<1	<0.8	<5	0.2	0.8	8.8	<0.3	1.1	0.82	2.7	36	<0.3	
C-3	5/18/1998			7.98	11.2	0.18			21.8	NA	NA	0.5	190	24.5	<1	<0.8	<5	0.2	0.8	8.7	<0.3	1.1	0.81	2.6	36	<0.3	
C-1	6/6/1998	103.0	2917	7.98	NA	0.18	7.3	19.6	NA	96	NA	0.5	188	24.4	<1	<0.8	<5	0.2	0.7	8.6	<0.3	1.1	0.77	2.6	35	<0.3	
C-2	6/6/1998	108.67	3078	8.00	NA	0.18			NA	90	NA	0.6	185	24.0	<1	<0.8	<5	0.2	0.7	8.5	<0.3	1.0	0.75	2.5	34	<0.3	
C-3	6/6/1998			7.99	NA	0.18			NA	90	NA	0.5	189	24.4	<1	<0.8	<5	0.2	0.7	8.6	<0.3	1.0	0.77	2.6	36	<0.3	
C-1	7/20/1998	62.75	1777	8.39	9.3	0.21	7.9	20.3	NA	110	NA	0.5	234	28.1	<1	<0.8	<5	0.3	1.1	10.3	<0.3	1.4	0.70	3.4	50	<0.3	
C-2	7/20/1998	60.07	1701	8.40	9.6	0.21	7.9	20.2	NA	106	NA	0.5	232	28.2	<1	<0.8	<5	0.3	1.1	10.4	<0.3	1.4	0.70	3.4	50	<0.3	
C-3	7/20/1998			8.40		0.21	8.0	20.2	NA	109	NA	0.6	230	28.0	<1	<0.8	<5	0.3	1.0	10.5	<0.3	1.5	0.67	3.3	49	<0.3	
Landers Fork site "LA"																											
LA-1	4/26/1998	32.68	925	8.14	15.5	0.21	8.6	17.4	26.4	NA	NA	0.4	129	27.2	<1	<0.8	<5	0.4	1.7	9.2	0.6	1.1	0.90	2.3	35	<0.3	
LA-2	4/26/1998	30.51	864	8.16	16.5	0.20			26.8	NA	NA	0.4	121	26.7	<1	<0.8	<5	0.4	1.7	9.1	0.6	1.1	0.86	2.2	35	<0.3	
LA-3	4/26/1998			8.14		0.20			26.0	NA	NA	0.4	126	27.2	<1	<0.8	<5	0.4	1.7	9.2	0.7	1.1	0.92	2.3	35	<0.3	
LA-1	5/18/1998	149.14	4224	8.04	10.2	0.20	7.0	5.0	25.7	NA	NA	0.3	112	27.5	<1	<0.8	<5	0.3	1.7	9.8	<0.3	1.0	0.90	2.2	31	<0.3	
LA-2	5/18/1998	148.71	4211	8.04	10.2	0.21			24.6	NA	NA	0.4	112	27.3	<1	<0.8	<5	0.3	1.6	9.7	<0.3	1.0	0.90	2.2	31	<0.3	
LA-3	5/18/1998			8.05	10.1	0.21			25.4	NA	NA	0.4	112	27.2	<1	<0.8	<5	0.3	1.6	9.7	<0.3	1.0	0.90	2.2	31	<0.3	
LA-1	6/6/1998	144.88	4103	8.08	NA	0.21	8.9	20.8	NA	108	NA	0.4	120	29.2	<1	<0.8	<5	0.3	1.8	10.3	<0.3	1.2	0.93	2.3	34	<0.3	
LA-2	6/6/1998	139.77	3958	8.09	NA	0.21			NA	108	NA	0.4	119	28.9	<1	<0.8	<5	0.3	1.8	10.3	<0.3	1.1	0.92	2.3	33	<0.3	
LA-3	6/6/1998			8.09	NA	0.21			NA	106	NA	0.4	120	29.0	<1	<0.8	<5	0.3	1.8	10.3	<0.3	1.0	0.92	2.3	33	<0.3	
LA-1	7/20/1998	64.49	1826	8.52	8.5	0.25	11.9	22.8	NA	124	NA	0.4	150	34.1	1	<0.8	<5	0.4	2.5	12.7	<0.3	1.5	0.86	3.0	48	<0.3	
LA-2	7/20/1998			8.52	8.5	0.25	11.9	22.7	NA	127	NA	0.4	152	34.7	<1	<0.8	<5	0.4	2.6	12.9	<0.3	1.5	0.86	3.0	49	<0.3	
LA-3	7/20/1998			8.51	8.5	0.25	11.8	22.7	NA	129	NA	0.4	153	34.7	<1	<0.8	<5	0.4	2.5	12.9	<0.3	1.5	0.88	3.1	49	<0.3	
Landers Fork site "LB"																											
LB-1	4/7/1998	1.18	33	7.78	11.0	0.27	5.3	7.4	34.4	NA	NA	0.3	238	38.6	<1	<0.8	<5	0.6	2.6	13.1	<0.3	1.6	1.1	3.7	50	<0.3	
LB-2	4/7/1998	1.69	48	7.79	10.8	0.26	5.4		35.1	NA	NA	0.3	245	39.7	<1	<0.8	<5	0.6	2.6	13.2	<0.3	1.5	1.2	3.8	51	0.4	
LB-3	4/7/1998			7.78	11.0	0.27	5.3		34.9	NA	NA	0.3	245	40.1	<1	<0.8	<5	0.6	2.6	13.3	<0.3	1.6	1.2	3.7	51	2.1	
LB-1	4/26/1998	3.63	103	7.72	15.0	0.28	7.8	16.9	36.4	NA	NA	0.3	264	42.9	<1	<0.8	<5	0.6	2.7	14.2	<0.3	1.6	1.2	3.9	56	<0.3	
LB-2	4/26/1998	3.6	102	7.70	15.5	0.28			36.2	NA	NA	0.3	263	42.7	<1	<0.8	<5	0.6	2.6	14.1	<0.3	1.6	1.2	3.8	55	<0.3	
LB-3	4/26/1998			7.72		0.28			36.5	NA	NA	0.2	269	43.1	<1	<0.8	<5	0.6	2.6	13.8	<0.3	1.5	1.3	3.9	55	<0.3	
LB-1	5/19/1998	218	6174	7.72	12.0	0.21	2.5	-1.5	24.9	NA	NA	0.4	151	28.4	1.0	<0.8	<5	0.3	1.4	10.1	<0.3	1.1	0.91	2.5	36	<0.3	
LB-2	5/19/1998	219	6202	7.75	12.1	0.21			25.1	NA	NA	0.4	153	28.5	<1	<0.8	<5	0.3	1.5	10.0	<0.3	1.1	0.91	2.5	36	<0.3	

SAMPLE NAME	SAMPLE DATE	STREAM-FLOW (cfs)	STREAM-FLOW (L/s)	pH (units)	D.O. (mg/L)	Conductivity (mS/cm)	Water Temp (Cel.)	Air Temp (Cel.)	Inorganic Carbon (mg/L)	Total Alkalinity (mg/L CaCO ₃)	Sulfate (µg/L)	As (µg/L)	Ba (µg/L)	Ca (mg/L)	Cr (µg/L)	Cu (µg/L)	Fe (µg/L)	K (mg/L)	Li (µg/L)	Mg (mg/L)	Mn (µg/L)	Na (mg/L)	S (mg/L)	Si (mg/L)	Sr (µg/L)	Zn (µg/L)	
LB-3	5/19/1998			7.72	11.9	0.21			25.5	NA	NA	0.4	151	28.5	<1	<0.8	<5	0.3	1.5	10.0	<0.3	1.2	0.92	2.5	36	<0.3	
LB-1	6/6/1998	252	7137	7.99	13.0	0.21	6.3	15.1	NA	112	NA	0.4	153	28.1	<1	<0.8	<5	0.3	1.5	9.9	<0.3	1.0	0.89	2.5	36	<0.3	
LB-2	6/6/1998	256	7250	8.00	13.2	0.21			NA	110	NA	0.4	152	28.4	<1	<0.8	<5	0.3	1.5	9.9	<0.3	1.0	0.88	2.5	36	<0.3	
LB-3	6/6/1998			7.98	13.2	0.21			NA	116	NA	0.4	155	28.6	<1	<0.8	<5	0.3	1.6	10.0	<0.3	1.1	0.89	2.6	36	<0.3	
LB-1	6/29/1998	413	11696	7.96	12.1	0.20	7.9	17.0	NA	107	NA	0.4	148	29.2	<1	<0.8	<5	0.3	1.5	10.2	0.5	1.3	0.83	2.7	36	<0.3	
LB-2	6/29/1998	420	11894	7.98	11.9	0.20	8.0	17.0	NA	110	NA	0.4	150	29.5	1.7	<0.8	<5	0.4	1.5	10.2	0.4	1.6	0.86	2.9	37	<0.3	
LB-3	6/29/1998			7.98	12.0	0.20	8.1	17.1	NA	106	NA	0.4	151	29.7	<1	<0.8	<5	0.3	1.6	10.3	0.5	1.2	0.84	2.7	37	<0.3	
LB-1	7/20/1998	129	3653	8.32	8.1	0.25	12.9	23.9	NA	121	NA	0.4	212	32.9	<1	<0.8	<5	0.4	2.1	12.1	<0.3	1.7	0.82	3.4	51	<0.3	
LB-2	7/20/1998	133	3767	8.35	8.2	0.25	12.9	24.0	NA	124	NA	0.4	211	33.0	<1	<0.8	<5	0.4	2.0	12.0	<0.3	1.5	0.81	3.4	51	<0.3	
LB-3	7/20/1998			8.35	8.2	0.25	13.0	24.0	NA	124	NA	0.4	213	32.0	<1	<0.8	<5	0.4	1.9	11.8	<0.3	1.4	0.81	3.4	50	<0.3	
LB-1	9/4/1998	25.91	734	7.86	9.1	0.26	11.5	23.9	33.7	125	NA	0.4	239	33.6	<1	<0.8	<5	0.5	2.2	11.8	<0.3	0.8	0.84	4.0	53	<0.3	
LB-2	9/4/1998	24.41	691	7.88	9.0	0.27	11.6	23.8	33.9	128	NA	0.4	241	34.2	<1	<0.8	<5	0.5	2.3	12.0	<0.3	0.8	0.85	4.0	54	<0.3	
LB-3	9/4/1998			7.86	9.0	0.27	11.5	23.7	34.1	128	NA	0.4	241	33.6	<1	<0.8	<5	0.5	2.2	11.9	<0.3	0.7	0.85	4.0	54	<0.3	
LB-1	10/6/1998	17.44	494	7.66	8.6	0.26	9.1	12.5	34.2	135	2.9	0.5	234	33.9	<1	<0.8	<5	0.5	2.4	12.0	<0.3	0.6	0.87	3.9	53	0.5	
LB-2	10/6/1998			7.68	8.6	0.26	9.0		34.2	140	3.0	0.5	236	34.3	<1	<0.8	<5	0.5	2.3	12.1	<0.3	0.7	0.87	3.9	54	<0.3	
LB-3	10/6/1998			7.67	8.7	0.26			34.5	133	3.0	0.5	236	34.0	<1	<0.8	<5	0.5	2.3	12.0	<0.3	0.9	0.88	3.9	53	<0.3	
LB-1	11/7/1998	4.58	130	7.92	11.1	0.27	4.0	-5.1	NA	132	NA	0.2	240	34.8	<1	<0.8	<5	0.5	2.4	12.4	<0.3	0.7	0.90	4.0	55	<0.3	
LB-2	11/7/1998			7.91	11.1	0.27	4.0		NA	133	NA	0.2	247	34.8	<1	<0.8	<5	0.6	2.5	12.5	<0.3	0.8	0.92	4.1	56	<0.3	
LB-3	11/7/1998			7.91	11.0	0.27			NA	133	NA	0.2	248	34.9	<1	<0.8	<5	0.6	2.4	12.5	<0.3	0.8	0.93	4.2	57	<0.3	
LB Seeps																											
LB SEEP-1	4/7/1998			7.44	6.7	0.26	5.0	8.0	35.8	NA	NA	0.3	215	33.4	<1	<0.8	<5	0.5	2.3	11.6	<0.3	1.8	1.0	3.4	43	<0.3	
LB SEEP-2	4/7/1998			7.47	6.9	0.27	5.1	8.1	35.8	NA	NA	0.3	226	25.2	<1	<0.8	<5	0.4	1.7	8.5	<0.3	1.0	1.1	3.5	34	1.4	
LB SEEP-3	4/7/1998			7.45	7.2	0.27	5.0	8.0	35.6	NA	NA	0.3	240	38.0	<1	<0.8	<5	0.6	2.7	12.9	<0.3	1.7	1.1	3.8	50	1.1	
LB SEEP-1	4/26/1998			7.69	14.0	0.28	4.6		36.4	NA	NA	0.3	253	41.6	<1	<0.8	<5	0.7	2.8	13.9	<0.3	1.8	1.2	4.0	55	<0.3	
LB SEEP-2	4/26/1998			7.67		0.28			35.7	NA	NA	0.3	251	41.0	<1	<0.8	<5	0.6	2.7	13.8	<0.3	1.6	1.2	3.9	53	<0.3	
LB SEEP-3	4/26/1998			7.67		0.28			36.1	NA	NA	0.3	252	40.8	<1	<0.8	<5	0.6	2.8	13.8	<0.3	1.7	1.2	4.0	53	<0.3	
Landers Fork, Site "LC"																											
LC-1	4/7/1998	24.07	682	7.97	9.9	0.25	6.3	8.2	33.6	NA	NA	1.0	262	37.2	<1	<0.8	<5	0.6	2.4	12.5	<0.3	1.6	1.2	4.0	55	<0.3	
LC-2	4/7/1998	24.75	701	7.95	9.9	0.25	6.3		33.9	NA	NA	1.0	253	35.8	<1	<0.8	<5	0.5	2.3	12.0	<0.3	1.6	1.1	3.9	53	<0.3	
LC-3	4/7/1998			7.98	9.8	0.25	6.2		33.7	NA	NA	1.0	254	34.2	<1	<0.8	<5	0.5	2.1	11.6	<0.3	1.5	1.1	3.9	50	<0.3	
LC-1	4/26/1998	25.39	719	7.80	17.0	0.27	7.6	15.8	33.7	NA	NA	0.9	275	36.3	1.1	<0.8	<5	0.5	2.3	13.0	<0.3	1.6	1.2	4.0	54	<0.3	
LC-2	4/26/1998	24.5	694	7.80	18.0	0.27			33.8	NA	NA	0.9	278	37.5	<1	<0.8	<5	0.6	2.4	13.4	<0.3	1.6	1.2	4.0	55	<0.3	
LC-3	4/26/1998			7.82		0.27			34.5	NA	NA	0.9	279	37.4	<1	<0.8	<5	0.5	2.4	13.4	<0.3	1.6	1.2	4.0	55	<0.3	
LC-1	5/19/1998	286.08	8102	7.74	10.5	0.22	3.2	7.0	26.0	NA	NA	0.4	169	29.4	<1	<0.8	<5	0.4	1.6	10.4	<0.3	1.1	0.95	2.7	38	<0.3	
LC-2	5/19/1998	284.82	8066	7.77	10.5	0.22			26.2	NA	NA	0.4	169	29.3	1.0	<0.8	<5	0.3	1.6	10.4	<0.3	1.2	0.94	2.7	38	<0.3	
LC-3	5/19/1998			7.71	10.6	0.22			26.0	NA	NA	0.4	167	29.2	<1	<0.8	<5	0.3	1.6	10.3	<0.3	1.1	0.94	2.7	38	<0.3	
LC-1	6/6/1998	292.28	8277	7.86	11.8	0.22	5.2	8.0	NA	116	NA	0.5	168	29.3	<1	<0.8	<5	0.3	1.6	10.3	<0.3	1.1	0.91	2.7	38	<0.3	
LC-2	6/6/1998	308.52	8737	7.85	11.7	0.22			NA	112	NA	0.5	168	29.3	<1	<0.8	<5	0.3	1.6	10.3	<0.3	1.1	0.90	2.7	38	<0.3	
LC-3	6/6/1998			7.86	11.7	0.22			NA	114	NA	0.5	169	29.1	<1	<0.8	<5	0.3	1.6	10.3	<0.3	1.1	0.91	2.7	38	<0.3	

SAMPLE NAME	SAMPLE DATE	STREAM- FLOW (cfs)	STREAM- FLOW (L/s)	pH (units)	D.O. (mg/L)	Con- ductivity (mS/cm)	Water Temp (Cel.)	Air Temp (Cel.)	Inorganic Carbon (mg/L)	Total Alkalinity (mg/L CaCO ₃)	Sulfate (µg/L)	As (µg/L)	Ba (µg/L)	Ca (mg/L)	Cr (µg/L)	Cu (µg/L)	Fe (µg/L)	K (mg/L)	Li (µg/L)	Mg (mg/L)	Mn (µg/L)	Na (mg/L)	S (mg/L)	Si (mg/L)	Sr (µg/L)	Zn (µg/L)	
LC-1	6/29/1998	554	15689	8.23	10.8	0.21	11.8	27.1	NA	108	NA	0.5	166	29.8	1.1	<0.8	<5	0.4	1.6	10.3	0.6	1.3	0.88	2.8	38	<0.3	
LC-2	6/29/1998			8.21	10.8	0.21	11.9	27.0	NA	107	NA	0.5	163	30.0	1.5	<0.8	<5	0.4	1.6	10.4	0.6	1.3	0.87	2.8	38	<0.3	
LC-3	6/29/1998			8.22	10.9	0.21	11.9	27.1	NA	104	NA	0.5	162	30.3	1.3	<0.8	<5	0.4	1.6	10.3	0.6	1.4	0.87	2.9	39	<0.3	
LC-1	7/20/1998	177.69	5032	8.33	8.5	0.25	13.9	26.7	NA	122	NA	0.5	230	33.9	<1	<0.8	<5	0.4	2.2	12.4	0.3	1.7	0.84	3.6	54	<0.3	
LC-2	7/20/1998			8.32	8.5	0.25	13.8	26.7	NA	118	NA	0.5	229	33.6	<1	<0.8	<5	0.4	2.2	12.3	0.3	1.5	0.82	3.6	53	<0.3	
LC-3	7/20/1998			8.32	8.5	0.25	13.8	26.8	NA	122	NA	0.5	231	33.8	<1	<0.8	<5	0.5	2.2	12.1	0.3	1.4	0.84	3.6	54	<0.3	
LC-1	9/4/1998	60.36	1709	7.98	9.1	0.27	11.1	22.5	34.1	131	NA	0.6	271	34.5	<1	<0.8	<5	0.6	2.4	12.1	<0.3	0.9	0.92	4.4	59	<0.3	
LC-2	9/4/1998	57.15	1618	7.98	9.1	0.27	11.2	22.7	34.4	126	NA	0.6	262	34.7	<1	<0.8	<5	0.6	2.5	12.2	<0.3	0.8	0.88	4.4	58	<0.3	
LC-3	9/4/1998			7.99	9.1	0.27	11.2	22.7	34.5	132	NA	0.6	271	34.2	<1	<0.8	<5	0.6	2.3	12.0	<0.3	0.8	0.90	4.4	59	<0.3	
LC-1	10/6/1998	41.74	1182	7.88	8.9	0.26	9.4	11.8	33.9	123	3.0	0.8	258	33.6	<1	<0.8	<5	0.5	2.4	11.8	<0.3	0.8	0.88	4.3	57	<0.3	
LC-2	10/6/1998			7.86	8.8	0.26	9.4		33.8	128	3.0	0.8	253	33.5	<1	<0.8	<5	0.5	2.4	11.8	<0.3	0.8	0.87	4.3	56	<0.3	
LC-3	10/6/1998			7.87	8.8	0.26	9.4		33.5	124	3.0	0.8	257	34.1	<1	<0.8	<5	0.5	2.4	11.9	<0.3	0.8	0.88	4.3	57	<0.3	
LC-1	11/7/1998	32.07	908	8.02	11.6	0.27	4.2	0.7	NA	131	NA	0.4	263	34.4	<1	<0.8	<5	0.5	2.4	12.2	<0.3	0.8	0.90	4.5	59	<0.3	
LC-2	11/7/1998			8.02	11.6	0.27			NA	132	NA	0.4	255	33.6	<1	<0.8	<5	0.5	2.4	11.9	<0.3	0.7	0.87	4.4	58	<0.3	
LC-3	11/7/1998			8.02	11.6	0.27			NA		NA																
LC-1	12/5/1998	27.01	765	NA	NA	0.28	4.0		33.1	135	NA	0.4	260	33.6	<1	<0.8	<5	0.5	2.3	11.9	<0.3	0.8	0.89	4.5	59	<0.3	
LC-2	12/5/1998			NA	NA	0.27			33.6	137	NA	0.4	263	33.5	<1	<0.8	<5	0.5	2.4	11.8	<0.3	0.8	0.90	4.5	59	<0.3	
LC-3	12/5/1998			NA	NA	0.27			33.9	139	NA	0.4	257	33.3	<1	<0.8	<5	0.5	2.3	11.8	<0.3	0.9	0.88	4.5	58	<0.3	
<u>LC Seeps</u>																											
LC SEEP-1	4/7/1998			7.49	6.0	0.27	3.8		36.5	NA	NA	0.9	289	42.2	<1	<0.8	<5	0.6	2.8	13.8	<0.3	1.8	1.21	4.6	64	2.7	
LC SEEP-2	4/7/1998			7.49	5.8	0.27	3.9		36.2	NA	NA	0.9	289	42.3	<1	<0.8	<5	0.6	2.7	13.7	<0.3	1.8	1.23	4.6	65	0.5	
LC SEEP-3	4/7/1998			7.50	5.9	0.27	4.0		36.4	NA	NA	0.9															
LC SEEP-1	4/26/1998			7.79	NA	0.29	3.9		37.0	NA	NA	0.9	287	38.9	<1	<0.8	<5	0.6	2.7	13.7	<0.3	2.3	1.29	4.5	60	0.5	
LC SEEP-2	4/26/1998			7.75	NA	0.27			36.9	NA	NA	1.0	289	40.3	<1	<0.8	<5	0.6	2.7	13.9	<0.3	2.0	1.27	4.5	62	<0.3	
LC SEEP-3	4/26/1998			7.79	NA	0.29			36.5	NA	NA	0.9	287	39.6	<1	<0.8	<5	0.6	2.8	14.0	<0.3	1.9	1.25	4.4	61	<0.3	
LC SEEP-1	10/6/1998			7.39	6.2	0.29	7.6		38.9	139	3.1	1.1	307	39.3	<1	<0.8	<5	0.6	2.9	13.1	<0.3	1.0	0.93	5.5	69	<0.3	
LC SEEP-2	10/6/1998			7.40	6.2	0.29	7.6		38.9	143	3.2	1.1	307	39.0	<1	<0.8	<5	0.7	2.9	13.1	<0.3	0.9	0.94	5.5	68	<0.3	
LC SEEP-3	10/6/1998			7.40	6.2	0.30	7.6		39.0	138	3.1	1.1	310	39.6	<1	<0.8	<5	0.6	2.9	13.2	<0.3	0.9	0.94	5.6	70	<0.3	
LC SEEP-1	11/7/1998			7.48	8.3	0.30	5.7		NA	145	NA	0.5	308	37.5	<1	<0.8	<5	0.7	2.9	13.0	<0.3	1.0	0.95	5.7	69	1.0	
LC SEEP-2	11/7/1998			7.48	8.2	0.30	5.8		NA		NA																
LC SEEP-3	11/7/1998			7.48	8.3	0.30	5.7		NA		NA																
LC SEEP-1	12/5/1998			7.12	NA	0.28	6.3		37.4	130	NA	0.5	292	36.3	<1	<0.8	<5	0.6	2.8	12.5	<0.3	0.9	0.93	5.4	67	<0.3	
LC SEEP-2	12/5/1998			7.13	NA						NA																
LC SEEP-3	12/5/1998			7.13	NA						NA																
<u>Landers Fork, Site "LD"</u>																											
LD-1	4/7/1998	16.34	463	8.10	9.8	0.25	8.3	9.7	32.5	NA	NA	1.0	256	33.4	<1	<0.8	<5	0.5	2.1	11.3	<0.3	1.5	1.11	3.9	50	<0.3	
LD-2	4/7/1998	17.85	506	8.08	9.8	0.25	8.4		33.1	NA	NA	0.9	246	33.4	<1	<0.8	<5	0.5	2.1	11.3	<0.3	1.5	1.08	3.8	50	<0.3	
LD-3	4/7/1998			8.10	9.7	0.25	8.3		33.2	NA	NA	0.9	251	34.0	<1	<0.8	<5	0.5	2.2	11.5	<0.3	1.5	1.10	3.8	51	<0.3	
LD-1	7/20/1998	134.49	3809	8.38	8.3	0.25	15.1	29.1	NA	122	NA	0.5	228	33.5	<1	<0.8	<5	0.4	2.1	12.2	0.3	1.8	0.85	3.6	54	<0.3	

SAMPLE NAME	SAMPLE DATE	STREAM-FLOW (cfs)	STREAM-FLOW (L/s)	pH (units)	D.O. (mg/L)	Conductivity (mS/cm)	Water Temp (Cel.)	Air Temp (Cel.)	Inorganic Carbon (mg/L)	Total Alkalinity (mg/L CaCO ₃)	Sulfate (µg/L)	As (µg/L)	Ba (µg/L)	Ca (mg/L)	Cr (µg/L)	Cu (µg/L)	Fe (µg/L)	K (mg/L)	Li (µg/L)	Mg (mg/L)	Mn (µg/L)	Na (mg/L)	S (mg/L)	Si (mg/L)	Sr (µg/L)	Zn (µg/L)	
LD-2	7/20/1998	135.03	3824	8.39	8.3	0.25	15.1	29.1	NA	117	NA	0.5	229	33.7	<1	<0.8	<5	0.5	2.2	12.3	0.3	1.9	0.84	3.8	54	<0.3	
LD-3	7/20/1998			8.39	8.3	0.25	15.2	29.0	NA	119	NA	0.5	227	33.4	<1	<0.8	<5	0.4	2.1	12.2	0.3	1.6	0.82	3.6	53	<0.3	
LD-1	8/17/1998	72.08	2041	8.31	9.7	0.26	12.5	23.9	NA	150	2.9	0.5	237	32.8	<1	<0.8	<5	0.5	2.2	11.5	<0.3	1.0	0.86	3.9	54	<0.3	
LD-2	8/17/1998			8.31	9.7	0.26	12.6	24.0	NA	145	2.9	0.6	244	33.4	<1	<0.8	<5	0.5	2.2	11.7	<0.3	0.8	0.84	3.9	55	<0.3	
LD-3	8/17/1998			8.32	9.7	0.27	12.5	23.9	NA	120	2.9	0.6	246	33.6	<1	<0.8	<5	0.5	2.2	11.8	<0.3	1.0	0.89	3.7	56	<0.3	
LD-4	8/17/1998								NA	130	2.9	0.5	247	33.5	<1	<0.8	<5	0.5	2.2	11.7	<0.3	0.9	0.88	3.7	56	<0.3	
LD-5	8/17/1998								NA	130	2.9	0.5	245	33.3	<1	<0.8	<5	0.5	2.2	11.7	<0.3	0.9	0.88	3.7	55	<0.3	
LD-6	8/17/1998								NA	135	2.9	0.5	243	33.8	<1	<0.8	<5	0.5	2.2	11.7	<0.3	0.9	0.87	3.7	55	<0.3	
LD-7	8/17/1998								NA	130	2.9	0.5	247	33.1	<1	<0.8	<5	0.5	2.2	11.7	<0.3	0.7	0.87	3.9	57	<0.3	
LD-8	8/17/1998								NA	125	2.9	0.5	251	33.5	<1	<0.8	<5	0.5	2.2	11.7	<0.3	0.8	0.86	4.0	56	<0.3	
LD-9	8/17/1998								NA	135	2.9	0.5	245	33.7	<1	<0.8	<5	0.5	2.2	11.7	<0.3	0.9	0.88	3.7	55	<0.3	
LD-10	8/17/1998								NA	125	2.9		242	33.7	<1	<0.8	<5	0.5	2.2	11.7	<0.3	0.7	0.85	3.7	55	<0.3	
Blackfoot River, site "BH"																											
BH-1	4/29/1998	78.62	2227	7.80	NA	0.19	5.6	14.4	18.9	NA	NA	0.2	144	21.3	<1	<0.8	32	0.7	1.5	10.2	3.9	1.9	13.2	5.3	74	32.6	
BH-2	4/29/1998	76.87	2177	7.80	NA	0.19			17.2	NA	NA	0.2	144	21.0	<1	<0.8	34	0.7	1.5	10.1	3.9	1.9	13.3	5.4	73	32.5	
BH-3	4/29/1998			7.79	NA	0.19			18.2	NA	NA	0.2	144	21.0	<1	<0.8	39	0.7	1.5	10.1	3.9	1.9	13.3	5.4	73	30.6	
BH-1	5/19/1998	55.75	1579	7.86	11.7	0.21	7.6	18.2	20.2	NA	NA	0.2	174	21.8	<1	<0.8	34	0.7	1.7	10.6	4.4	1.9	11.4	5.5	77	24.0	
BH-2	5/19/1998	55.17	1562	7.88	11.7	0.21			20.1	NA	NA	0.3	173	21.8	<1	<0.8	33	0.7	1.7	10.6	4.4	1.8	11.3	5.5	76	24.1	
BH-3	5/19/1998			7.87	11.8	0.21			20.2	NA	NA	0.3	173	21.6	<1	<0.8	32	0.7	1.7	10.6	4.4	1.9	11.4	5.5	75	23.7	
BH-1	6/5/1998	84.7	2399	7.90	11.8	0.19	11.7	14.7	NA	86	NA	0.3	163	21.3	<1	<0.8	31	0.6	1.6	9.7	4.9	2.3	5.77	5.4	71	21.8	
BH-2	6/5/1998	85.98	2435	7.92	12.0	0.19			NA	84	NA	0.3	163	21.6	<1	<0.8	38	0.6	1.6	9.8	4.9	2.3	5.71	5.4	72	18.5	
BH-3	6/5/1998			7.90	11.9	0.19			NA	64	NA	0.3	165	21.6	<1	<0.8	38	0.6	1.6	9.6	4.9	2.2	5.79	5.4	73	21.2	
BH-1	7/20/1998	70.89	2008	8.32	7.8	0.21	18.0	22.7	NA	94	NA	0.5	229	25.3	<1	<0.8	35	0.8	2.2	11.1	5.4	2.7	4.09	6.7	106	5.2	
BH-2	7/20/1998			8.33	7.8	0.21	18.0	22.8	NA	91	NA	0.5	226	25.0	<1	1.1	35	0.8	2.2	11.1	5.4	2.7	4.09	6.7	105	3.1	
BH-3	7/20/1998			8.33	7.8	0.21	17.9	22.8	NA	93	NA	0.4	225	24.7	<1	<0.8	34	0.8	2.1	11.0	5.4	2.7	4.07	6.7	103	2.7	
BH-1	8/17/1998	33.65	953	8.16	9.4	0.24	11.9	18.0	NA	100	13.3	0.4	240	26.8	<1	0.8	23	0.9	2.3	11.6	2.6	2.1	4.15	6.7	114	0.9	
BH-2	8/17/1998	31.7	898	8.20	9.4	0.24	11.9	18.1	NA	105	13.4	0.4	226	26.2	<1	<0.8	21	0.8	2.2	11.3	2.5	1.9	4.00	6.3	110	2.0	
BH-3	8/17/1998			8.18	9.4	0.24	11.8	18.1	NA	100	13.4	0.4	223	26.4	<1	<0.8	22	0.8	2.2	11.4	2.5	1.9	3.97	6.5	108	2.0	
Blackfoot River, site "BB"																											
BB-1	4/7/1998	37.65	1066	8.10	10.7	0.21	7.1	8.1	22.0	NA	NA	0.2	168	25.0	<1	<0.8	21	0.9	2.1	11.1	4.4	2.3	11.4	5.9	125	1.5	
BB-2	4/7/1998	34.91	989	8.12	10.7	0.21	7.2		22.6	NA	NA	0.3	170	24.7	<1	<0.8	34	0.9	2.1	11.2	4.4	2.5	11.7	6.0	126	1.7	
BB-3	4/7/1998			8.12	10.6	0.21	7.1		21.8	NA	NA	0.3	172	24.8	<1	<0.8	29	0.9	2.0	11.1	4.4	2.3	11.7	6.0	125	2.4	
BB-1	4/29/1998	71.81	2034	7.93	NA	0.18	6.8	15.4	18.2	NA	NA	0.2	135	20.3	<1	0.9	23	0.7	1.7	9.4	3.1	2.2	11.9	5.5	97	15.6	
BB-2	4/29/1998	76.66	2171	7.93	NA	0.19			17.5	NA	NA	0.2	135	20.2	<1	0.9	27	0.7	1.7	9.4	3.2	2.0	11.9	5.5	96	18.9	
BB-3	4/29/1998			7.92	NA	0.18			17.7	NA	NA	0.2	135	20.0	<1	0.9	26	0.7	1.7	9.3	3.2	2.0	12.0	5.5	95	18.9	
BB-1	5/19/1998	64.27	1820	7.97	11.3	0.19	8.6	18.2	18.7	NA	NA	0.3	162	20.2	<1	<0.8	30	0.7	1.8	9.7	3.4	2.2	10.3	5.8	95	15.0	
BB-2	5/19/1998	62.08	1758	7.96	11.4	0.19			18.6	NA	NA	0.3	159	20.1	<1	<0.8	25	0.7	1.8	9.5	3.3	2.1	10.4	5.8	96	13.9	
BB-3	5/19/1998			7.96	11.4	0.19			18.5	NA	NA	0.3	158	19.8	<1	<0.8	25	0.7	1.8	9.4	3.3	1.9	10.4	5.8	94	14.1	
BB-1	6/5/1998	85.66	2426	7.88	12.1	0.18	11.9	18.2	NA	82	NA	0.3	150	19.8	<1	<0.8	30	0.6	1.7	8.8	3.9	2.5	5.1	5.7	90	11.0	
BB-2	6/5/1998	87.41	2475	7.89	12.1	0.18			NA	78	NA	0.3	153	19.9	<1	<0.8	31	0.6	1.7	8.8	3.9	2.6	5.2	5.7	91	11.1	
BB-3	6/5/1998			7.89	12.2	0.18			NA	80	NA	0.4	153	20.3	<1	<0.8	19	0.6	1.7	8.8	3.9	2.6	5.2	5.8	93	8.5	

SAMPLE NAME	SAMPLE DATE	STREAM-FLOW (cfs)	STREAM-FLOW (L/s)	pH (units)	D.O. (mg/L)	Conductivity (mS/cm)	Water Temp (Cel.)	Air Temp (Cel.)	Inorganic Carbon (mg/L)	Total Alkalinity (mg/L CaCO ₃)	Sulfate (µg/L)	As (µg/L)	Ba (µg/L)	Ca (mg/L)	Cr (µg/L)	Cu (µg/L)	Fe (µg/L)	K (mg/L)	Li (µg/L)	Mg (mg/L)	Mn (µg/L)	Na (mg/L)	S (mg/L)	Si (mg/L)	Sr (µg/L)	Zn (µg/L)	
BB-1	6/29/1998	217.99	6173	7.80	10.1	0.16	15.0	25.1	NA	77	NA	0.4	157	19.3	<1	1.253	12	0.6	1.7	8.1	5.9	3.0	3.3	5.6	84	10.3	
BB-2	6/29/1998	212.78	6026	7.75	10.1	0.16	15.0	25.2	NA	77	NA	0.4	159	19.6	<1	1.121	7	0.6	1.7	8.1	6.0	2.9	3.3	5.8	86	7.9	
BB-3	6/29/1998			7.77	10.2	0.16	15.0	25.1	NA	73	NA	0.4	156	19.3	1.2	1.278	11	0.6	1.7	8.1	5.8	3.3	3.3	5.7	84	5.7	
BB-1	7/20/1998	66.66	1888	8.34	6.9	0.21	16.8	23.9	NA	89	NA	0.5	212	23.6	<1	<0.8	34	0.7	2.4	10.4	4.6	3.3	3.5	7.0	129	2.1	
BB-2	7/20/1998			8.34	6.9	0.20	16.9	24.1	NA	82	NA	0.5	216	23.9	<1	<0.8	34	0.8	2.4	10.4	4.6	3.1	3.6	7.1	133	2.5	
BB-3	7/20/1998			8.35	6.9	0.21	16.7	24.1	NA	85	NA	0.5	214	24.0	1.1	1.02	32	0.8	2.5	10.5	4.6	3.2	3.5	7.0	134	2.6	
BB-1	9/4/1998	18.83	533	7.89	8.5	0.24	10.2	15.9	28.1	105	NA	0.3	229	27.3	<1	<0.8	17	0.9	2.8	11.5	1.3	2.2	3.5	7.3	147	1.4	
BB-2	9/4/1998	20.3	575	7.86	8.5	0.24	10.2	15.9	28.0	103	NA	0.3	228	27.1	<1	1.01	18	0.9	2.7	11.5	1.3	3.4	3.7	7.1	144	0.8	
BB-3	9/4/1998			7.88	8.5	0.24	10.3	15.7	27.8	107	NA	0.4	243	27.7	<1	<0.8	20	1.0	2.8	11.8	1.5	2.3	3.8	7.4	150	0.8	
BB-1	10/6/1998	20.87	591	7.76	9.2	0.23	7.0	10.5	27.6	104	12.5	0.4	227	27.6	<1	<0.8	15	0.9	2.7	11.7	1.5	2.3	3.9	7.1	146	0.5	
BB-2	10/6/1998			7.77	9.2	0.22	7.2	10.5	27.5	102	12.5	0.5	222	27.0	<1	<0.8	15	0.8	2.6	11.5	1.5	2.2	3.8	7.0	142	0.5	
BB-3	10/6/1998			7.78	9.3	0.22	7.0	10.4	27.5	107	12.5	0.5	223	27.1	<1	<0.8	15	0.8	2.6	11.5	1.6	2.2	3.8	7.1	142	0.7	
BB-1	11/7/1998	11.27	319	8.35	13.7	0.25	3.0	-2.5	NA	108	NA	0.2	221	27.2	<1	<0.8	15	0.8	2.6	11.9	1.3	2.3	4.1	7.3	148	0.5	
BB-2	11/7/1998			8.35	13.7	0.25	3.0		NA	102	NA	0.2	217	27.3	<1	<0.8	15	0.8	2.5	11.8	1.4	2.3	4.1	7.2	145	0.5	
BB-3	11/7/1998			8.37	13.7	0.25	3.0		NA	109	NA		226	27.5	<1	<0.8	15	0.9	2.6	12.0	1.4	2.4	4.2	7.4	151	0.6	
BB-1	12/5/1998	10.7	303	8.17	NA	0.24	0.0		28.0	111	NA	0.1	223	28.1	<1	<0.8	13	0.8	2.6	12.1	2.0	2.4	4.6	7.3	147	5.4	
BB-2	12/5/1998			8.17	NA	0.25			27.4	110	NA	0.1	214	26.9	<1	<0.8	12	0.8	2.4	11.6	1.9	2.3	4.4	7.0	139	5.1	
BB-3	12/5/1998			8.18	NA	0.26			27.5	104	NA	0.2	221	28.1	<1	<0.8	12	0.8	2.5	12.1	2.0	2.5	4.6	7.3	146	2.8	
Blackfoot River, site "BC"																											
BC-1	4/7/1998	40.33	1142	8.10	10.8	0.21	6.9	8.0	22.9	NA	NA	0.3	186	26.1	1.01	<0.8	27	0.9	2.2	11.5	2.0	2.3	11.3	6.1	130	1.2	
BC-2	4/7/1998	37.27	1055	8.08	10.8	0.21	6.9		23.0	NA	NA	0.3	175	25.6	<1	<0.8	16	0.8	2.2	11.3	2.0	2.5	11.0	5.9	125	1.2	
BC-3	4/7/1998			8.09	10.8	0.21	6.9		22.9	NA	NA	0.3	179	25.9	<1	<0.8	24	0.9	2.2	11.4	2.0	2.2	11.1	5.9	130	1.1	
BC-1	4/29/1998	79.95	2264	7.93	14.5	0.19	8.0	17.0	18.7	NA	NA	0.2	146	21.4	<1	<0.8	23	0.7	1.8	9.7	2.2	2.0	11.8	5.6	103	23.1	
BC-2	4/29/1998	83.7	2370	7.94	15.5	0.19			18.6	NA	NA	0.3	142	21.2	<1	<0.8	16	0.7	1.8	9.5	2.2	2.1	11.5	5.5	100	6.3	
BC-3	4/29/1998			7.92		0.19			18.3	NA	NA	0.3	142	21.4	<1	0.87	20	0.7	1.8	9.7	2.2	2.2	11.5	5.6	101	4.1	
BC-1	5/19/1998	70.03	1983	7.91	11.6	0.20	10.0	22.6	19.7	NA	NA	0.3	167	21.1	<1	<0.8	21	0.7	2.0	9.9	2.2	2.3	10.7	5.8	100	2.7	
BC-2	5/19/1998	66.92	1895	7.90	11.5	0.20			19.5	NA	NA	0.3	165	20.7	<1	<0.8	20	0.7	1.9	9.8	2.2	2.1	10.7	5.8	98	9.6	
BC-3	5/19/1998			7.92	11.6	0.20			19.6	NA	NA	0.3	163	20.4	<1	<0.8	20	0.7	1.9	9.7	2.2	2.0	10.6	5.7	96	9.7	
BC-1	6/5/1998	98.01	2776	7.80	10.8	0.19	11.0	10.6	NA	96	NA	0.3	162	21.5	<1	<0.8	21	0.6	1.8	9.3	2.8	2.6	5.1	5.7	97	13.4	
BC-2	6/5/1998	99.42	2816	7.79	10.6	0.19			NA	82	NA	0.3	160	20.9	<1	<0.8	25	0.6	1.8	9.1	2.8	2.5	5.0	5.7	94	18.8	
BC-3	6/5/1998			7.82	10.8	0.19			NA	82	NA	0.3	159	20.7	<1	<0.8	21	0.6	1.8	9.1	2.7	2.6	5.0	5.7	93	17.2	
BC-1	6/29/1998	242.31	6862	7.78	10.5	0.17	13.9	26.1	NA	74	NA	0.3	158	20.5	<1	1.489	10	0.6	1.8	8.5	5.5	4.0	3.4	6.4	90	6.1	
BC-2	6/29/1998	249.7	7072	7.75	10.5	0.17	14.0	26.2	NA	85	NA	0.3	159	20.0	1.7	1.036	9	0.6	1.8	8.4	6.2	3.0	3.3	5.7	86	9.0	
BC-3	6/29/1998			7.77	10.6	0.17	14.0	26.1	NA	75	NA	0.3	165	19.8	<1	0.994	10	0.6	1.8	8.3	6.7	2.5	3.3	5.6	87	4.6	
BC-1	7/20/1998	64.02	1813	8.25	7.9	0.21	17.7	30.4	NA	93	NA	0.5	218	25.1	<1	<0.8	24	0.8	2.6	10.9	3.3	3.4	3.8	7.0	137	1.8	
BC-2	7/20/1998			8.28	7.9	0.21	17.7	30.4	NA	89	NA	0.4	218	24.8	<1	<0.8	23	0.8	2.5	10.7	3.3	3.3	3.6	7.0	137	1.4	
BC-3	7/20/1998			8.27	7.9	0.21	17.7	30.5	NA	90	NA	0.5	218	24.8	<1	<0.8	25	0.8	2.5	10.6	3.3	3.2	3.7	7.0	137	2.2	
BC-1	8/17/1998	37.61	1065	8.26	9.7	0.23	12.3	22.0	NA	95	12.6	0.4	214	26.3	<1	<0.8	16	0.8	2.6	10.8	1.0	2.4	3.7	6.8	141	0.5	
BC-2	8/17/1998	39.04	1106	8.28	9.7	0.23	12.3	22.1	NA	110	12.8	0.4	211	26.1	<1	<0.8	16	0.8	2.6	10.8	1.0	2.4	3.7	6.8	140	0.5	
BC-3	8/17/1998			8.28	9.7	0.24	12.4	22.1	NA	105	12.8	0.4	211	25.9	<1	<0.8	15	0.8	2.6	10.8	1.0	2.3	3.7	6.8	139	0.5	

Montana

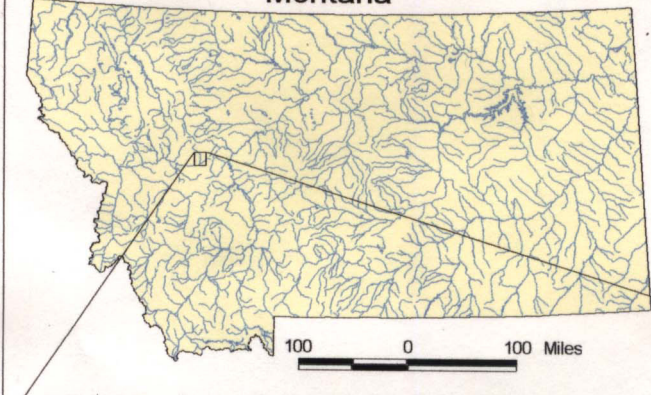
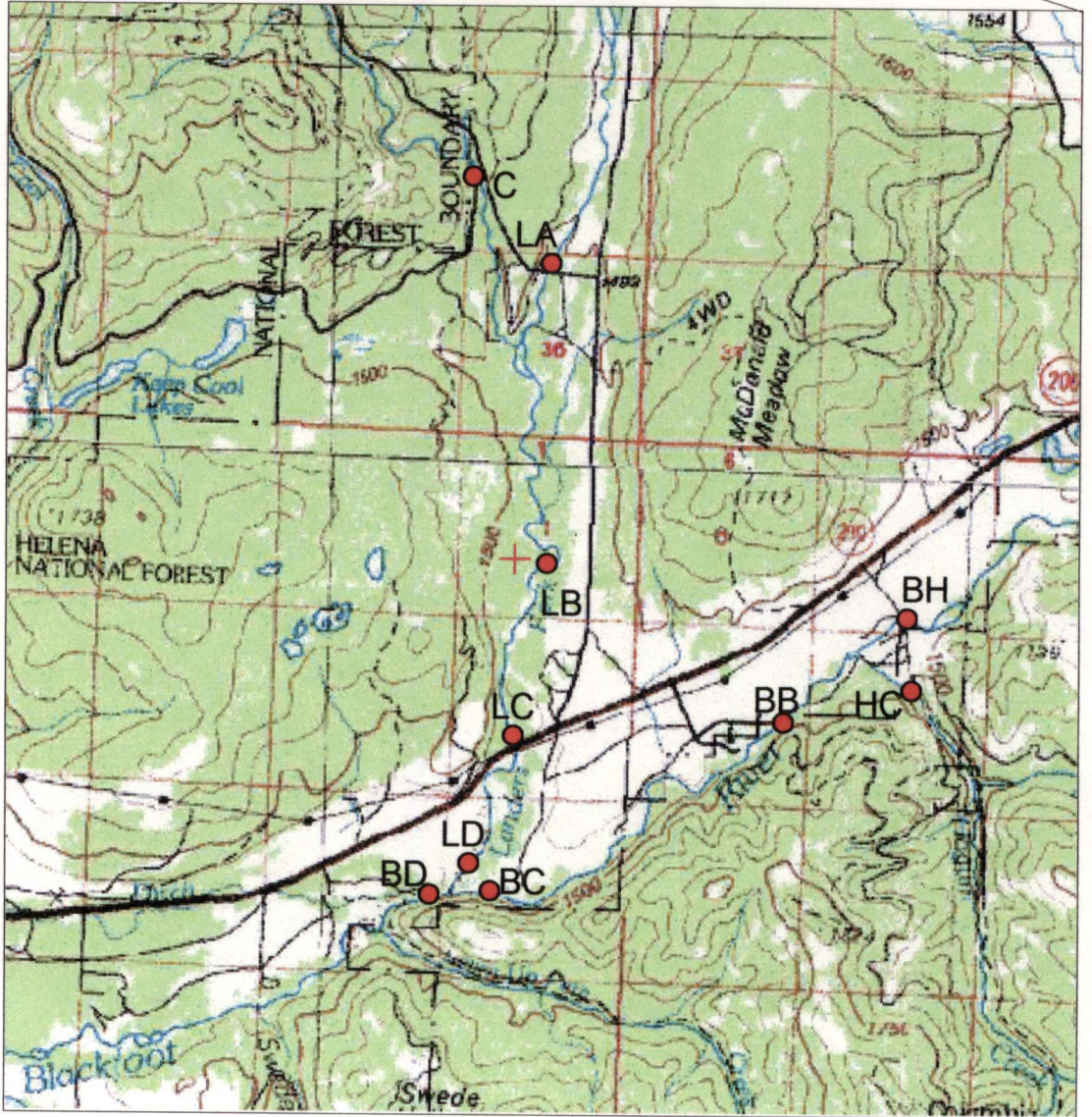
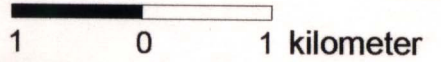
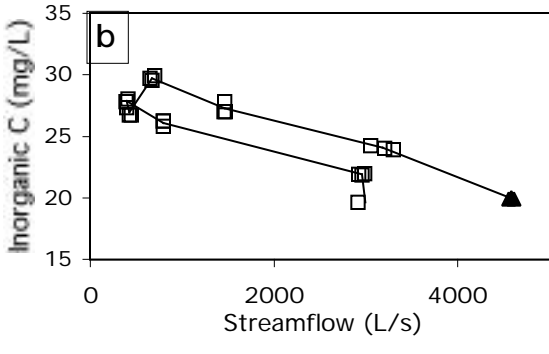
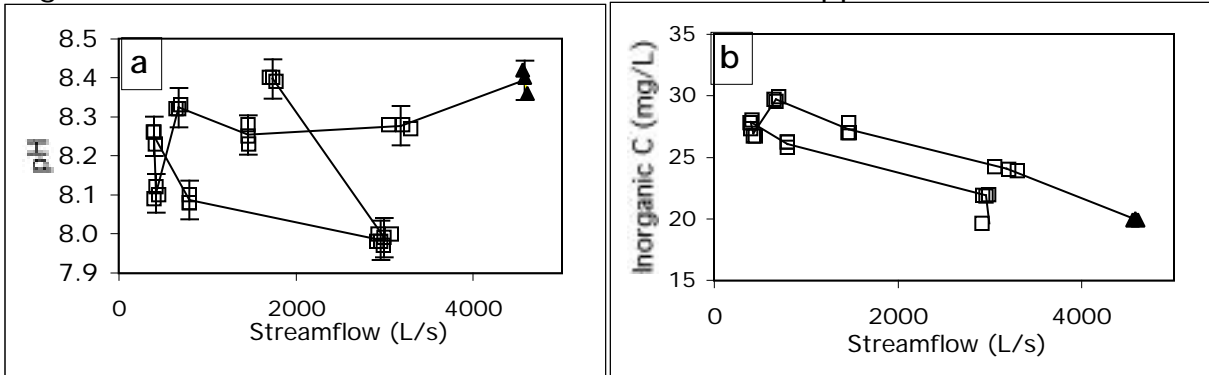


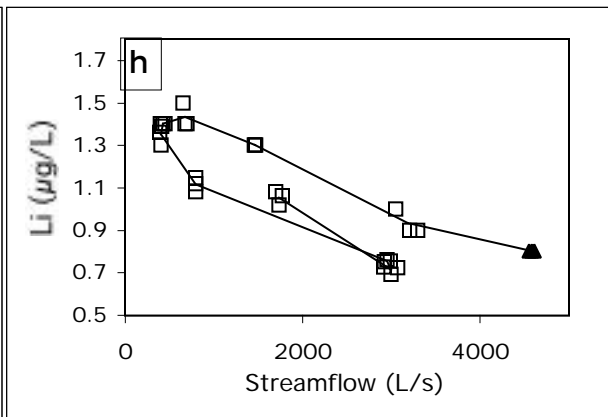
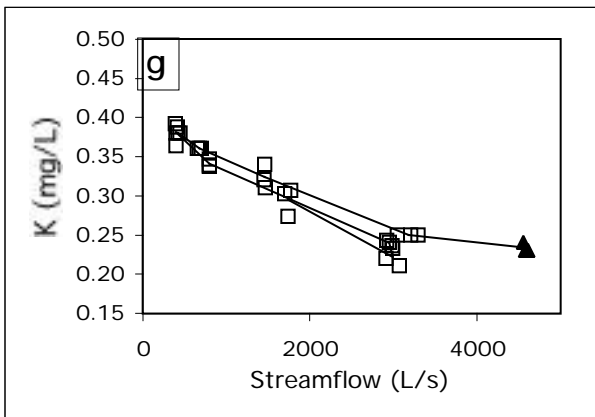
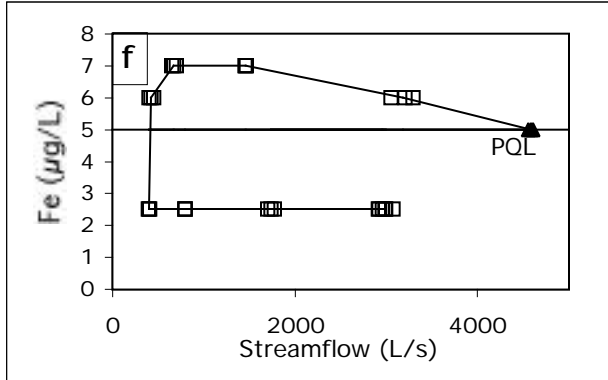
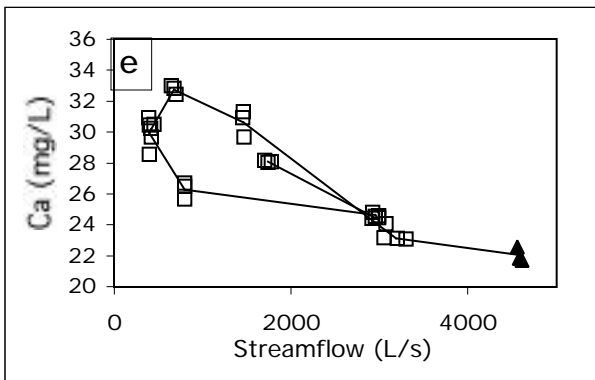
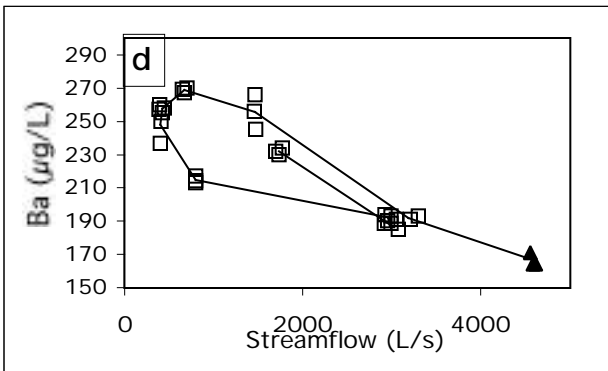
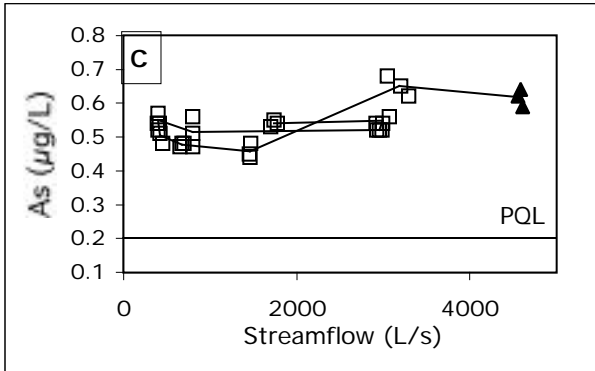
Figure 1. Site Location Map



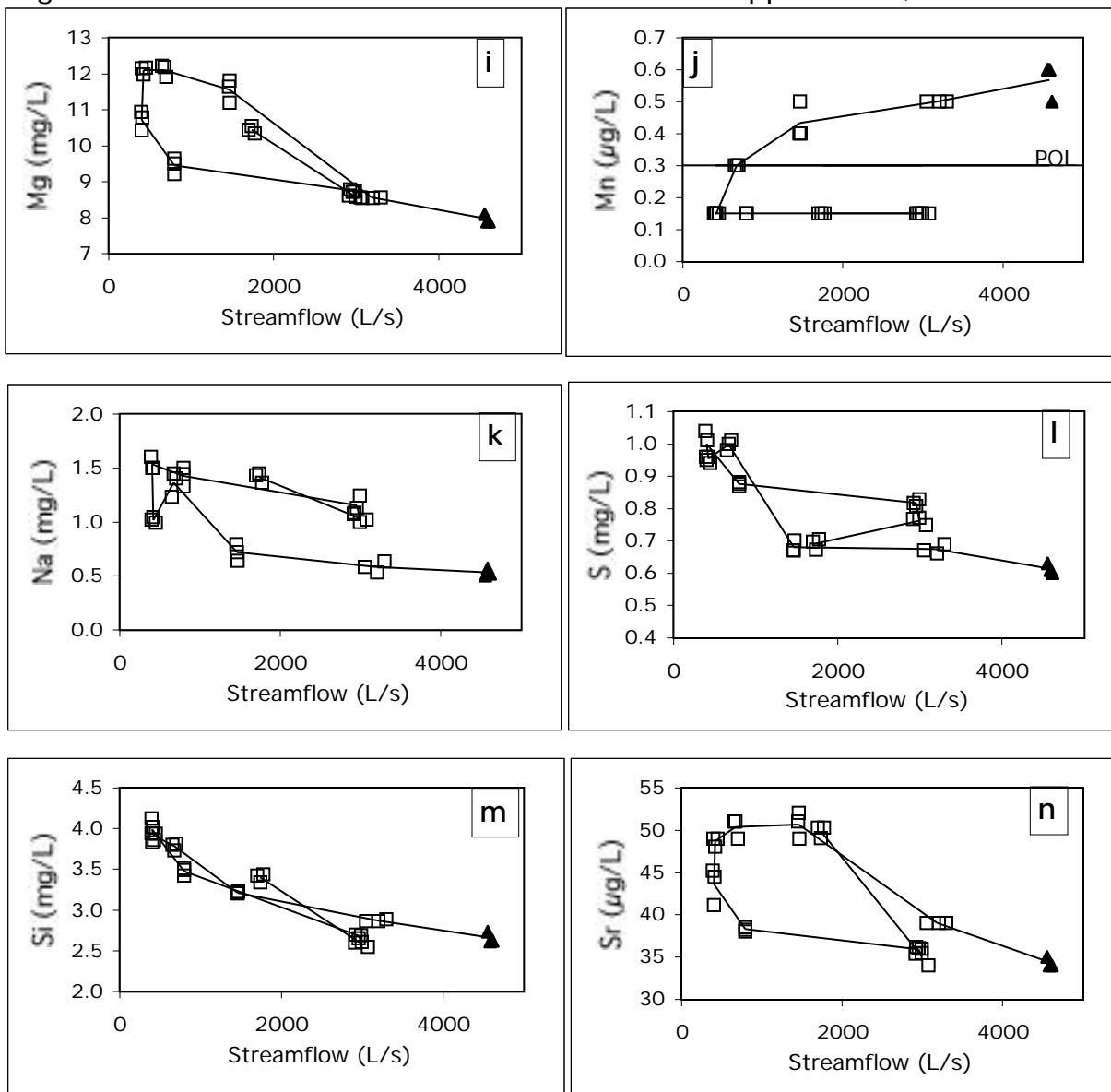
Figures 2a-2h: Streamflow vs. concentrations at Copper Creek, SITE "C"



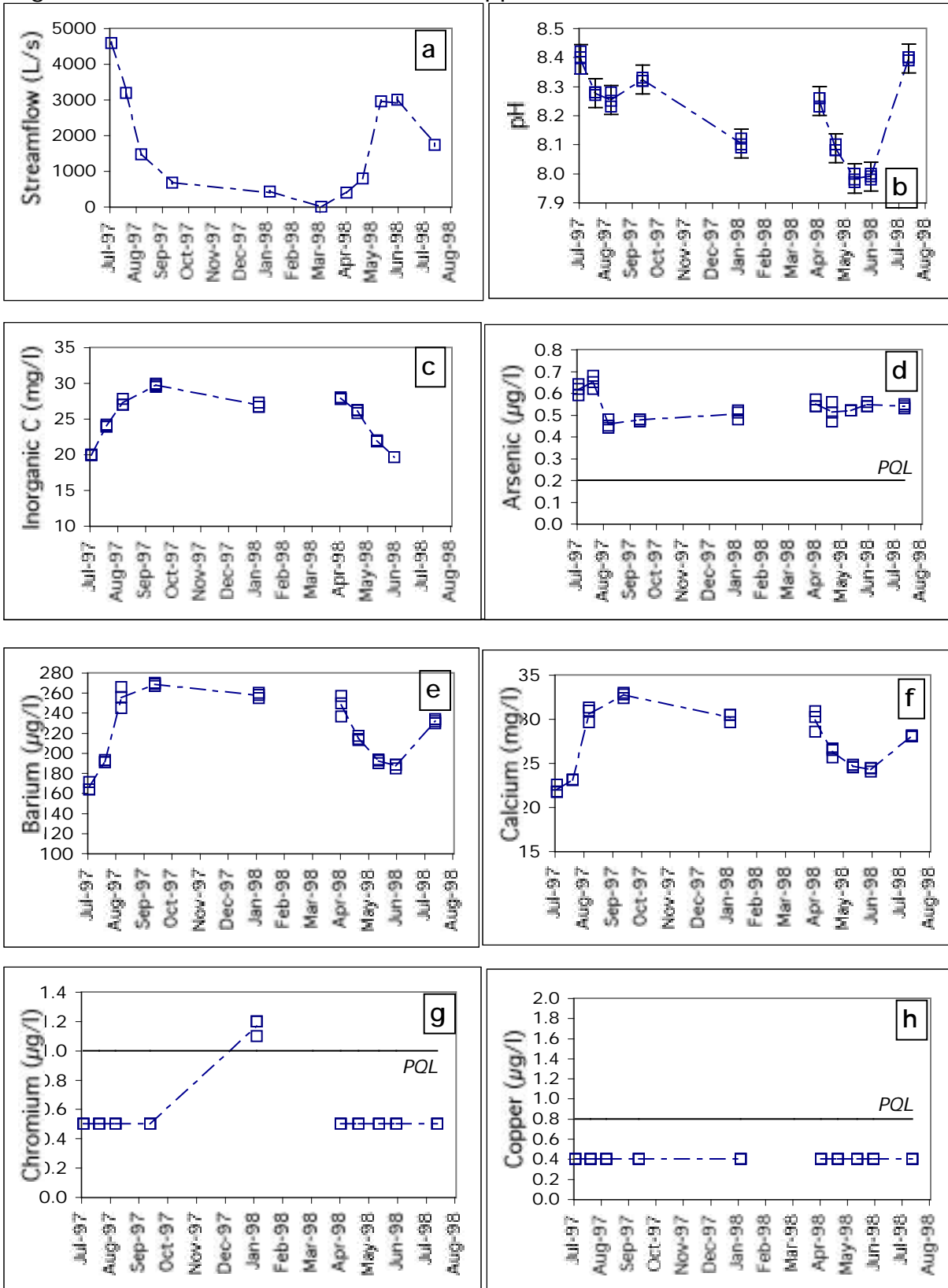
(Triangles indicate first sampling date, 7/3/97)



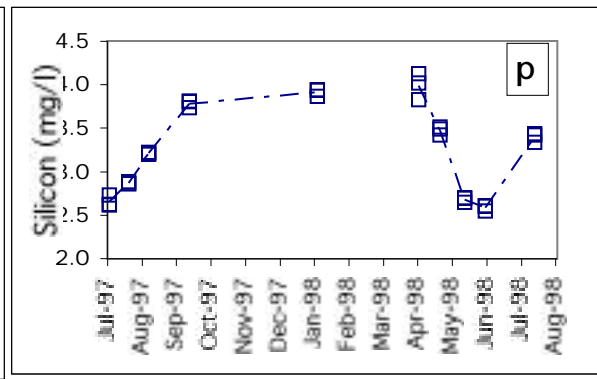
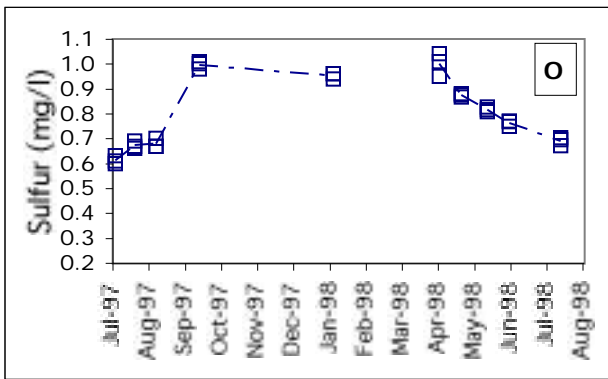
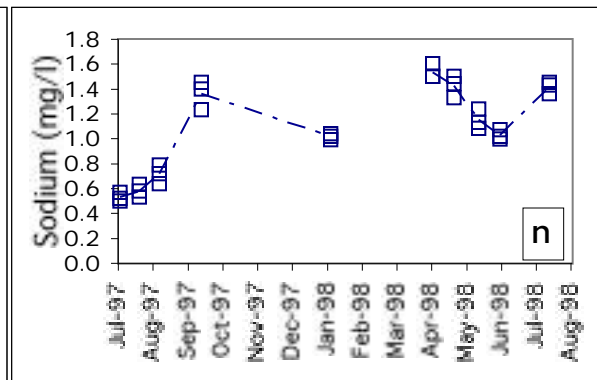
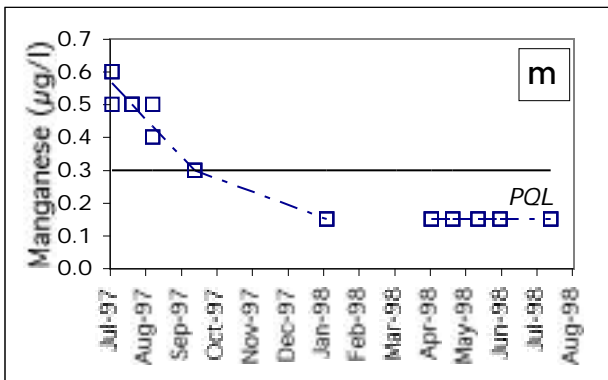
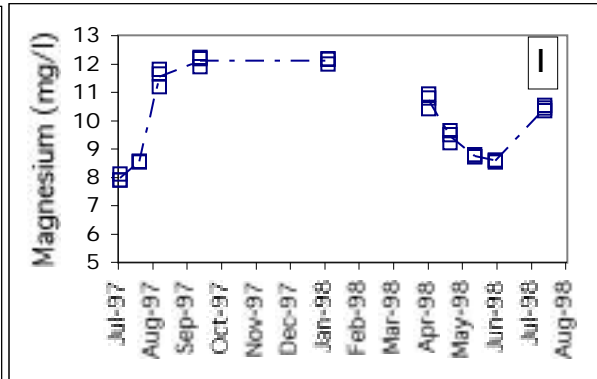
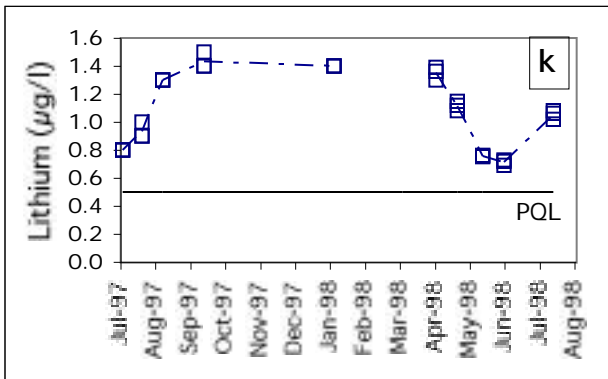
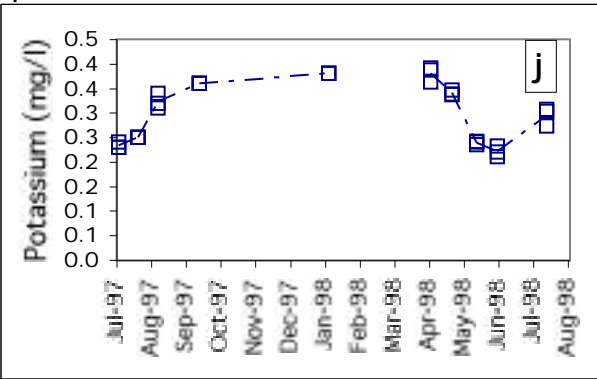
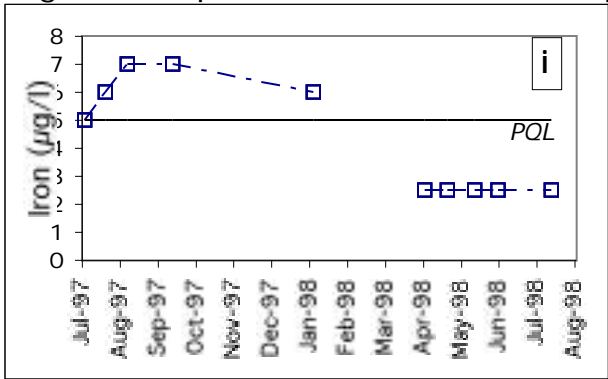
Figures 2i-2n: Streamflow vs. concentrations at Copper Creek, SITE "C"



Figures 3a-3h: Trends over time at Copper Creek, Site "C"



Figures 3i-3p: Trends over time at Copper Creek, Site "C"



Figures 3q-3r: Trends over time at Copper Creek, Site "C"

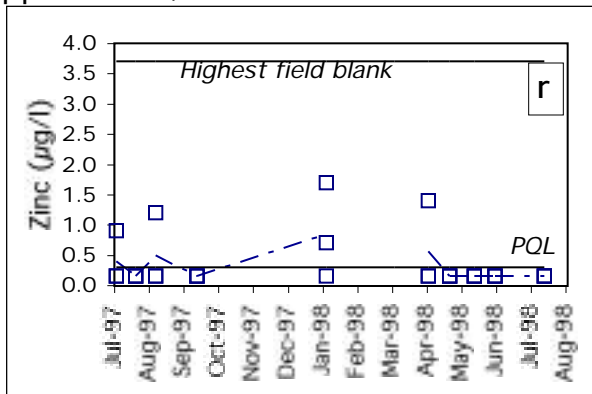
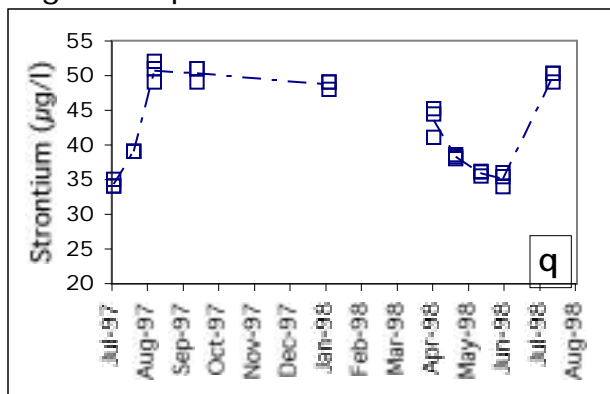


Figure 4a: Inorganic carbon, Ca, and Mg loads at site C

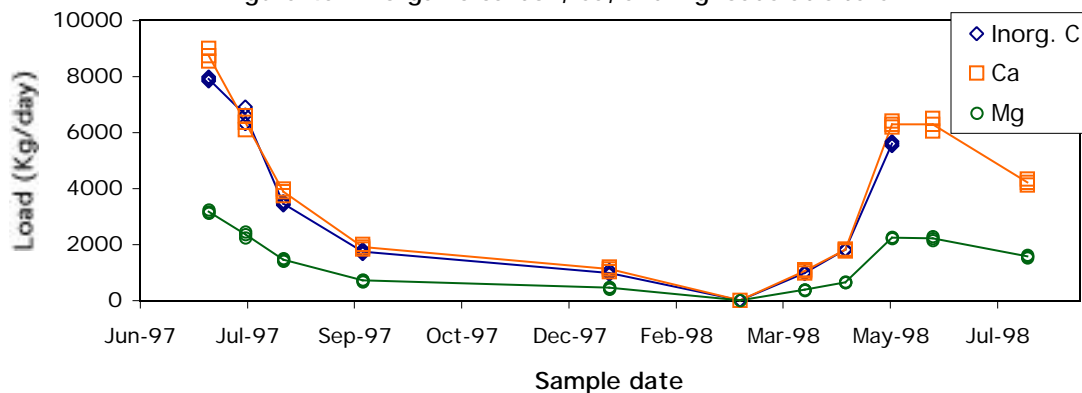


Figure 4b: As, Li, Mn loads at site C

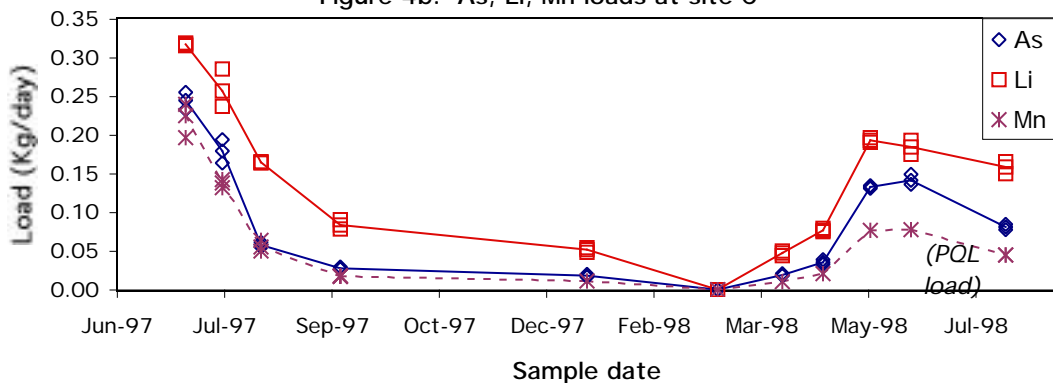


Figure 4c: Ba, Sr loads at site C

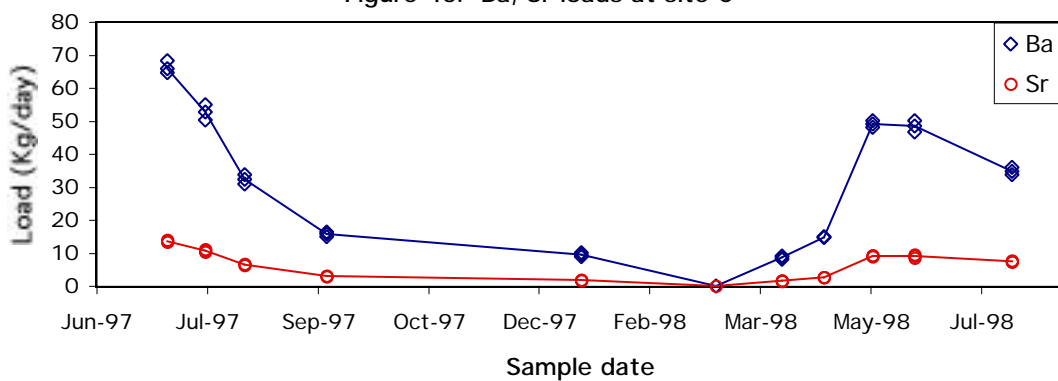


Figure 4d: Fe load at site C

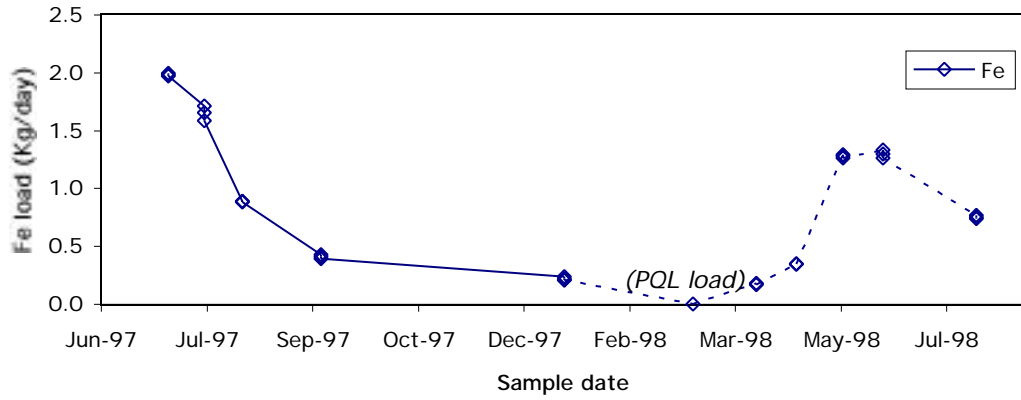
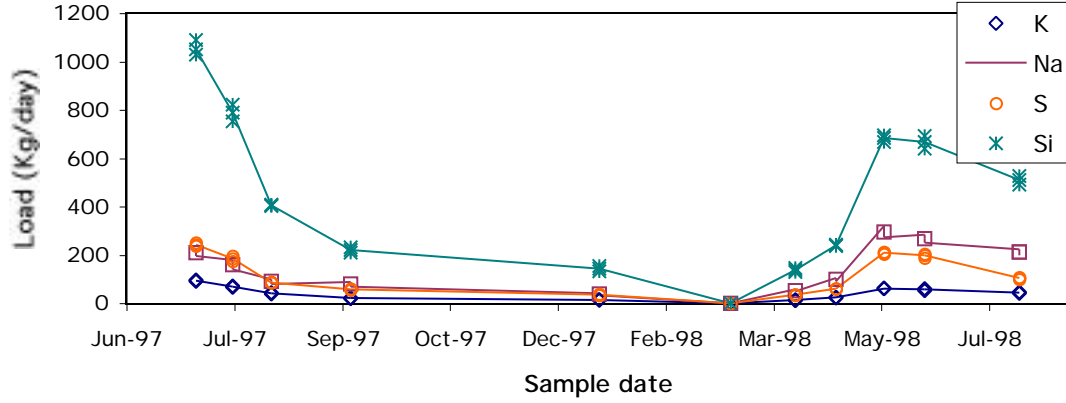
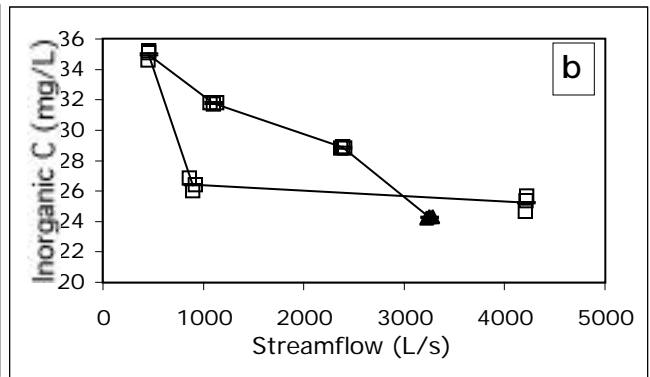
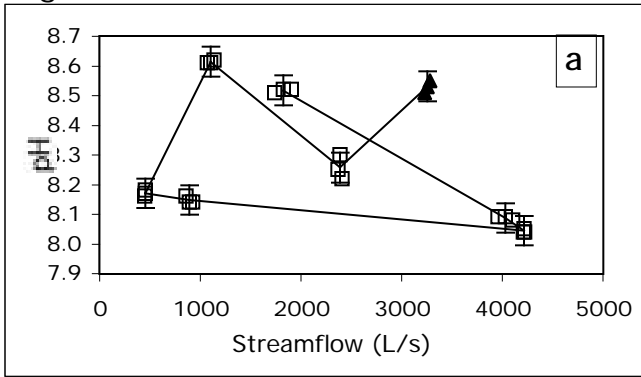


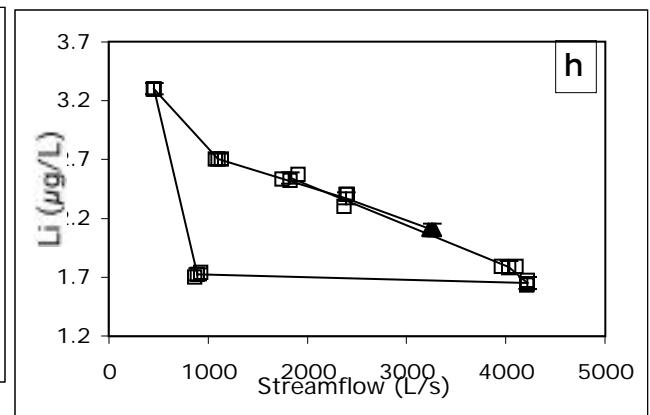
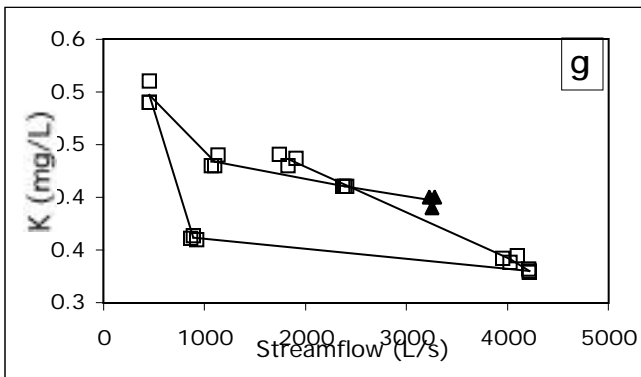
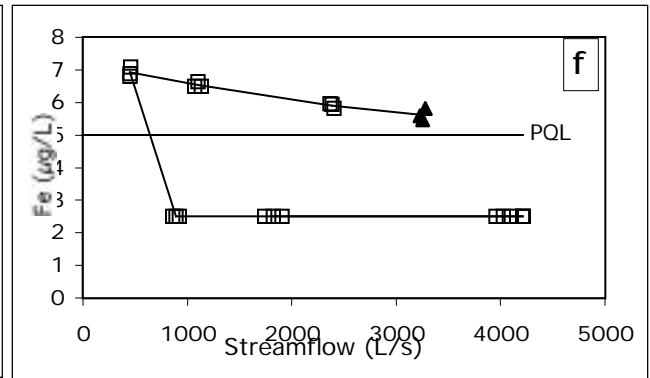
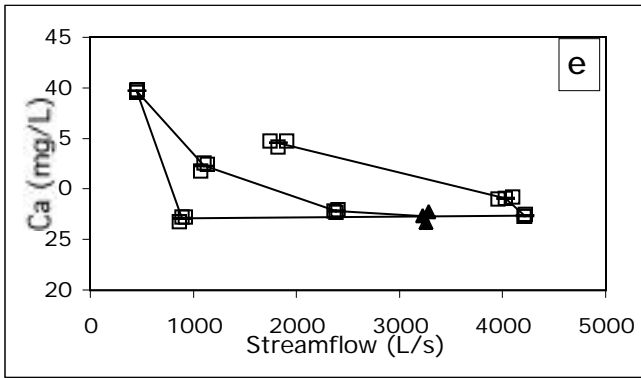
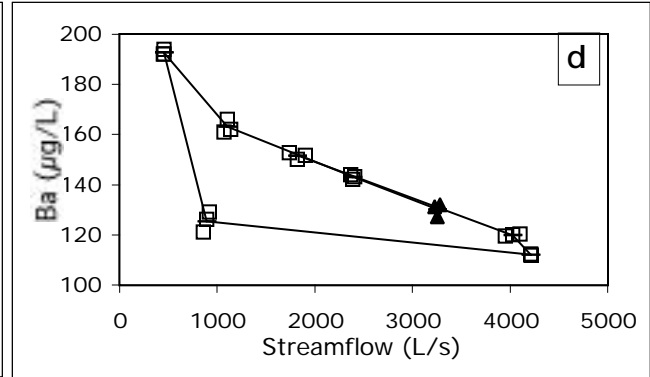
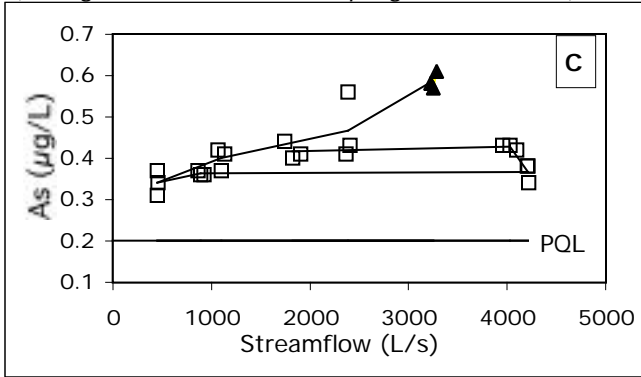
Figure 4e: K, Na, S, Si loads at site C



Figures 5a-5h: Streamflow vs. concentrations at Landers Fork site "LA"



(Triangles indicated first sampling date, 7/3/97)



Figures 5i-5n: Streamflow vs. concentrations at Landers Fork site "LA"

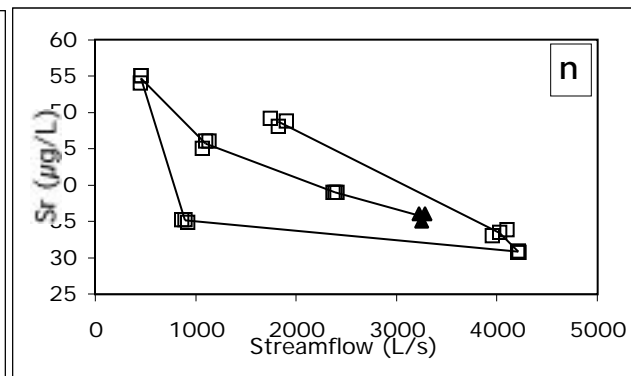
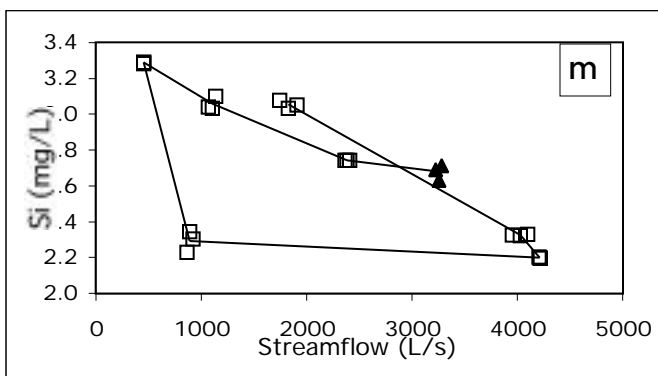
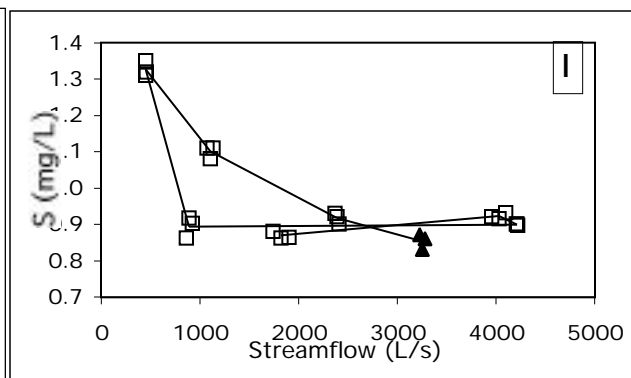
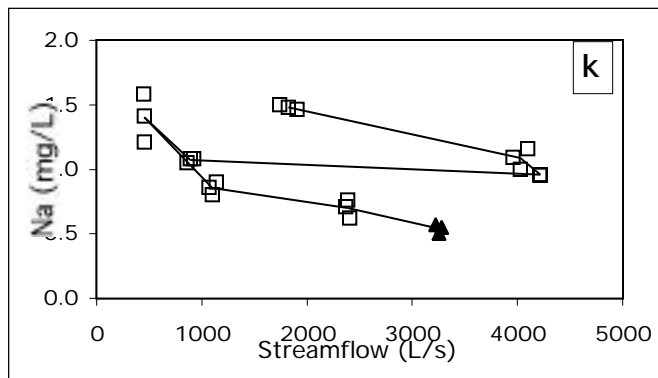
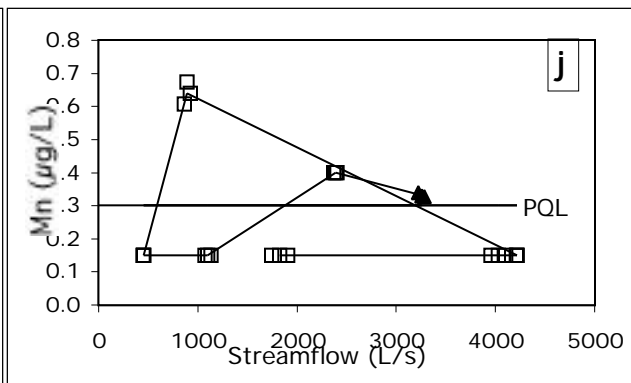
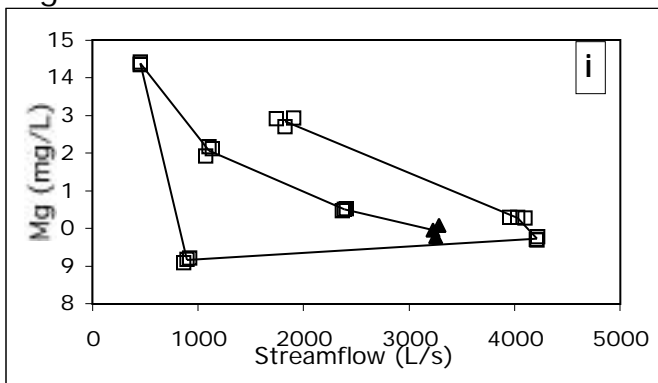


Figure 6a-6h: Trends over time at Landers Fork site "LA"

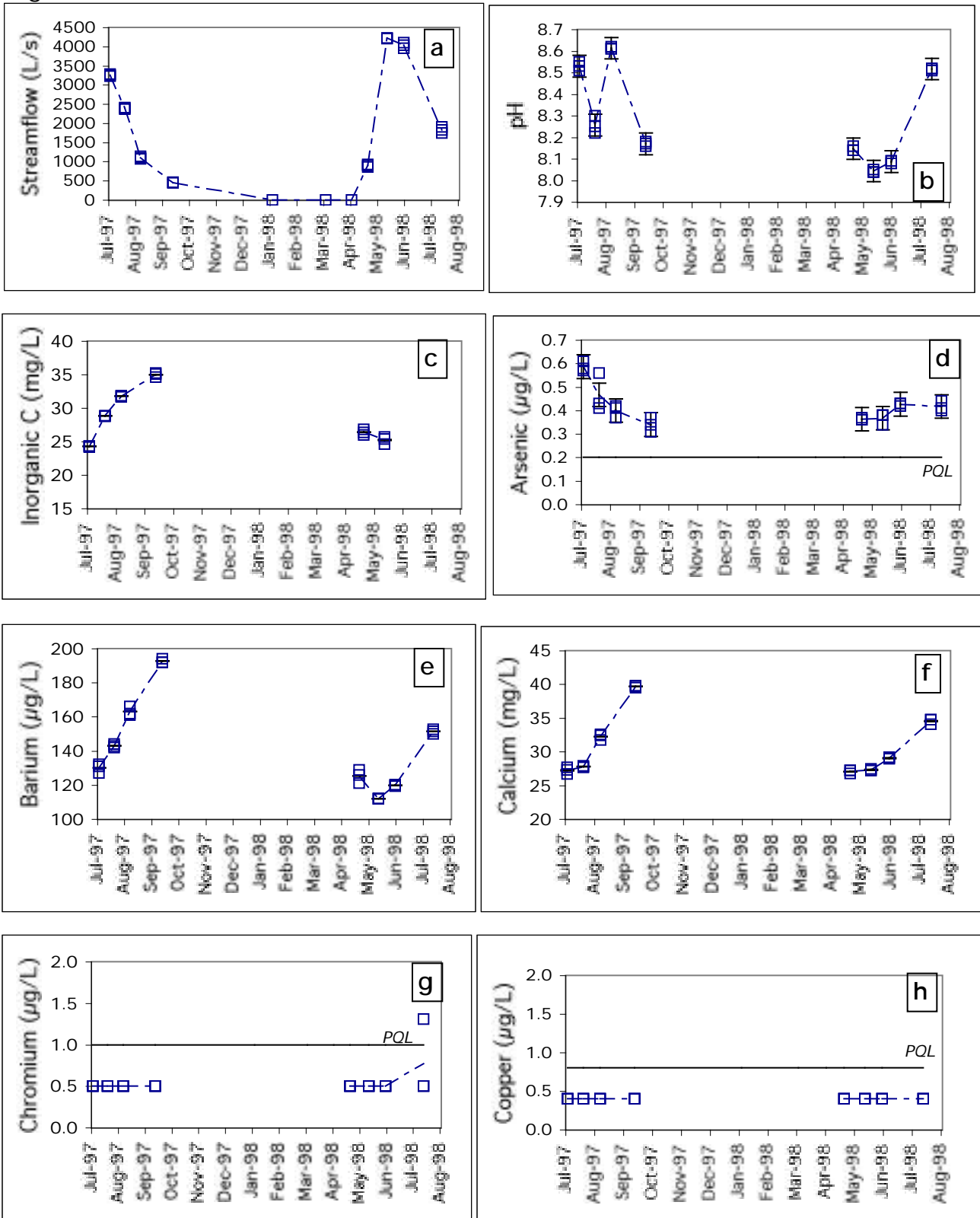


Figure 6i-6p: Trends over time at Landers Fork site "LA"

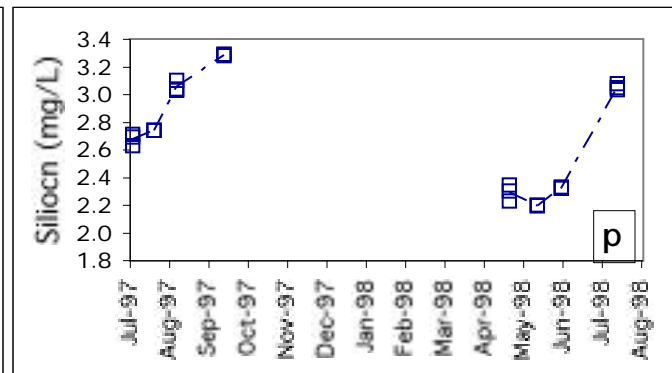
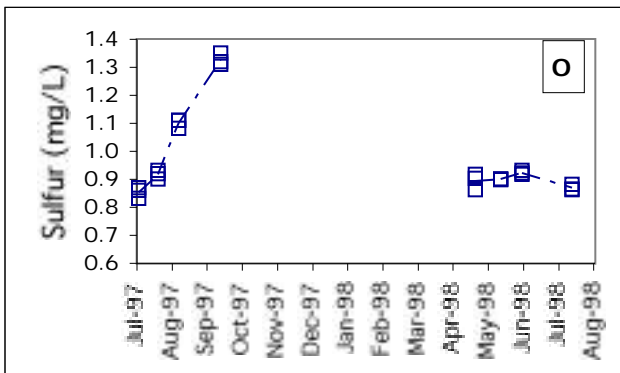
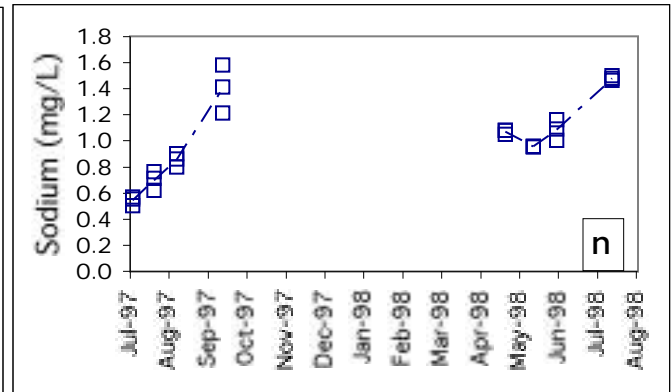
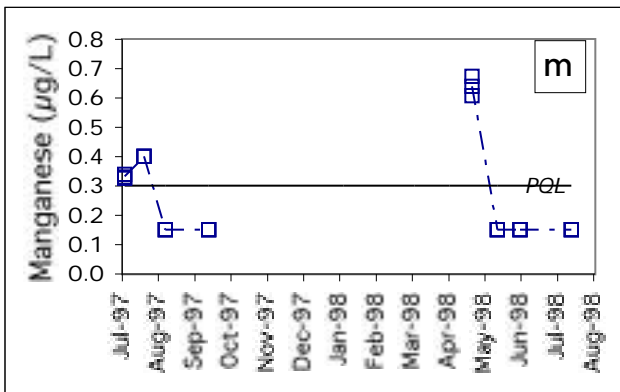
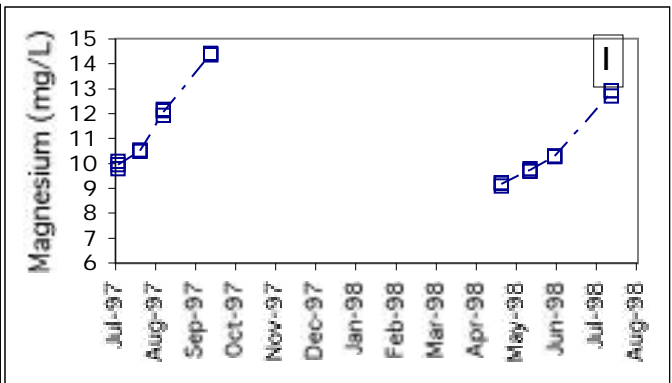
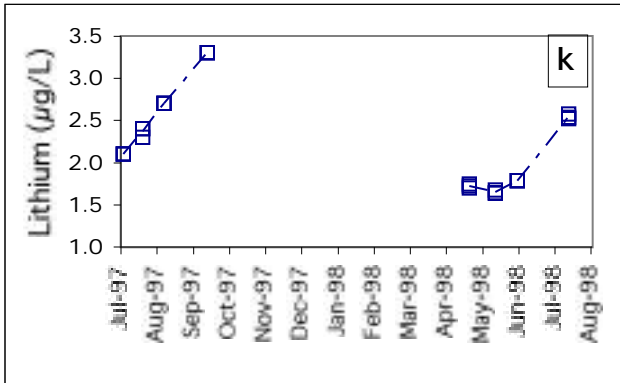
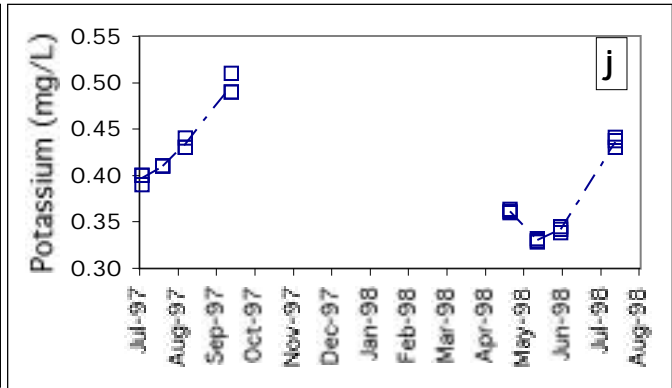
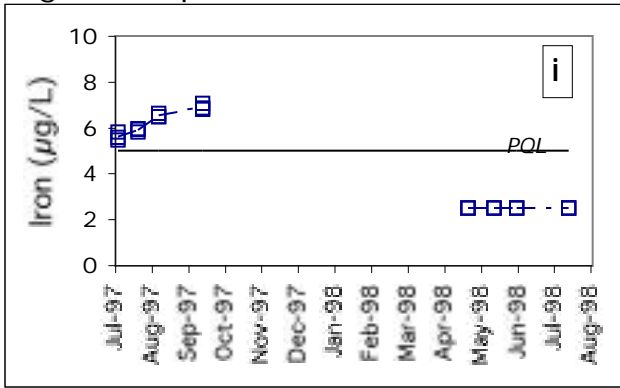


Figure 6q-6r: Trends over time at Landers Fork site "LA"

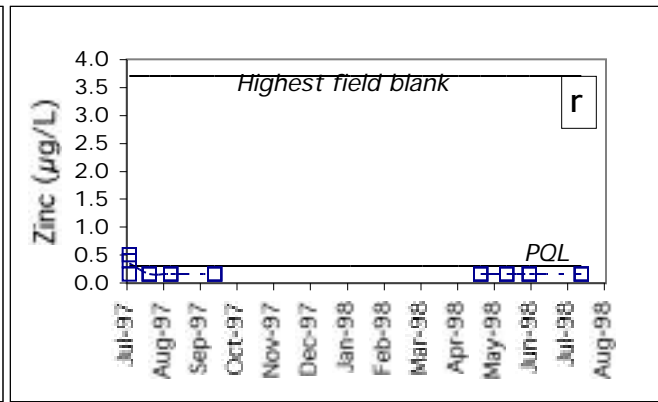
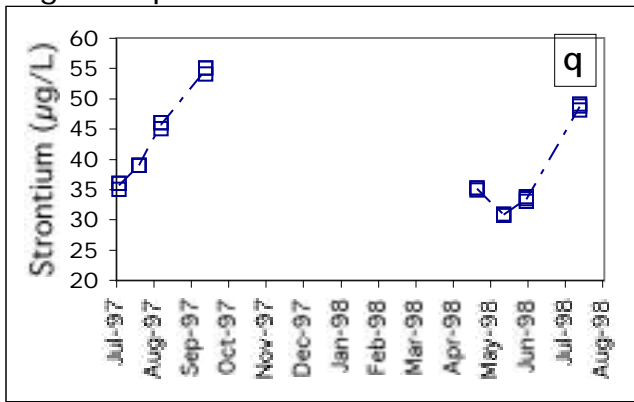


Figure 7a: Inorganic carbon, Ca, and Mg loads at site LA

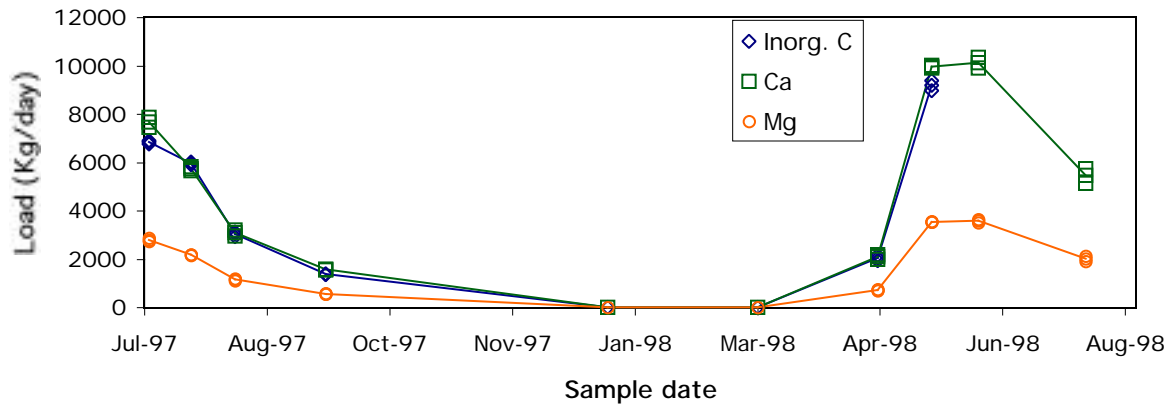


Figure 7b: As and Mn loads at site LA

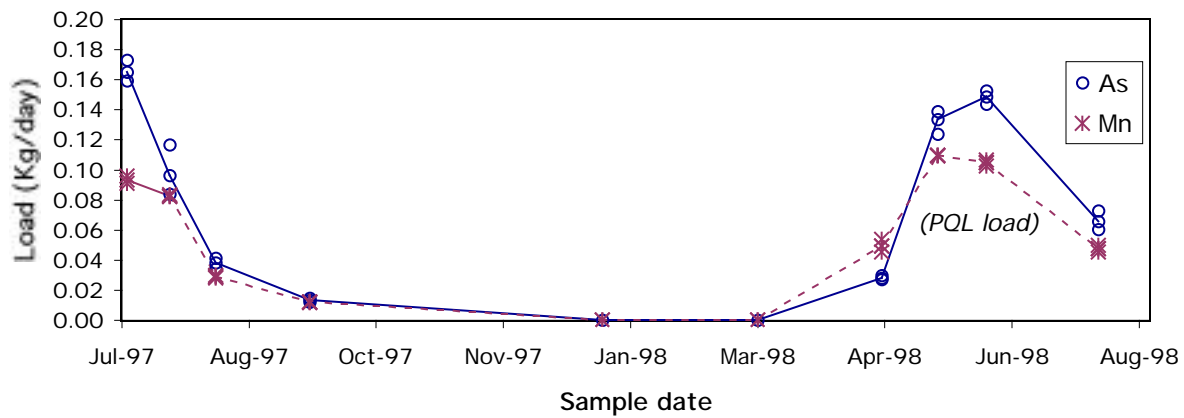


Figure 7c: S, Si, and Na loads at site LA

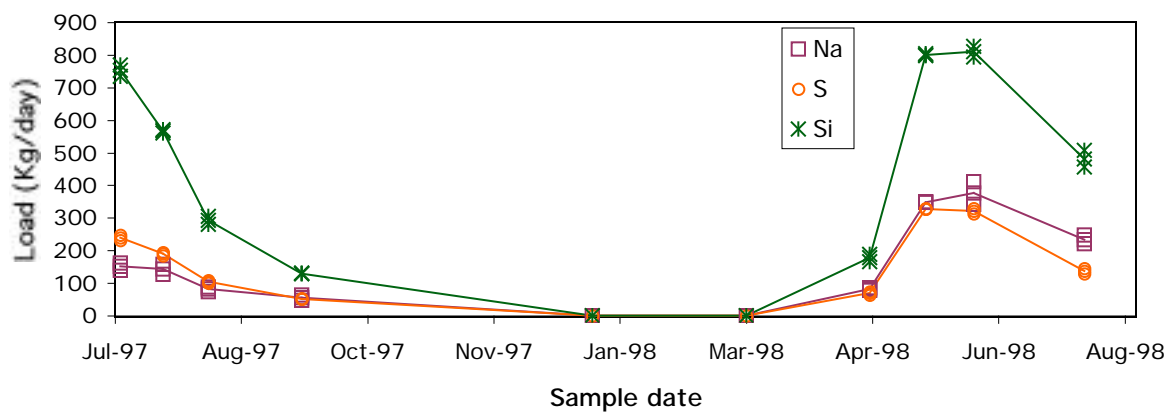


Figure 7d: Fe and Li loads at site LA

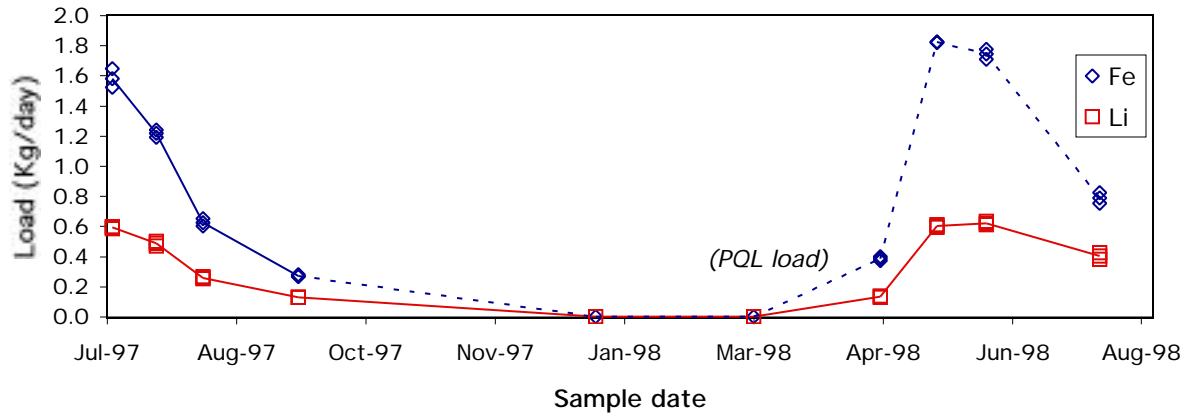
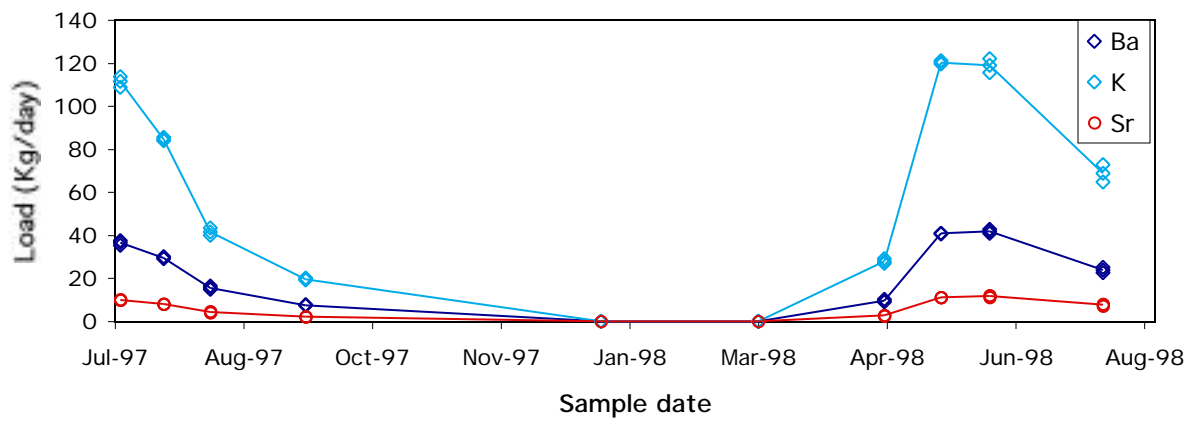
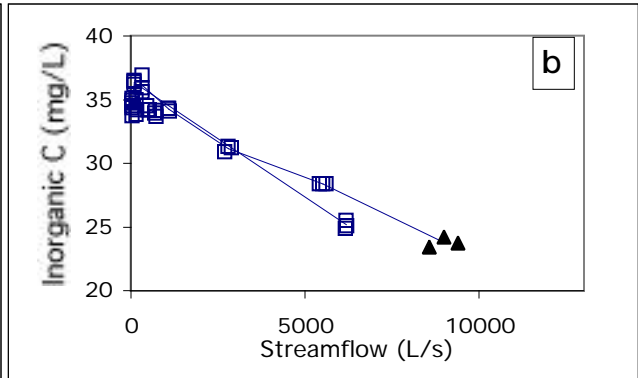
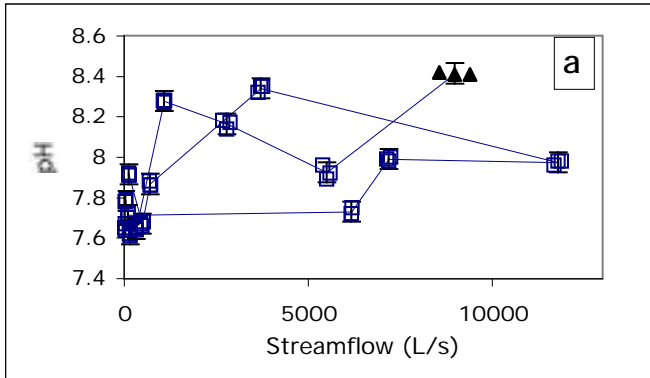


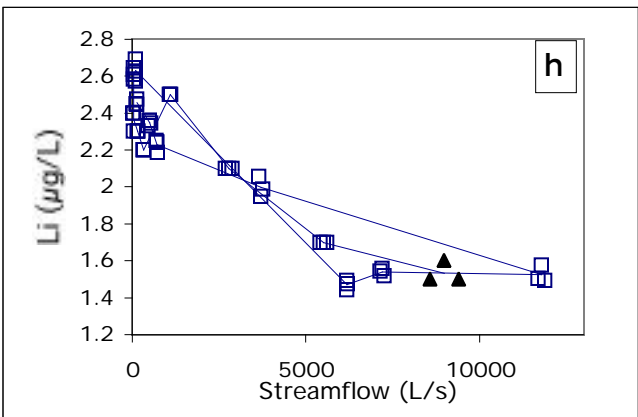
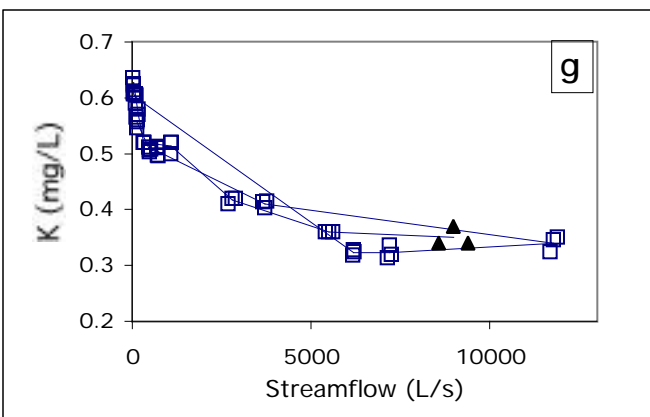
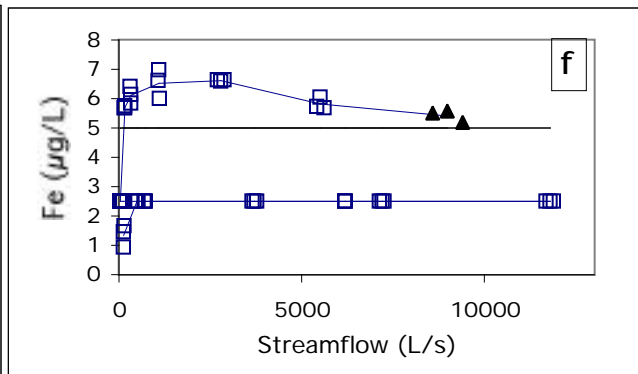
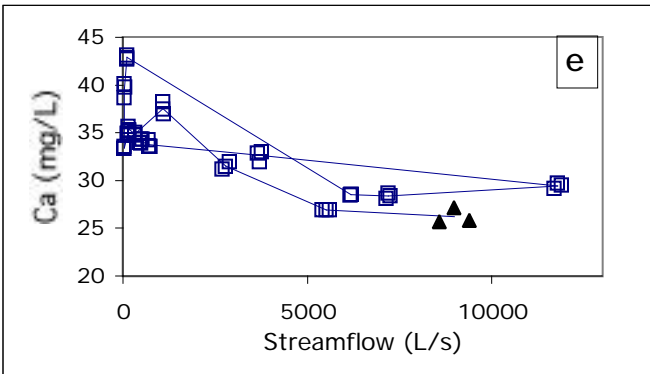
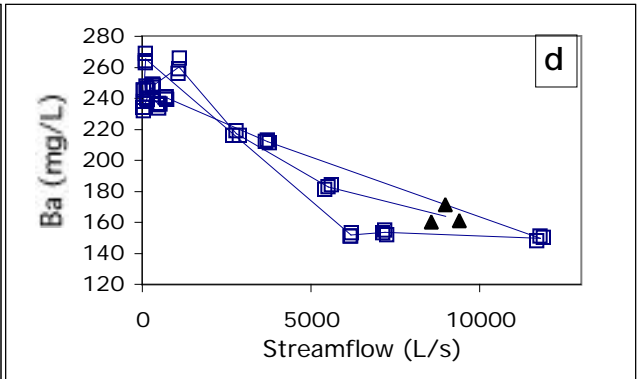
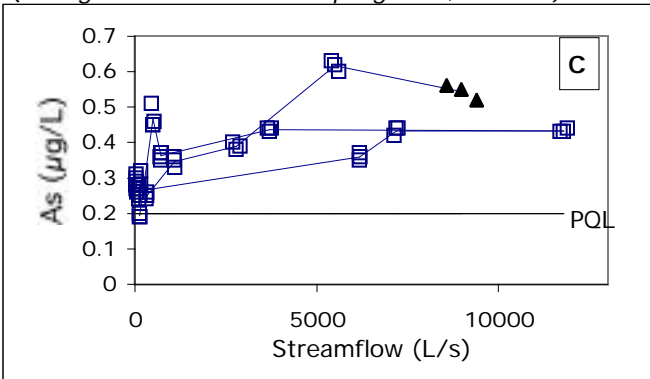
Figure 7e: Ba, K, and Sr loads at site LA



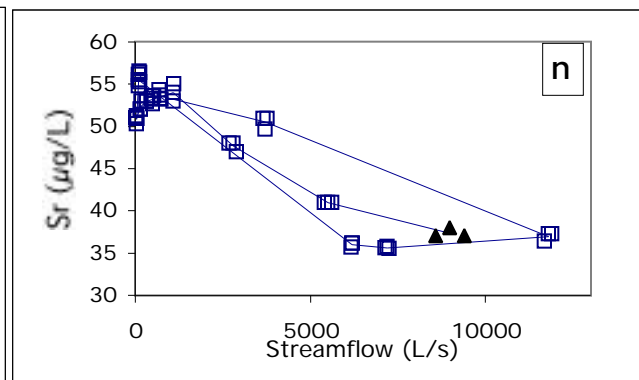
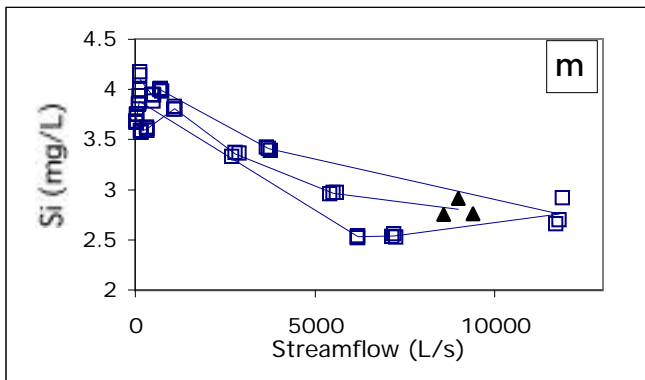
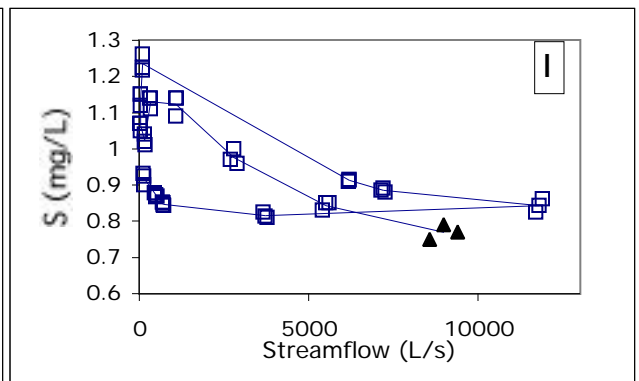
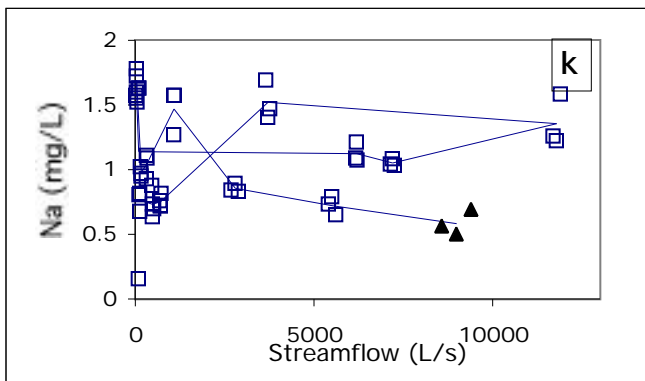
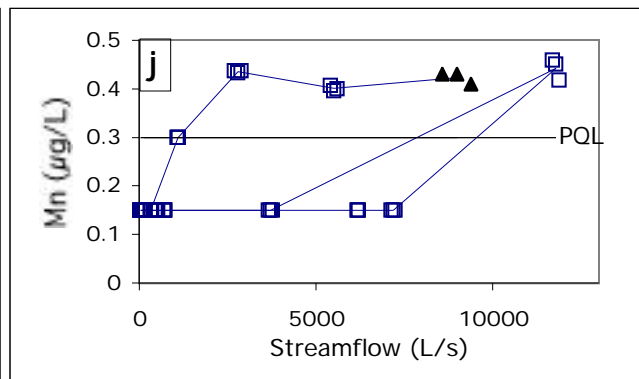
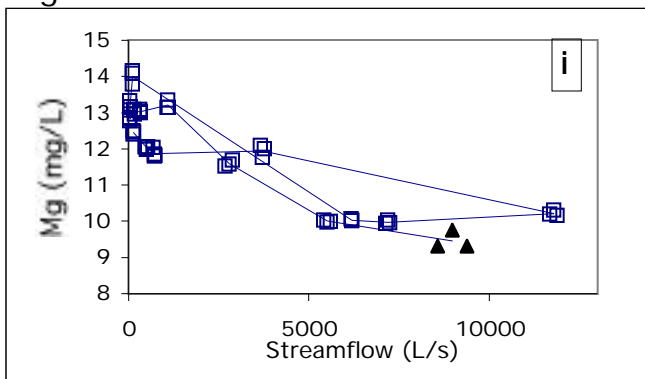
Figures 8a-8h: Streamflow versus concentrations at Landers Fork site "LB"



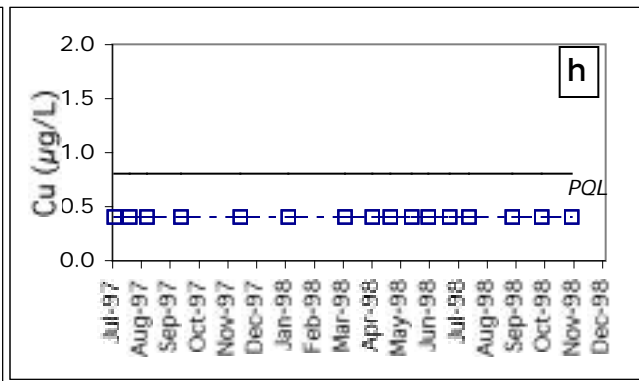
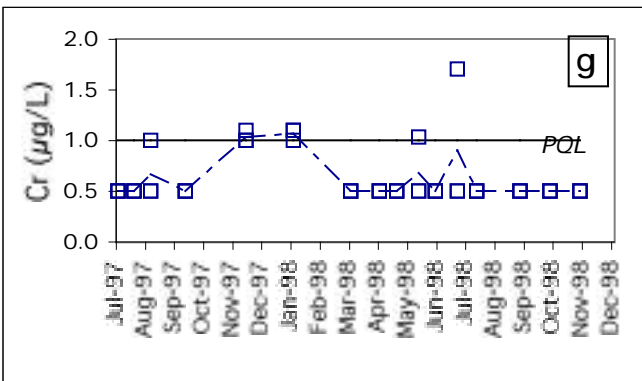
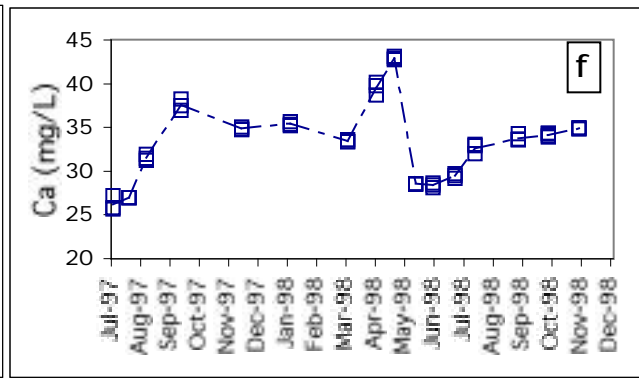
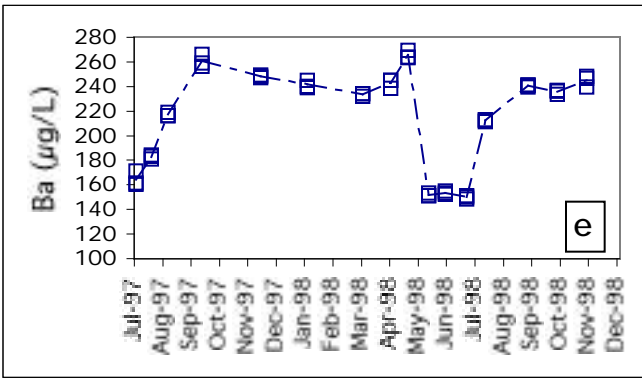
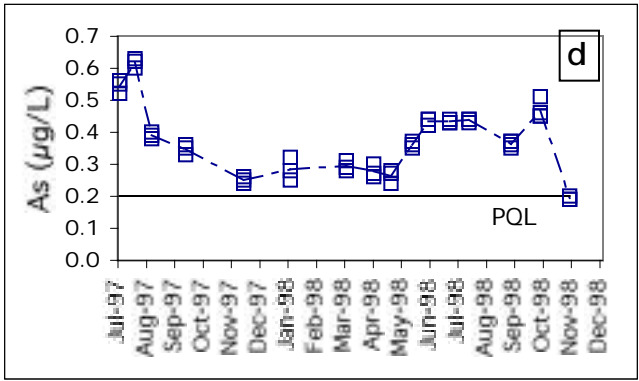
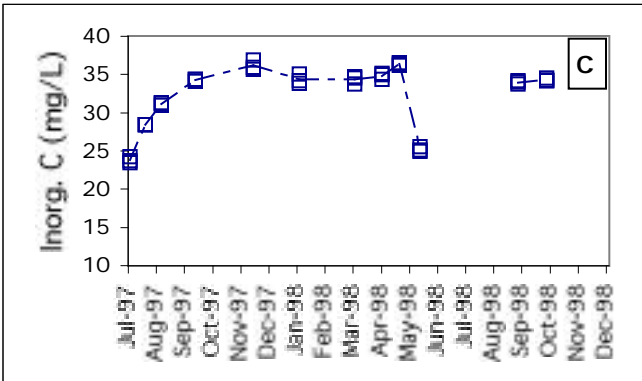
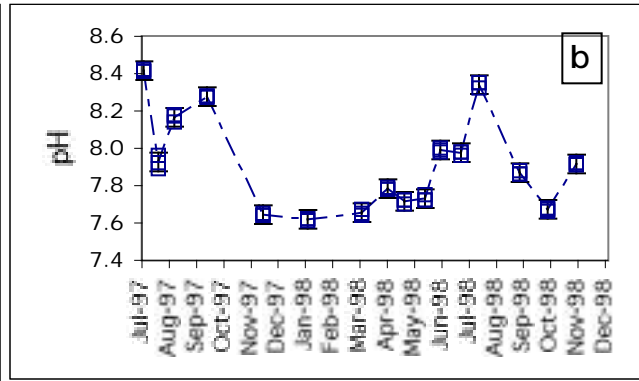
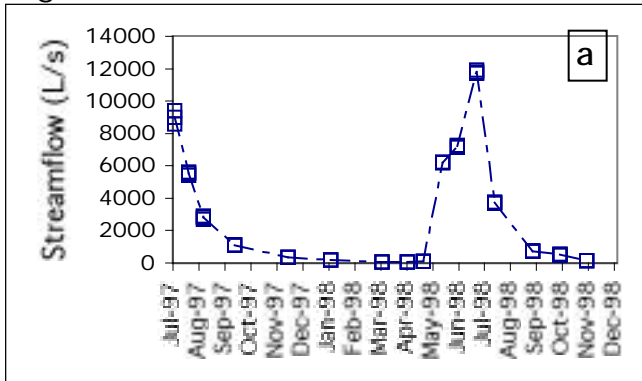
(Triangles indicate first sampling date, 7/3/97)



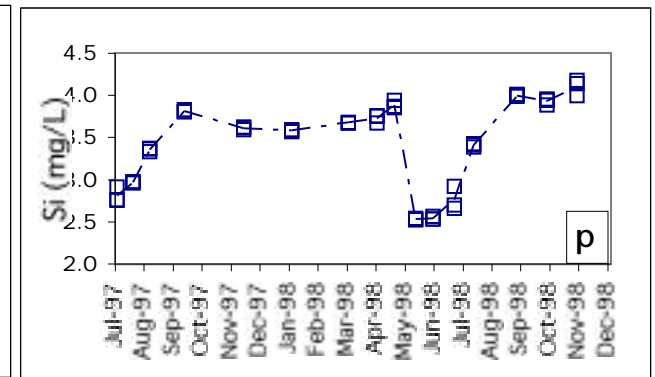
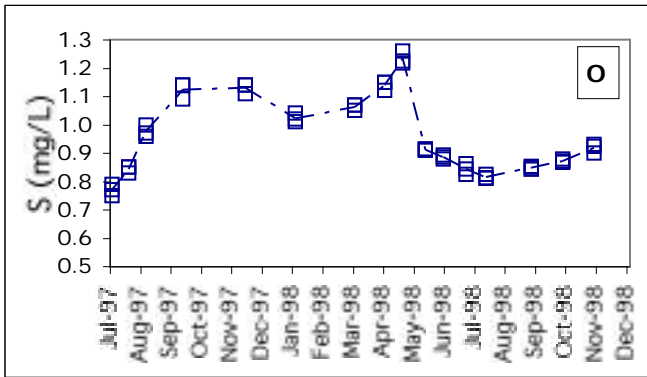
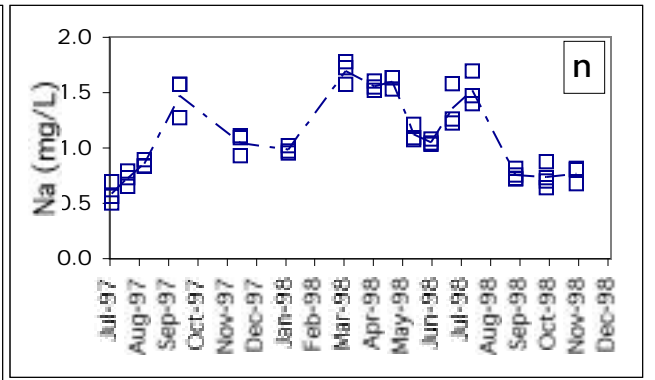
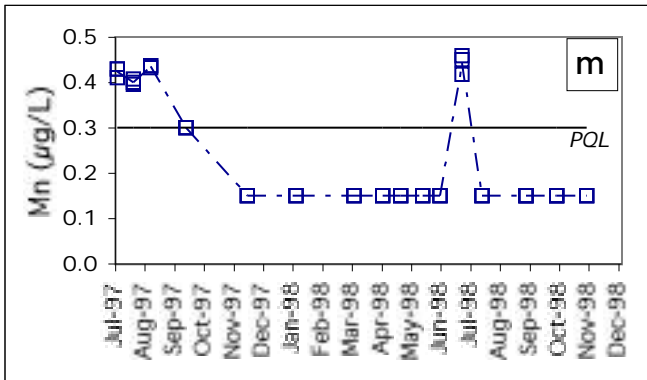
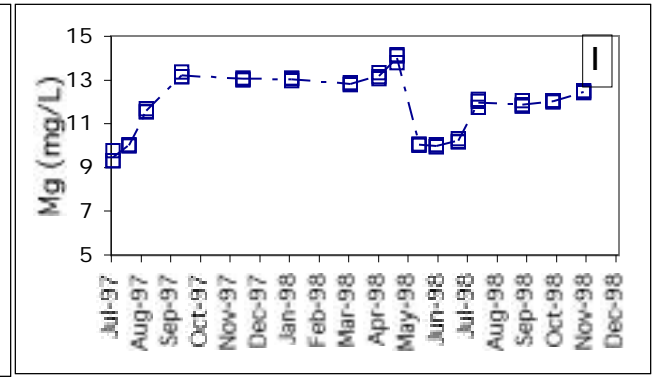
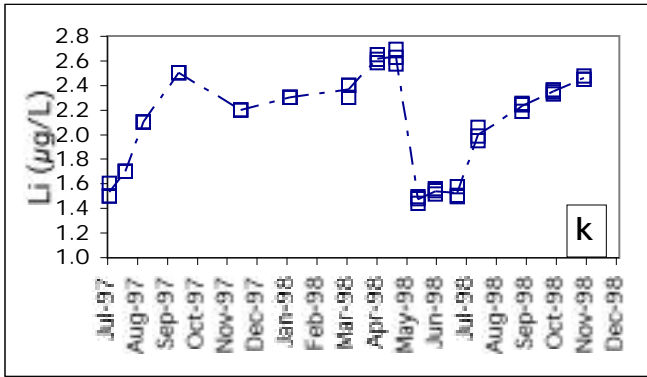
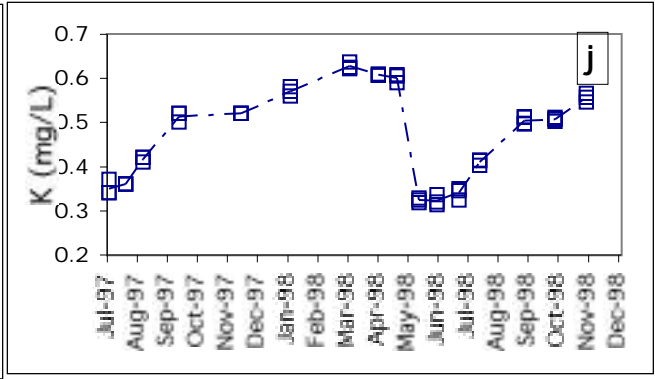
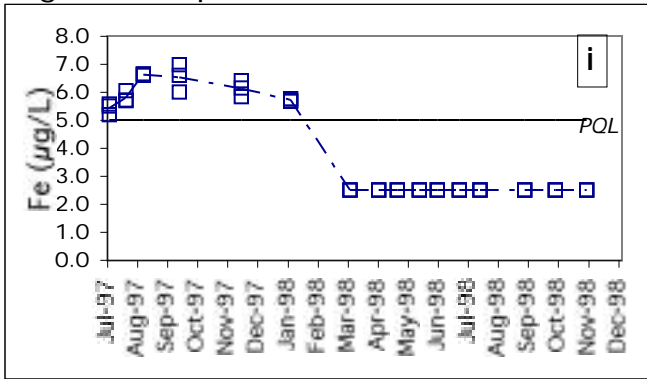
Figures 8i-8n: Streamflow versus concentrations at Landers Fork site "LB"



Figures 9a-9h: Trends over time at Landers Fork site "LB"



Figures 9i-9p: Trends over time at Landers Fork site "LB"



Figures 9q-9r: Trends over time at Landers Fork site "LB"

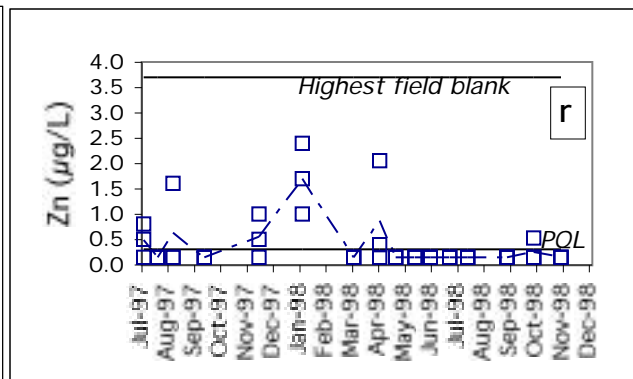
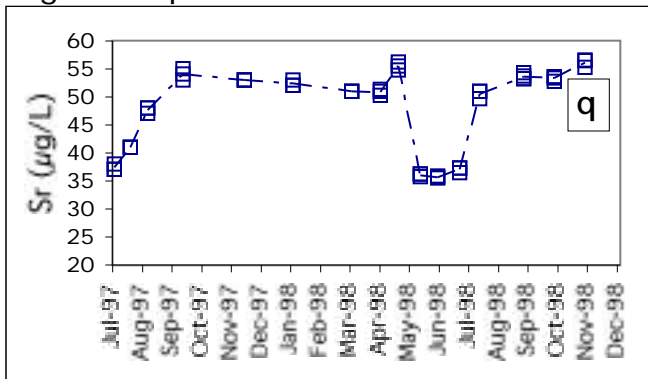


Figure 10a: Inorganic carbon, Ca, and Mg loads at site LB

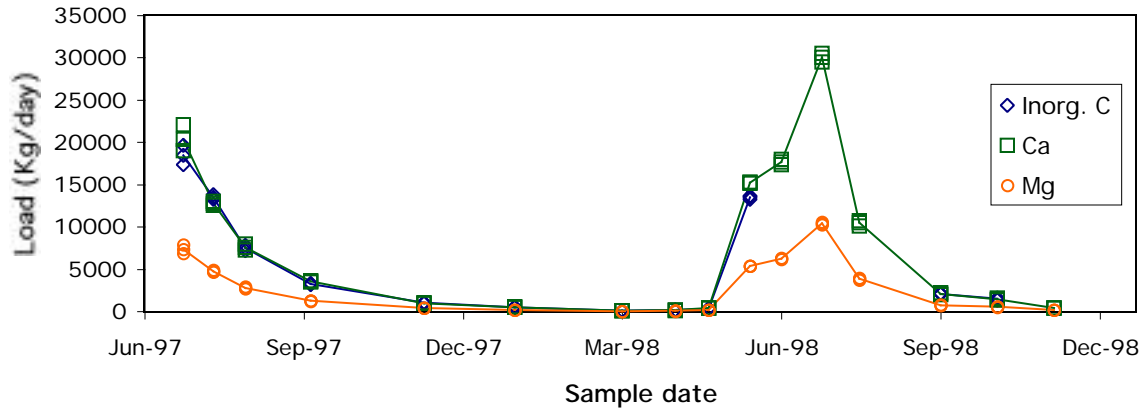


Figure 10b: As and Mn loads at site LB

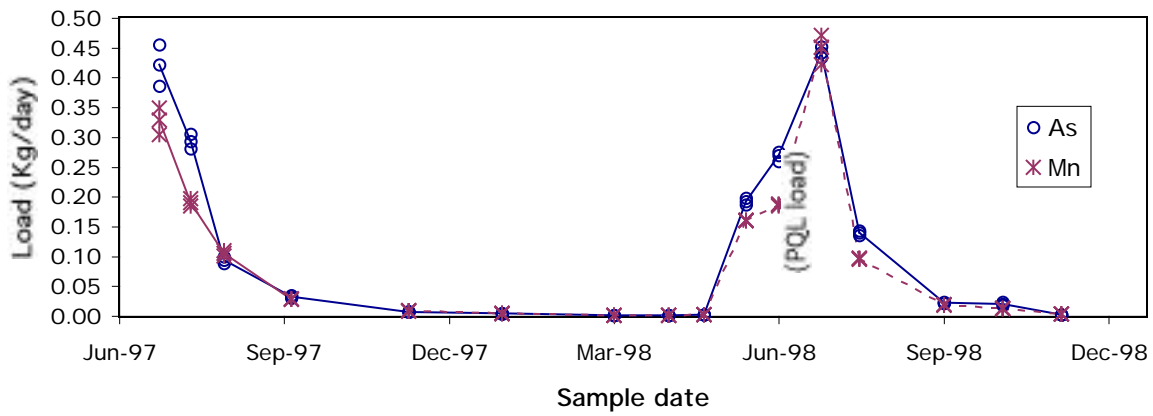


Figure 10c: S, Si, and Na loads at site LB

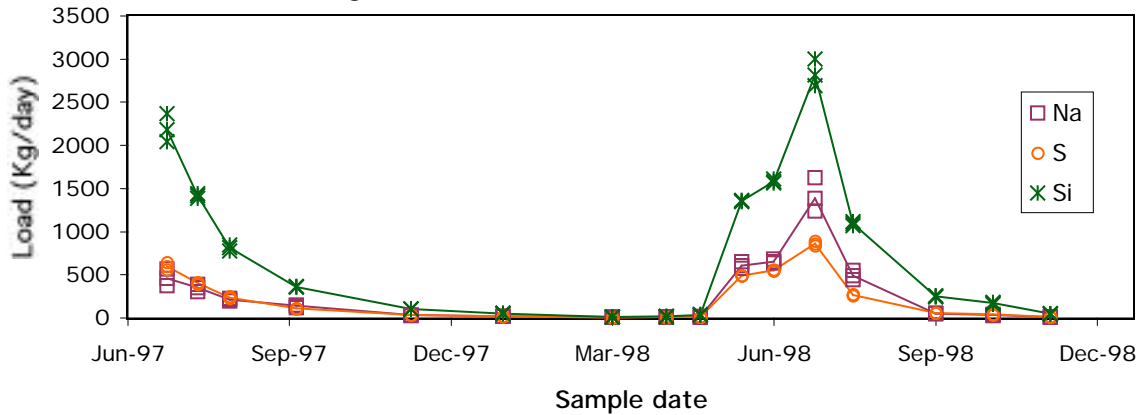


Figure 10d: Fe and Li loads at site LB

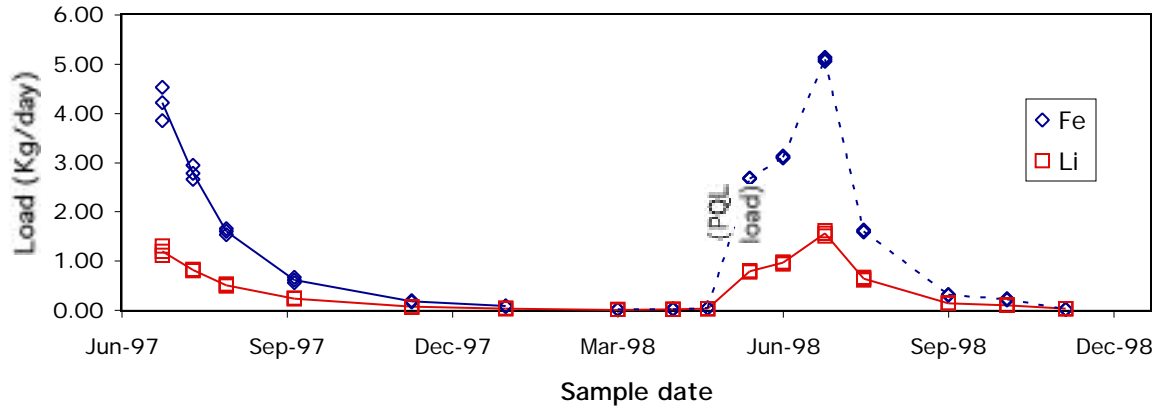


Figure 10e: Ba, K, and Sr loads at site LB

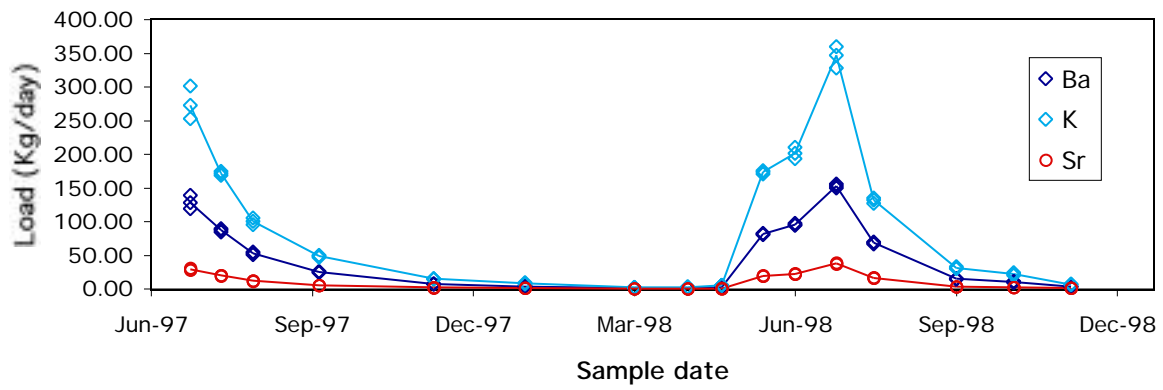
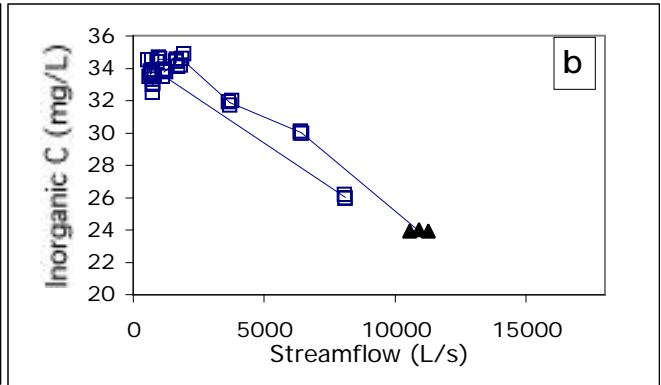
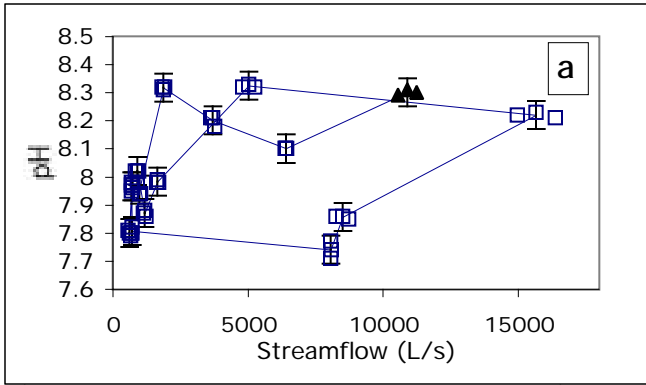


Figure 11a-11h: Streamflow vs. concentrations at Landers Fork site "LC"



(Triangles indicate first sampling date, 7/3/97)

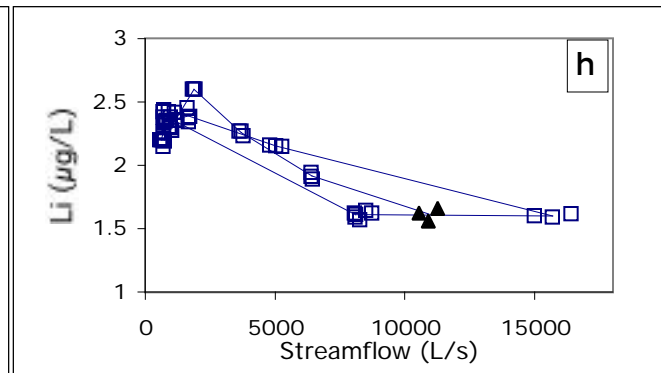
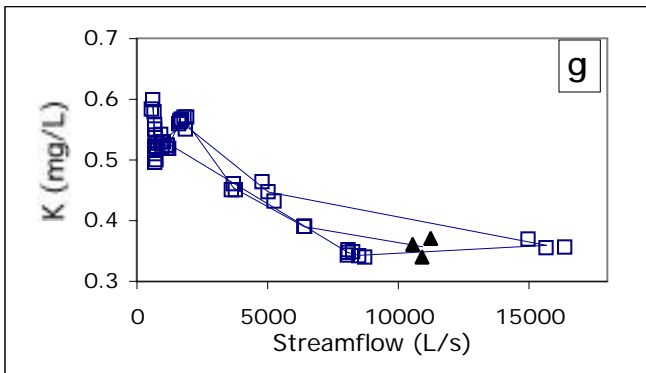
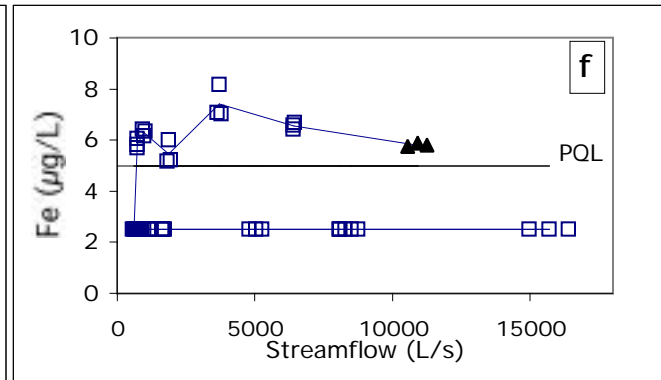
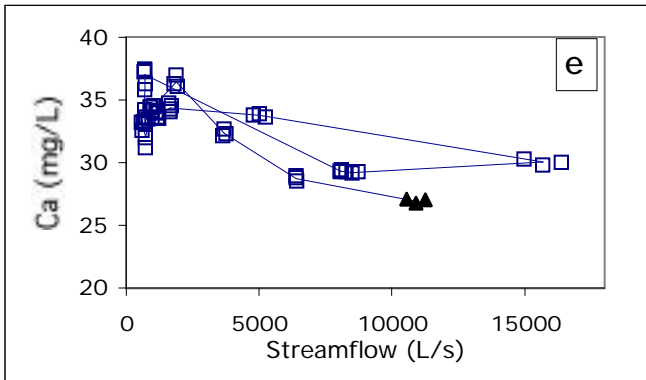
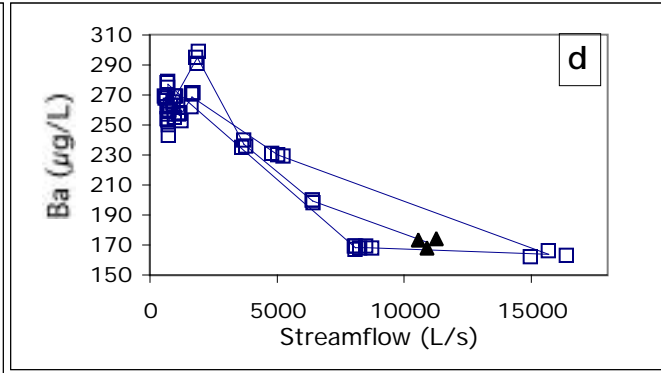
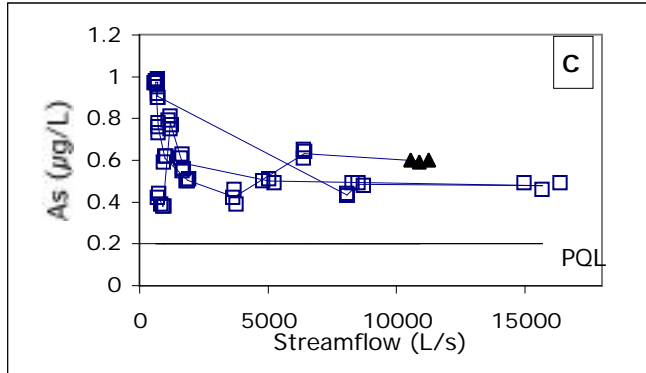


Figure 11i-11n: Streamflow vs. concentrations at Landers Fork site "LC"

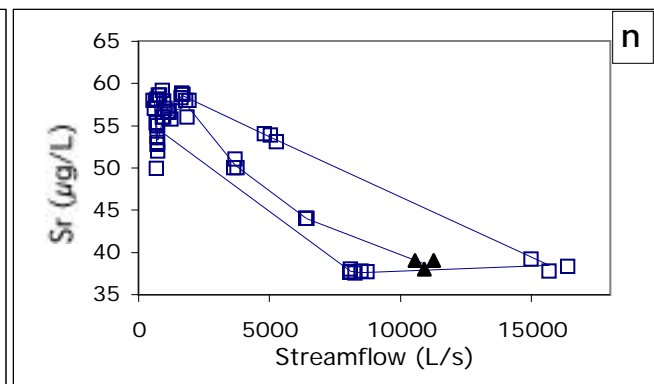
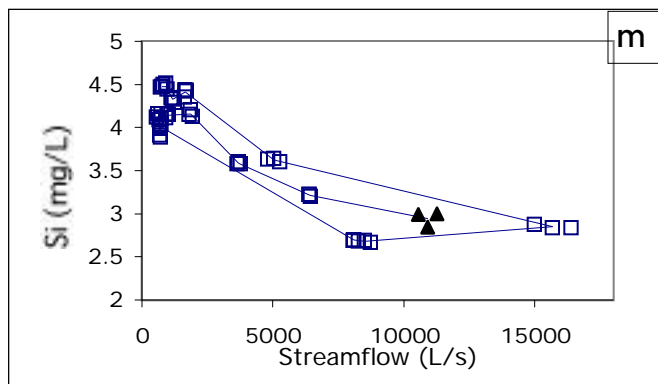
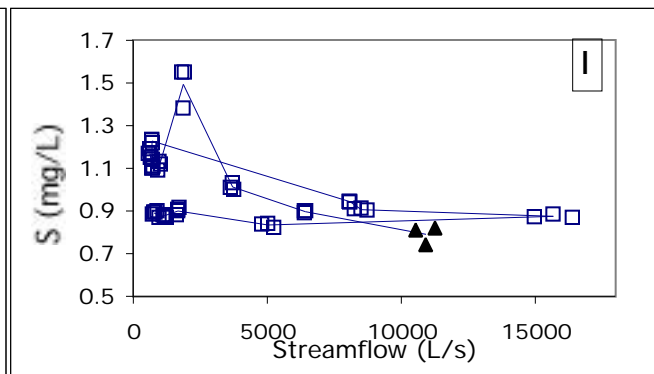
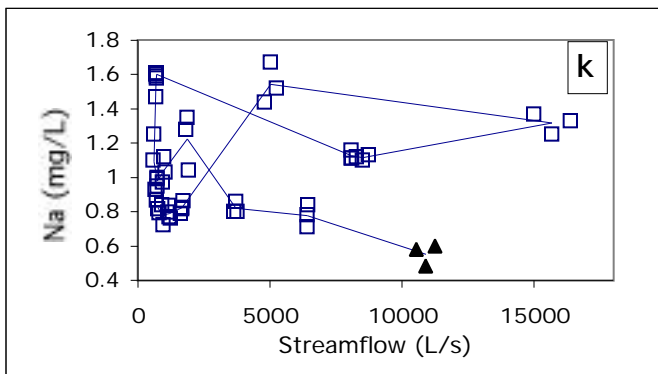
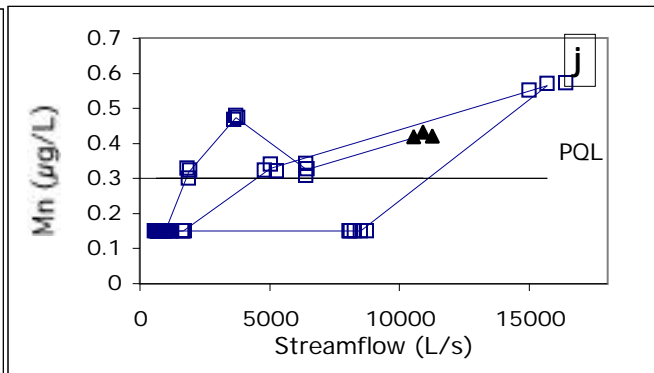
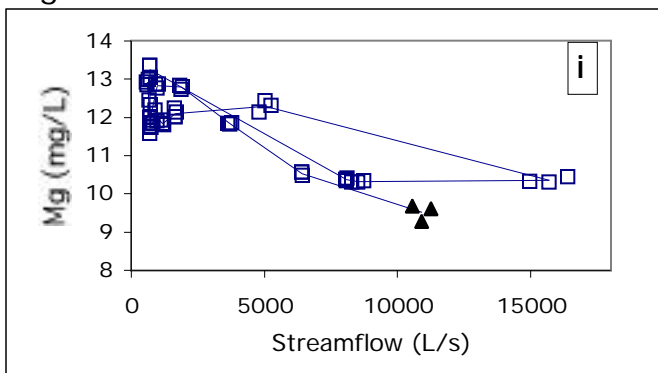


Figure 12a-12h: Trends over time at Landers Fork site "LC"

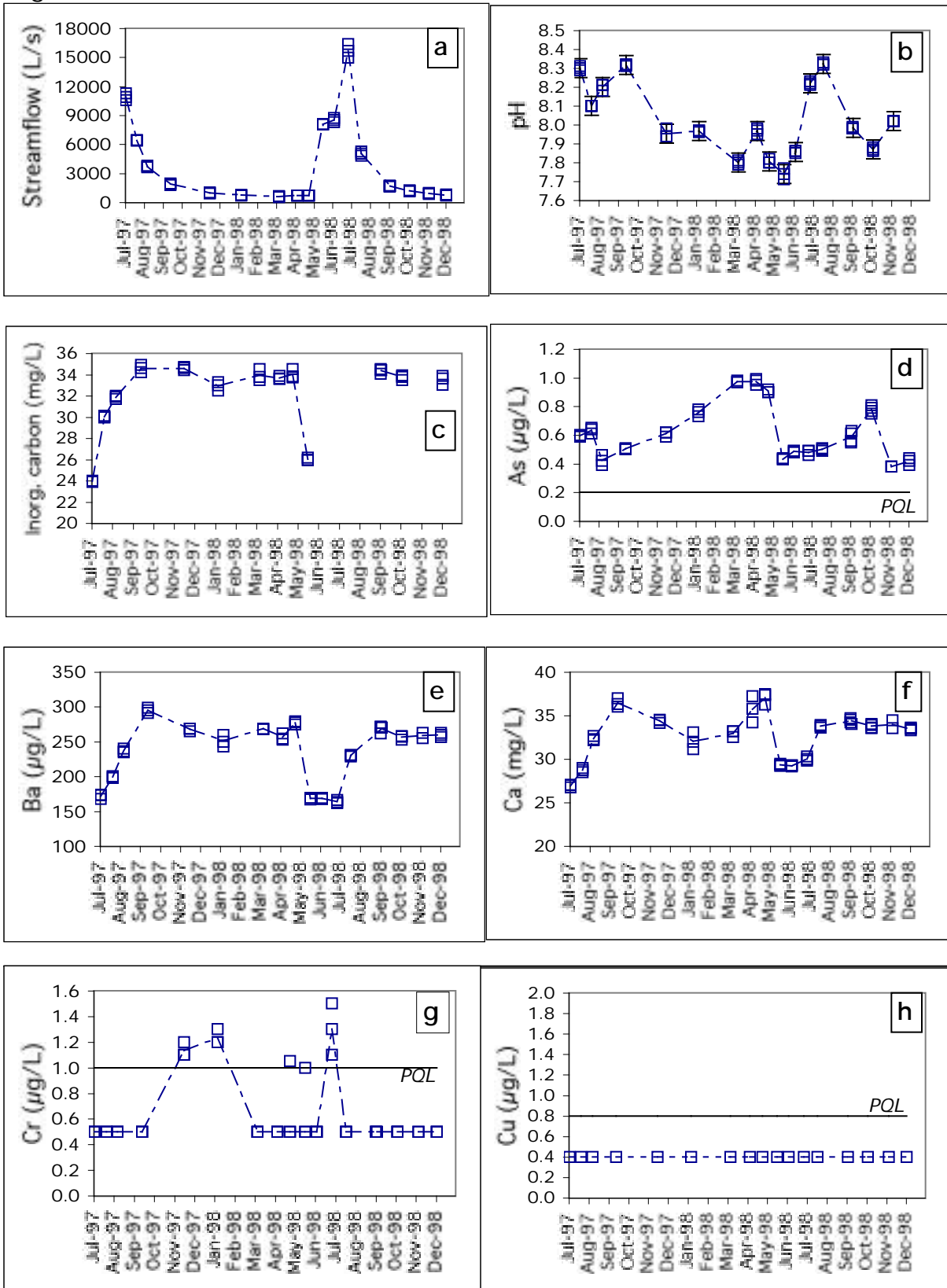


Figure 12i-12p: Trends over time at Landers Fork site "LC"

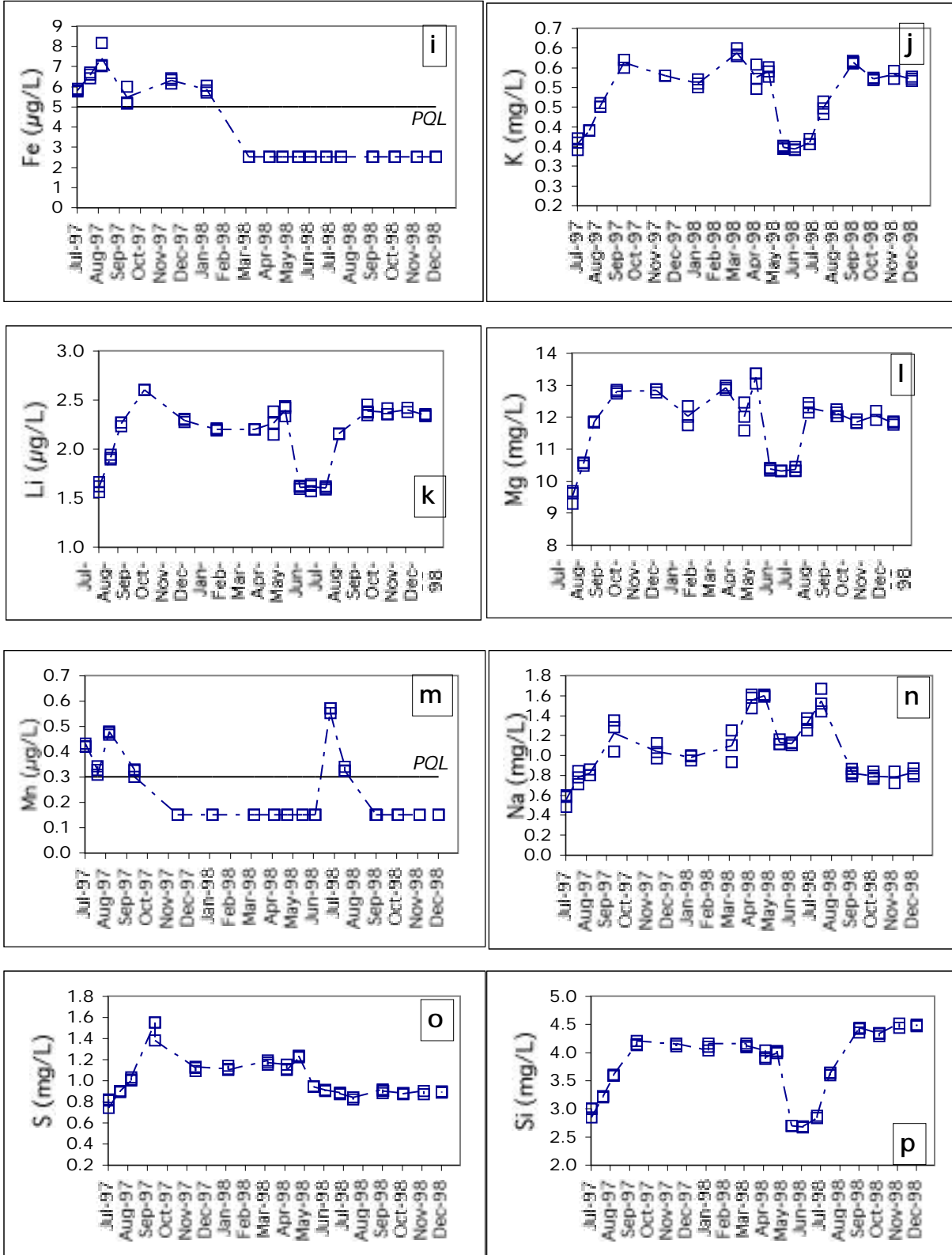


Figure 12q-12r: Trends over time at Landers Fork site "LC"

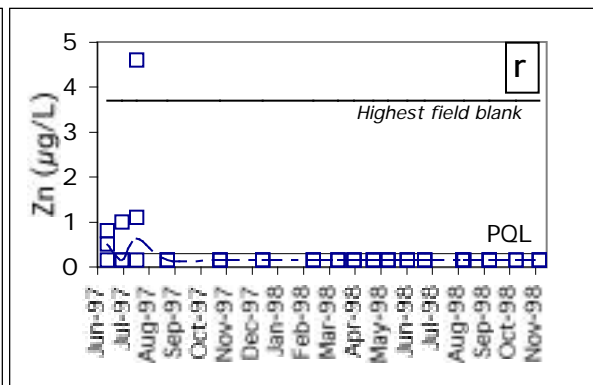
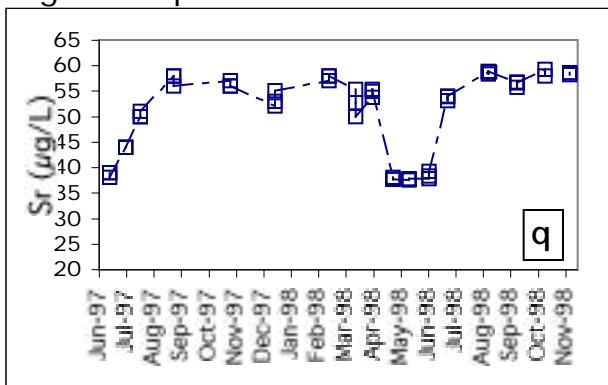


Figure 13a: Inorganic carbon, Ca, and Mg loads at site LC

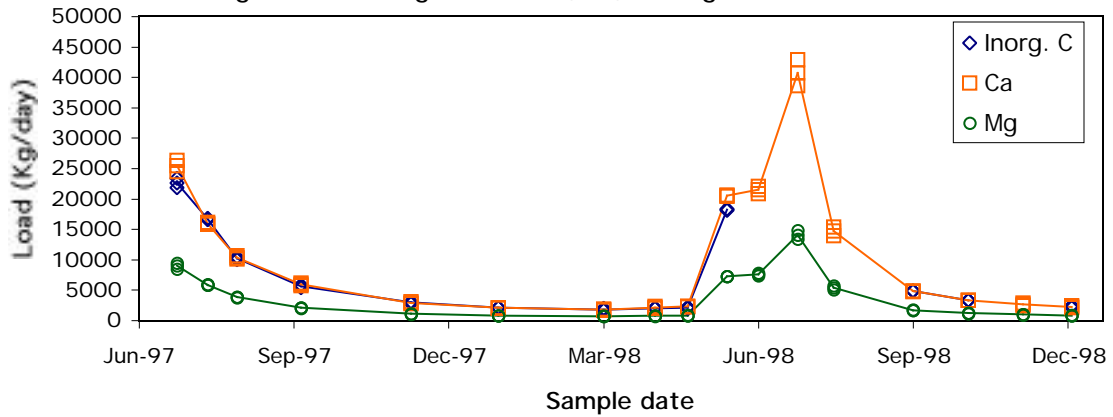


Figure 13b: Na, S, and Si loads at site LC

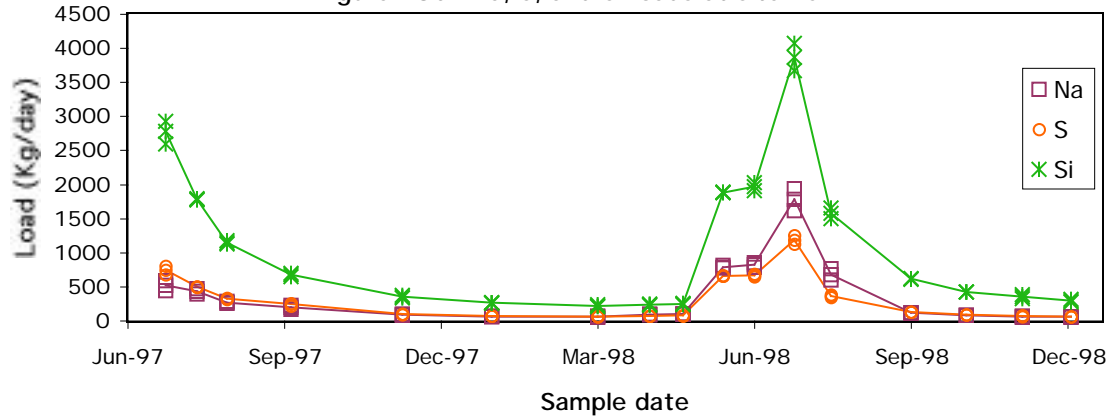


Figure 13c: As and Mn loads at site LC

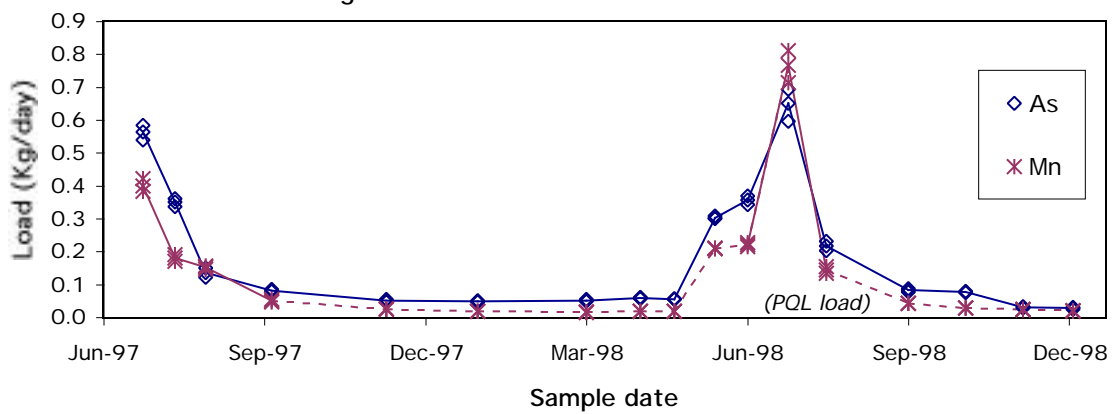


Figure 13d: Ba, K, Sr loads at site LC

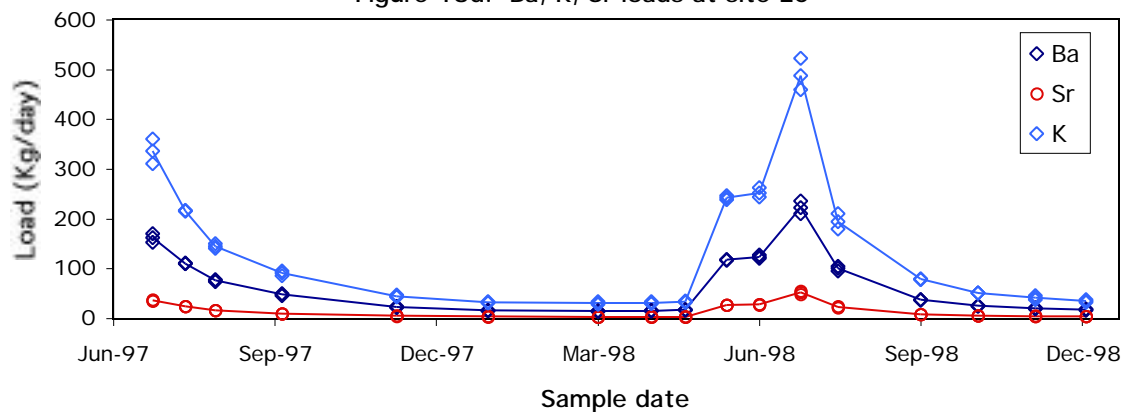
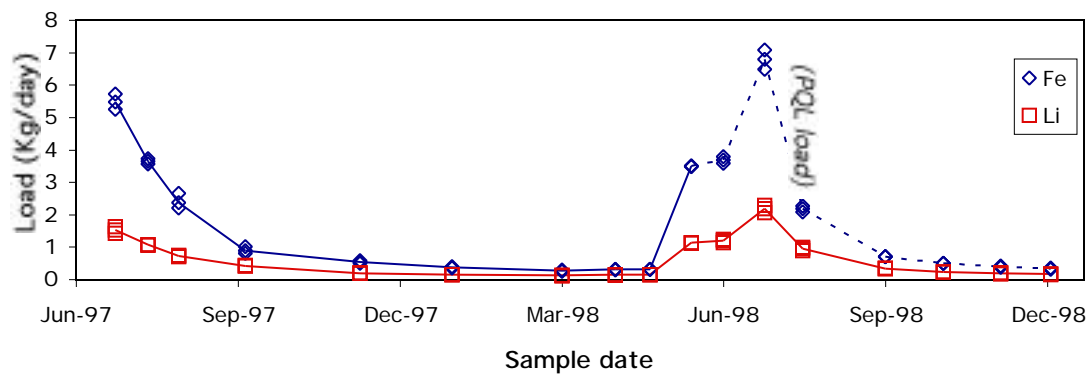
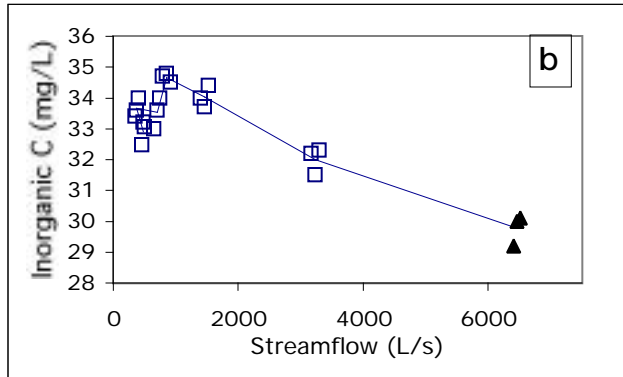
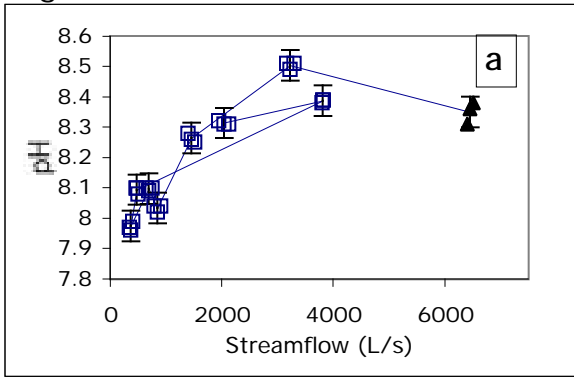


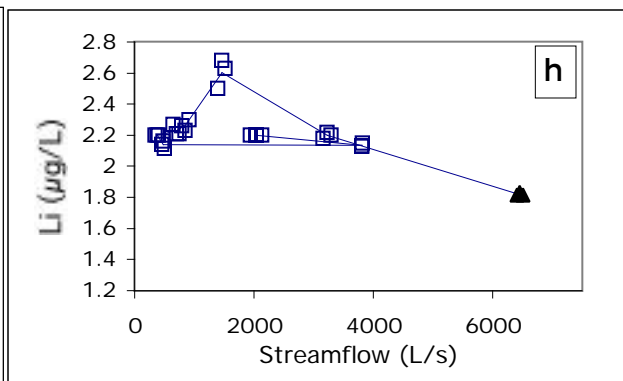
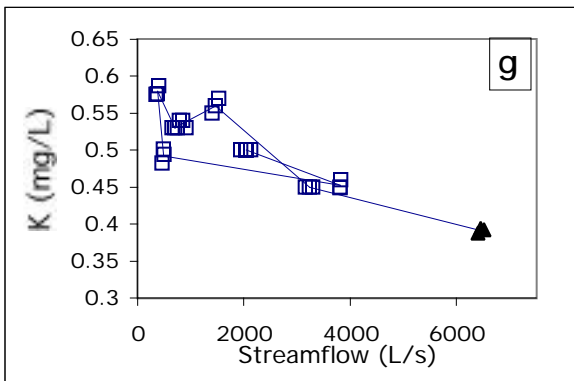
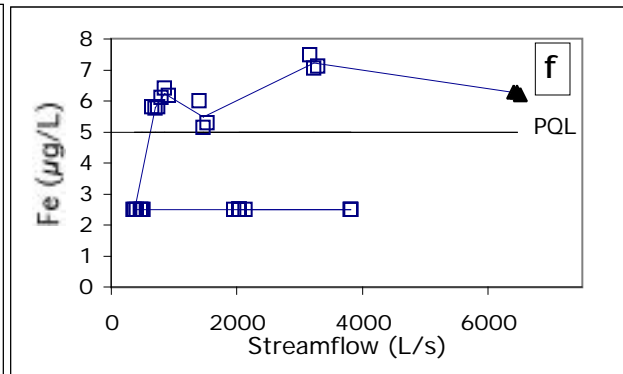
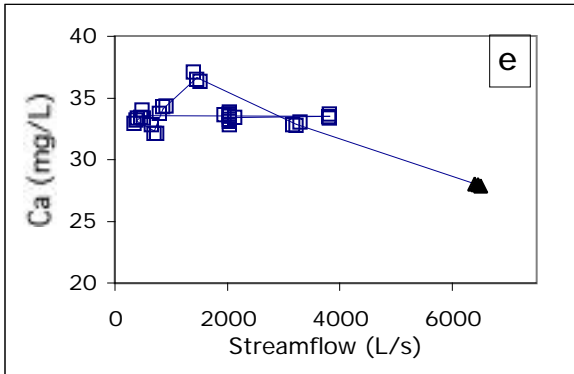
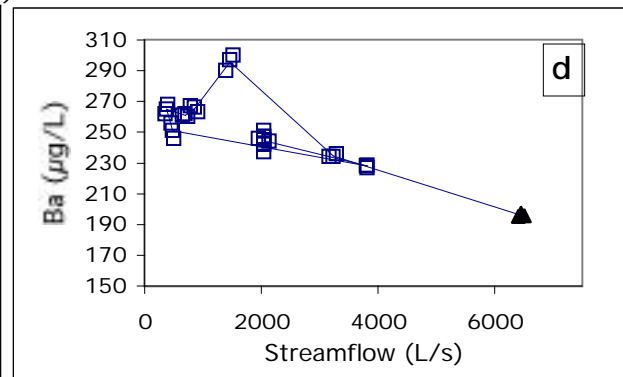
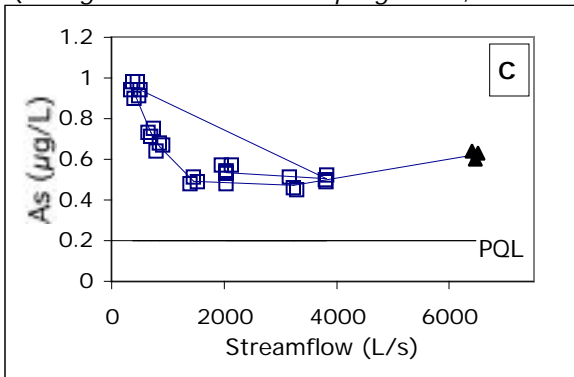
Figure 13e: Fe and Li loads at site LC



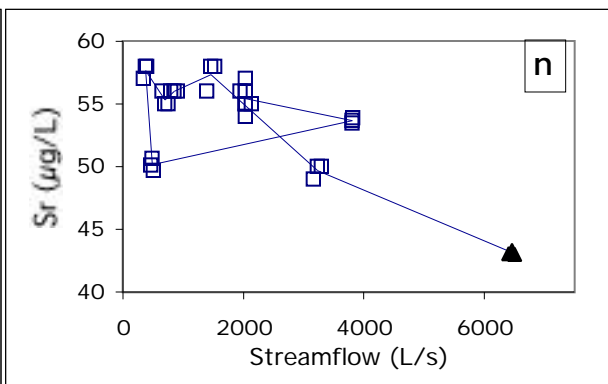
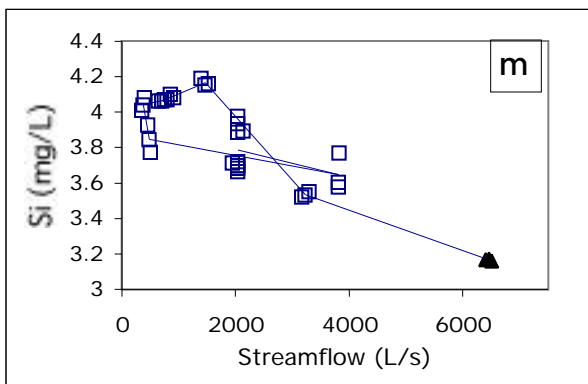
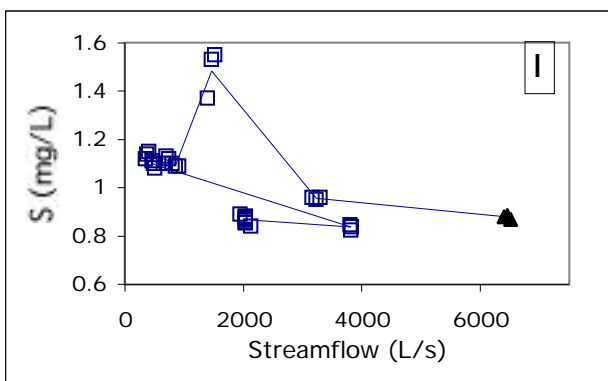
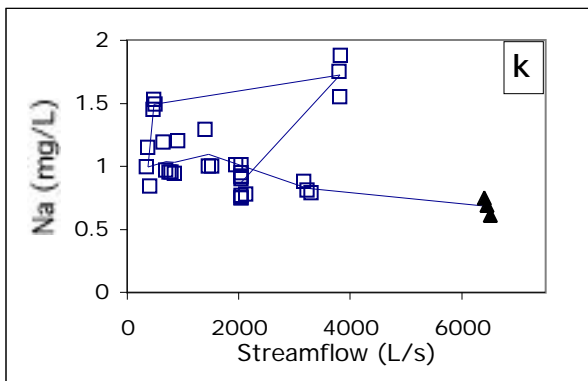
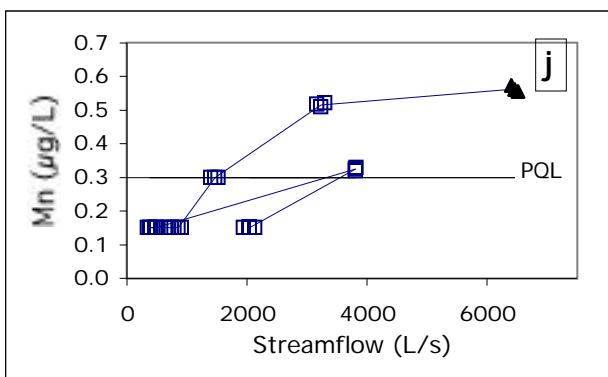
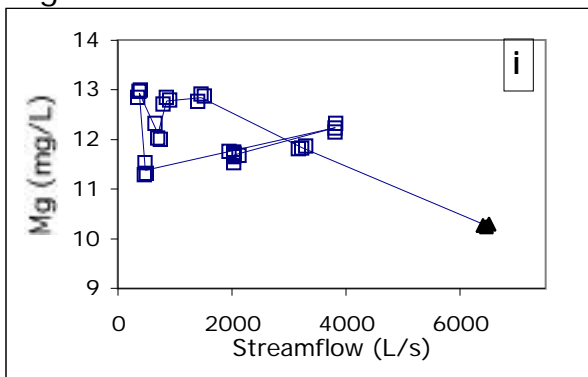
Figures 14a-14h: Streamflow vs. concentrations at Landers Fork "LD"



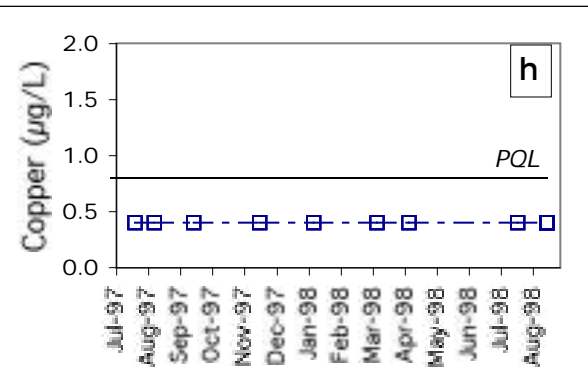
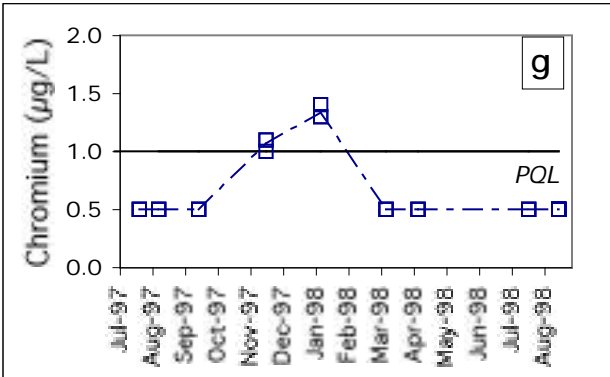
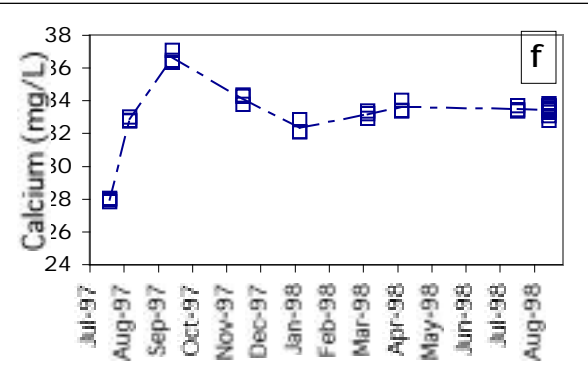
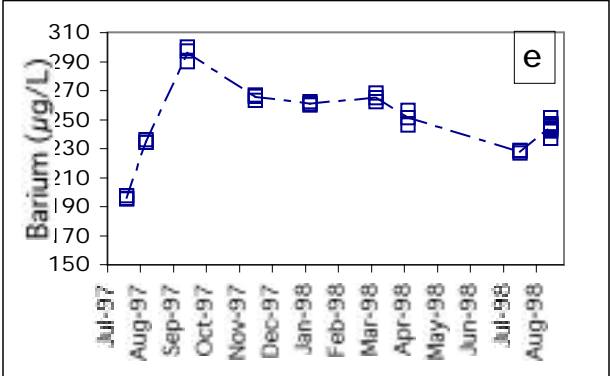
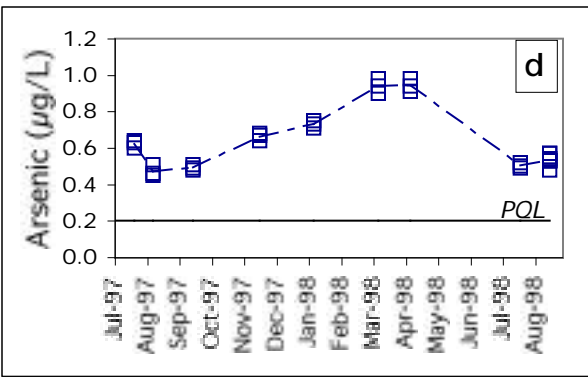
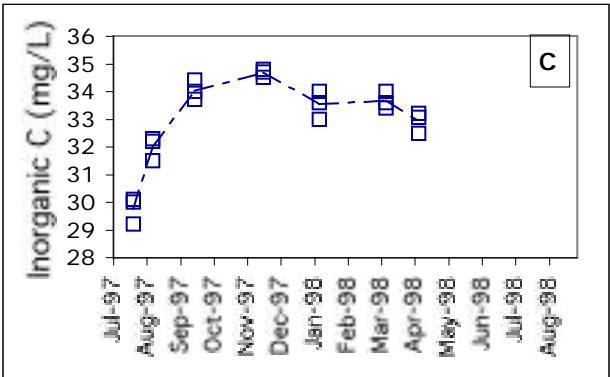
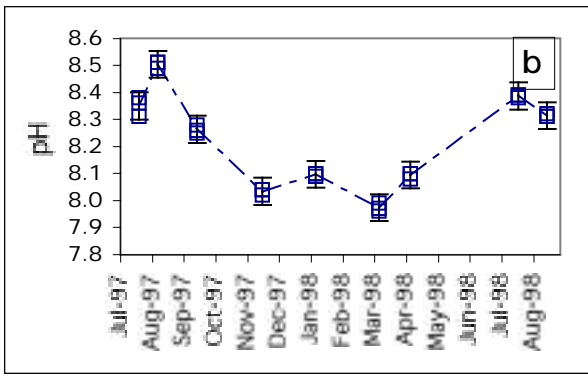
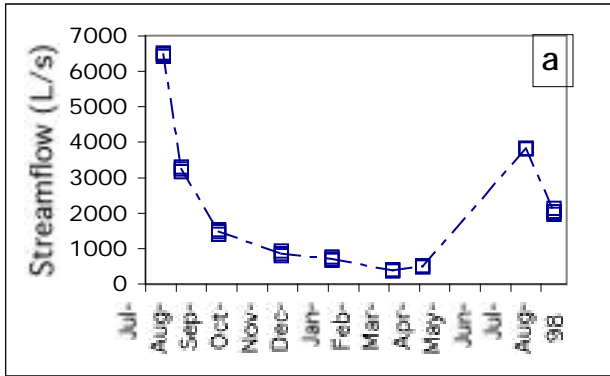
(Triangles indicate first sampling event, 7/20/97)



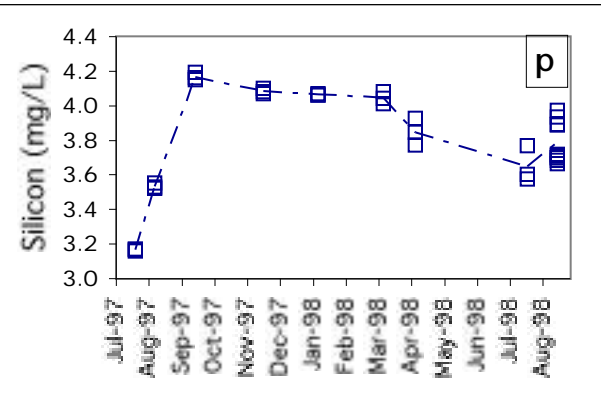
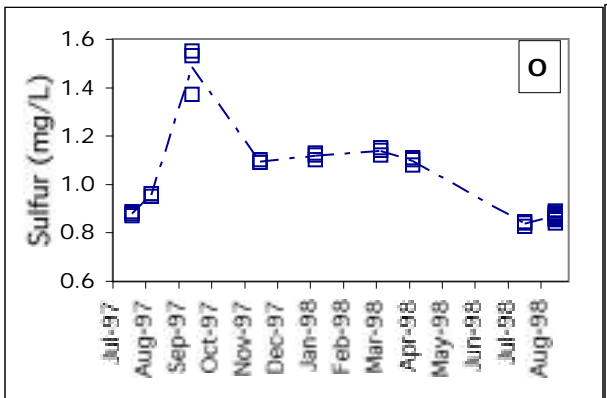
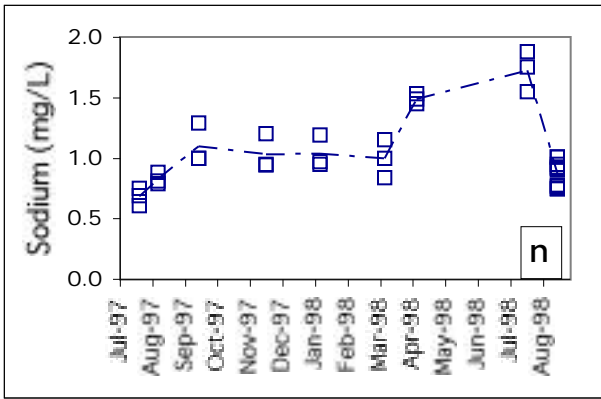
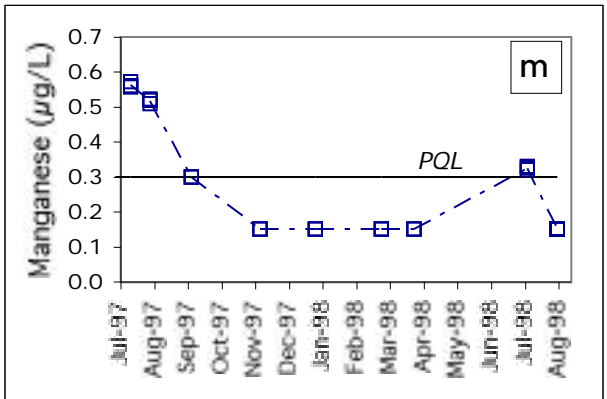
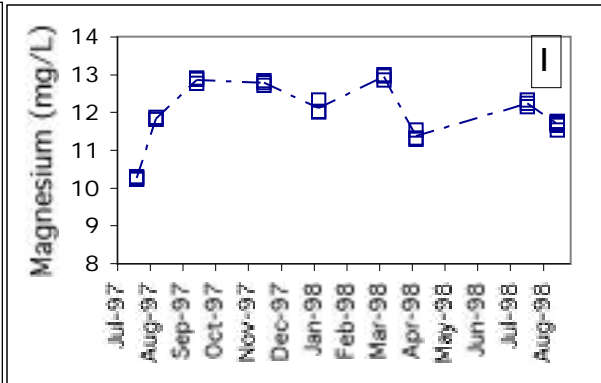
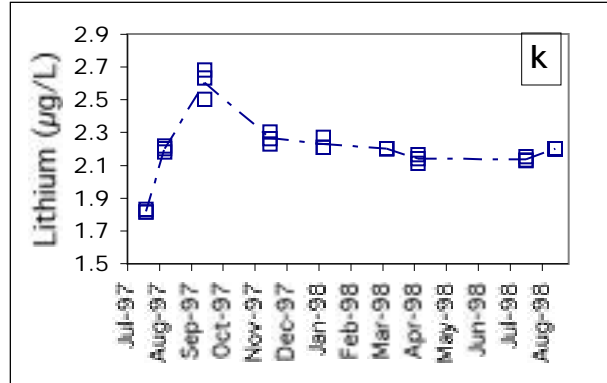
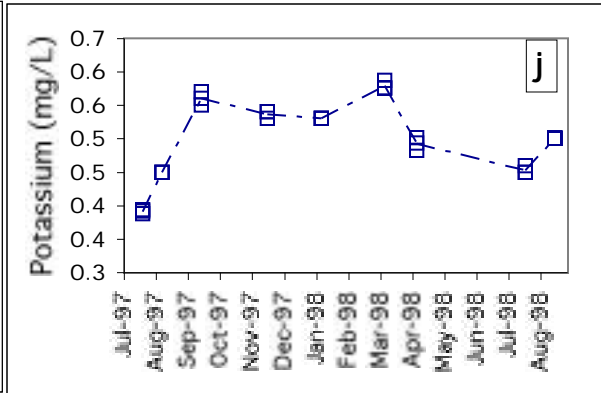
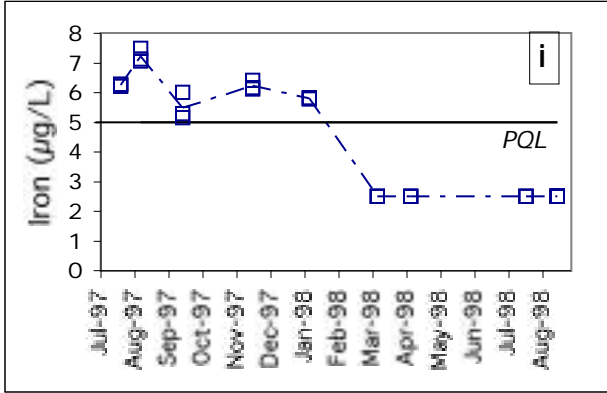
Figures 14i-14n: Streamflow vs. concentrations at Landers Fork "LD"



Figures 15a-15h: Trends over time at Landers Fork site "LD"



Figures 15i-15p: Trends over time at Landers Fork site "LD"



Figures 15q-15r: Trends over time at Landers Fork site "LD"

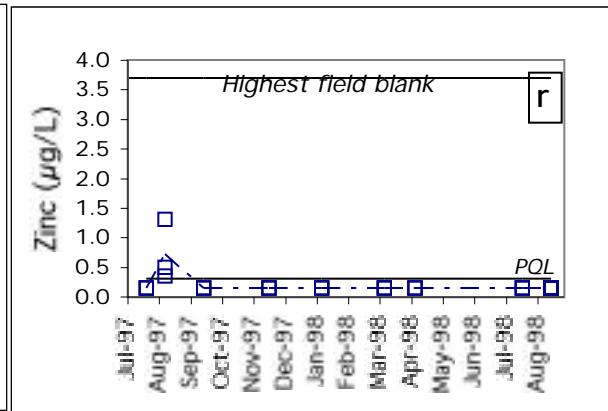
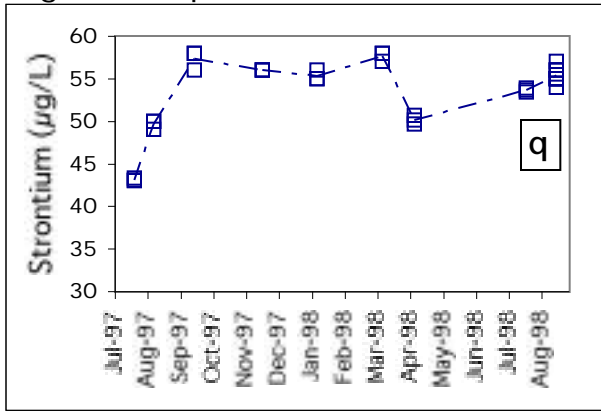


Figure 16a: Inorganic carbon, Ca, and Mg loads at site LD

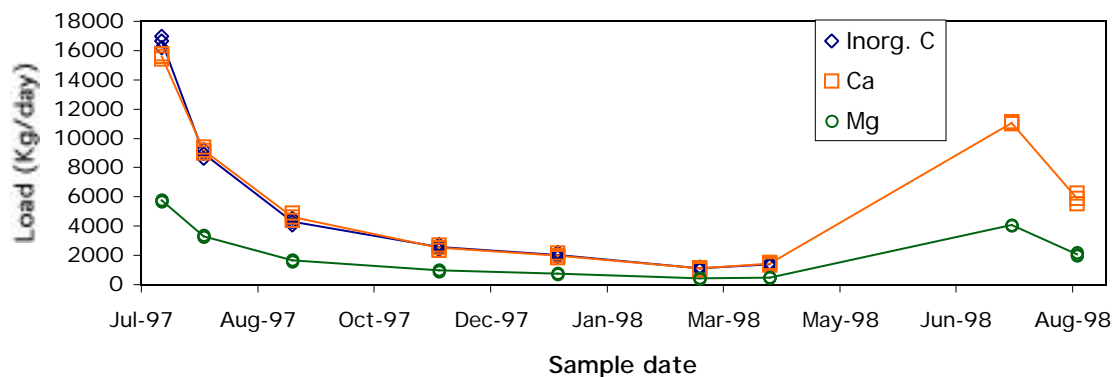


Figure 16b: Na, S, and Si loads at site LD

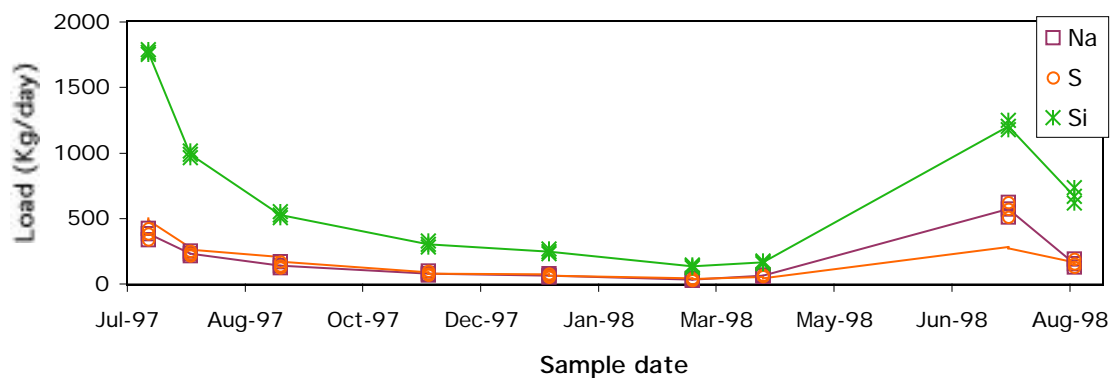


Figure 16c: As and Mn loads at site LD

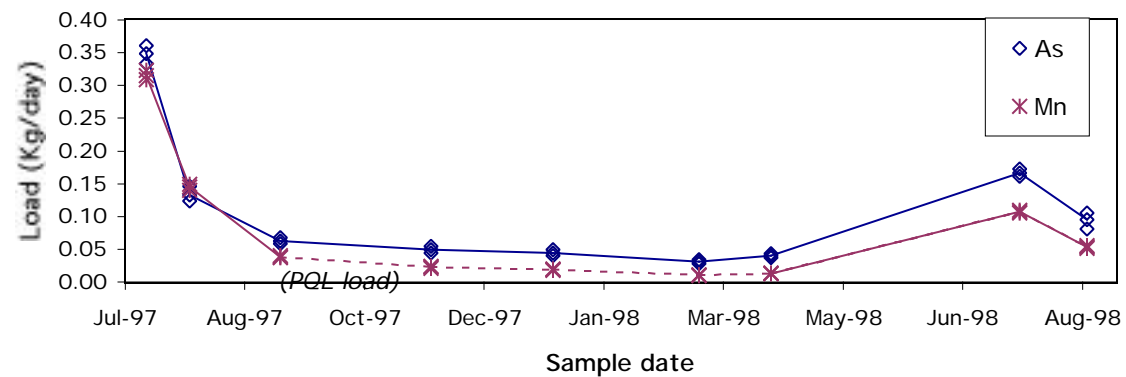


Figure 16d: Ba, K, Sr loads at site LD

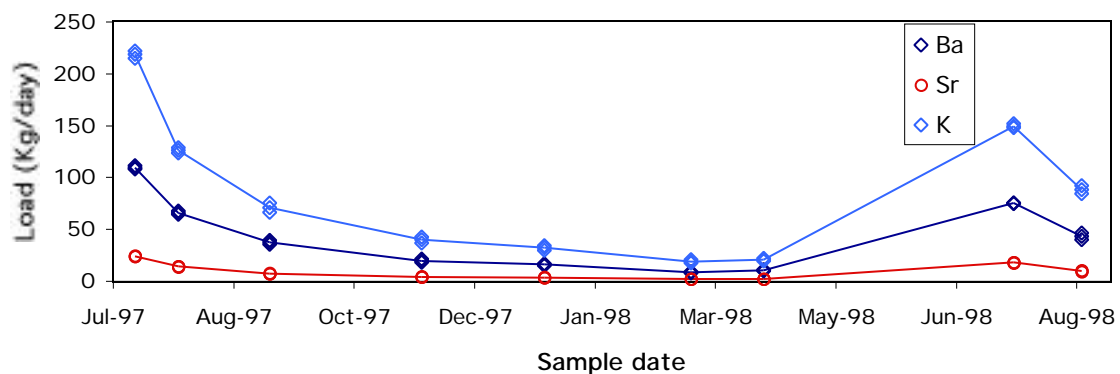
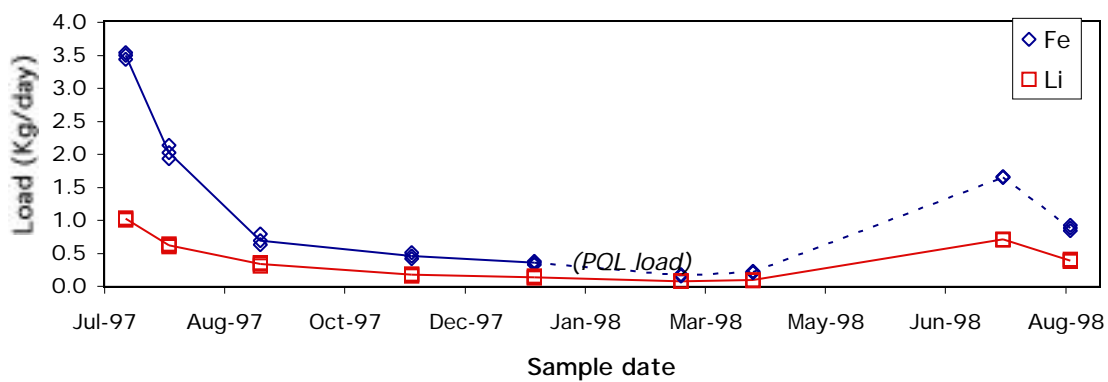
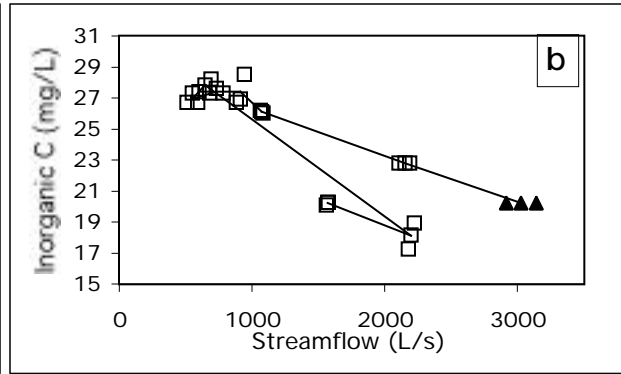
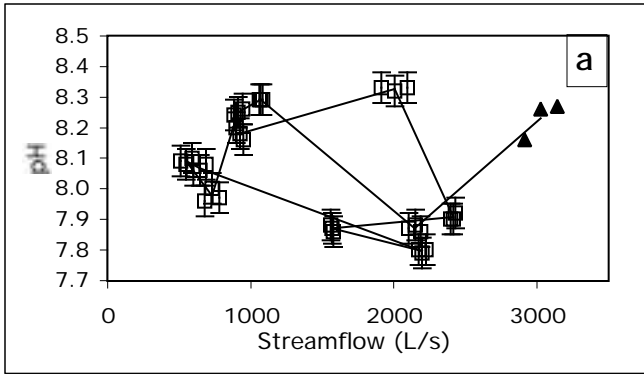


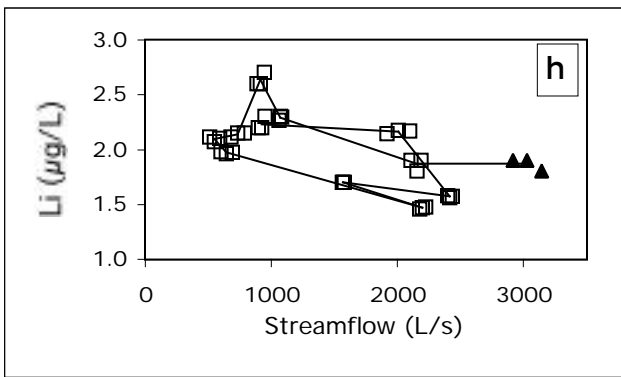
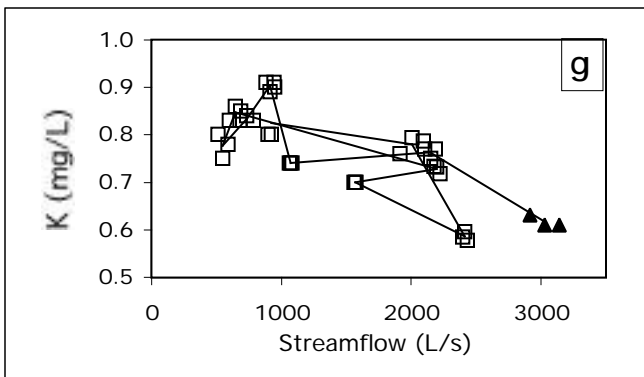
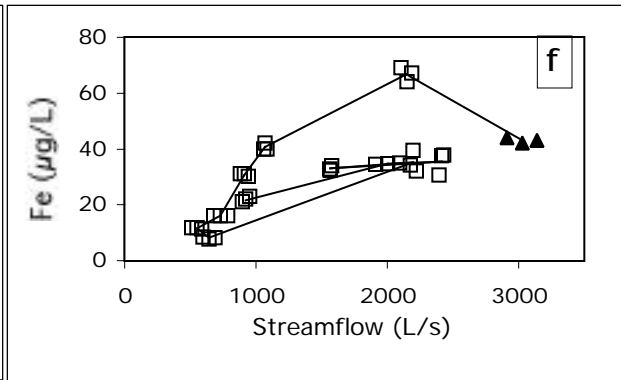
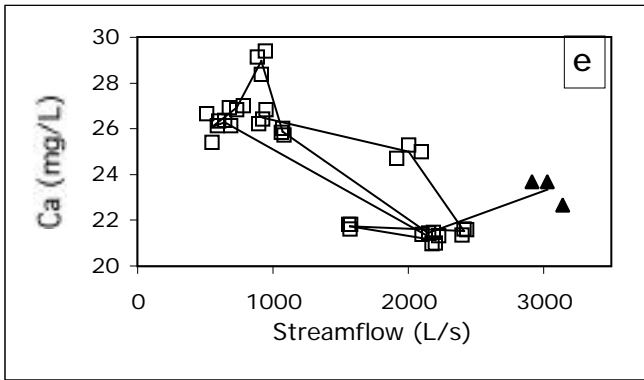
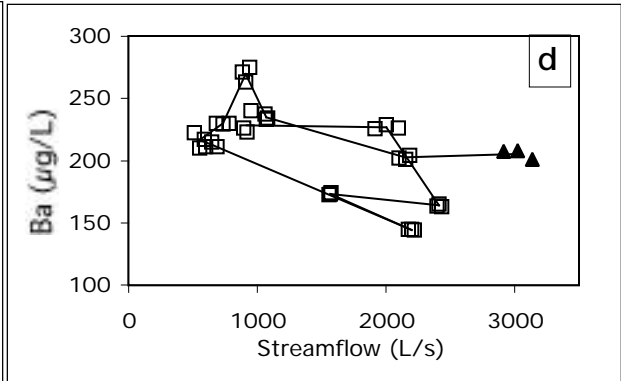
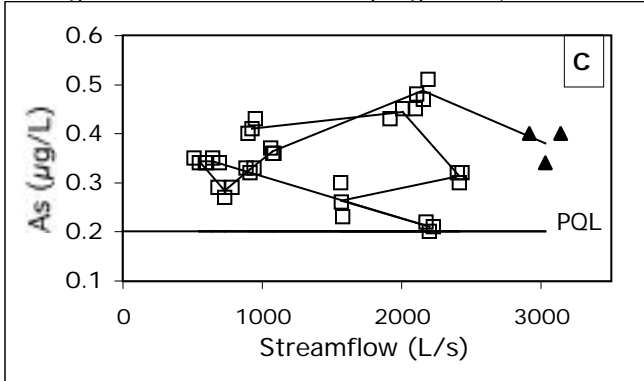
Figure 16e: Fe and Li loads at site LD



Figures 17a-17h: Streamflow v. concentrations at Blackfoot River site "BH"



Triangles indicate the first sampling event, on 7/4/97



Figures 17i-17o: Streamflow v. concentrations at Blackfoot River site "BH"

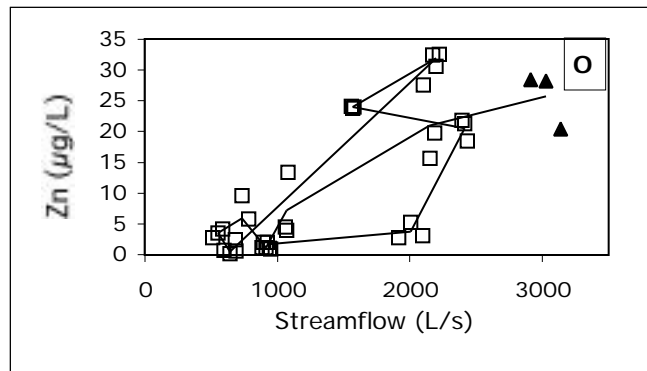
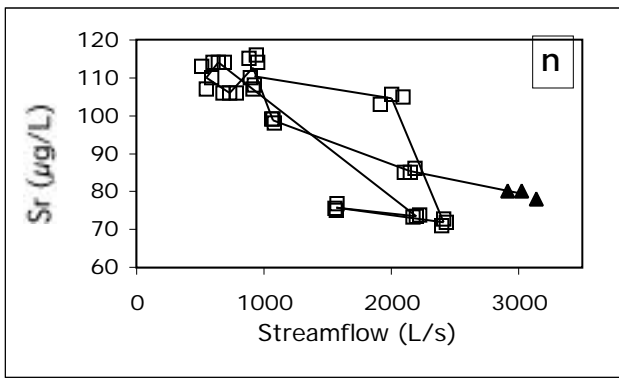
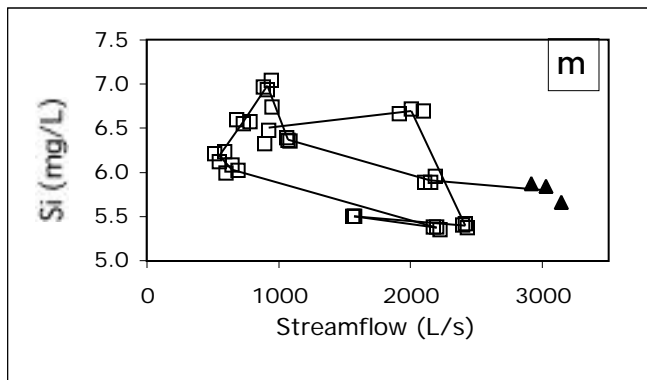
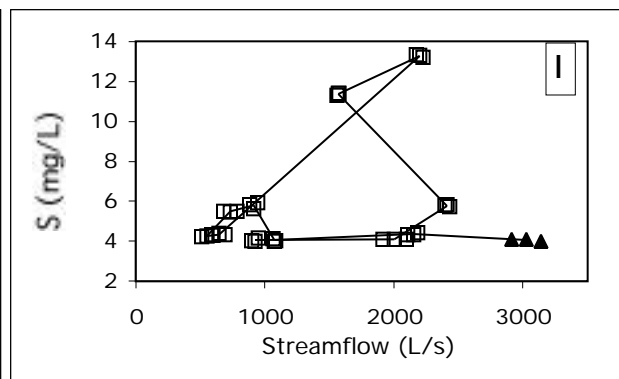
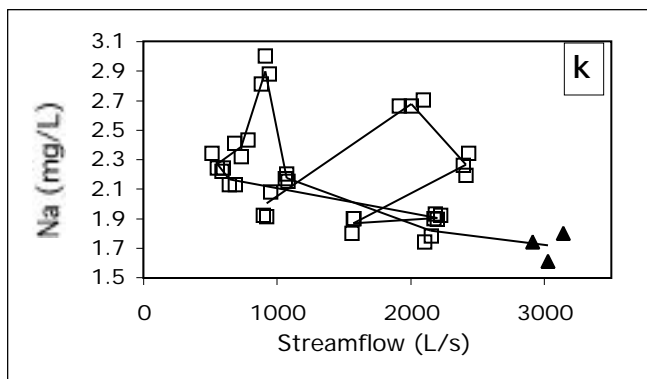
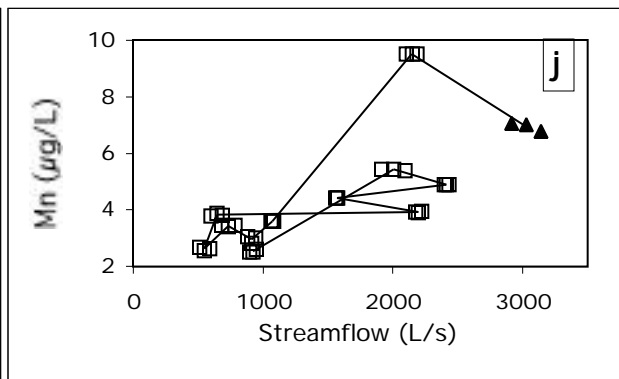
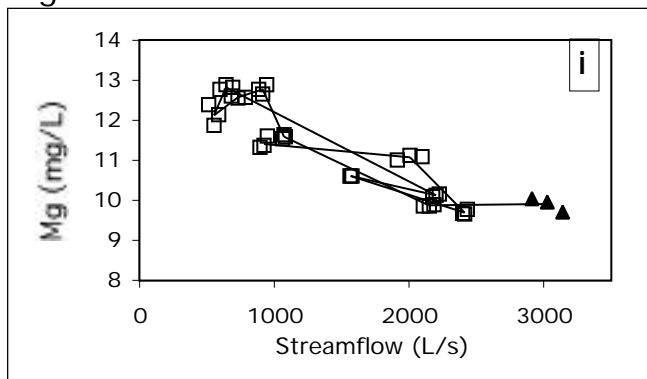


Figure 18a-18h: Trends over time at Blackfoot River site "BH"

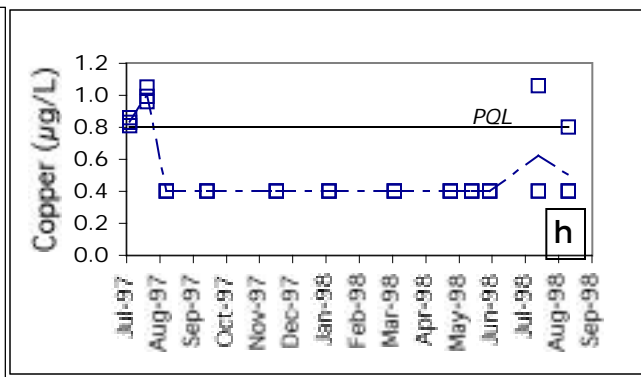
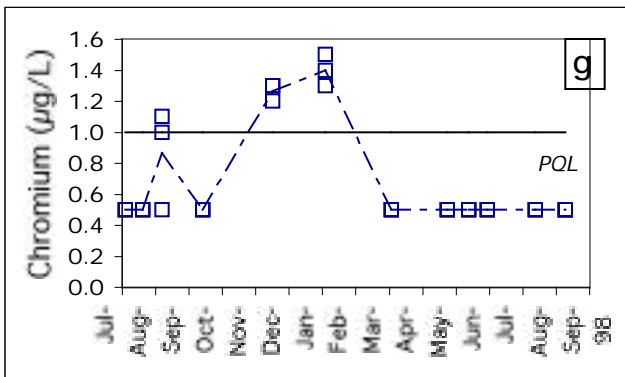
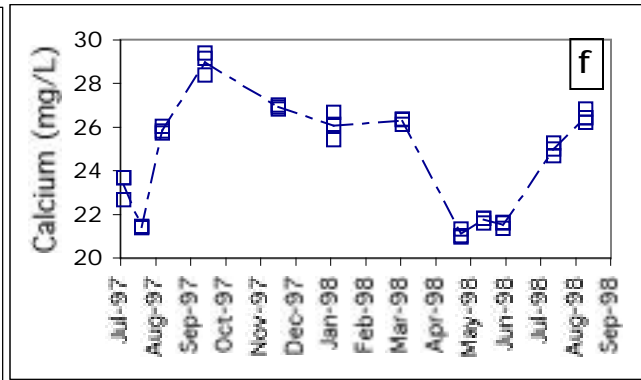
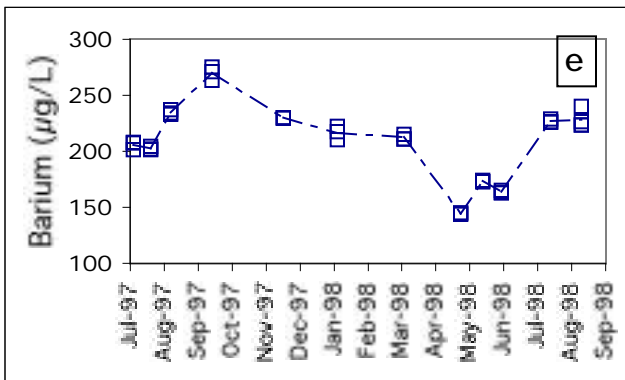
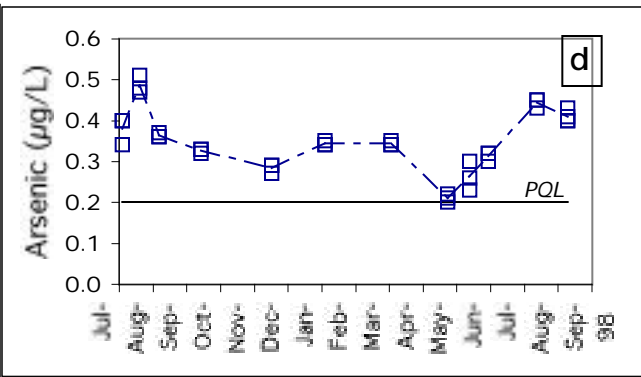
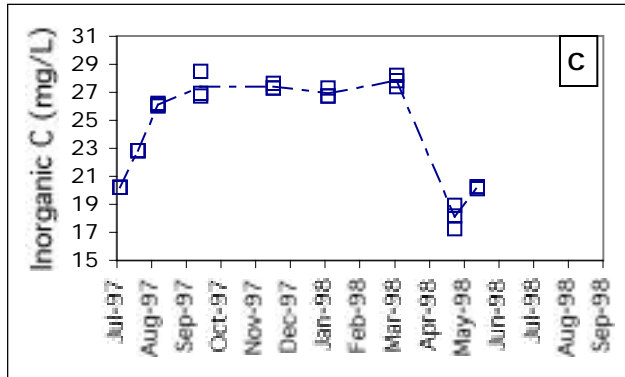
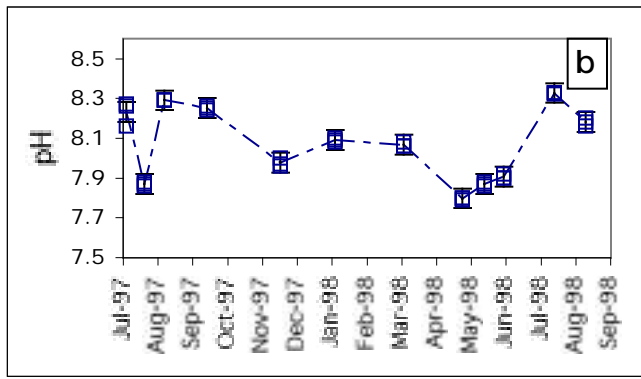
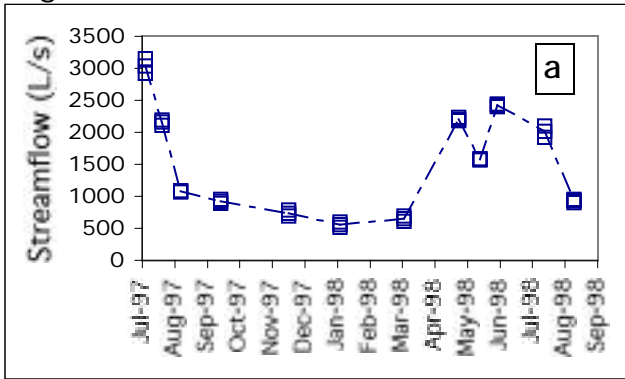


Figure 18i-18p: Trends over time at Blackfoot River site "BH"

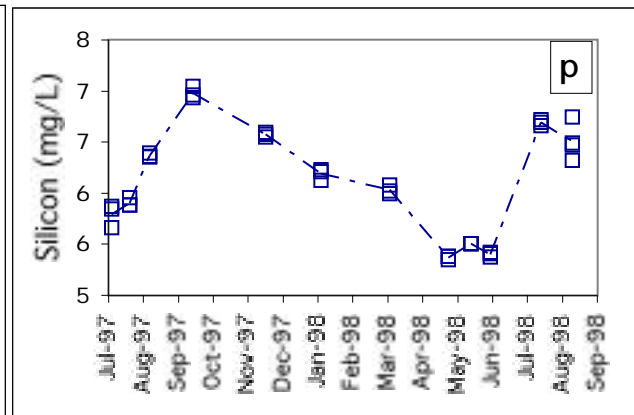
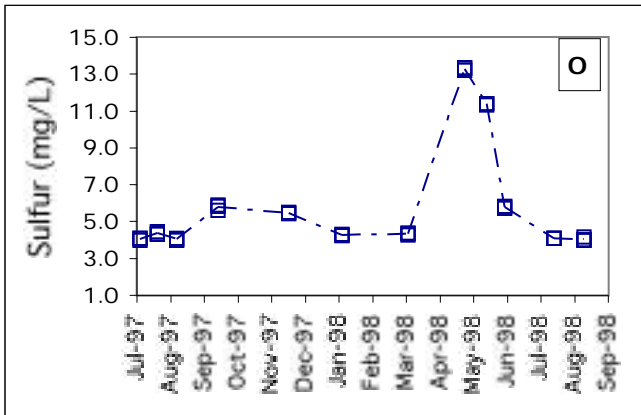
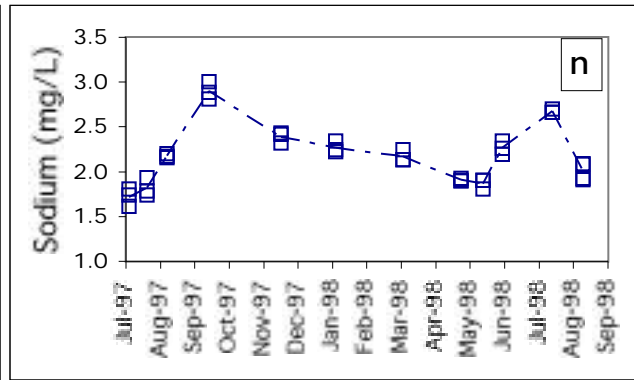
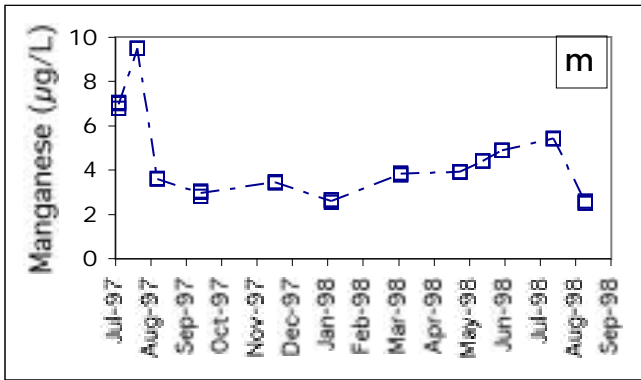
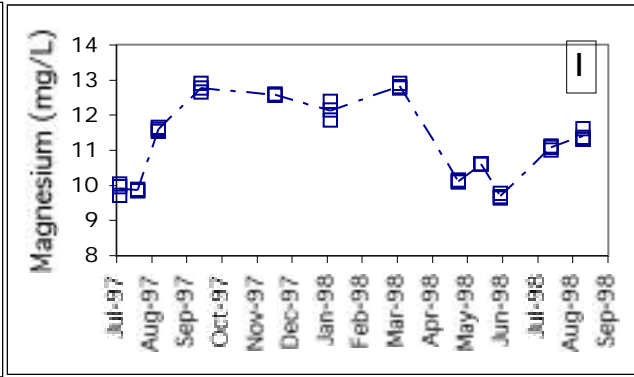
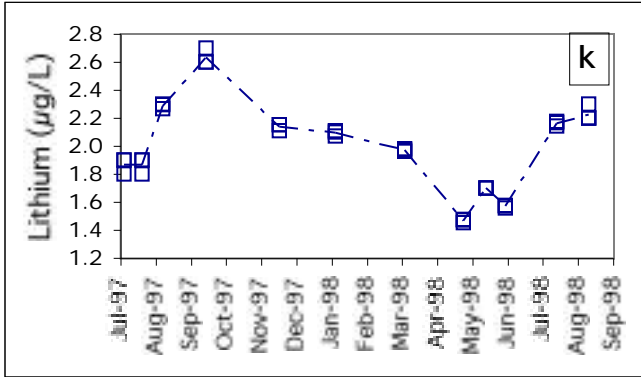
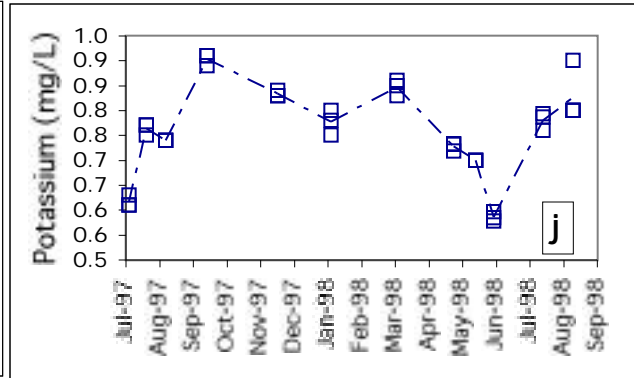
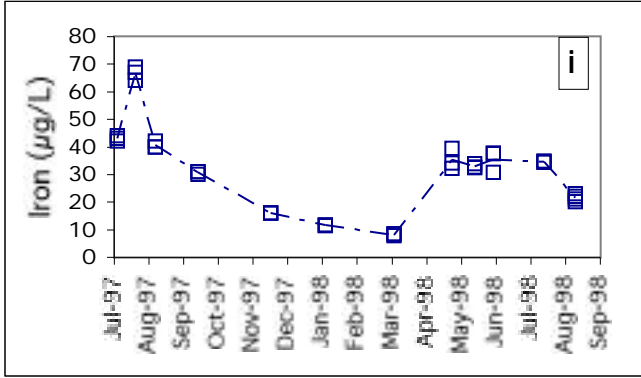


Figure 18q-18r: Trends over time at Blackfoot River site "BH"

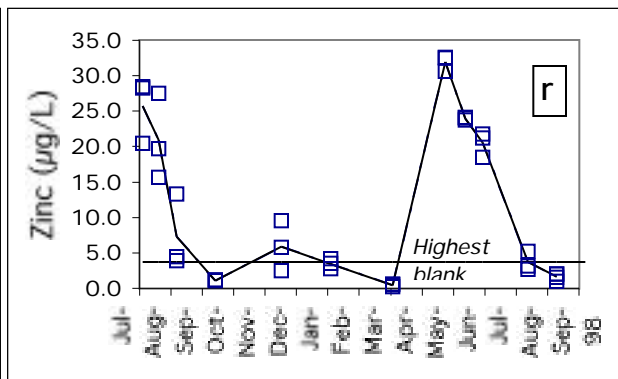
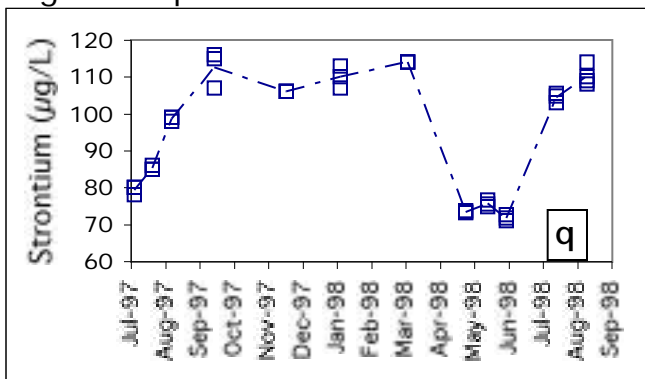


Figure 19a: Inorganic carbon, Ca, and Mg loads at site BH

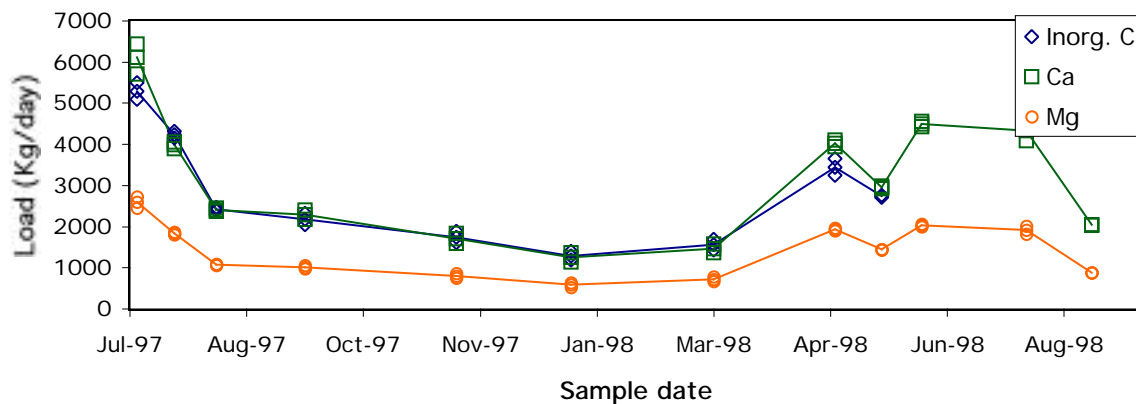


Figure 19b: As, Cr, Cu, and Li loads at site BH

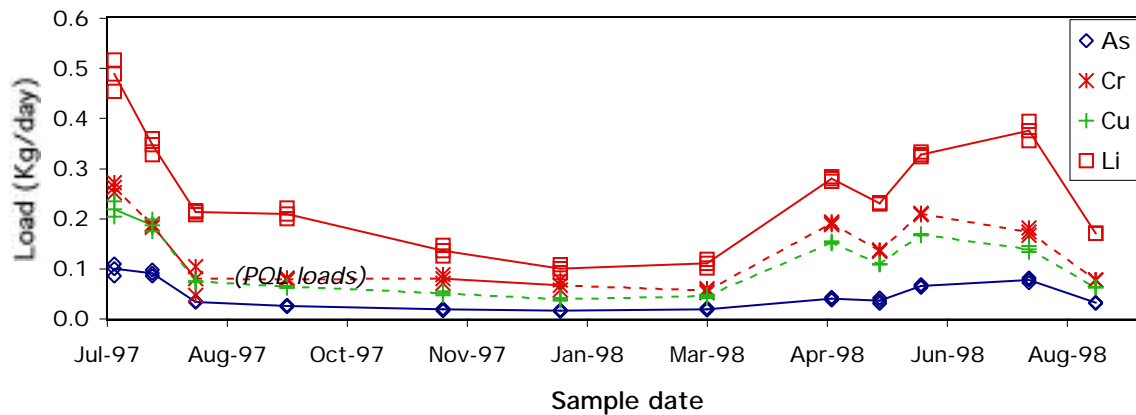


Figure 19c: Ba, Fe, K, and Sr loads at site BH

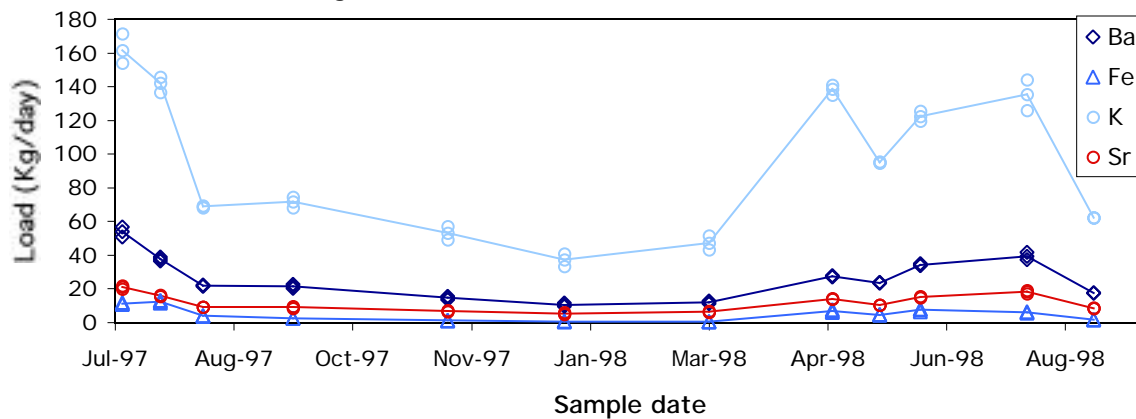


Figure 19d: Mn and Zn loads at site BH

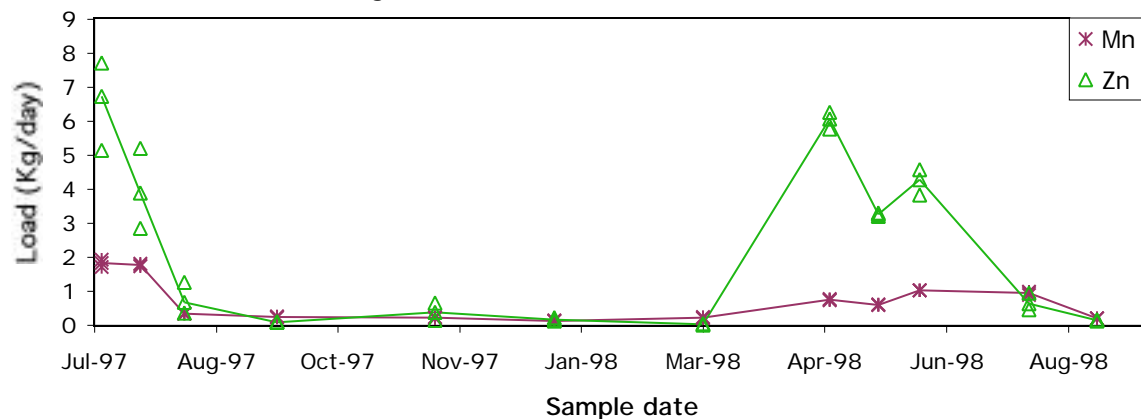
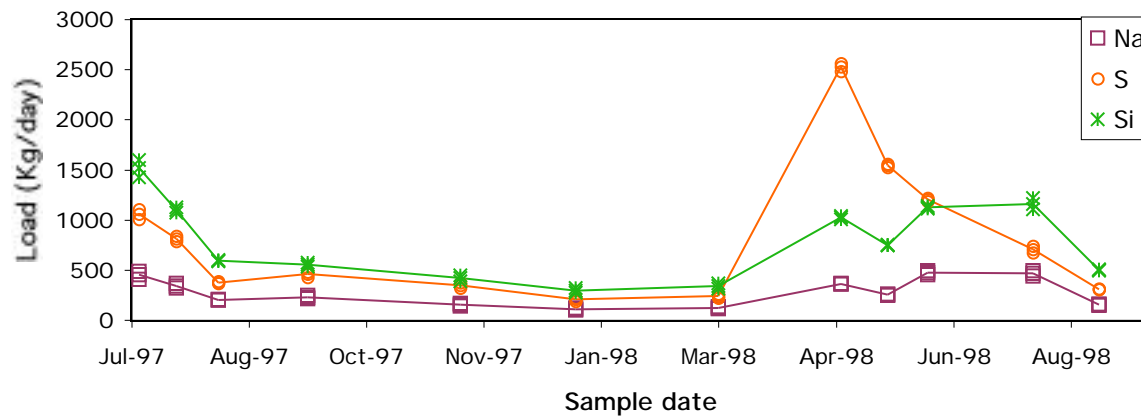
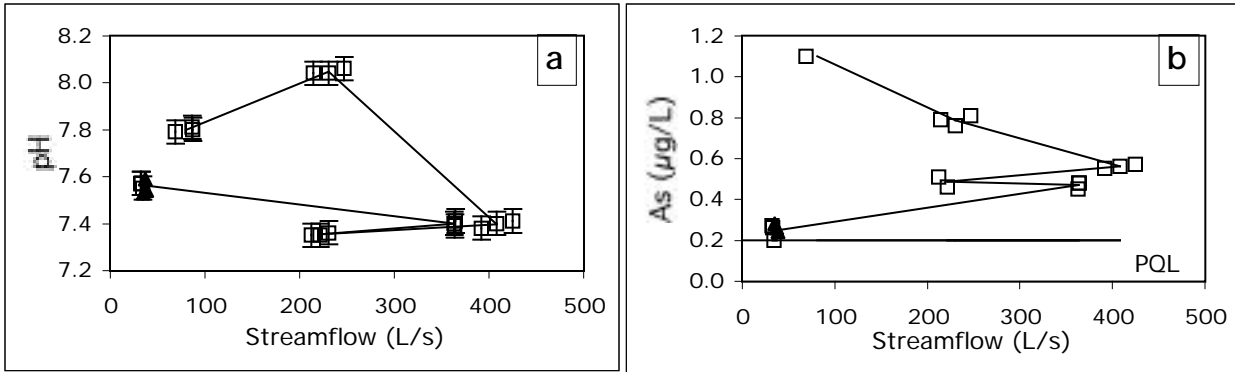


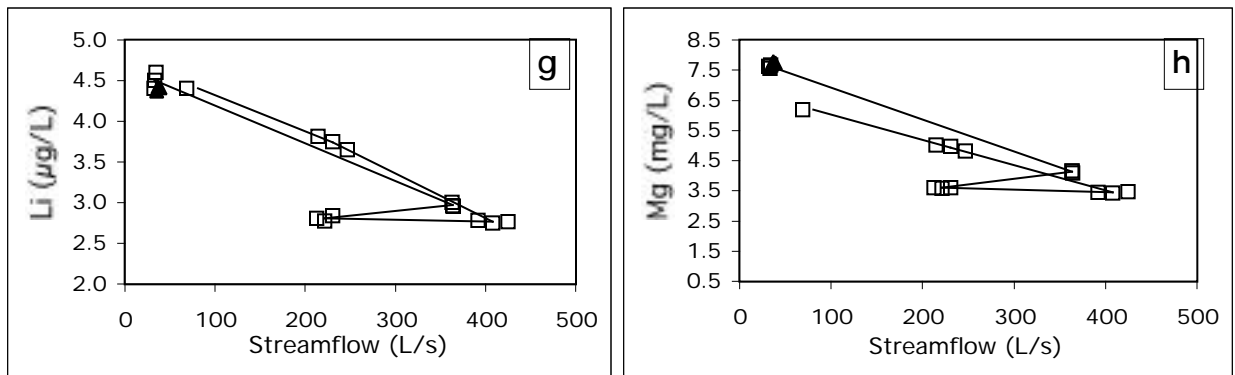
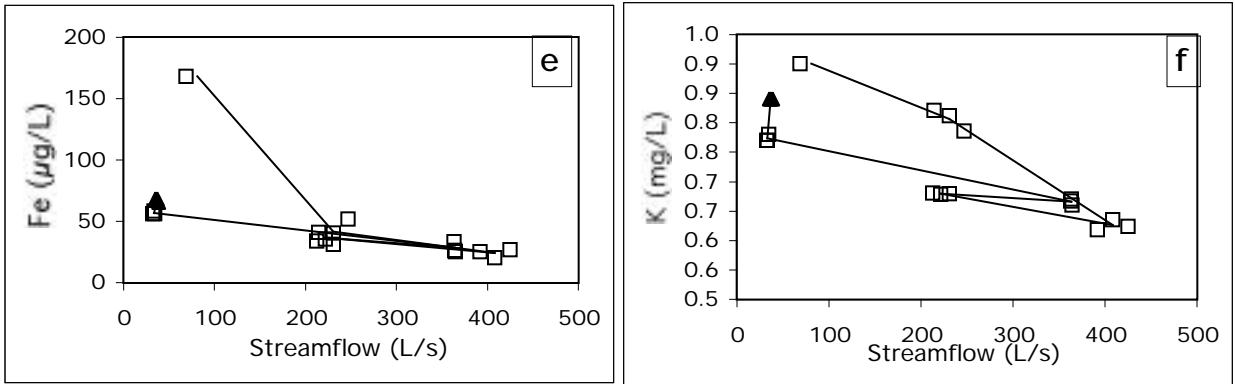
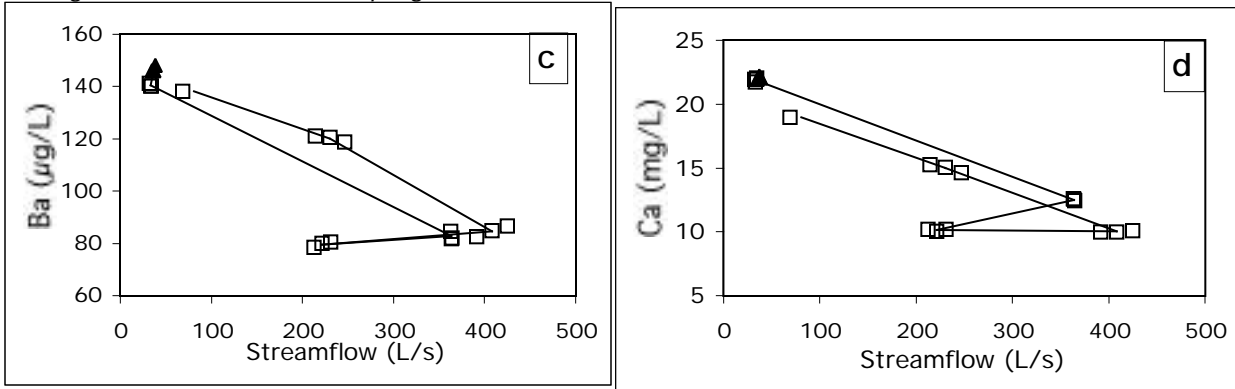
Figure 19e: Na, S, and Si loads at site BH



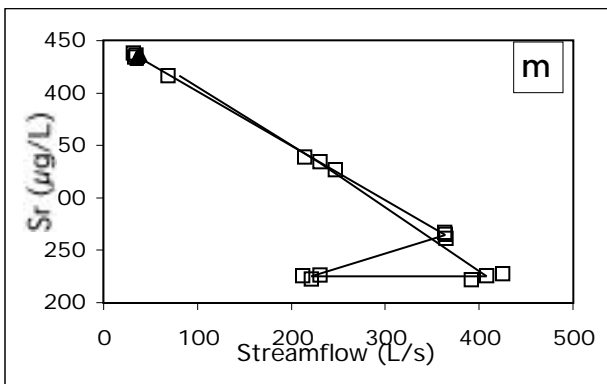
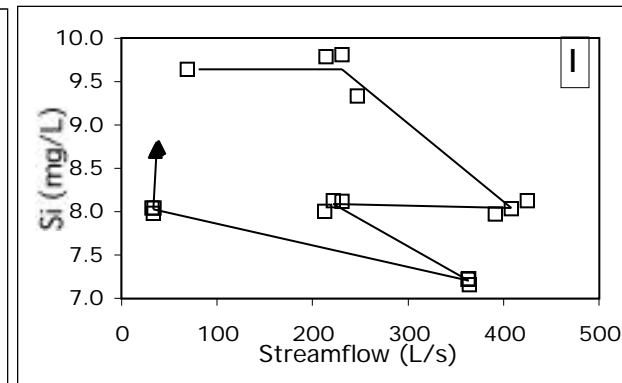
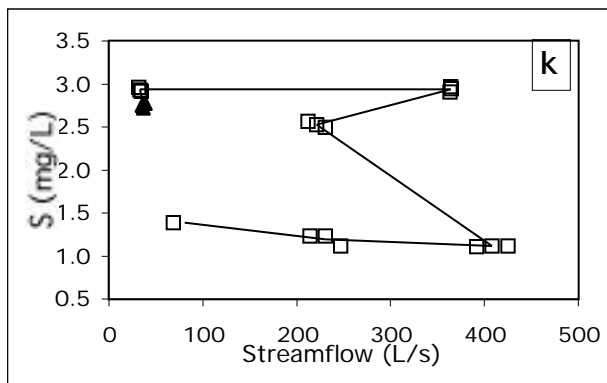
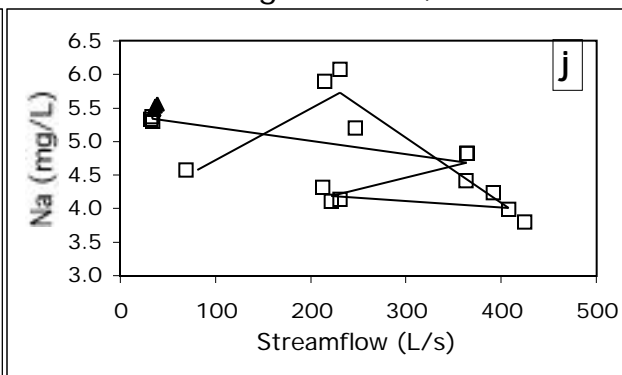
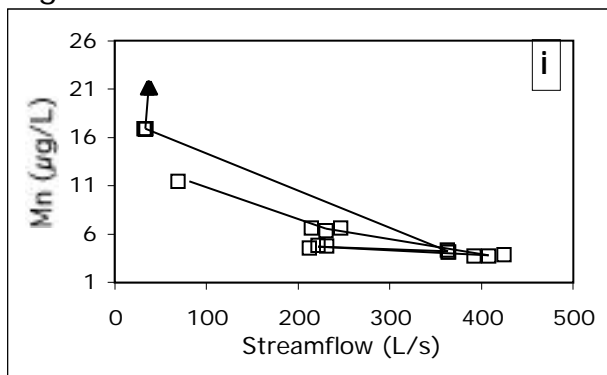
Figures 20a-20h: Streamflow vs. concentrations at Hogum Creek, site "HC"



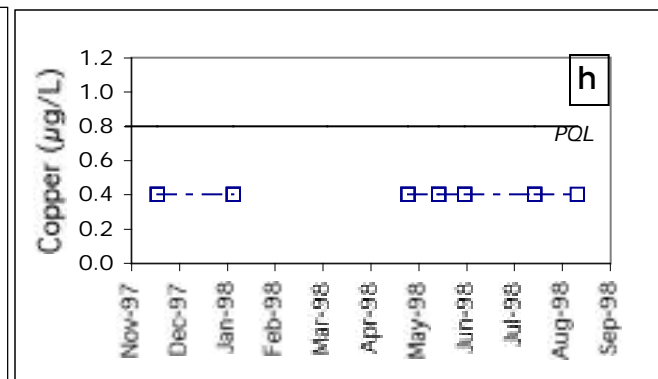
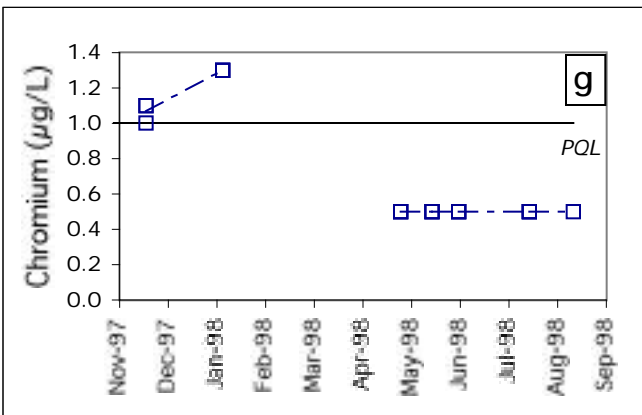
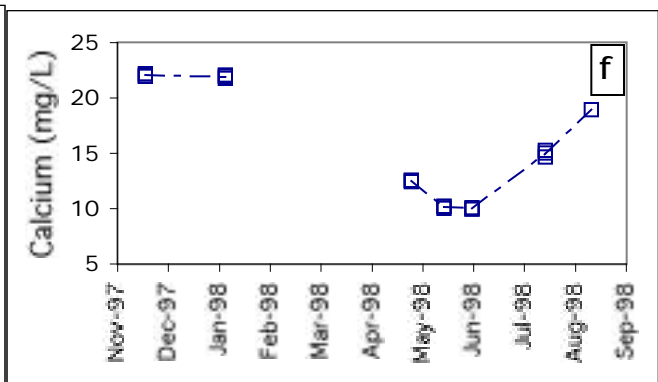
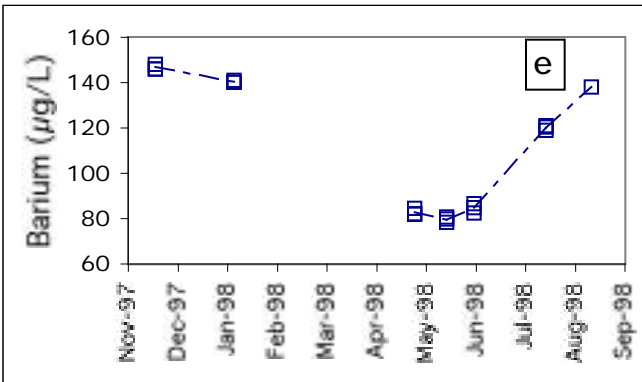
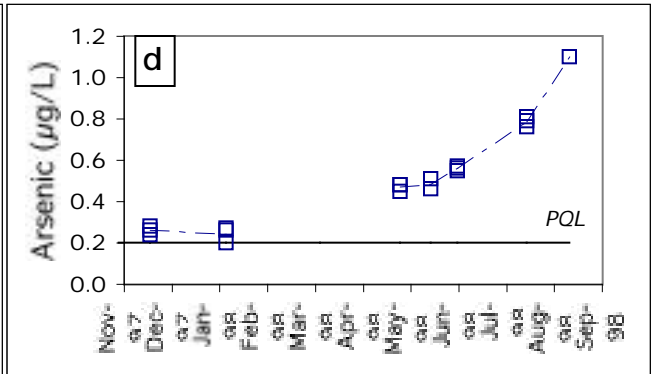
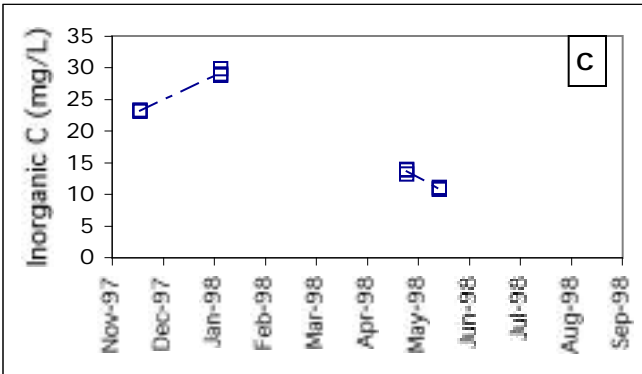
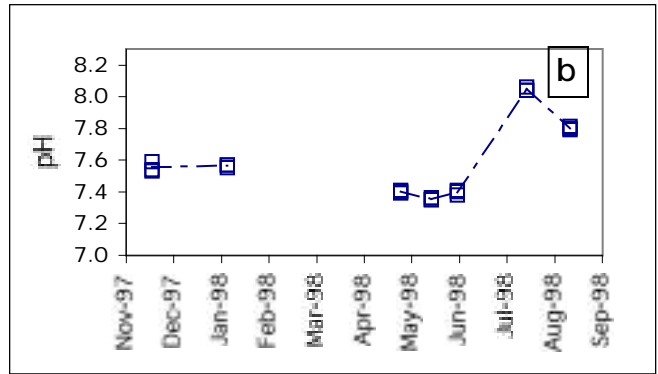
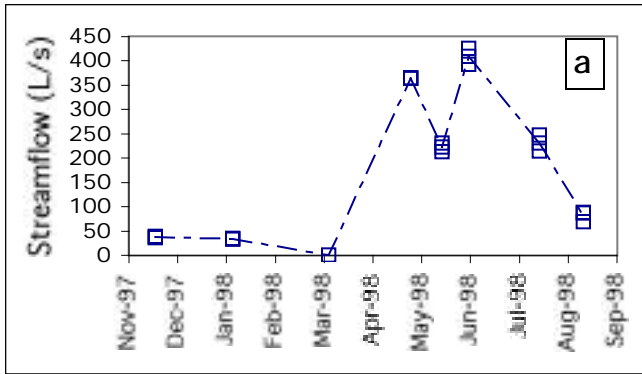
Triangles indicate the first sampling event, on 11/18/97



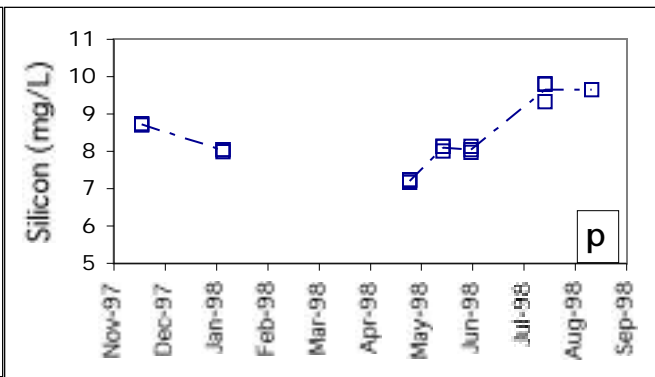
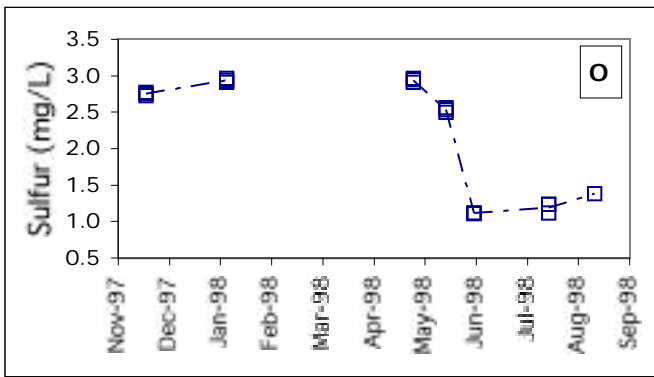
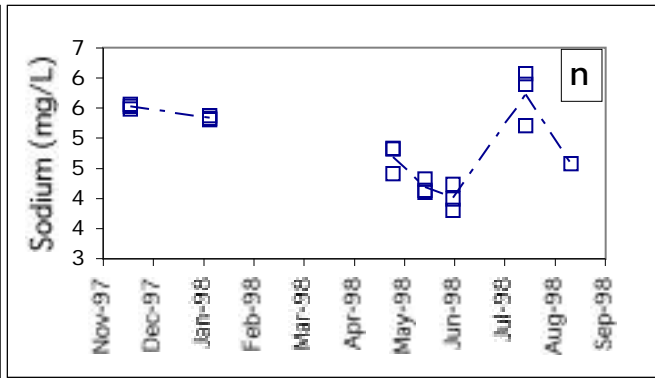
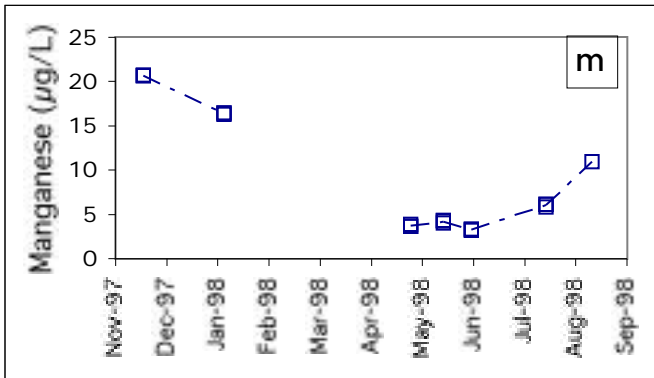
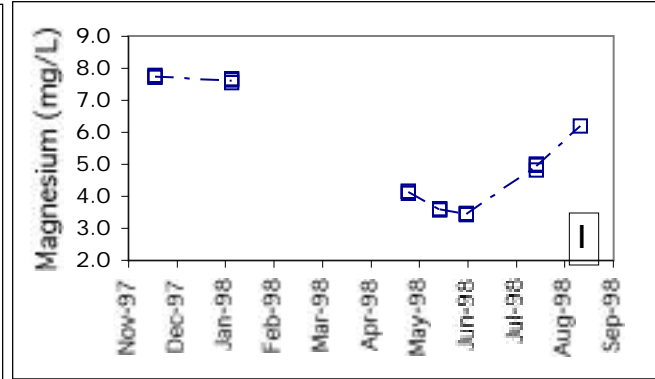
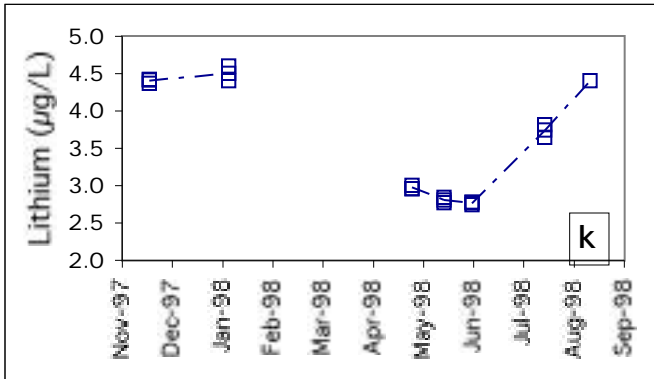
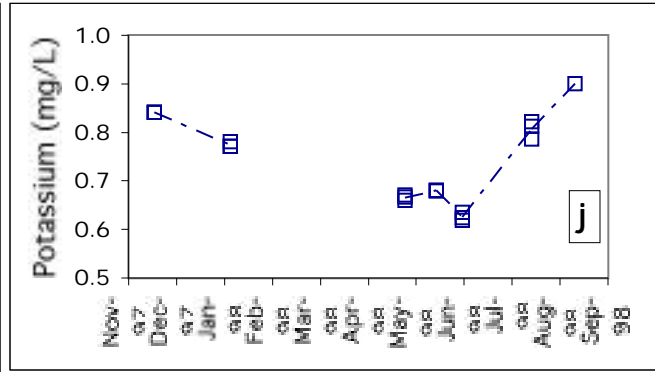
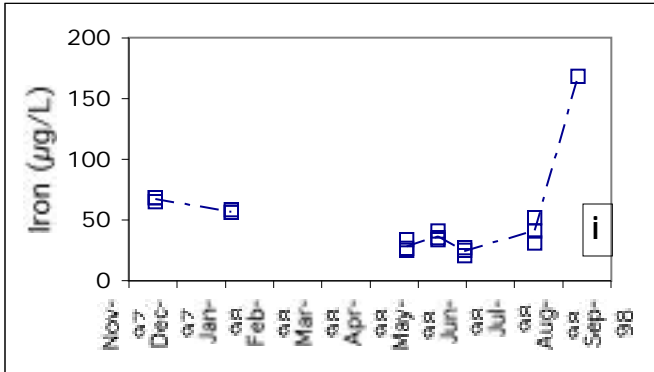
Figures 20i-20m: Streamflow vs. concentrations at Hogum Creek, site "HC"



Figures 21a-21h: Trends over time at Hogum Creek, site "HC"



Figures 21i-21l: Trends over time at Hogum Creek, site "HC"



Figures 21q-21r: Trends over time at Hogum Creek, site "HC"

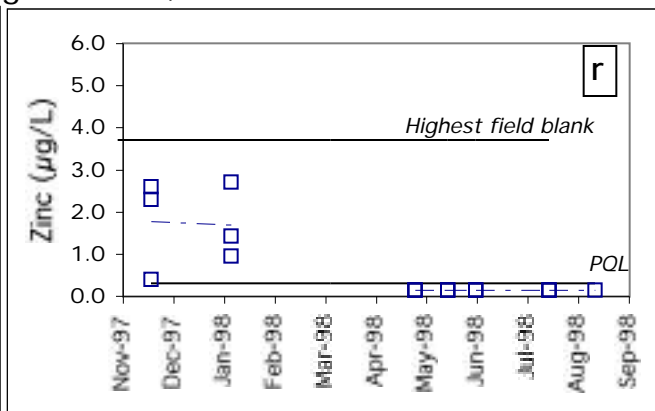
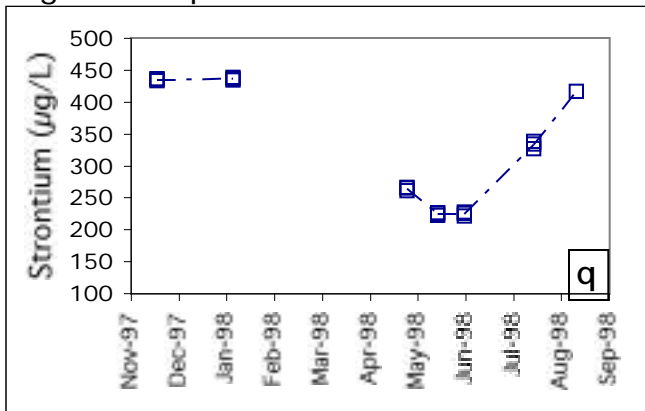


Figure 22a: Inorganic carbon, Ca, and Mg loads at site HC

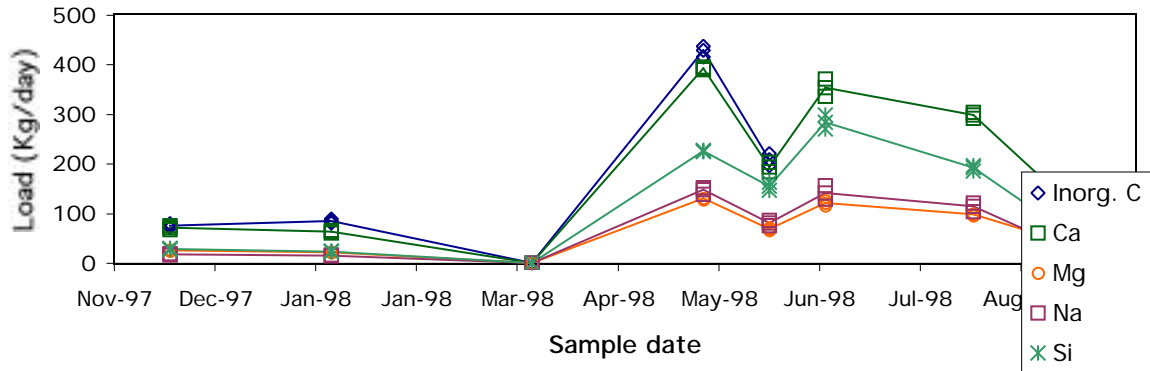


Figure 22b: As and Cr loads at site HC

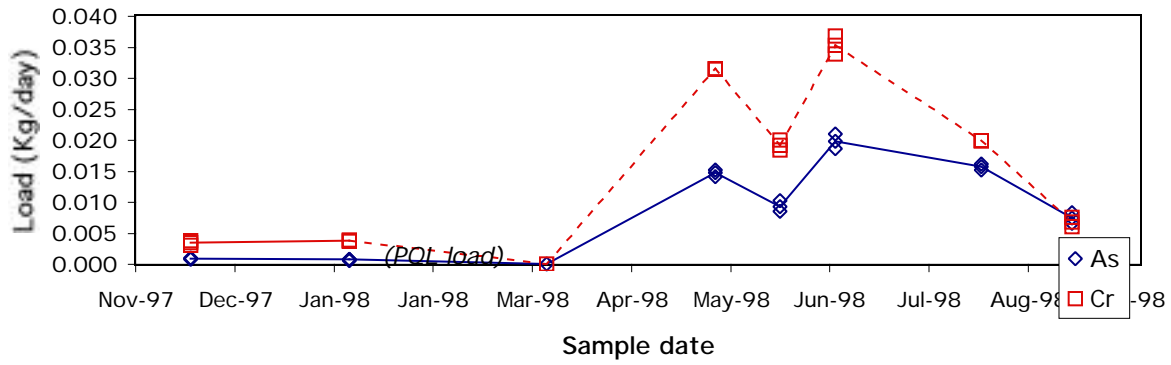


Figure 22c: Li and Mn loads at site HC

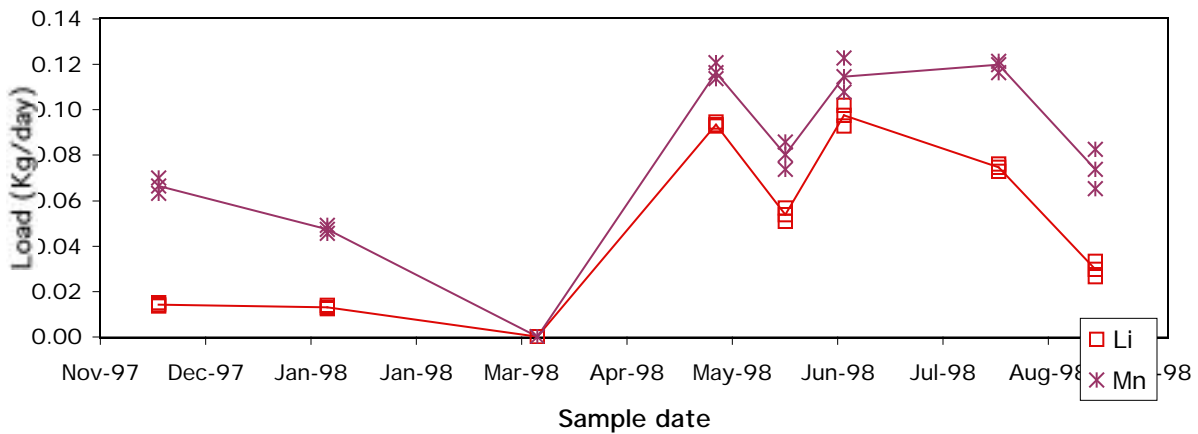


Figure 22d: Ba, Fe, and Sr loads at site HC

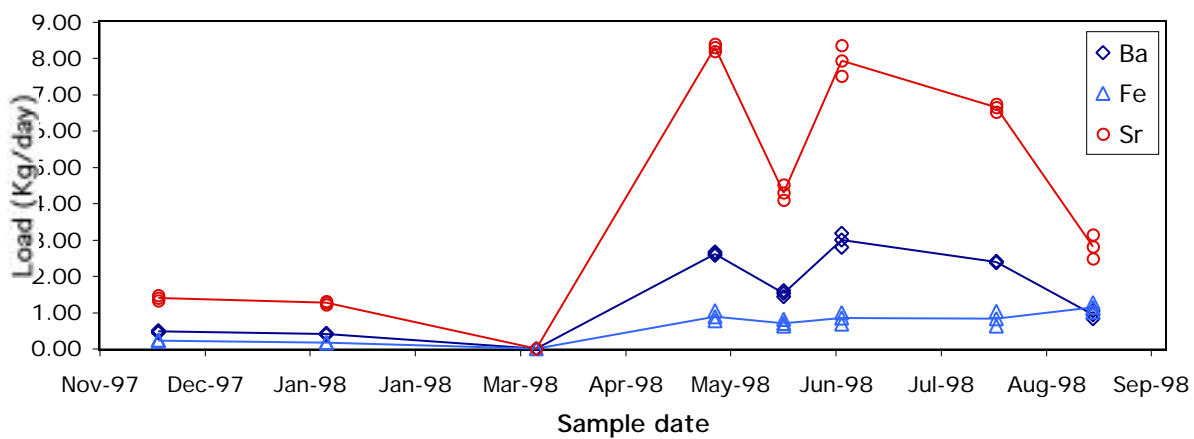
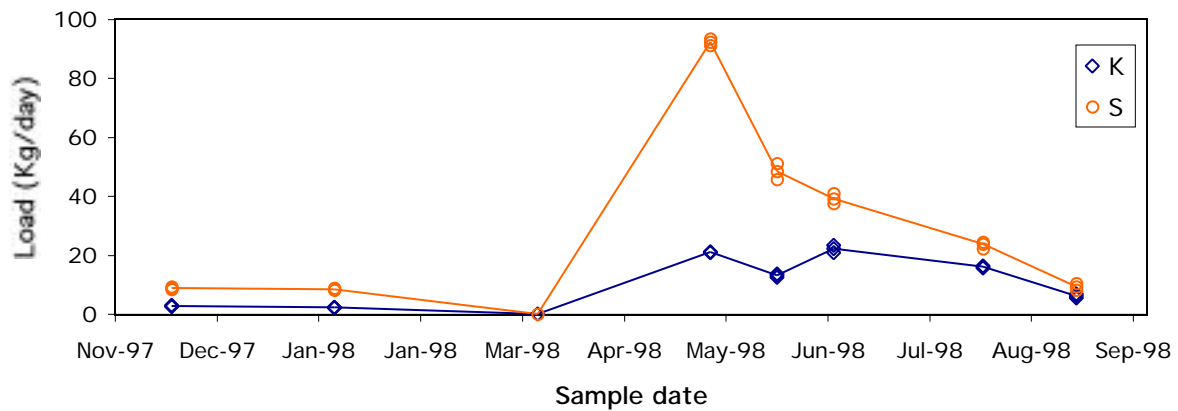
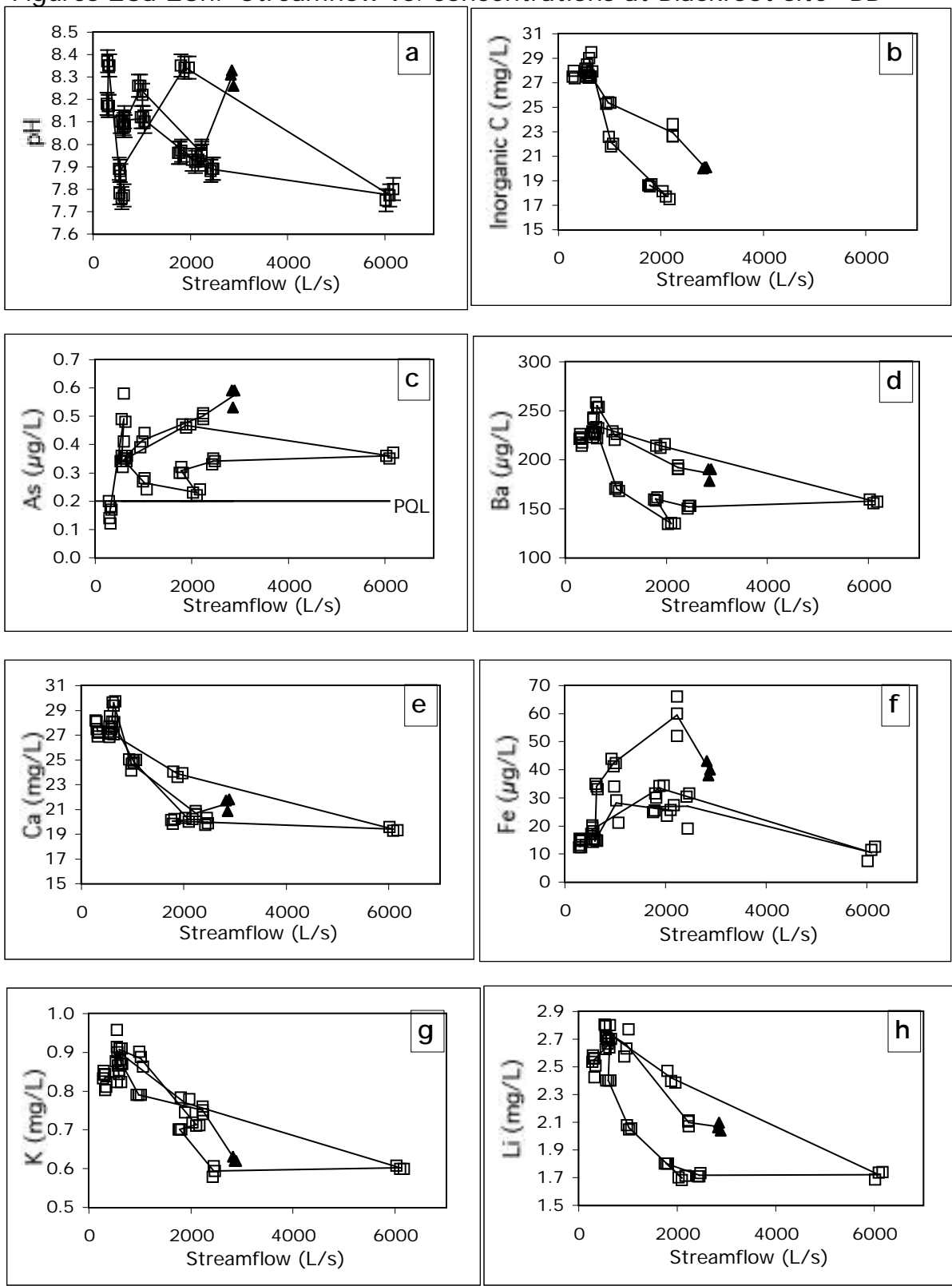


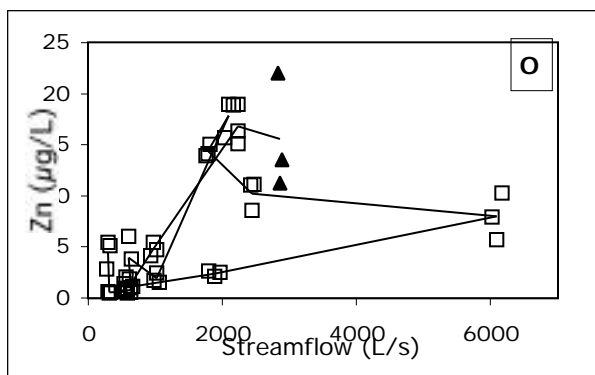
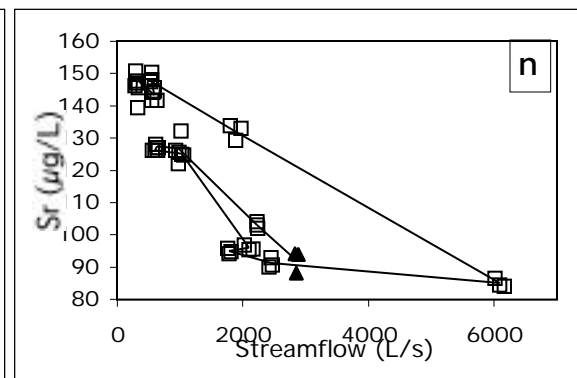
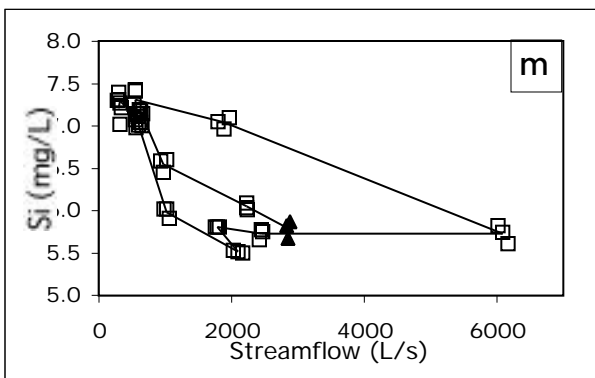
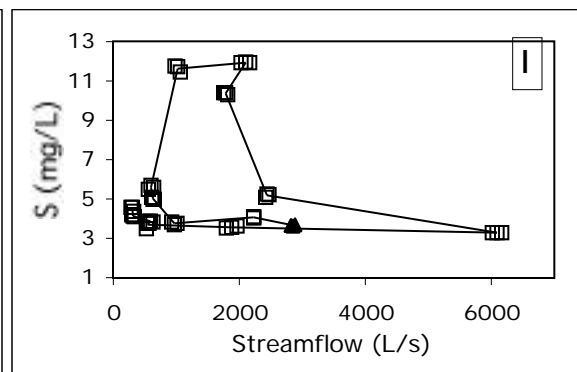
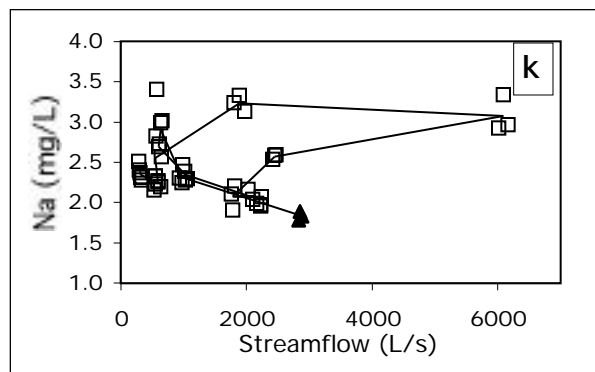
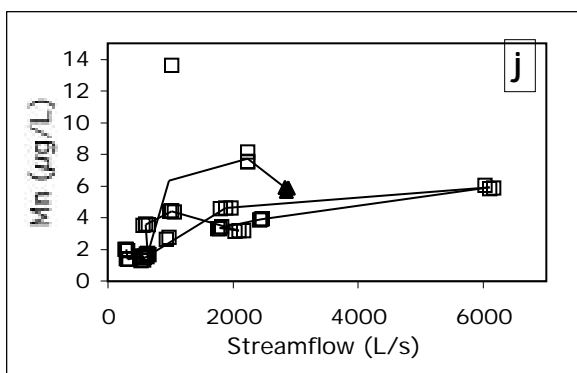
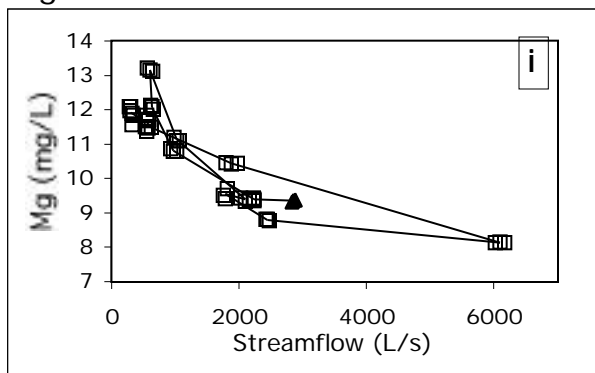
Figure 22e: K and S loads at site HC



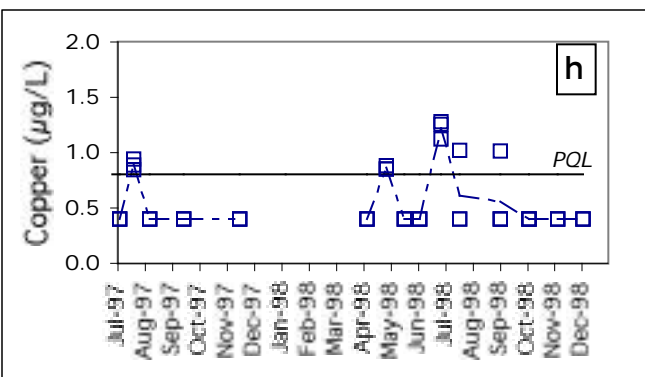
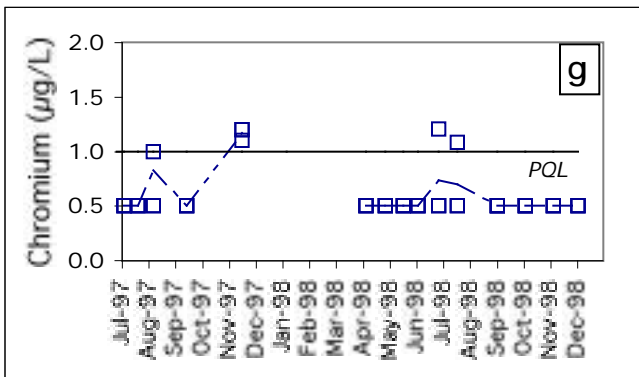
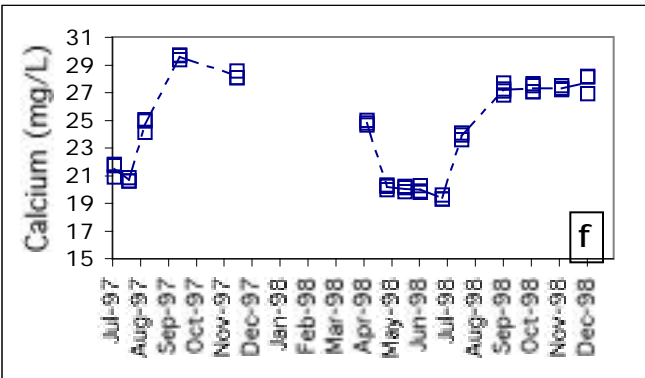
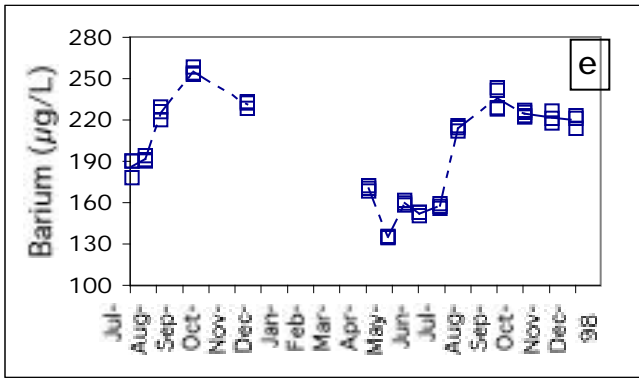
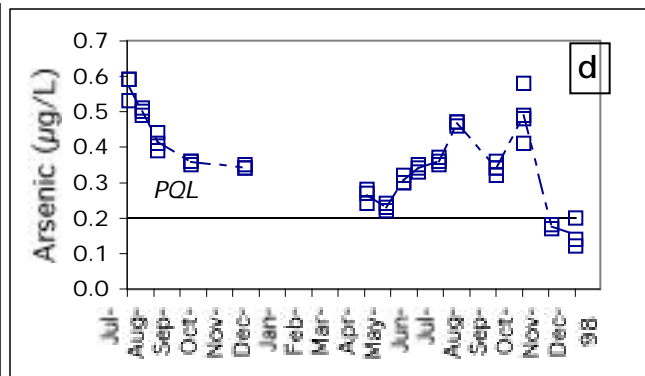
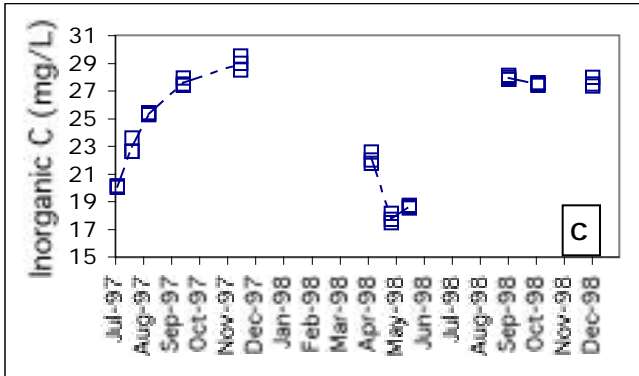
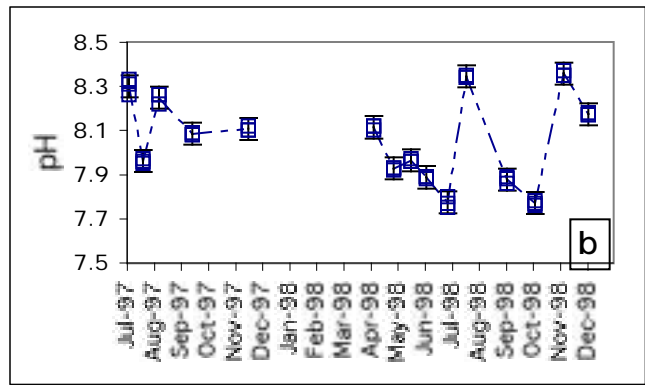
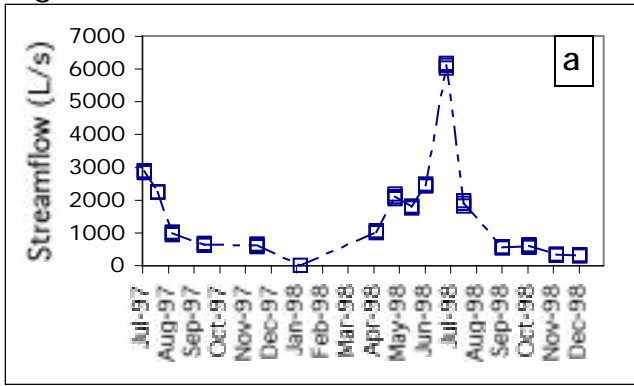
Figures 23a-23h: Streamflow vs. concentrations at Blackfoot site "BB"



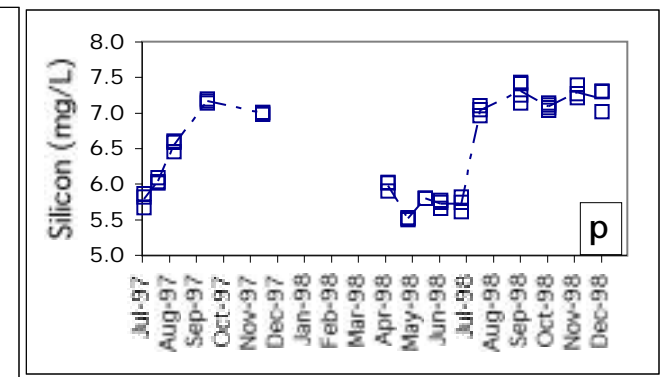
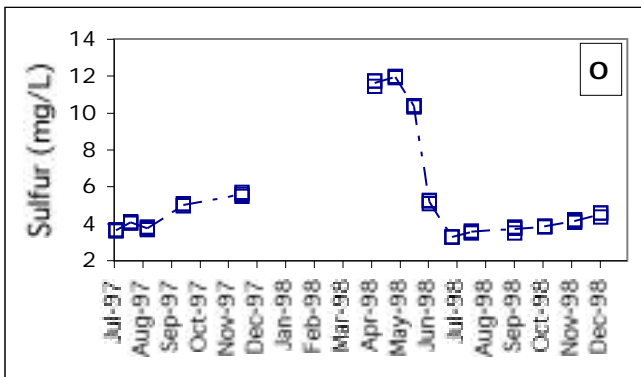
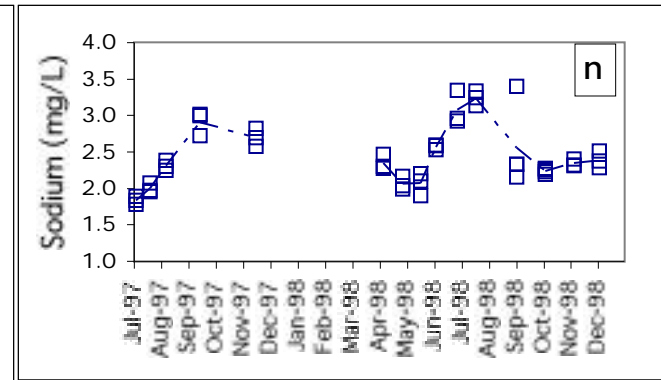
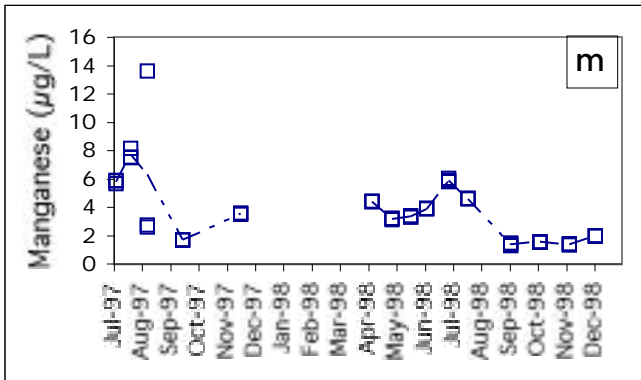
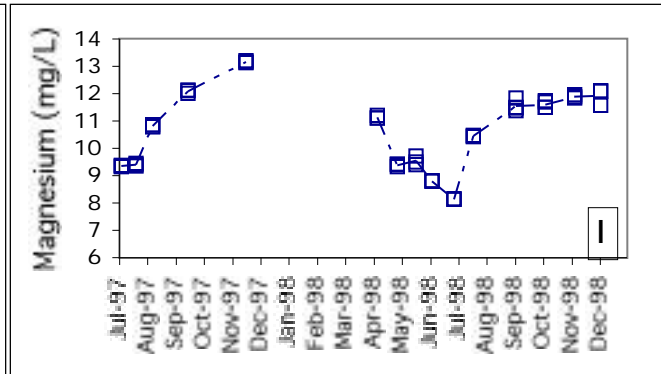
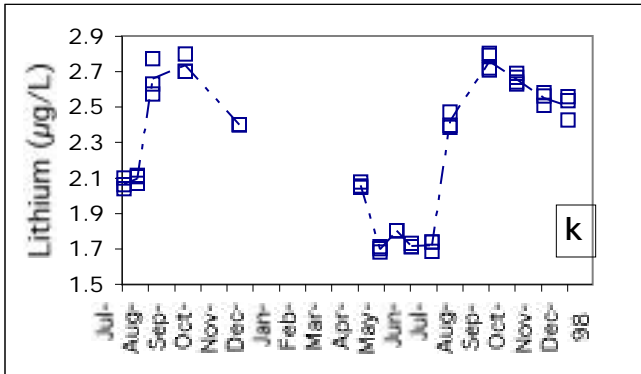
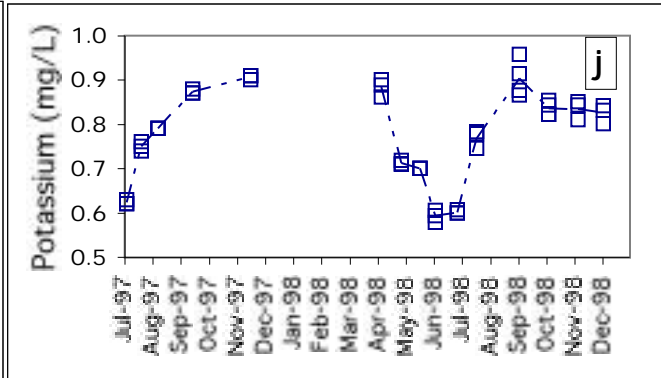
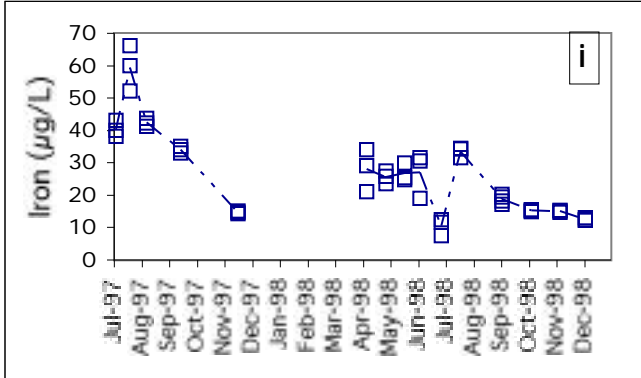
Figures 23i-23o: Streamflow vs. concentrations at Blackfoot site "BB"



Figures 24a-24h: Trends over time at Blackfoot River site "BB"



Figures 24i-24p: Trends over time at Blackfoot River site "BB"



Figures 24q-24r: Trends over time at Blackfoot River site "BB"

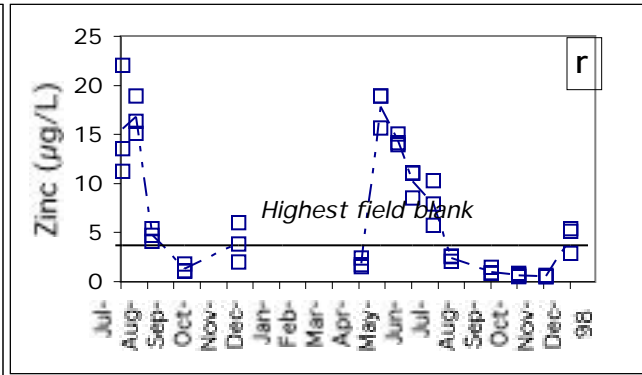
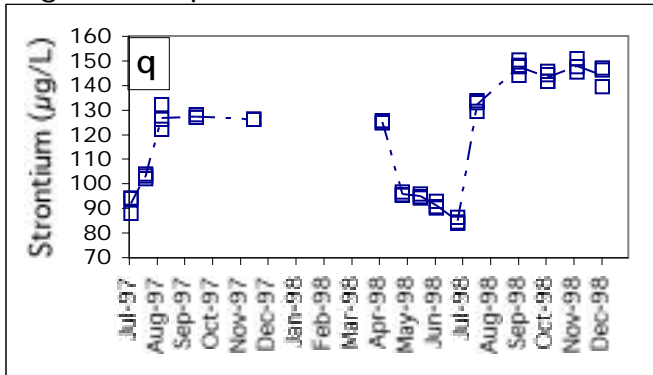


Figure 25a: Inorganic carbon, Ca, and Mg loads at site BB

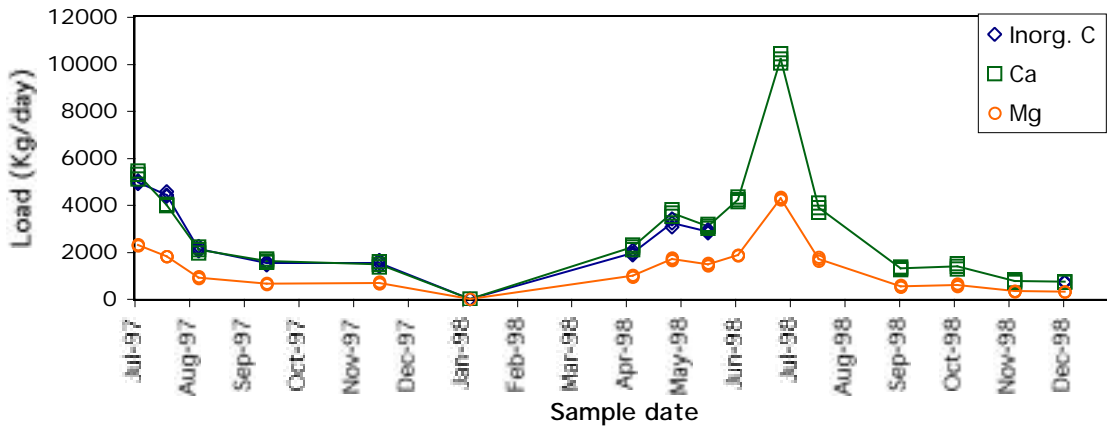


Figure 25b: As, Cr, Cu, and Li loads at site BB

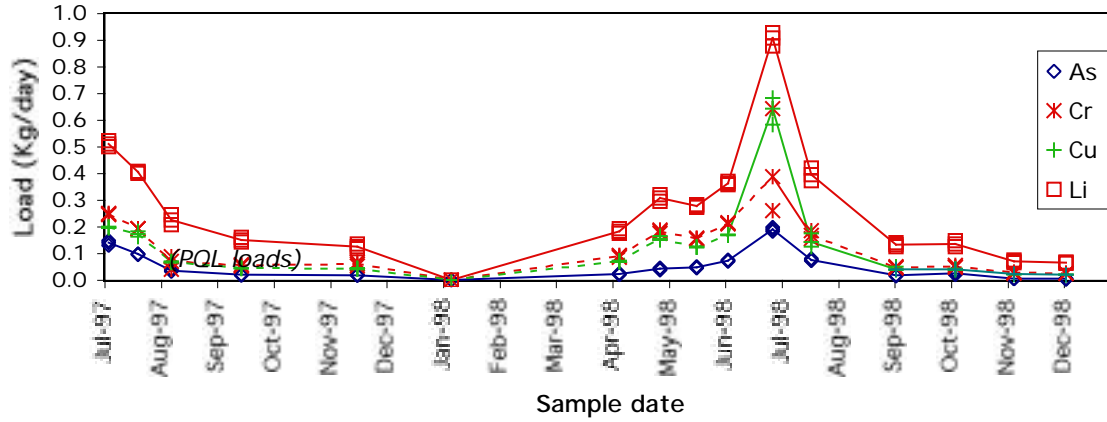


Figure 25c: Ba, Fe, K, and Sr loads at site BB

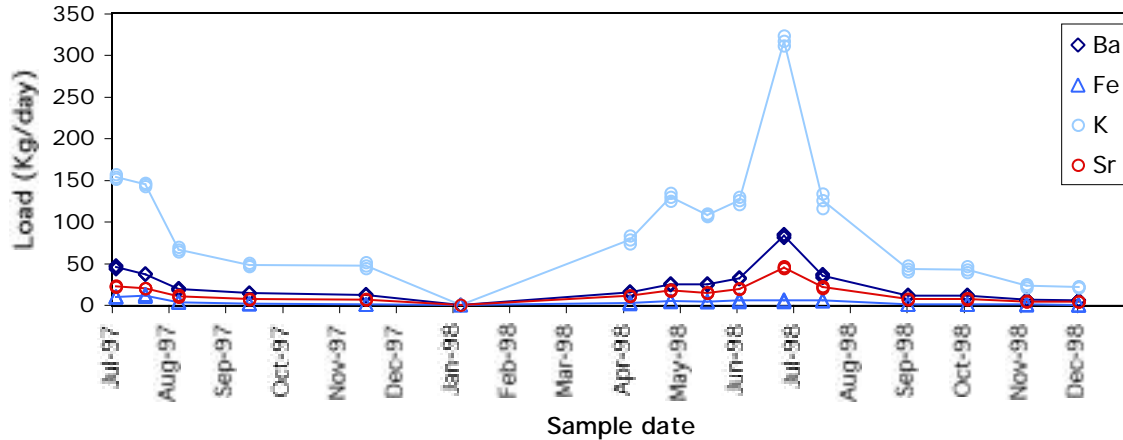


Figure 25d: Mn and Zn loads at site BB

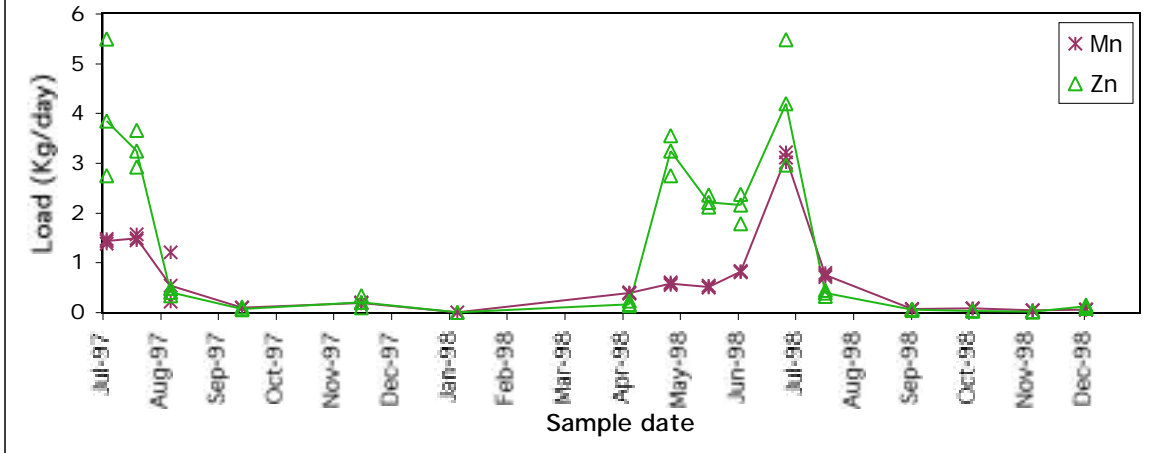
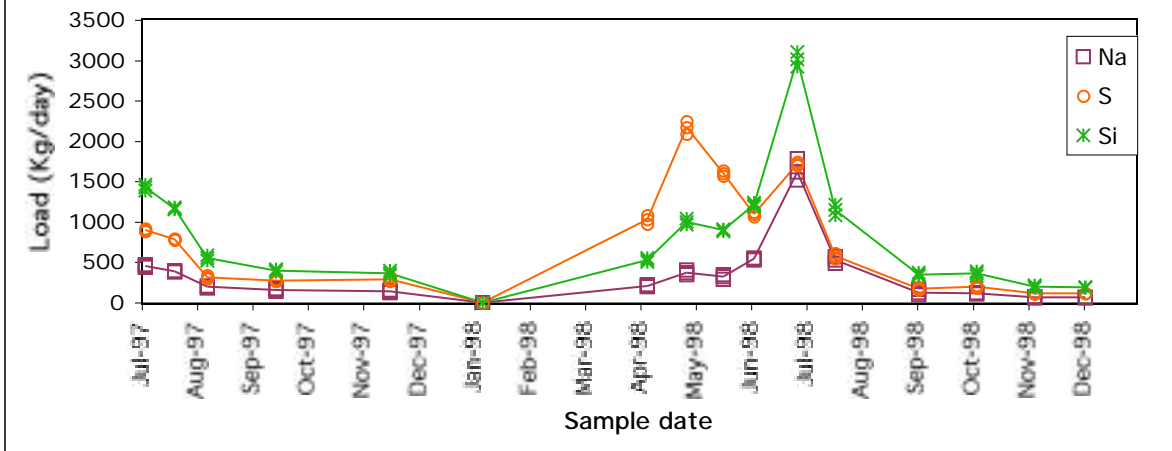
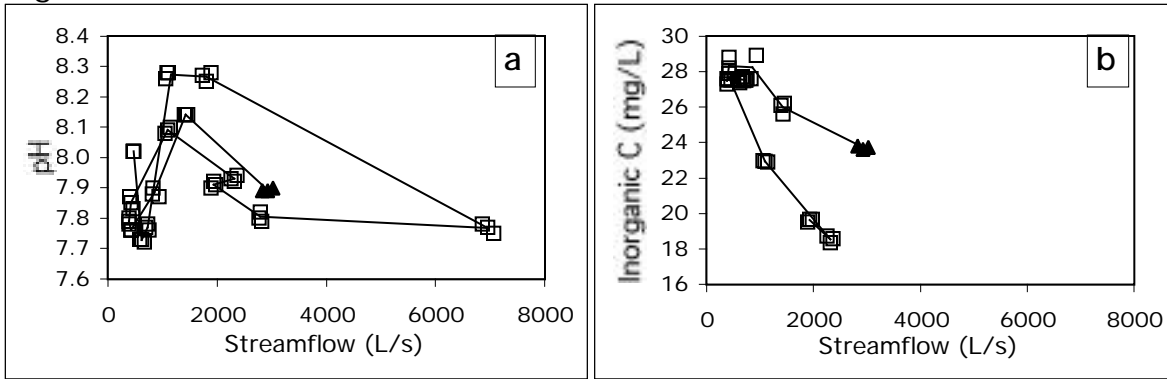


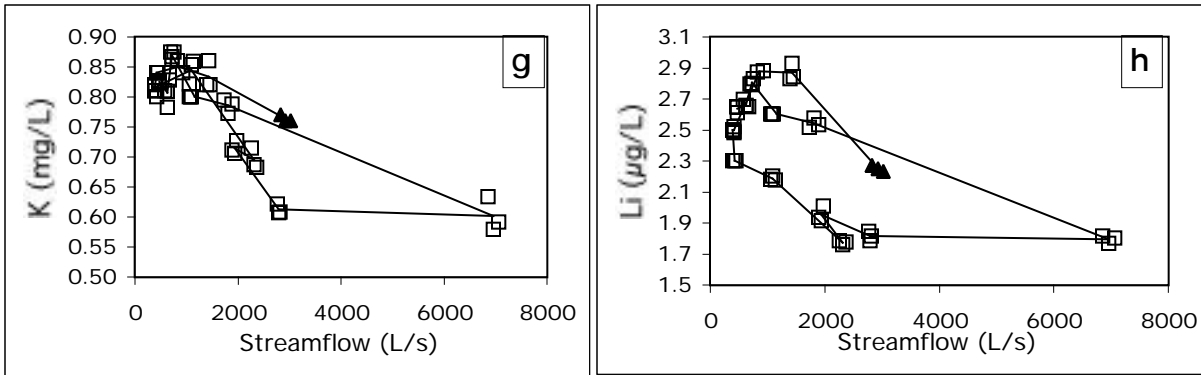
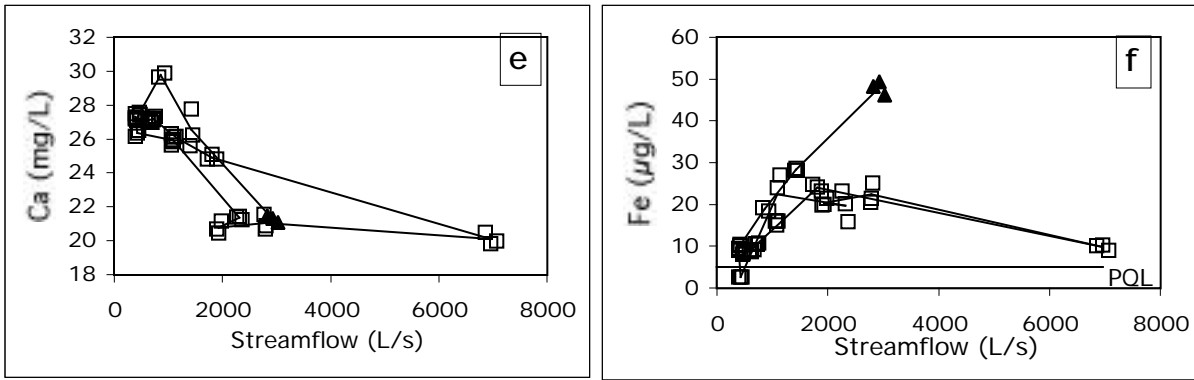
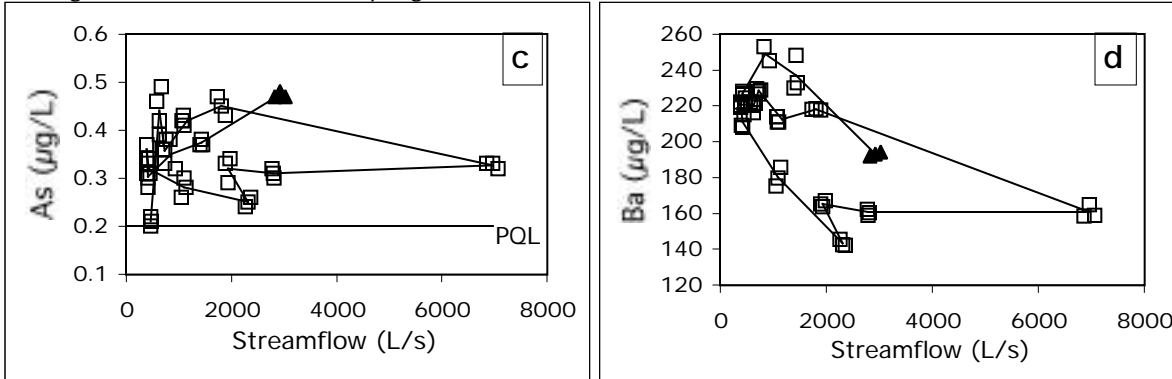
Figure 25e: Na, S, and Si loads at site BB



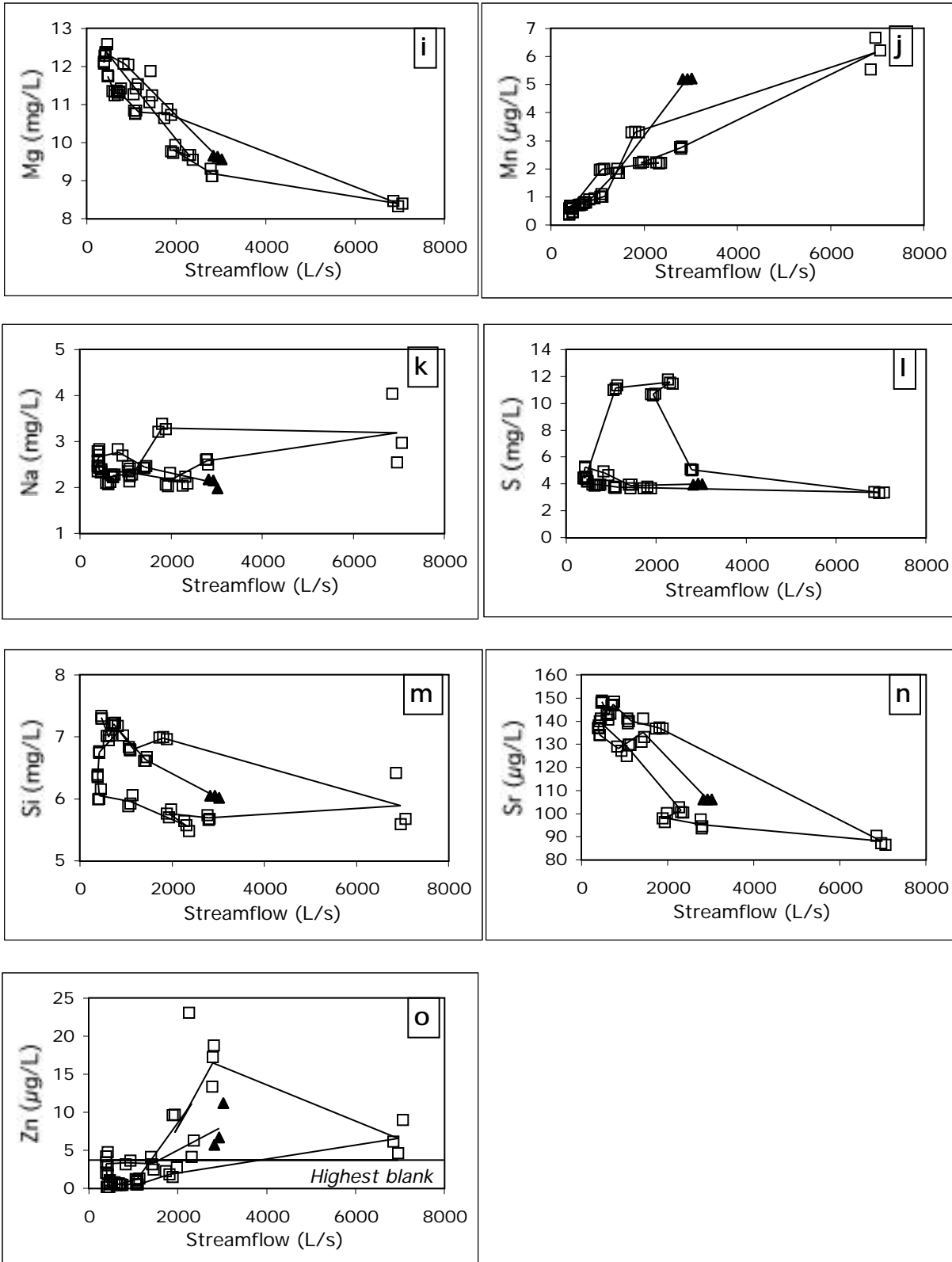
Figures 26a-26h: Streamflow vs. concentrations at Blackfoot site "BC"



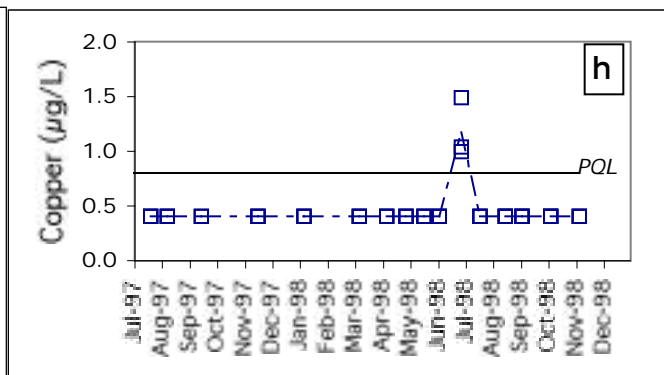
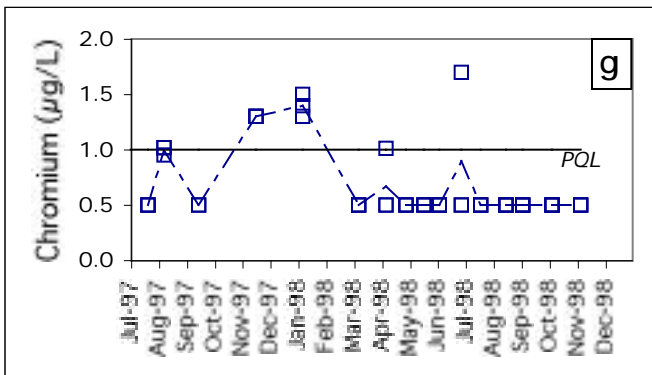
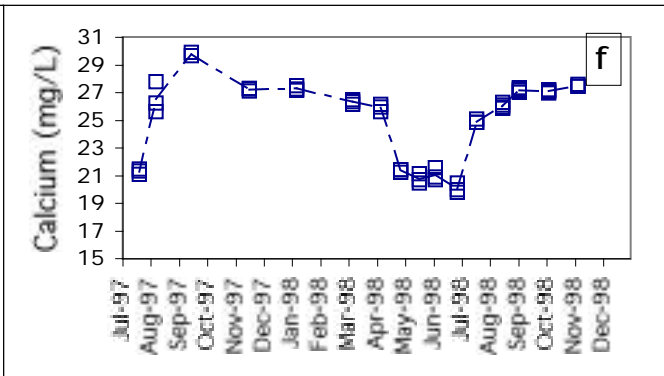
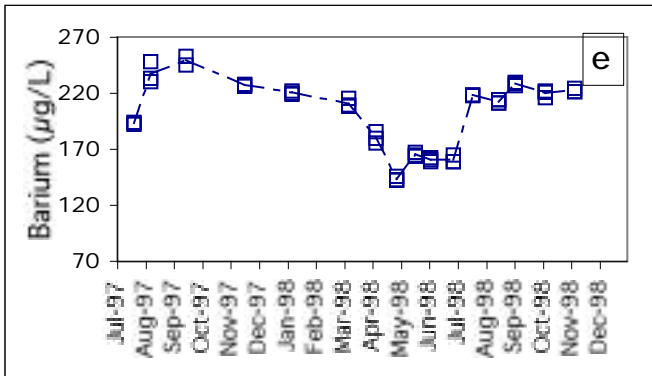
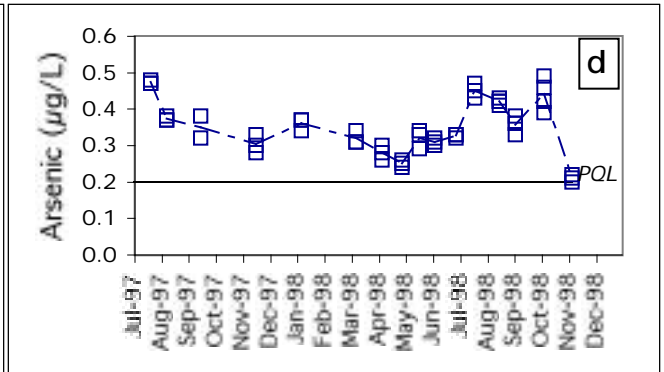
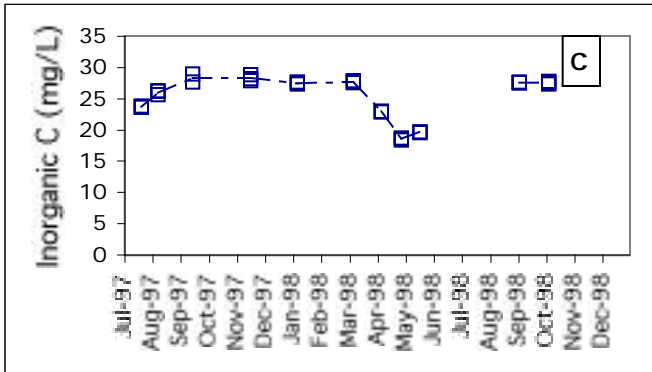
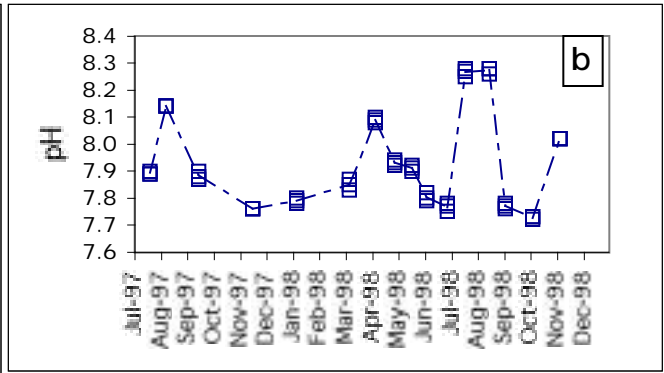
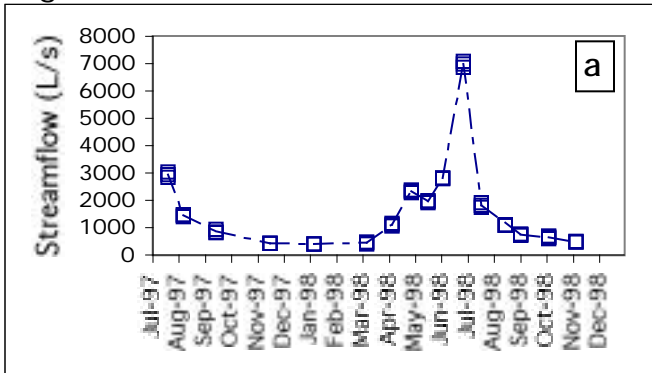
Triangles indicate the first sampling event, on 7/20/97



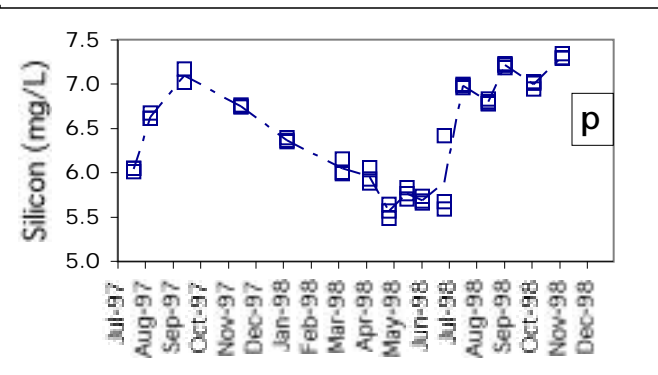
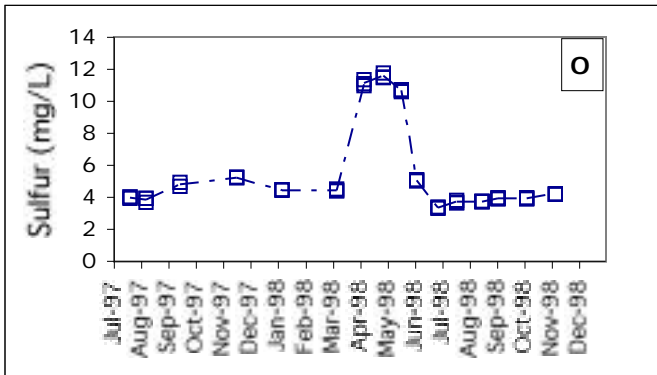
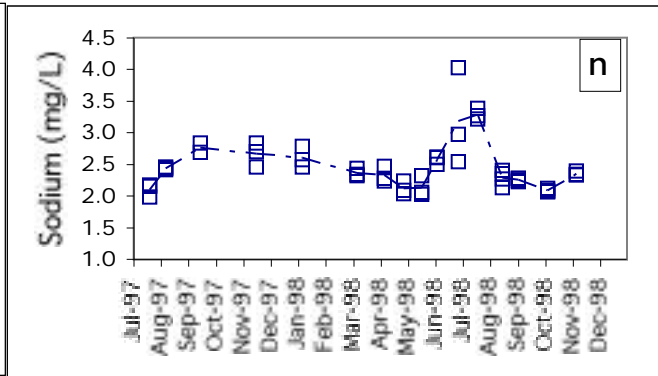
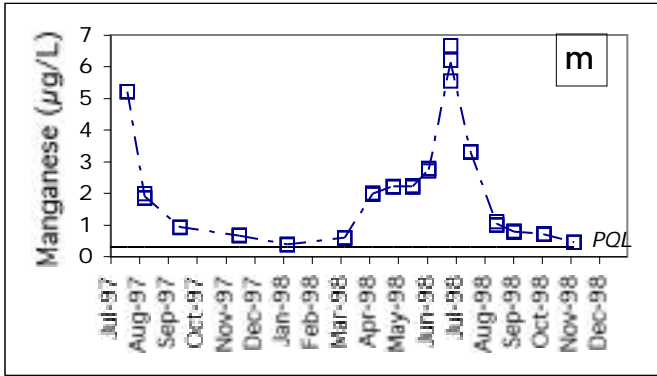
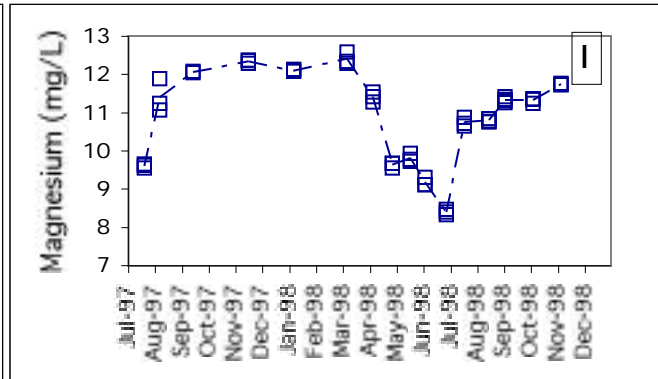
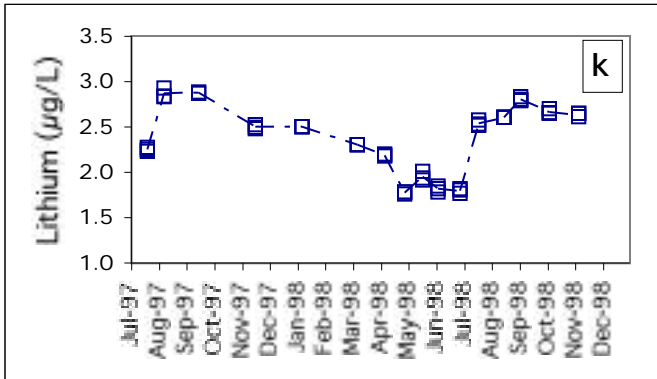
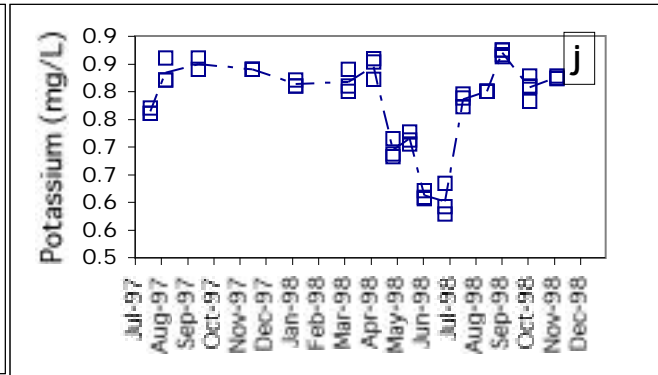
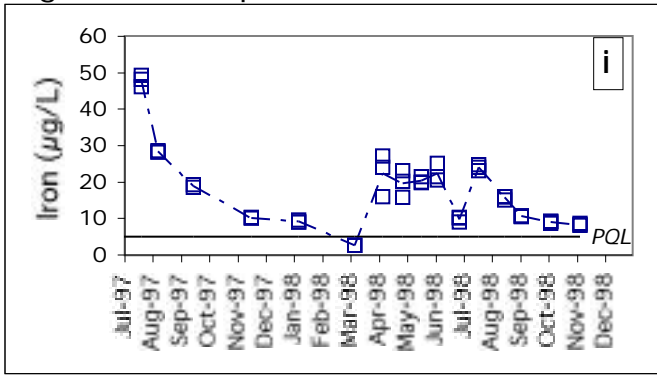
Figures 26i-26o: Streamflow vs. concentrations at Blackfoot site "BC"



Figures 27a-27h: Trends over time at Blackfoot River site "BC"



Figures 27i-27p: Trends over time at Blackfoot River site "BC"



Figures 27q-27r: Trends over time at Blackfoot River site "BC"

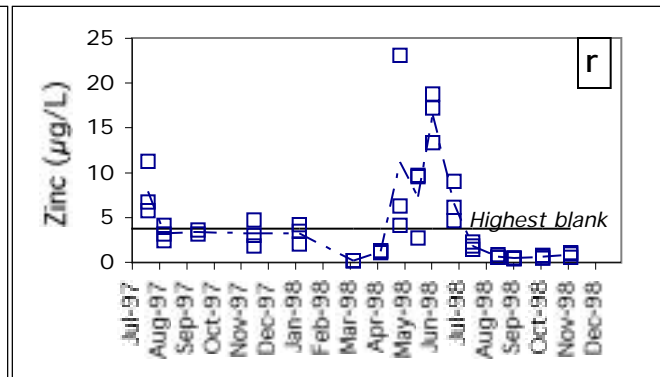
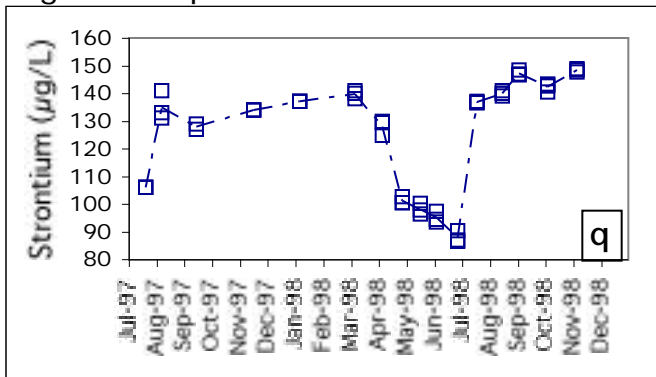


Figure 28a: Inorganic carbon, Ca, and Mg loads at site BC

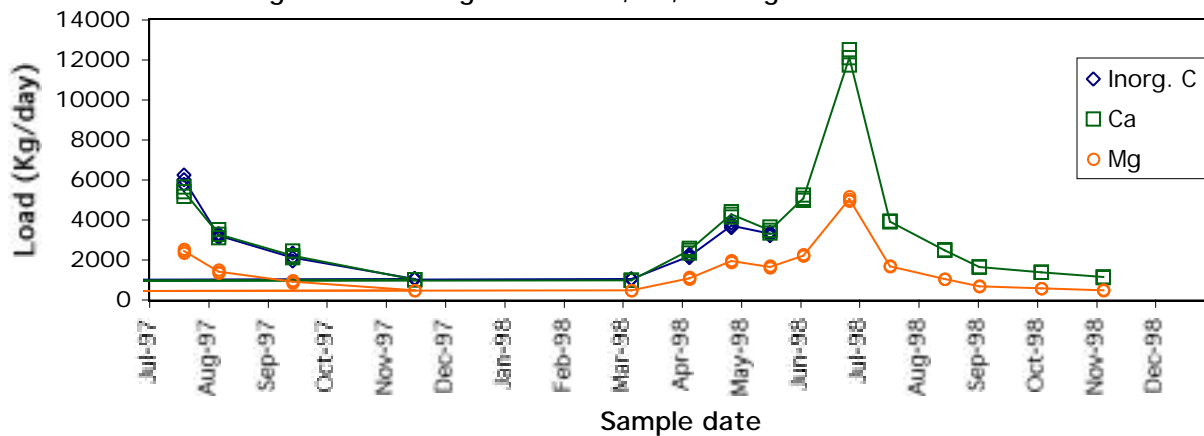


Figure 28b: As, Cr, Cu, and Li loads at site BC

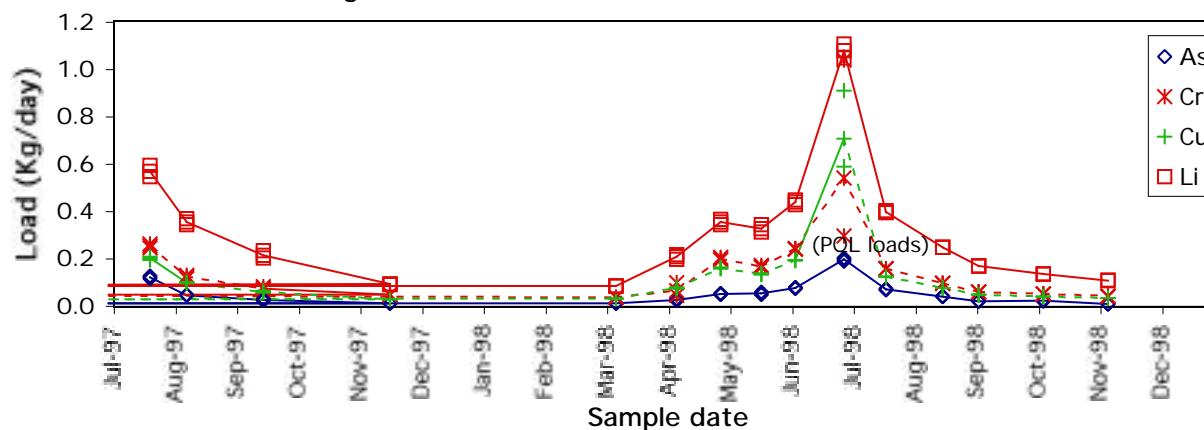


Figure 28c: Ba, Fe, K, and Sr loads at site BC

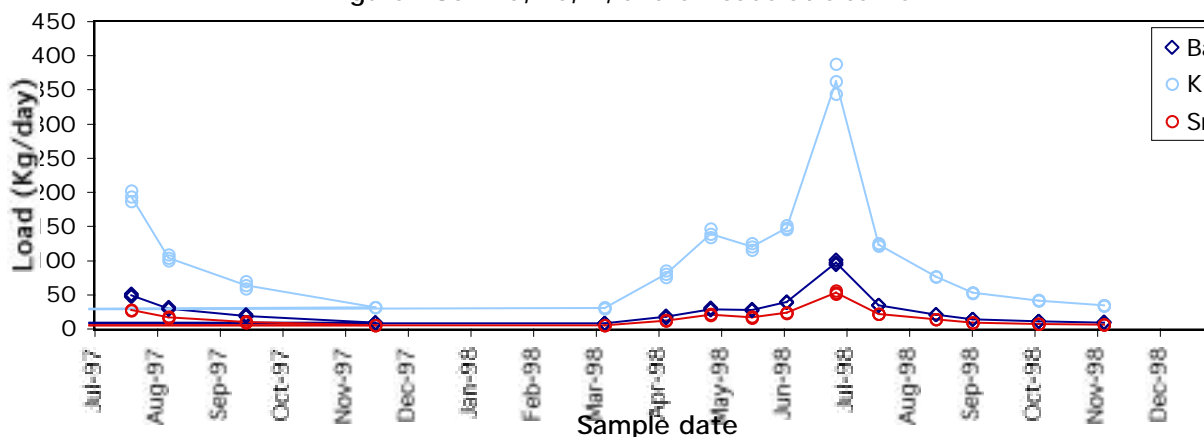


Figure 28d: Fe, Mn, and Zn loads at site BC

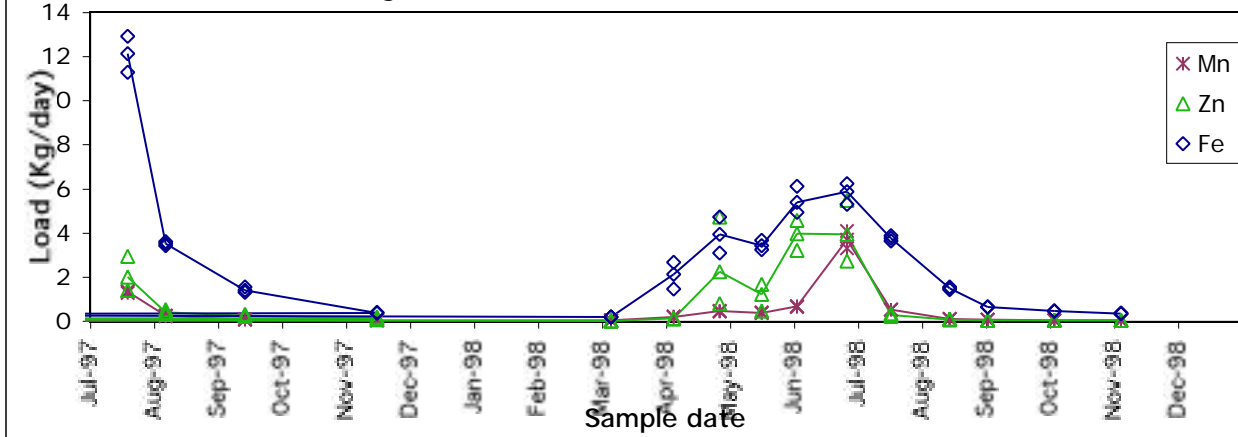


Figure 28e: Na, S, and Si loads at site BC

