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Report to the

Fundy Model Forest

on

Stream Water Quality and Quantity Monitoring

within the

Hayward Brook Watershed Study

1993 -1999

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Introduction

This report provides an overview of water quality within the Hayward and Holmes Brooks during 1993 to 1999. These watersheds have been monitored as part of the Hayward Brook Watershed Study (HBWS). The HBWS began as a multi-partner research study in 1993 with a focus on assessing the response of terrestrial and aquatic ecosystems to current forest management (Parker 1997). To undertake the assessment various studies were conducted by multiple research agencies. The projects included breeding bird surveys (Parker 1997), bryophytes structure (Hovey 1996), vascular plant structure (Roberts and Zhu 1998), fish community structure (Chiasson 1996), and buffer zone management (Krause 1997).

The water monitoring project was conducted by Environment Canada, Atlantic Region. The objective was to assess the response of water chemistry and quantity of sub-watersheds subjected to various forest harvesting treatments. A second objective was to assess the use of self contained automated water quality and quantity monitoring stations which can monitor stream stage (height) and selected water quality variables (Pomeroy et al. 1998). Stream chemistry was characterized based on data from monthly surface water grab samples and automated monitoring equipment. Selected water quality variables were recorded in-situ using a Hydrolab water quality probe. Automated sensors include pH, specific conductance, temperature, turbidity, and dissolved oxygen. Water quality variables were recorded every 60 minutes using a Hydrolab H-20 probe, and stage height was recorded every 30 minutes using a Tavis transducer. Stage height measurements were combined with manual measurements of stream velocity to calculate daily discharge measurements in cubic meters per second. Monthly surface water samples were analyzed for major ions, nutrients, metals and physical variables at Environment Canada’s Environmental Laboratory in Moncton, New Brunswick (Appendix 1). Interpretation of the data has been produced in a series of annual report and individual reports (Delorey 1998, Castonguay 2001). These are available through the Fundy Model Forest in Sussex, New Brunswick. In 2001 a thesis interpreting stream chemistry and discharge data for 1993 to 1997 is expected to be released (Stanley 2001). In 2001 a second thesis on stream turbidity and landuse is expected to be released (Pomeroy 2001).

This annual report will provide an overview of the stream chemistry and discharge for the period of 1993 to 1999. In 1999 station NB01BU0072 (Fig. 1) was removed after sufficient data for interpretation of the treatment within the buffer zone had been collected. In 1998 station NB01BU0073 was removed after the basin was harvested as per the forest management plan. In 1999 three water monitoring stations remained active.

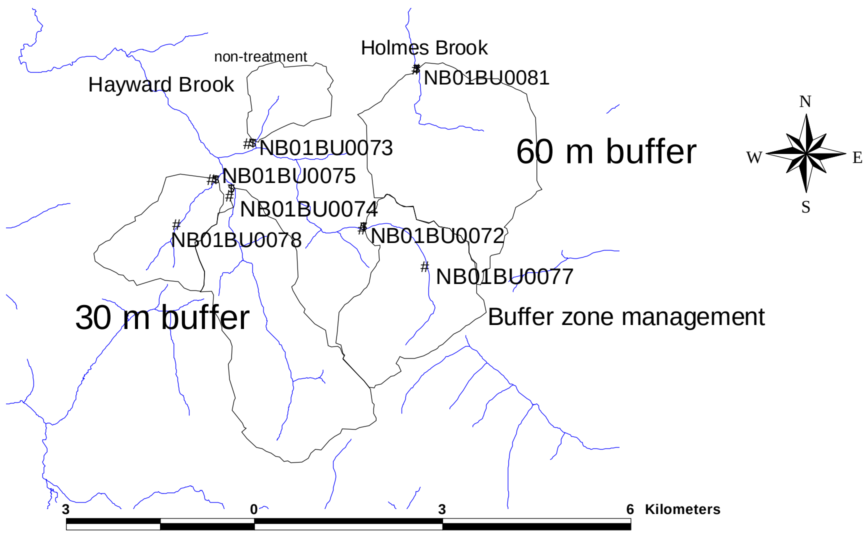
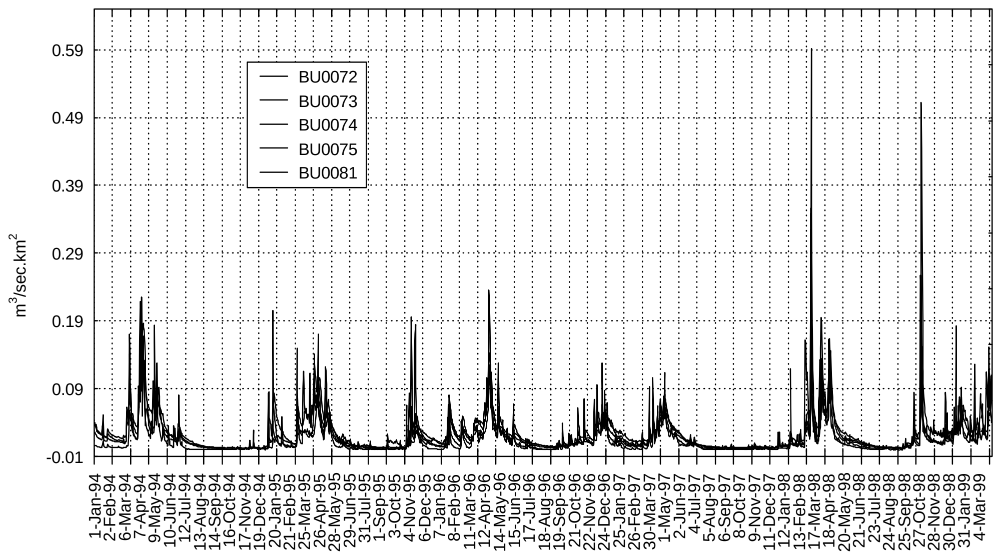


Figure1. Forest treatments in the Hayward and Holmes Brooks

Results:

Daily mean discharge (m^3/sec) was calculated for each stream using 30 minute records of stage height. These values are combined with periodic velocity measurements to develop a stage height-discharge curve for each watershed. The streams within the HBWS have similar discharge when the daily mean discharge is corrected for sub-watershed size which range between 1.4 to 6.5 km^2 (Fig. 2).

Figure 2: Daily mean discharge per kilometer^2 (m^3/sec. km^2) at water stations in the Hayward Brook Watershed Study during March 1994 to March 1999.



Each stations recorded similar annual cycles of low summer flows, and high spring flows caused by snow melt and precipitation.   To provide an overview of the mean and range of discharge, boxplots for those streams with a 30 m buffer ; NB01BU0074 and NB01BU0075 are shown (Fig. 3a,b). The daily discharge in these figures has not been normalized for basin size. The higher flow from the larger sub-watershed NB01BU0075 produces a wide range of flow data.

Figure 3a: Boxplot of daily mean discharge (M3/sec) for stream NB01BU0074 at Hayward Brook during 1994 to 1998
Median; Box: 25%, 75%; Whisker: Min, Max

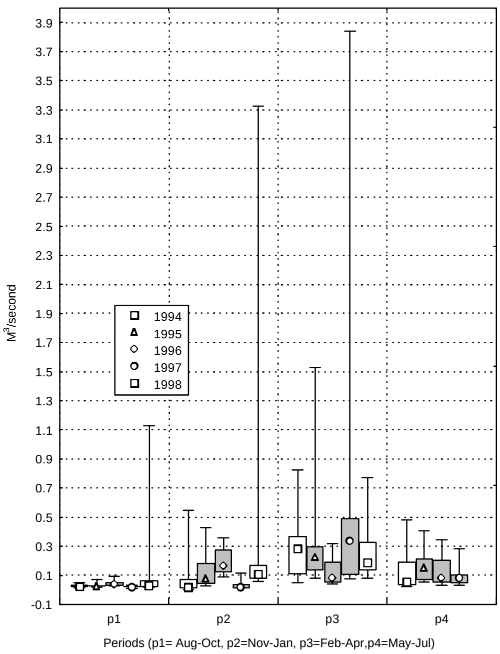
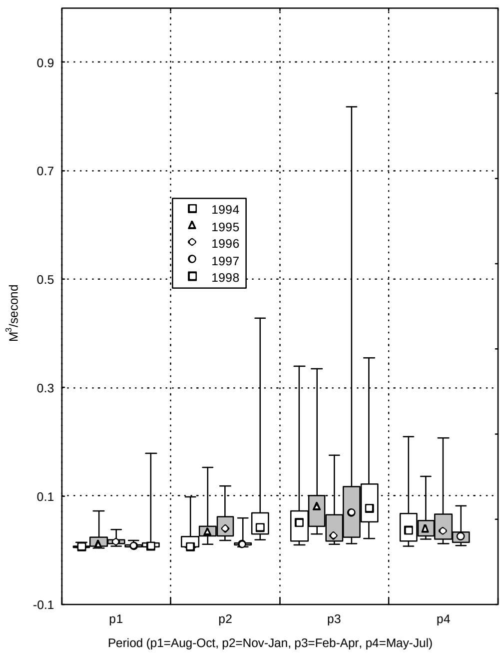


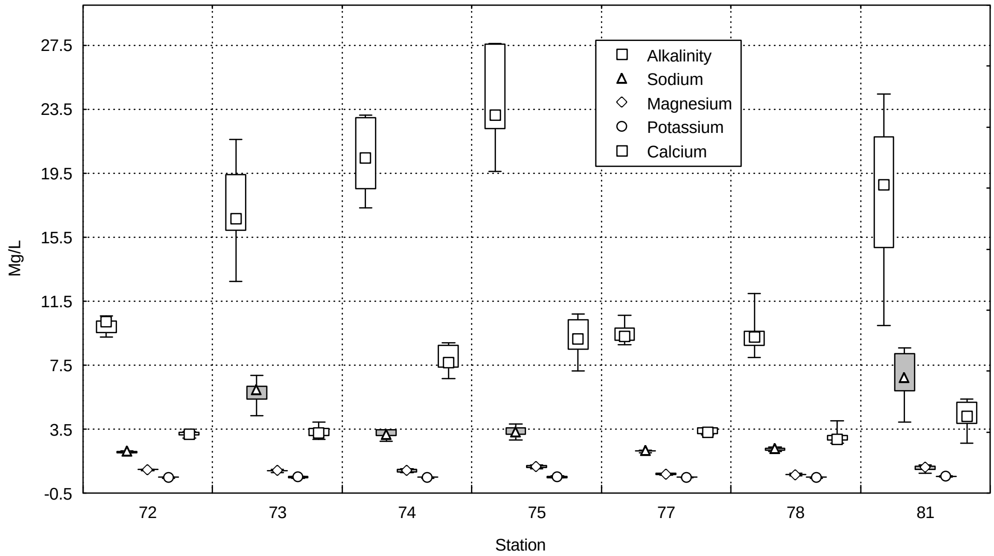
Figure 3b: Box Plot of daily mean discharge (M3/sec) at stream NB01BU0075 at Hayward Brook during 1994 to 1998
Median; Box: 25%, 75%; Whisker: Min, Max



During the sampling period of 1993 to 1999 a total of 913 surface water samples were collected, and analysed for water chemistry. Of these samples 115 represent the 1998 to 1999 period. The annual mean concentration for variables are shown in Appendix 2.   The water chemistry within the study area varies as a result of the forest soil units. In the study area the Sunbury, Salisbury and Parry forest soil units are found (Fahmy and Colpitts 1995). The Parry forest soil units contain large amounts of soluble elements, and as a result the concentrations of major ion (calcium, magnesium, potassium, sodium, chloride) in these streams are the highest found in the area (Stations; NB01BU0074, BU0075, BU0081). Those streams which have lower ranges of ions (NB01BU0072, BU0078) are located in the Sunbury or Salisbury soils.

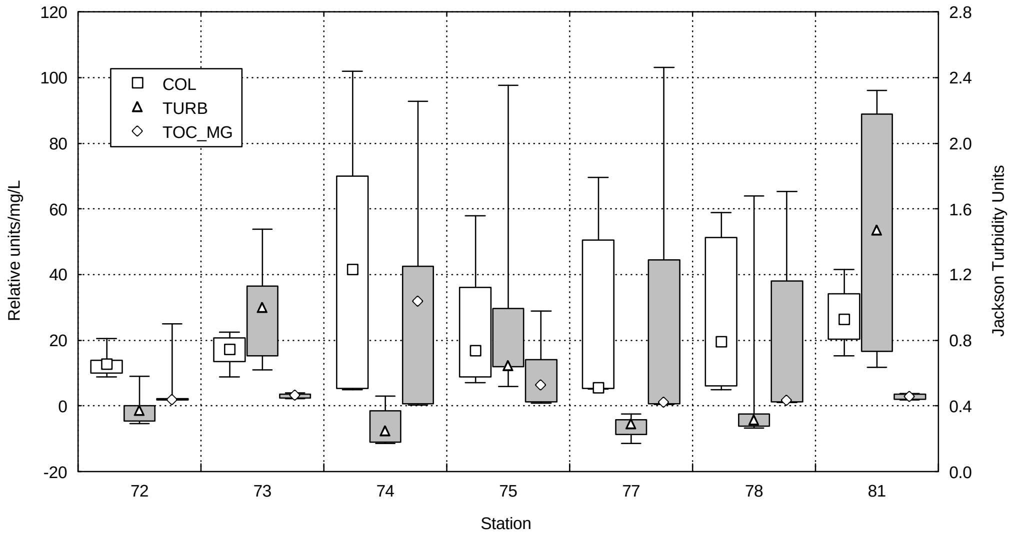
Specific conductance which is a numerical expression of water to conduct an electrical current provides a measurement of the water's mineral concentration (Inland Waters Directorate 1979). Conductance (Conduc., Appendix 2) is strongly influenced by the forest soil unit. Stream NB01BU0072 and BU0078 have lower conductance when compared to the concentrations found in the streams NB01BU0074 and BU0075 of the Parry soils. As selected ions are responsible for the water's capacity to neutralize an acid (Alkalinity), the range of values for this variable in each stream are similar to those for conductance. The carbonates and bicarbonates are the major ions responsible for neutralizing acids. The relationship between alkalinity and selected major ions are shown in Figure 4.

Figure 4: Box Plots of Alkalinity and selected major ions (mg/L) for streams in
Hayward Brook Watershed Study during 1993 to 1999
Median; Box: 25%, 75%; Whisker: Min, Max



The colour of the water ranges between 10 and 100 relative units (Fig. 5). The major variables contributing to the colour include turbidity and total organic carbon. In streams NB01BU0074 and BU0077 the main contributor is dissolved organic carbon. These streams are smaller, and have a low discharge. Turbidity was the major contributor in stream NB01BU0075 where the continuous erosion from an established county road maintained elevated suspended sediments (Pomeroy et al. 1995).

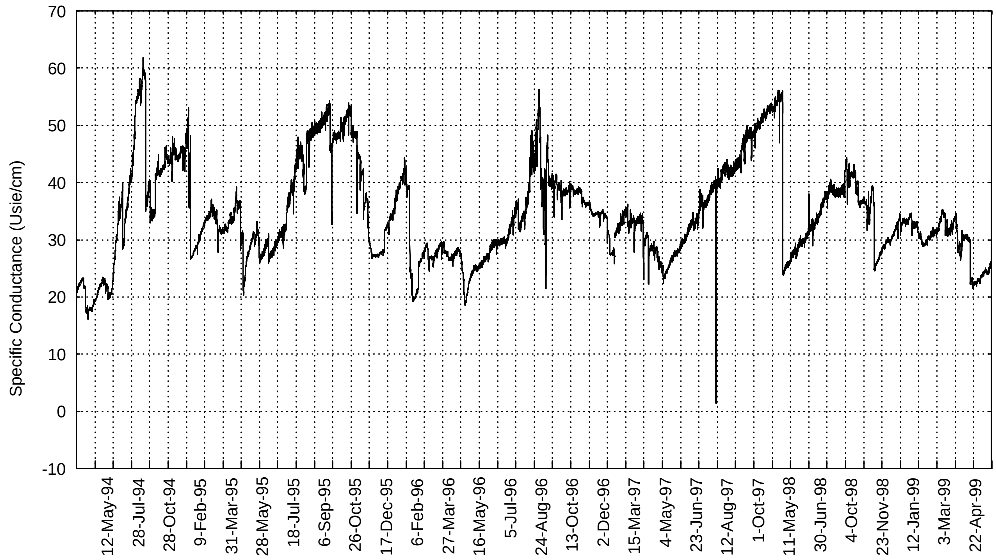
Figure 5: Boxplots of annual Apparent Colour (relative units), Total Organic
carbon, and turbidity (Jackson turbidity units) for streams in the
Hayward Brrok Watershed Study during 1993 to 1999
Median; Box: 25%, 75%; Whisker: Min, Max



Continuous data collected from the automated monitoring stations includes pH, specific conductance, turbidity, temperature, and dissolved oxygen. This data provides a temporal view of the water quality, and is being interpreted in various reports. The raw data for specific conductance in stream NB01BU0072 is shown below and represents 35428 readings (Fig. 6). The period includes 23-May-1994

@13:15:00 to 18-May-1999 @ 10:15:00. The figure shows the annual cycle of higher conductance during low stream flows and depressed conductance during high runoff. During dry periods groundwater supplies the majority of the stream flow. Groundwater has high concentrations of dissolved ions due to dissolution of minerals, and this creates high conductance readings. Periods of low conductance is due to a dilution of ion concentrations by high discharge. Conductance can increase during high flows if erosion or surface runoff supplies additional ions to the stream.

Figure 6: Hourly specific conductance (Usie/cm) for stream NB01BU0072
in the Hayward Brook Watershed Study during 1994 to 1999.
(graph contains 35428 records - every hour between May 1994 to May 1999)



Conclusion:

This report provides an overview of the water quality and quantity data which has been collected within the Hayward Brook Watershed Study under funding from the Fundy Model Forest. With this support the project continues collect surface water data at three stations. A more detailed assessment of the patterns and trends within this dataset is currently being assessed in various thesis. These reports will be forwarded to the Fundy Model Forest.

The author would like to acknowledge the efforts of Peter DeLong, and Guy Leger (Environment Canada, Meteorological Service Canada, Environmental Monitoring Division - Fredericton) for their support and dedication to maintaining the water quality probes and stations.

Appendix 1.0: Water quality analyses schema for surface water grab samples.

Variable Name	**Units**
Apparent Colour	Relative Units
Specific Conductance	Usie/cm
Turbidity	Jackson T. Units
Nitrogen, Dissolved Nitrate	Mg/L
Total Nitrogen	Mg/L
Alkalinity Gran (CACO3)	Mg/L
Iron Extractable	Mg/L
PH	Ph Units
Sodium Extractable	Mg/L
Magnesium Extractable	Mg/L
Phosphorous total	Mg/L
Sulphate, Dissolved	Mg/L
Chloride, Dissolved	Mg/L
Potassium, Dissolved	Mg/L
Calcium, Dissolved	Mg/L
Carbon, Total inorganic	Mg/L
Carbon, Total organic	Mg/L
Aluminum Extractable	Mg/L
Manganese, Extractable	Mg/L
Zinc, Extractable	Mg/L

Appendix 2.0: Annual means of water chemistry from surface water grab samples during 1993 to 1999.

Station-year	Colour	Conduc	Turb	NO3-TN	Tnitro	Alkal	Ph	Na	Mg	AL	Tphos
BU72-1993	13.2	34.6	0.4	0.010	0.04	10.2	7.1	2.1	0.9	36.6	0.007
BU72-1994	10.0	35.3	0.4	0.020	0.03	9.5	7.0	2.0	0.9	24.7	0.007
BU72-1995	12.1	36.6	0.6	0.020	0.02	10.2	6.9	2.1	1.0	39.2	0.010
BU72-1996	13.8	33.8	0.3	0.010	0.02	9.2	7.0	2.0	0.9	13.8	0.007
BU72-1997	20.5	36.1	0.4	0.010	0.04	10.6	7.0	2.1	1.0	6.0	0.009
BU72-1998	8.8	37.4	0.3	0.010	0.02	10.2	7.0	2.1	1.0	25.5	0.006
BU73-1993	8.9	53.1	0.6	0.028	0.08	19.4	7.1	6.2	0.9	39.1	0.005
BU73-1994	14.8	50.2	1.5	0.021	0.06	16.6	7.0	6.1	0.9	61.4	0.007
BU73-1995	22.4	49.5	1.1	0.027	0.06	15.9	7.0	5.8	0.9	56.3	0.014
BU73-1996	19.7	42.8	1.1	0.020	0.06	12.7	7.0	4.4	0.8	44.6	0.009
BU73-1997	13.4	56.6	0.7	0.020	0.06	21.6	7.2	6.9	1.0	12.9	0.009
BU73-1998	20.6	50.7	0.9	0.020	0.04	16.7	7.1	5.4	0.9	18.6	0.007
Station-year	**Colour**	**Conduc**	**Turb**	**NO3-TN**	**Tnitro**	**Alkal**	**Ph**	**Na**	**Mg**	**AL**	**Tphos**
BU74-1993	5.0	67.9	0.2	0.012	0.02	23.0	7.5	3.4	1.0	12.5	0.007
BU74-1994	5.3	62.7	0.3	0.020	0.01	19.2	7.4	3.1	0.9	10.6	0.007
BU74-1995	7.0	61.6	0.5	0.020	0.01	18.5	7.2	3.1	0.8	18.7	0.013
BU74-1996	41.5	56.5	0.2	0.020	0.01	17.3	7.3	2.8	0.8	25.0	0.008
BU74-1997	68.1	65.6	0.4	0.010	0.01	20.8	7.3	3.2	0.9	56.1	0.009
BU74-1998	L 5.0	66.2	0.2	0.010	0.01	20.4	7.3	3.1	0.9	71.5	0.008
BU74-1999	70.0	72.9	0.2	0.010	0.01	23.1	7.4	3.5	1.0	8.5	0.008
BU75-1993	8.8	79.3	0.6	0.018	0.03	27.6	7.5	3.8	1.3	44.0	0.004
BU75-1994	7.1	73.6	0.6	0.020	0.04	23.1	7.4	3.4	1.1	24.0	0.005
BU75-1995	20.3	71.3	2.4	0.021	0.03	22.5	7.2	3.3	1.1	60.1	0.028
BU75-1996	16.8	62.2	1.0	0.010	0.02	19.6	7.3	2.8	1.0	38.6	0.007
BU75-1997	12.8	69.0	0.5	0.010	0.02	22.3	7.4	3.2	1.1	0.0	0.008
BU75-1998	36.0	76.7	0.6	0.010	0.02	24.9	7.4	3.3	1.2	46.5	0.006
BU75-1999	58.0	83.4	0.7	0.010	0.01	27.6	7.5	3.6	1.2	0.0	0.007
Station-year	**Colour**	**Conduc**	**Turb**	**NO3-TN**	**Tnitro**	**Alkal**	**Ph**	**Na**	**Mg**	**AL**	**Tphos**
BU77-1993	5.5	35.3	0.3	0.012	0.02	10.6	7.0	2.2	0.7	13.7	0.008
BU77-1994	5.3	32.7	0.4	0.020	0.02	8.8	6.9	2.0	0.6	13.6	0.010
BU77-1995	5.2	34.1	0.2	0.020	0.01	9.1	6.9	2.1	0.7	13.7	0.010
BU77-1996	50.5	34.1	0.3	0.010	0.01	9.3	7.0	2.1	0.7	32.7	0.009
BU77-1997	69.7	36.7	0.2	0.01	0.02	9.8	6.9	2.2	0.7	45.4	0.013
BU78-1993	5.0	31.6	0.3	0.015	0.02	9.6	7.1	2.3	0.6	10.6	0.005
BU78-1994	6.1	30.1	1.7	0.020	0.02	8.0	6.9	2.1	0.6	21.3	0.011
BU78-1995	8.9	33.4	0.4	0.020	0.02	9.1	6.9	2.3	0.6	20.8	0.008
BU78-1996	30.2	31.7	0.3	0.010	0.01	8.8	7.0	2.2	0.6	12.0	0.006
BU78-1997	51.2	32.4	0.3	0.010	0.01	9.3	7.0	2.2	0.6	43.0	0.007
BU78-1998	58.9	41.2	0.3	0.010	0.02	12.0	7.0	2.4	0.7	22.7	0.006
Station-year	**Colour**	**Conduc**	**Turb**	**NO3-TN**	**Tnitro**	**Alkal**	**Ph**	**Na**	**Mg**	**AL**	**Tphos**
BU81-1994	15.4	73.9	1.0	0.027	0.04	21.8	7.4	8.2	1.2	41.0	0.008
BU81-1995	26.7	55.8	1.9	0.020	0.04	14.8	7.0	5.9	1.0	61.4	0.015
BU81-1996	34.1	39.2	2.2	0.010	0.04	10.0	7.0	4.0	0.8	38.7	0.006
BU81-1997	26.1	61.1	2.3	0.010	0.03	17.9	7.2	6.4	1.1	0.2	0.010
BU81-1998	20.3	68.1	0.6	0.010	0.03	19.6	7.2	7.0	1.1	20.5	0.009
BU81-1999	41.5	80.7	0.7	0.010	0.03	24.5	7.3	8.6	1.2	0.0	0.010

Station-year	So4	K	Ca	Mn	Fe	Zn	TOC	TIC	Cl	Sed	Sio2
BU72-1993	3.8	0.5	3.2	0.01	0.05	0.01	1.8	3.4	2.6		8.3
BU72-1994	3.7	0.4	3.2	0.01	0.04	0.01	1.8	3.0	1.8	1.0	8.1
BU72-1995	4.1	0.5	3.4	0.01	0.05	0.01	2.2	3.0	1.8	2.8	8.2
BU72-1996	3.3	0.5	2.9	0.01	0.03	0.01	1.7	2.5	1.7	1.0	7.8
BU72-1997	3.4	0.5	3.3		0.03	0.01	25.1	2.6	1.7		7.7
BU72-1998	3.7	0.4	3.2		0.03	0.01	1.9	2.8	1.8		8.0
BU73-1993	4.5	0.5	3.9	0.01	0.04	0.01	2.2	5.9	2.5		6.0
BU73-1994	4.1	0.5	3.1	0.01	0.06	0.01	3.2	5.0	2.3	3.5	4.9
BU73-1995	4.0	0.5	3.3	0.01	0.06	0.01	4.0	4.7	2.2	2.4	5.2
BU73-1996	3.3	0.4	2.9	0.01	0.07	0.01	3.5	3.6	2.0	4.0	4.6
BU73-1997	3.3	0.5	3.5		0.06	0.01	2.5	5.0	2.2		4.7
BU73-1998	3.5	0.5	3.3		0.05	0.01	3.0	5.9	2.3		5.0
Station-year	**So4**	**K**	**Ca**	**Mn**	**Fe**	**Zn**	**TOC**	**TIC**	**Cl**	**Sed**	**Sio2**
BU74-1993	8.8	0.5	8.9	0.01	0.02	0.01	0.3	6.9	2.3		8.5
BU74-1994	7.2	0.5	7.7	0.01	0.02	0.01	0.6	5.7	2.1	1.0	8.0
BU74-1995	7.1	0.5	7.4	0.01	0.04	0.01	1.2	5.4	2.0	4.3	8.0
BU74-1996	6.1	0.5	6.7	0.01	0.02	0.01	0.6	4.5	1.9	1.0	7.4
BU74-1997	7.0	0.5	7.9		0.03	0.01	0.4	5.1	2.0		7.7
BU74-1998	7.3	0.4	7.6		0.01	0.01	1.0	4.9	2.1		7.9
BU74-1999	8.0	0.5	8.7	0.01	0.01	0.07	0.8	5.9	2.0		
BU75-1993	9.4	0.6	10.7	0.02	0.06	0.01	0.9	8.2	3.0		10.5
BU75-1994	8.0	0.5	9.1	0.01	0.03	0.01	1.3	7.3	2.5	1.4	9.3
BU75-1995	7.4	0.5	8.7	0.04	0.15	0.02	2.6	6.4	2.4	36.2	9.3
BU75-1996	5.8	0.5	7.1	0.02	0.10	1.0	6.3	5.2	2.2	7.0	8.5
BU75-1997	6.6	0.5	8.5		0.06	0.01	1.0	5.3	2.4		9.0
BU75-1998	7.7	0.5	9.2		0.06	0.01	2.2	14.6	2.5		8.6
BU75-1999	8.5	0.5	10.3	0.01	0.05	0.02	1.2	6.8	2.4		
Station-year	**So4**	**K**	**Ca**	**Mn**	**Fe**	**Zn**	**TOC**	**TIC**	**Cl**	**Sed**	**Sio2**
BU77-1993	4.2	0.5	3.6	0.01	0.01	0.01	0.6	3.8	1.5		
BU77-1994	3.5	0.5	3.1	0.01	0.02	0.01	0.7	2.8	1.7	1.0	
BU77-1995	3.7	0.5	3.3	0.01	0.02	0.01	1.1	2.8	1.7	1.7	
BU77-1996	3.2	0.5	3.2	0.01	0.01	0.01	0.5	2.9	1.7	1.0	
BU77-1997	3.2	0.5	3.6		0.06	0.01	0.4	2.5	2.6		
BU78-1993	3.2	0.5	2.8	0.01	0.02	0.01	1.3	3.4	1.7		
BU78-1994	3.1	0.5	2.6	0.02	0.10	0.01	1.1	2.5	1.7	1.3	
BU78-1995	3.3	0.5	3.1	0.01	0.04	0.01	1.8	2.8	1.6	1.2	
BU78-1996	2.9	0.5	2.8	0.01	0.02	0.01	0.8	2.5	1.6	1.0	
BU78-1997	2.8	0.5	2.9		0.03	0.01	0.5	2.3	1.6		
BU78-1998	4.0	0.4	4.0		0.02	0.01	1.4	3.1	1.8		
Station-year	**So4**	**K**	**Ca**	**Mn**	**Fe**	**Zn**	**TOC**	**TIC**	**Cl**	**Sed**	**Sio2**
BU81-1994	5.7	0.5	5.2	0.01	0.07	0.01	2.4	6.0	5.4	3.0	
BU81-1995	4.6	0.5	3.9	0.02	0.09	0.01	3.7	4.4	4.2	5.6	
BU81-1996	3.2	0.5	2.6	0.01	0.10	0.01	3.6	2.6	3.0	5.0	
BU81-1997	4.3	0.6	4.1		0.16	0.01	1.9	4.2	4.3		
BU81-1998	4.9	0.5	4.5		0.08	0.01	3.1	4.7	4.8		
BU81-1999	5.7	0.5	5.4	0.01	0.07	0.01	1.9	6.0	5.4		

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