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Winter Low Flow Stream Discharge Measurements Using the Salt Slug Injection Method

By Laberge Environmental Services

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TECHNICAL REPORT

WINTER LOW FLOW STREAM DISCHARGE MEASUREMENTS USING THE SALT SLUG INJECTION METHOD

FIELD TRIALS AND METHOD DEVELOPMENT FOR USE IN LOCAL MINE MONITORING APPLICATIONS

FOR THE
MINING ENVIRONMENT RESEARCH GROUP (MERG)

BY
LABERGE ENVIRONMENTAL SERVICES
JULY, 1999

MEASURING STREAM DISCHARGE IN LATE WINTER LOW FLOW USING THE SALT SLUG INJECTION METHOD

SUMMARY

WHY MEASURE STREAM FLOW IN THE WINTER?

It's late winter. Everything looks frozen in the Yukon, but there is life under the ice and snow of creeks and rivers. This time of year is critical for many species, and especially for aquatic life. Fish and their food may be waiting out the winter in streams where there are deep pools or undercut banks with enough water and oxygen to survive. The weather above, although it may be starting to warm up, is still going down to minus 30 for lows. The environment under the ice and snow is much warmer, with water temperatures just above zero and ground water at about four degrees. The annual water cycle is at its lowest point. Ground water is still flowing to streams but this part of the water cycle, called base flow, is nearing its lowest volume of the year.

Meanwhile, a mining company is busy above processing ore or planning a mine. The environmental people who work for the mining companies and for the government are monitoring the streams above and below the mine area to see if there are any harmful effects on the sensitive streams, or they are trying to establish the basic characteristics, called baseline conditions, of the area. These people want to know what the rate of flow is in the stream, called the discharge.

HOW IS IT USUALLY DONE, AND HOW IS THIS METHOD DIFFERENT?

Normally, a velocity meter is used to measure the speed of the current, and the cross sectional area is measured. These are multiplied to calculate the discharge. In late winter this method doesn't work very well because of cold, ice, and very small flows.

This project was done to test a method of measuring discharge without having to use a current meter. The method is called the Salt Slug Injection Method of Stream Flow Measurement, or the Salt Dilution Method. It is based on the conservation of mass, that is to say that the total mass of a substance is not affected by a chemical change in that substance. The substance is salt, or sodium chloride ($NaCl$), exactly the same as the kind on the table. In this method, salt is used as a tracer.

When added to a stream in a carefully weighed amount, it increases the concentration of sodium on the stream for a brief time and distance. The concentration of sodium is directly proportional to the electrical conductance (conductivity) of the water. So conductivity is measured before and during the time when a wave of salt dissolved in the water passes by a point. Then the discharge is calculated using an arithmetic formula that converts the rise in conductivity to rate of flow in cubic meters per second.

Using salt as a tracer to measure stream flow has been tested in other places in open water, but it has not been tested in low flow conditions in the Yukon as a way to measure discharge in mine monitoring areas. The objective of this project was to see if this method is practical and accurate for use in local conditions in late winter.

WHAT WERE THE RESULTS?

The discharge calculated by the salt dilution method was compared to other methods and seemed to give very similar results. A computerized method was also tried, where a laptop computer is connected to the conductivity meter to do all the arithmetic automatically, but we found that it was not very easy to keep all the equipment from freezing up, and the software was clunky. It was better to keep equipment to a minimum and record the increase in conductivity by hand. Using a spreadsheet helps to do the calculations back in the office. The addition of salty water to a stream was looked at to see if there was any harm done to the aquatic life in the stream by the method itself, and there was no harm that we could measure.

We concluded that the Salt Dilution method is a good alternative to find out the discharge in small streams under ice.

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1.0 PROJECT BACKGROUND

Assessing the impact of a mining project requires knowledge of the water balance. Study of stream flow variation over the open water season can be readily accomplished with a variety of conventional methods, but understanding the behaviour of streams in winter low flow is hampered by uncertainty. Knowledge of absolute low flow can be vital in anticipating environmental effects of mining projects and describing the possible effects of climate change.

Operating and closed mine sites often have water licences or, in the case of B.C. sites, Waste Management Act permits, that require measurement of discharge and other parameters during the winter months. These data are routinely not recorded because mine environmental staff have no streamflow measurement protocols for small streams in winter.

Streamflow has been measured using variations of dye dilution and tracers of all kinds for many years, but these were always cumbersome. Recently, advances in instrumentation have allowed a variation of the salt dilution method to be a practical method for streamflow measurement.

Geoff Kite of the National Hydrology Research Institute (NHRI) has experimented with a streamflow measurement technique using injection of a salt slug and calculation of flow based on the conservation of mass. The method is described in re ***Measuring glacier outflows using a computerised conductivity system***, Journal of Glaciology, Vol. 40, No. 134, 1994 (attached as Appendix A), **and *Computerised Streamflow Measurement Using Slug Injection***, Hydrological Processes, Vol. 7, 227-223 (1993). A software program converts the conductivity readings to flow, with a computer coupled to the conductivity meter through a digital/analog converter.

This report summarizes a project undertaken by Laberge Environmental Services for the Mining Environment Research Group (MERG) during the late winter low flow period of 1998/1999. The Salt Slug Injection method of stream flow monitoring as described by Kite was tested to determine its applicability to Yukon mining monitoring situations under late winter low flow conditions. Transfer of technology to user groups was accomplished through this report and accompanying information pamphlet, a workshop, and direct training experience.

1.1 GENERAL BENEFIT TO THE YUKON

- An inexpensive and reliable method of measuring the discharge of small streams in winter will help everyone to better understand the effects on local ecosystems from mine drainage.

- Low flow can be a critical event for aquatic ecosystems. It would be of considerable benefit to people who are designing, maintaining treatment systems, and monitoring impacts to know what the low flow regime is when the affected watershed is most vulnerable.

- The production of the report and pamphlet will cause more low flow measurements of good quality to be made. The mining technical community will benefit from transfer of the technology and through improvements that will no doubt arise from people putting the method to use.

- Data gaps will be filled in water licence monitoring programs where no other method of flow measurement was previously possible.

- Yukon companies will benefit by the addition of more cold weather technical monitoring skills that can be applied in the Yukon and elsewhere in cold regions.

2.0 PROJECT OBJECTIVE

The overall objective of this project was to transfer technology in winter aquatic survey techniques, particularly low flow discharge measurements.

To help encourage the collection of reliable flow measurements in small streams under winter low flow conditions, the salt slug injection method, a modification of the salt dilution method, needed to be verified and explained to those who want to use it. Modifications, if any, to the method to suite local conditions needed to be explored.

Information on how to do the measurement was to be published and widely distributed to the mining community and anyone else interested in the study of the aquatic environment in winter.

To gain widespread use and credibility in the Yukon environmental monitoring community, the method was checked for precision and accuracy and the issue of environmental effects examined.

3.0 PROJECT TEAM

The project team consisted of Stu Withers, Ken Nordin and Bonnie Burns of Laberge Environmental Services (LES), with assistance from government agencies and the mining community.

LES has been involved in mine environment monitoring for over twenty years in the Yukon. Areas of expertise cover the design and implementation of complex biophysical monitoring programs including surface and groundwater water quality, hydrometric surveying, benthic invertebrate monitoring, limnological studies, contaminated site investigations and assessments, contaminants sampling, fish and wildlife habitat assessments, and vegetation community mapping.

This project required the co-operation and contributions of the mining community and government agencies. Contributions to the project were in the form of access to difficult monitoring problems, logistical support, technical review, lab testing, field assistance and monitoring.

Two agencies of government were very helpful: the Water Resources Division of DIAND, and the Environmental Protection branch of Environment Canada. Wayne Kettly, Jean Beckerton, Gerry Whitley, and Doug Davidge provided direct input in the form of lab and field work, advice, and review.

The closed Faro Mine under receivership was a field test and demonstration site. Erik Denholm, under contract to the receiver Deloitte and Touche Inc., was very helpful in providing support at the mine site and advice on the project.

The Silvertip Project near Rancheria owned by Imperial Metals was also a test site. Access and assistance there was provided through the Silvertip Mining Corporation.

The National Hydrology Research Institute (NHRI) in Saskatoon, particularly Tom Carter, provided assistance and lent equipment to the project.

The work of Dr. Kite, formerly of NHRI is also gratefully acknowledged.

4.0 METHODOLOGY

The methods used in this project consisted of field tests that attempted to show that the method is practical, precise, and accurate. Demonstration of the technique was part of the project. A workshop was held to allow more demonstration and hands on instruction to those interested. To address the issue of environmental effects, an attempt was made to observe any effect on the drift component of the benthic macroinvertebrates community. Other details of the methodology are described below:

4.1 Reproducing Results at Study Streams - Precision

At selected sites, several measurements were repeated to observe the variance among discharge numbers over the same reach. In all cases measurements were varied by changing input variables including mass of salt, time interval, or mixing length.

4.1.1 Optimising Mass and Mixing Length

The mass of salt and mixing length recommended in the literature were examined by reducing them and observing the resulting changes in the quality of the measurement. These variables were adjusted so as to determine the optimum combinations for Yukon conditions.

4.2 Reliability Checks - Accuracy

At two sites, accurate flow measurements were taken using either a carefully calibrated weir or recently calibrated Price type velocity meters in open water sections. These measurements represented values of known precision and accuracy to compare with values obtained by the salt slug injection method at the same sites.

4.3 Checking the Method in High Conductivity Streams

The method was checked in streams with high background conductivity to determine if this affected the procedure or the results.

4.4 Checking for Complete Mixing

To determine if there was any notable difference in conductivity across the section, two or more probes were placed in the stream during the recording of the salt wave, and compared.

4.5 Environmental Effects Monitoring

Two environmental experiments were made. The first was an LC_{50} bioassay of a salt solution prepared with Wolf Creek water. The second was observation of changes to benthic community drift after adding a salt slug to the Ibex River. Both were performed by Environmental Protection, Environment Canada.

4.6 Testing Computerized Method

The use of a computer coupled to a conductivity meter as configured by Kite and provided by the N.H.R.I. will was tried at two sites.

4.7 Computerized Calculation Sheet

A spreadsheet originally compiled by Gerry Whitley of DIAND was used throughout the project for ease in calculations and record keeping. A printout of the blank spreadsheet is attached as appendix B.

4.8 Technology Transfer

A workshop was held to demonstrate the method. Two mine monitoring sites were used in the project where mine monitoring personnel were shown how to conduct measurements. A simplified instruction sheet has been written to be distributed within the mine monitoring community.

4.9 Study Streams

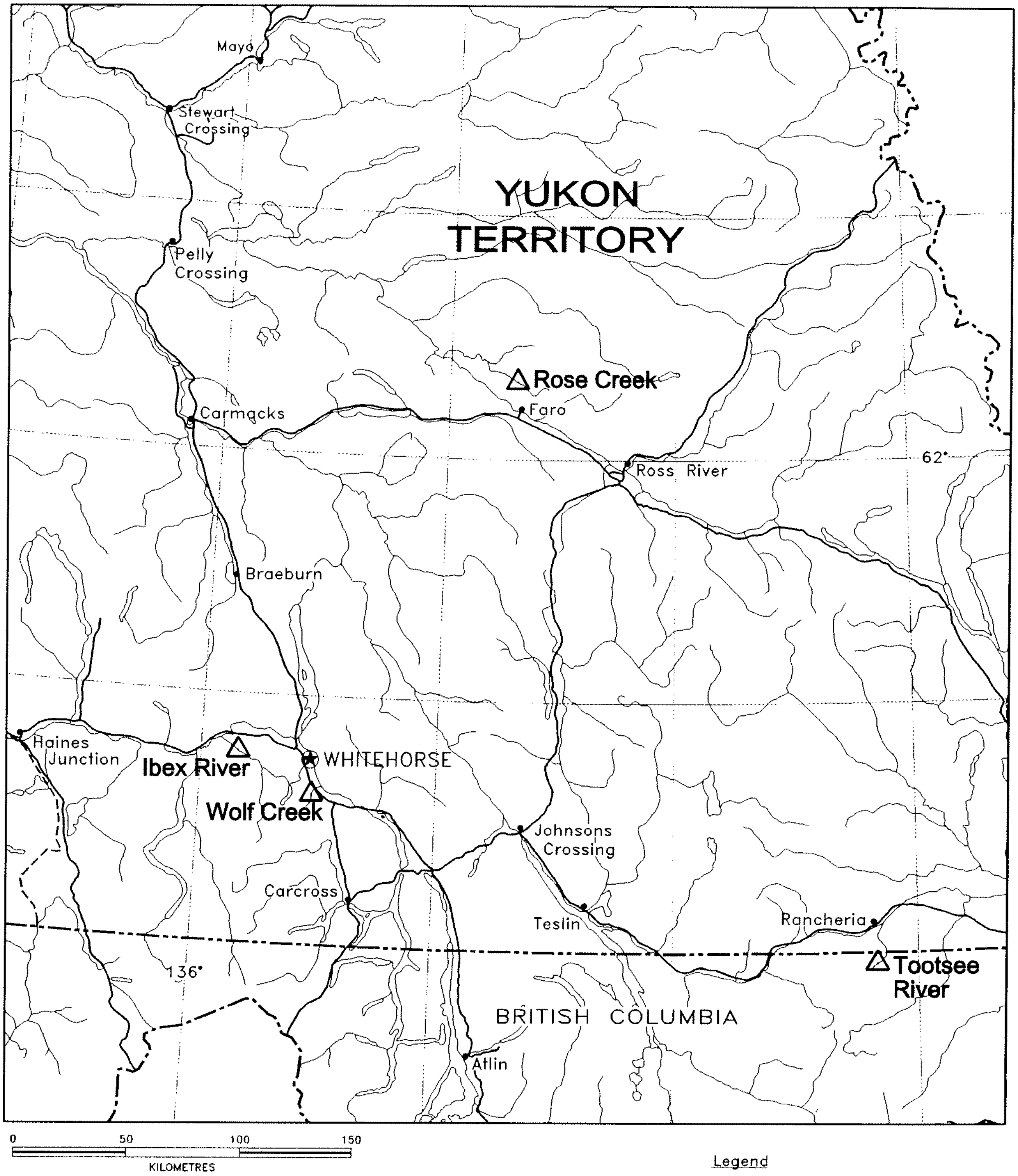
The study streams were selected for both ease of access and availability of verification methods, as well as being representative of real Yukon mine monitoring applications. See Figure One - Test Site Locations.

Rose Creek Drainage, Faro Mine
Sites on Rose Creek:
North Fork of Rose Creek at R-7
Rose Creek Diversion Canal near X10
Seepage From the Cross Valley Dam at X12 and X13

The water balance in this basin, and especially in the Rose Creek Diversion Canal has been a tough monitoring problem over the years. Application of this method at the Faro site was thought to benefit environmental management of this site.

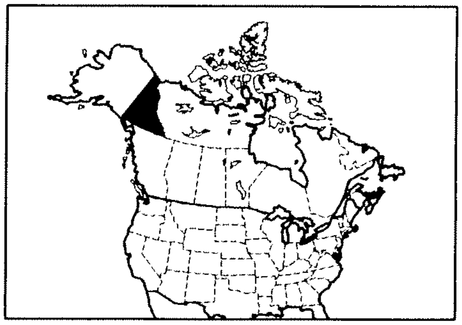
Wolf Creek
Wolf Creek upstream of the Alaska Highway was used for field trials because it is accessible and gauged. This site was used for the workshop as well.

Ibex River
The Ibex has been gauged under a number of projects over the years, and is also a good site for field trials because there are normally open water leads for current metering and injection points. The Ibex was used for the benthic invertebrate drift test.



Lambert Conformal Conic Projection
with Standard Parallels at 49°N and 77°N

Legend
△ Test Site Locations



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Winter Low Flow Stream Discharge Measurements Using the Salt Slug Injection Method

Test Site Locations

SCALE: None	FILE: 166L_1	DATE: 99.07.14
	DRAWN:	FIGURE 1

Tootsee River drainage, Silvertip Mineral Exploration Property
Sites in the Tootsee drainage;
Tootsee River Upstream of Silvertip Creek WQ4
Tootsee River Downstream of Silvertip Creek WQ11
Silvertip Creek Upstream of Camp Creek WQ2
Silvertip Creek Upstream of Wetland WQ25

This site offered a number of flow measurement challenges at low flow. A B.C. government waste permit requires the company to collect "peak metals/pre-freshet" data including water quality, benthics, and flow.

5.0 Conducting a Salt Dilution Streamflow Measurement:

The following is a description of the method used in this project to measure discharge by slug injection, a modification of the salt dilution method.

Necessary Equipment List-

☐ Conductivity meter, temperature compensated, capable of 0.1 *u*S/cm accuracy in low range.

☐ Pre weighed plastic bags of common table salt, either coarse or fine, non-iodized, containing no added ingredients such as "invert sugar".

☐ A mixing bucket of at least 20 litres and a stir stick.

☐ A stop watch.

☐ A field note book.

☐ A calculator.

☐ A measuring tape of at lest 30m.

Optional Equipment:

☐ Computerized conductivity system as configured by NHRI

☐ Data logging conductivity meter.

☐ Streamflow calculation spreadsheet.

Of course, all necessary winter sampling gear is also required, which depending on the program, could include snowmobile and skimmer, ice auger, ice chisel, shovel, snowshoes, and all other equipment associated with safe winter monitoring events.

APPENDIX A

APPENDIX A

Kite, 1994

Journal of Glaciology, Vol. 40, No. 134, 1994

Measuring glacier outflows using a computerized conductivity system

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ABSTRACT. The traditional method of calculating glacier outflows by measuring velocities and areas is difficult, inaccurate and sometimes dangerous in fast mountain streams. The salt-dilution method offers a more accurate alternative but, until now, its use has been restricted because of the difficulty of mixing chemical solutions and measuring chemical concentrations in the field. A computer program has been written which uses a laptop microcomputer to control measurements of stream conductivity and which quickly computes the stream flow directly in the field. The development of this method is described and examples are presented of the application of the method for glaciers in the Rocky Mountains and the Coast Mountains of Canada.

INTRODUCTION

The traditional velocity–area method of estimating flows by measuring velocity at a series of points along a cross-section is most appropriate in large rivers with uniform, steady flow. However, small mountain streams such as glacier outflows are usually turbulent and the velocity–area method becomes unsuitable because of the numerous approximations involved (Kite, 1989) and because of the basic design of the current meters commonly used (Kenney, 1977).

Fortunately, the rapid turbulent flows that make current meters unsuitable for mountain streams and glacier outflows are the ideal environment for dilution techniques of flow measurement. The basic principle of dilution gauging is the conservation of mass of some form of tracer. A known mass of tracer is introduced to the stream and its concentration is measured at some downstream point. The tracer may be introduced as a continuous source or as an "instantaneous" slug injection. Although other tracers such as radioactive isotopes, fluorescent dyes and microbiological agents have been used, sodium chloride (NaCl) is the most common tracer used in North America.

The range of stream flow that may be measured using the dilution technique is limited by practical and environmental considerations to about 15 $\mathrm{m^3\,s^{-1}}$ (Church, 1973). However, by taking advantage of natural salt sources in tributary rivers, the dilution method can be extended to measure the flows of much larger rivers (Kite, 1989).

Other methods of dilution gauging require cumbersome and time-consuming mixing of accurately measured solutions and manpower-intensive measurement and calculation techniques (Benischke and Harum, 1990). However, at the comparatively low conductivities found in North American glacial streams, the concentration/conductivity relationship can be considered linear (Kite, 1993). The introduction of compact conductivity meters and laptop computers enables the use of this relationship to improve measurement and computational accuracy in the field (Gees, 1990). This paper describes the development of a computerized dilution measurement system and its application in mountain streams and glacier outflows in Canada and the U.S.A. This new system obviates the need for preparation of solutions in the field and automates the computation of discharge.

METHOD

A slug of sodium chloride is injected into a stream and the concentration of the stream is monitored at some downstream point. From conservation of mass, the stream flow Q ($\mathrm{m^3\,s^{-1}}$) is calculated as:

$$Q = \frac{M_s}{\int_0^T (C_t - C_0)\,\mathrm{d}t} \tag{1}$$

where M_s (kg) is the mass of NaCl injected, T (s) is the time of passage of the salt slug, C_t ($\mathrm{kg\,m^{-3}}$) is the concentration of NaCl in the river at time t during the passage of the wave and C_0 ($\mathrm{kg\,m^{-3}}$) is the natural concentration of salts in the river before addition of the salt slug.

In practice, it is easier and more convenient to compute the stream flow from conductivity instead of concentration, so that:

$$Q = \frac{1000 M_s \Gamma_{g,25}}{t \sum (L_r - L_0)} \tag{2}$$

where the integral has been replaced by a summation, t is the sampling interval in seconds, L_r is the recorded conductivity in $\mu\mathrm{S\,cm^{-1}}$ and L_0 is the natural conductivity of the river in the same units. $\Gamma_{g,25}$ is the gram-conductivity of NaCl (i.e. the conductivity, in $\mu S\ cm^{-1}$, of 1 g of NaCl in 1 m^3 of solution at 25°C) and is used to convert the measured conductivity into units of concentration needed for the mass balance.

In the field, conductivity is measured by a four-electrode sensor using an induced alternating current in a closed loop. The magnitude of the induced current is proportional to the conductance of the solution. The sensor also measures temperature and converts the conductivity to 25°C equivalent. The output from the sensor is converted to digital form and transferred to the RS-232C port on a laptop microcomputer. The equipment used is shown in Figure 1.

A stream-flow measurement consists of the following steps:

1. Before going into the field, the user weighs convenient amounts of dry sodium chloride into sealed plastic bags. Masses of 1 kg have been found convenient.

2. In the field, the user loads a computer program into the laptop microcomputer. The program is written in FORTRAN, occupies about 60 kbytes as a compressed executable and is suitable for use on any DOS microcomputer. The program uses menus and windows to guide the user through the measurement. From the opening menu, the user is guided to check and, if necessary, correct the microcomputer-system time and date. All data input to the computer by the user or by the probe will be labeled with a date and time, and recorded in a log file.

3. The user is then prompted to place the sensor in the centre of the stream at about mid-depth. The program will take ten temperature measurements at 2 s intervals and records the average.

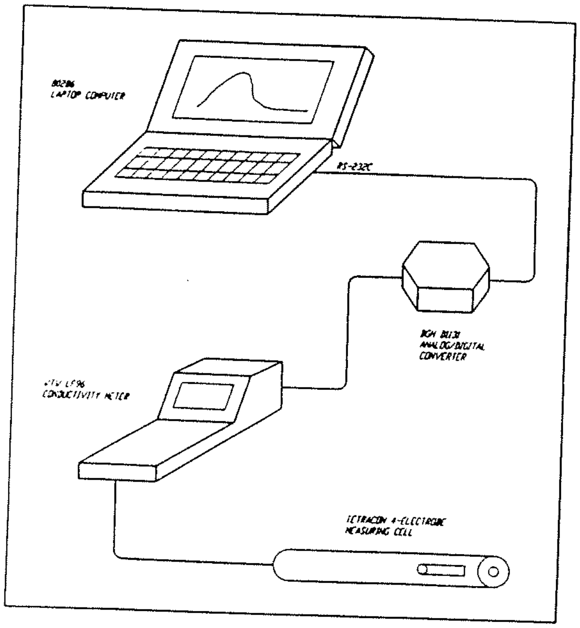

Fig. 1. Equipment used for conductivity measurements.

4. Next, the user is prompted to set a suitable scale on the conductivity meter. The program then computes and records the natural background conductivity of the river using an average of ten readings at 2 s intervals.

5. The program prompts the user for estimates of stream width, depth and velocity, and displays an estimate of the mass of salt needed for the flow measurement. This mass M_s is estimated from the experimental relationship (Kite, 1993):

$$M_s = 0.13\delta_c A^{\frac{3}{2}} \tag{3}$$

where δ_c is the required rise in conductivity in $\mu S\ cm^{-1}$ (the program assumes this is 50% of the background conductivity) and A (m^2) is an estimated stream cross-sectional area. The figure of 50% is deliberately very conservative in order to ensure good separation from the background conductivity; experienced operators may use lower figures to conserve salt.

In practice, the program first calculates a mixing length L_m (m) from the experimental relationship

$$L_m = 260\sqrt{A}, \tag{4}$$

displays this for the user's information in selecting a river reach, and then uses L_m to estimate M_s. It should be emphasized that the figures calculated for mixing length and mass of salt are estimates only, since no general mathematical relationships are available; a comparison with other formulae for mixing length has been given in Kite (1993). The program has a lower limit of 0.5 kg for M_s. This lower limit has been shown appropriate for streams in the Rocky Mountains but, in Europe, lower values are used (personal communication from R. Benischke, 1992).

6. The field worker selects a mass of salt to use based on the program's estimate of needs and on the available selection of pre-weighed bags of salt and, if necessary, changes the default value calculated by the program.

7. The program then prompts the user to start recording conductivity and to inject the slug of salt at a distance upstream at least equal to the mixing length. The computer will record the salt wave (Fig. 2), remove the effect of background conductivity, compute the area beneath the remaining curve and calculate the discharge. The start of the salt wave is determined as the point at which two consecutive measurements are at least two standard deviations above the background conductivity. The end of the salt wave is determined as the point at which two consecutive measurements are within two standard deviations of the initial background conductivity. The effect of the background conductivity is then taken as the area within the quadrilateral between the start and end points and the line of zero conductivity. This accounts for any small change in background conductivity which may have taken place during the measurement. All the data are recorded in a dated log file for later review.

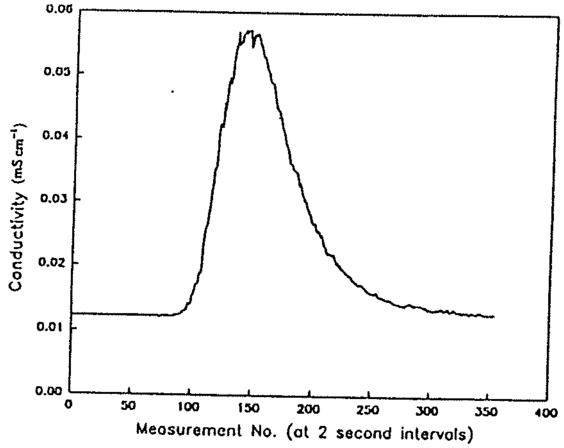

Fig. 2. River conductivity during a dilution measurement, Sentinel Creek.

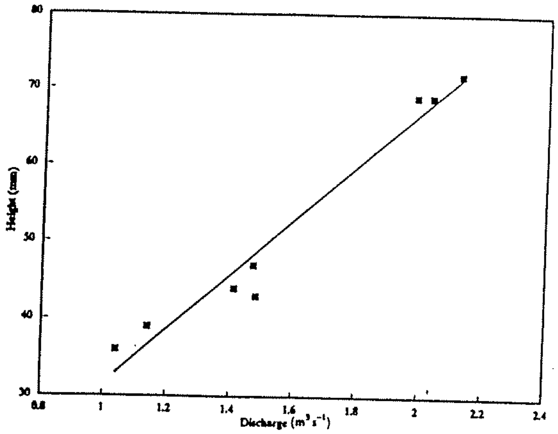

Fig. 3. Rating curve for Sentinel Creek.

RESULTS

Measurements using the salt-dilution method are compared to simultaneous current-meter measurements or with stream flows computed from previously established rating curves for mountain streams and glacier outflows in Alberta, British Columbia and Wyoming in Table 1.

Exact comparisons are difficult because of the inaccuracy of current meters at low flows and the consequent errors in rating curves but, with the exception of measurements at Nash Fork and Little Red Deer River, the results are in good agreement.

Since most glacier outflows are not permanently gauged, it was of interest to see whether the computerized salt-dilution method could be used to establish rating curves. Figures 3 and 4 show curves developed for the outflows from Sentinel and Place Glaciers in the Coast Mountains of British Columbia. Table 2 clearly demonstrates the repeatability of the measurements.

The measurement program at Place Glacier was also used to investigate the effect of using slugs of coarse- and fine-grained solid salt (last column in Table 2). Figure 4 shows that using coarse-grained salt gave slightly (<5%) higher estimates of stream flow because the salt was slower to dissolve and gave a more prolonged, less distinct, wave. For reference, one measurement was made using the conventional salt solution; no significant difference in accuracy was found.

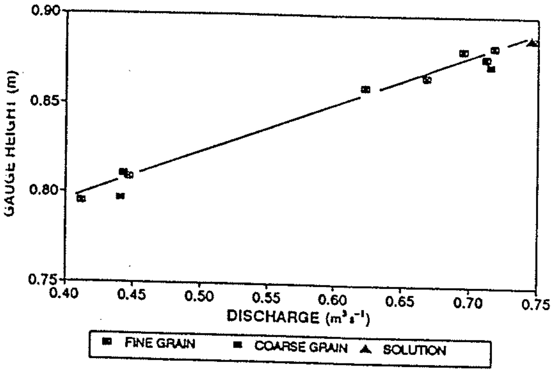

Fig. 4. Rating curve for Place Creek.

Further series of measurements were made at Sphinx, Upper Garibaldi and Lower Barrier Glaciers but they are not given here.

Table 1. Summary of measured stream flows

Stream or glacier	*Date*	*Background conductivity* µS cm⁻¹	*Measured stream flow* m³ s⁻¹	*Stream flow from current meter or rating curve** m³ s⁻¹
Jumping Pound	11 Jun 1991	197	0.88	0.92
McGillivray	13 Jun 1991	224	2.02	1.92
Castle Creek	13 Jun 1991	114	0.18	0.15
Nash Fork	4 Sep 1991	110	0.03	0.04
Nash Fork	5 Sep 1991	113	0.05	0.07
Trap Creek	27 Sep 1991	360	0.75	0.85
Sheep River	27 Sep 1991	341	2.58	2.60
Little Red Deer	28 Sep 1991	415	1.32	0.77*

Stream flows are from current meter except for * which is from a rating curve.

Table 2. Summary of glacier outflow measurements

Date	*Time* h	*Stage* m	*Discharge* $m^3 s^{-1}$	*Comment*
a. Sentinel Glacier				
23 Jul 1991	1215	0.036	1.04	
23 Jul 1991	1445	0.047	1.47	
25 Jul 1991	1525	0.069	2.03	
25 Jul 1991	1545	0.069	1.98	
25 Jul 1991	2015	0.072	2.12	
26 Jul 1991	1120	0.044	1.41	
26 Jul 1991	1140	0.043	1.48	
5 Aug 1991	0955	0.039	1.14	
b. Place Glacier				
7 Oct 1991	1620	4.160	0.623	Fine grain
7 Oct 1991	1642	4.166	0.668	Fine grain
7 Oct 1991	1730	4.173	0.715	Coarse
7 Oct 1991	1757	4.177	0.712	Fine
7 Oct 1991	1823	4.180	0.695	Fine
7 Oct 1991	1848	4.183	0.718	Fine
7 Oct 1991	1957	4.187	0.748	Fine
7 Oct 1991	2013	4.188	0.745	Solution
8 Oct 1991	0925	4.112	0.443	Fine
8 Oct 1991	0943	4.110	0.447	Fine
8 Oct 1991	1237	4.098	0.441	Coarse
8 Oct 1991	1302	4.096	0.412	Fine

DISCUSSION

Salt dilution is a more suitable method of measuring glacier outflows where the stream flow is rapid and turbulent, and the traditional current meter is least accurate. A computerized measurement system using conductivity has been developed which, by using sodium chloride granules, has eliminated the need for manual preparation of chemical solutions in the field and has made the measurement procedure quick and easy.

The procedure is controlled by a computer program which, run on a laptop microcomputer, guides the user through the procedure, takes all the measurements needed and computes the stream flow within a few seconds. The method and the equipment developed have been tested in Canada and the U.S.A., and gave results which compare with simultaneous current-meter measurements and with data from rating curves.

The cost of the measuring equipment is approximately:

Conductivity meter and probe	US$980
Analogue/digital converter	US$300.

On top of this would be the cost of a laptop microcomputer. This total cost is comparable to that of a conventional current-meter set and will provide an expanded capability for data-collection agencies and field workers.

The computer program is available from the author at no cost by sending a blank diskette.

ACKNOWLEDGEMENTS

Conductivity measurements at Sentinel and Place Glaciers were made by H. Laudon and at the Nash Fork of the Little Laramie River by C. Senft. The author wishes to acknowledge the useful comments made by Dr R. Benischke and by an anonymous referee.

REFERENCES

Benischke, R. and T. Harum. 1990. Determination of discharge rates in turbulent streams by salt tracer dilution applying a microcomputer system. Comparison with current meter measurements. *International Association of Hydrological Sciences Publication* 193 (Symposia at Lausanne 1990 — *Hydrology in Mountainous Regions. I*), 215–221.

Church, M. 1973. Some tracer techniques for streamflow measurements. *Tech. Bull. Br. Geomorphol. Res. Group.*

Gees, A. 1990. Flow measurement under difficult measuring conditions: field experience with the salt dilution method. *International Association of Hydrological Sciences Publication* 193 (Symposia at Lausanne 1990 — *Hydrology in Mountainous Regions. I*), 255–262.

Kenney, B.C. 1977. Response characteristics affecting the design and use of current direction vanes. *Deep-Sea Res.*, **24**, 289–300.

Kite, G.W. 1989. An extension to the salt dilution method of measuring streamflow. *Wat. Res. Devel.*, **5**(1), 19–24.

Kite, G.W. 1993. Computerized streamflow measurement using slug injection. *Hydrological Processes.*, **7**, 227–233.

The accuracy of references in the text and in this list is the responsibility of the author, to whom queries should be addressed.

MS received 12 March 1992 and in revised form 11 November 1992

Methodology:

Preliminary Considerations:

Pre weigh salt in plastic bags, using a top loading balance.

The mass of salt is critical to the computations. Accuracy is recommended to one milligram for weights under one kilogram, and 0.01 kg for weights over one kilogram. The mass of salt required for a measurement is dependant on turbulence and volume of flow as well as background conductivity. Pre weigh masses of 0.1500 to 0.2500 kg for flows up to 0.5 m^3/s and 0.50 kg bags for flows over 0.5 m^3/s. Bags are then used in combinations as required to produce a well defined salt wave.

Background conductivity and flow conditions affect the recommended mass to use - see discussion in Section 6 below.

Stream Reconnaissance:

Select a reach. Two openings in the ice are required - one to inject the slug and one to measure the resulting rise in conductivity below a mixing length. The reach should not have any loss or gain of water, and should have uniform flow. Avoid braids, backwaters, and islands. Open leads where the flow is turbulent are good for injection and measurement points. Most of the time you won't be so fortunate, and holes will have to be opened with an auger or chisel. Look for depressions in the snow, and check for hollow sounding areas. These will usually indicate thin ice over flowing water.

Recommended mixing length:
Too long a mixing length will lessen the salt wave and takes too much time, while too short a mixing length will underestimate flow because of incomplete mixing. See discussion in section 6 below.

Measurement Steps:

- ☐ Set up your conductivity meter at the measurement site. Set up your field note, record site locations, background conductivity, temperature, mixing length, date, time of injection, recording interval (a convenient interval such as 10, 15, or 30 seconds), and observations such as weather conditions, snow and ice cover conditions, and stream observations.

- ☐ Choose an appropriate salt bag and record the mass.

- ☐ Mix the salt in a plastic bucket at the injection point until all the salt is dissolved. This may take up to five minutes, depending on the mass used. At the predetermined time zero, or on a signal mark, dump the solution into the creek at the injection point, rising the bucket to make sure all of the mass reports to the creek.

- ☐ At the measurement site, observe the conductivity, and start your stopwatch as soon as conductivity begins to rise. Record the travel time (time taken for the start of the wave to reach the measurement point). Record measurements of conductivity at each time interval until the salt wave has passed and the conductivity returns to background.

Calculations:

The discharge of a stream may be calculated as the mass of NaCl divided by the integral of the increase over background concentration of salts in the stream. To make things practical, conductivity is measured instead of NaCl concentration. The relationship of NaCl to conductivity is conveniently linear for the range of natural conductivity in the Yukon. For streams with very high background conductivity, some adjustment may be needed.

The gram conductivity of NaCl ($\Gamma_{g,25}$) is the conductivity in μS/cm of 1 gram of NaCl in 1 m^3 at 25^0 C. This converts mass of salt to concentration. Experiments performed by Water Resources Division of D.I.A.N.D., and experience, has shown that the number to use for this term in local conditions is approximately 2.01. To correct for background conductivity, use $\Gamma_{g,25} = 2.14 - 0.0003\ C_o$ where C_o is the background concentration of salts in the stream.

The basic stream flow calculation then results as the following:

$$Q = \frac{1000\, M_s \Gamma_{g,25}}{\tau \Sigma (L_r - L_0)}$$

Where:

Q	discharge in m^3/sec
M_s	mass of salt in kg
$\Gamma_{g,25}$	gram conductivity, assume 2.01 $\mu S/cm/m^3$
t	time interval in seconds
L_r	recorded conductivity in μS/cm
L_0	background conductivity in μS/cm

If calculating flow manually, simply use a calculator to find the summation of differences between the conductivity at time interval t, and complete the equation to compute flow.

If using the spreadsheet, simply enter the recorded conductivity, mass of salt, and other values as prompted.

6.0 RESULTS AND DISCUSSION

Within the limitations of the study, it was shown that the method appears to yield reproducible results for small stream flows under ice. It was also shown that the method produced accurate results when compared to other methods of flow measurement. The method was successfully demonstrated to a number of people interested in low flow monitoring. The method is not thought to cause any significant environmental effects. Technology transfer can be achieved through publication of an instruction sheet. Details of individual study components follow.

The method was applied to two mine monitoring networks. A total of 50 discharge measurements were made under ice. Twenty three of these were used in an analysis of precision and accuracy. It was observed that the method is practical for use in small ice covered streams in the region.

6.1 Reproducing Results at Study Streams

Precision error occurs when several measurements of discharge at the same stream reach result in different values. Although precision can be expressed by several types of indices, standard deviation is the only one presented here. Due to logistical and time constraints, the number of measurements at a given site ranged from only two to six. A more detailed analysis of precision would have required a larger number of measurements. To compensate for the few measurements, at least two of the three variables were changed (i.e. mass of salt, mixing length, and time interval) for each successive measurement.

Sources of error in this method arise from placing the probe in a dead zone with low lateral velocity, errors in reading and recording conductivity, errors in weighing and recording salt mass, incomplete mixing of the slug or the salt wave, and selection of too long or too short a mixing length.

The flow measured by salt dilution generally showed little variation. The standard deviation of the recorded flows ranged from 0.0051 to 0.0002. The number of repeated measurements is too low for a complex precision analysis, but the tests completed seem to indicate excellent precision.

Table One summarises results of measurements related to precision and accuracy. Raw data is attached as Appendix C.

6.1.1 Optimizing Mass and Mixing Length

The mass of salt used for the slug injection depends on the expected volume of flow to be measured and the background conductivity. If too little is used, the rise in conductivity may be difficult to measure, and if too much is used, there may be environmental effects and incomplete mixing. This project, and previous experience has shown that a rise in conductivity anywhere between 10 and 50% above background will yield good results. The relationship $M_s = 0.13(\text{Background Conductivity}/2)A^{2/3}$ was derived by Kite in 1993. A more recent relationship $M_s = 0.0008\ Q_e\ \delta_c\ T$ where Q_e is the estimated discharge in cubic meters per second, and δ_c is the required increase in conductivity, and T is the travel time, or Mixing length /estimated velocity. While use of either formula will yield good results, it tends to exaggerate the amount of salt needed, especially for small streams within the range of 100 to 400 μS/cm. In this project, and in past experience, it was found that use of 0.25Kg increments of salt to yield 5Kg per m^3/sec of expected flow was adequate, and represents the approximate lowest practical amount to produce a well defined salt wave.

Other practical limitations to the mass of salt to use are solubility at cold temperatures and volume of mixing solution bucket used. A saturated solution of NaCl in typical Yukon waters in winter low flow would be about 200 grams/litre. A typical mixing bucket is 20 litres, so no more than 4Kg could be added for the slug injection in any case.

It is recommended that a practical approach be taken to the mass of salt to use for the injection slug. Pre weighed plastic bags of 0.25 to 0.5 Kg should be prepared. Estimate the discharge of the stream either from past experience of the system, or by estimates of velocity and area in the field. **Use a trial of 5Kg per m^3/sec of this estimated flow and**

observe the resultant rise in conductivity. If the conductivity is not raised at least 10%, repeat the measurement using another increment of salt.

There must be extra care taken, however, to ensure careful weight measurements, accurate recording of conductivity, and complete dissolution of the salt prior to injection to compensate for the lesser increase in conductivity and consequent introduction of error.

The mixing length recommended from the literature, in the form of $L = 260A^{1/2}$ (1) where L is the mixing length and A is the cross sectional area of flow, was also observed to be excessive for small streams. It was observed that if this recommended mixing length was used, the method might exaggerate the flow due to attenuation of the salt wave and inability to detect the rise in conductivity. Also, it may be inconvenient to find a reach that satisfied the mixing length requirement. Appropriate mixing length was examined by trying lesser mixing lengths using comparable masses of salt and observing any changes to the resultant flow measurement.

There is insufficient data to recommend a new prescribed mixing length formula, but good results were obtained with mixing lengths as little as 1/2 of that suggested by the above formula (calculated flows showed little variation with the lesser mixing lengths).

It is suggested that turbulence at the injection point, and the slope of the creek are more important to complete mixing than the cross sectional area of flow. Again, a practical approach is recommended. In winter low flow, areas of strongest turbulence will produce open leads or thin ice. These coincide with practical choices in selection of the reach. The mixing length then tends to be dictated by logistics and individual stream characteristics. Therefor, select injection and measurement points where there is turbulent flow and where these points are a reasonable distance apart, say at least 30 m. Check the selected mixing length against the relationship Mixing Length = $260A^{1/2}$. If the selected or practical length is at least one half of this number, either proceed with the measurement or try to find a longer reach accordingly.

6.2 Reliability Checks - Accuracy

The test of accuracy was to compare the salt dilution method to other flow measurement techniques of known accuracy. At the Wolf Creek trials, a Price type current meter was used with at least 20 velocity measurements. Such a measurement should be within 7% error.

At the Faro Mine, salt dilution flows were compared to the flow over a 90^0 V-notch weir at the sample site X-11, seepage from the Cross Valley Dam. This site satisfies limits of application such as low approach velocity, free falling nappe, and adequate depth within the stilling pond. If these conditions are met, a weir of this type should be within 3% error.

At Wolf Creek, the median discharge by salt dilution was 6.5% and 5.0% higher than the discharge measured by velocity - area. At the Faro Mine, the flow over the weir at X11 was observed to be 0.0204 m^3/sec based on the weir equation. The median of 6 salt dilution measurements was 0.0211 m^3/sec, or 0.6% higher.

TABLE ONE - PRECISION AND ACCURACY TRIALS

Measurement Code	Mass NaCl (kg)	Mass/ Q Kg/cms	Mix Length (m)	Measured Flow (cms)	SaltDil Flow (cms)	Standard Deviation	Time Interval (sec)
Wolf T1 26.01.99	1.08	14	93.5	0.072	0.0853		10
Wolf T2 26.01.99	1.0417	13.6	93.5		0.07611		15
Wolf T3 26.01.99	0.467	6.1	93.5		0.07707	0.0050516	15
Wolf T4 27.01.99	0.5713	7.9	93.5	0.067	0.07175		15
Wolf T5 27.01.99	0.2144	2.9	93.5		0.07255		30
Wolf T6 27.01.99	0.5221	7.3	93.5		0.07038		30
Wolf T7 27.01.99	1.852	25	307.5		0.06696		30
Wolf T8 27.01.99	2.1132	29	307.5		0.0694		
Wolf T9 27.01.99	0.9463	13.1	214		0.07213	0.00210585	30
NF Rose T1 25.02.99	0.2811	2.6	62.5 N.R		0.1071		30
NF Rose T2 25.02.99	0.2499	2.4			0.10665		30
NF Rose T3 25.02.99	0.43174	4	150.9		0.10714		30
NF Rose T4 25.02.99	0.64929	6.1	62.5		0.10689	0.00022517	30
RCDCanal T1 25.02.99	0.1942	1.6	89.3		0.11937		30
RCDCanal T2 25.02.99	0.67885	5.7	89.3		0.11969		30
CVD X11 T3 26.02.99	1.05548	50	38		0.02028		10
CVD X11 T4 26.02.99	0.60289	28.6	44		0.021312		10
CVD X11 T5 26.02.99	0.40231	19.2	44		0.020933		10
CVD X11 T6 26.02.99	0.53987	25.7	55	0.0204	0.02195	0.00069912	10
Silvertip WQ22 T1	0.17234	4.9	105 N.R.		0.035749		15
Silvertip WQ22 T2	0.2072	5.9	105		0.03514		15
Silvertip WQ22 T3	0.1969	5.6	105		0.031187		15
Silvertip WQ22 T4	0.2438	7	105		0.03532	0.00212342	15

6.3 Checking the Method in High Conductivity Streams

The salt dilution method was applied at seepage from the cross valley dam at Faro, where conductivity was around 1,730 μS/cm. The gram conductivity of salt is non linear at higher conductivity. The value of 2.01 μS/cm per gram per cubic meter was used in the calculations at this site, and the resulting discharge value was very close to the value observed at the weir. For this reason, the gram conductivity of salt appears to be valid at least to the level of 1,730 μS/cm background conductivity.

6.4 Checking for Complete Mixing

At the Tootsee River, station WQ11, a salt wave was observed across an open lead using two conductivity probes at opposite sides of the channel. There were no differences in conductivity readings throughout the test. The channel was 4m wide, flow was turbulent, depth was even across the channel.

6.5 Environmental Effects

A bioassay sample was collected by Environment Canada of a salt solution prepared with Wolf Creek water in November, 1998. The 96 hour LC_{50} resulted in 70.4% mortalities in a 2% salt solution and zero mortalities in a 1% salt solution. These results were expected, as the effect of NaCl on fish is well known.

From a practical standpoint, the addition of a salt slug tracer in the amount recommended for a salt dilution measurement has no significant or lasting harmful effect.

The other observation consisted of an attempt to observe any change in the composition of benthic invertebrate drift before and during a salt slug injection measurement. At the Ibex River, four 343 micron invertebrate samplers were placed in the stream prior to a measurement. The invertebrates were recovered and the samplers were replaced. Then a salt slug of 2.5 kg was injected above the mixing length, resulting in a rate of 8.3 $Kg/m^3/sec$. The samplers were removed after passage of the salt wave and again enumerated to compare pre test drift of invertebrates to any changes caused by the addition of the slug. Underwater video footage was taken at the sampler location.

The results of this experiment are attached in a letter report prepared by Doug Davidge of Environment Canada, attached as Appendix D. It was concluded, within the limitations of this experiment, that there was no lasting negative impact on the benthic community caused by passage of the salt wave.

6.6 Testing Computerized Method

The computerized discharge measurement kit described by Kite was loaned to L.E.S. from December, 1994 to April, 1995. The same kit was again leased from the National Hydrology Research Institute in Saskatoon, Saskatchewan for the current project. The kit consists of two large Pelican cases containing an Orion 126 temperature compensated conductivity meter, a digital - analog converter, two 12 volt lithium batteries, a battery charger, communications cables and wiring. The software used to compute flow rate was included on diskette.

It was observed that the software program was difficult to load and operate with newer laptop PCs. The only times it functioned well were when it was run on older computers running DOS. The discharge calculated by the computer program yielded virtually the same result as that of the conductivity meter alone with hand calculations. Cold temperatures (-18 and -10 on two occasions) made the laptop very difficult to manage, especially the power supply.

It was concluded that the computerized method was not practical for winter flow measurements. A data logging conductivity meter may be a practical alternative for automated measurements, where the recorded data may be imported to a calculation spreadsheet similar to the one used in this project.

6.7 Computerized Calculation Sheet

A excel spreadsheet originally compiled by Gerry Whitley of DIAND was utilized throughout. The spreadsheet is an effective field note and is easy to use for calculations. A copy of the blank spreadsheet is attached as appendix B. It is also provided in electronic format.

6.8 Technology Transfer

A workshop was held to demonstrate the method on March 30, 1999. A field demonstration was held at Wolf Creek. The workshop was attended by 13 people, representing government, consultants, and one first nation.

Two mine monitoring sites, the Faro mine site and the Silvertip mineral exploration property, were used as test and demonstration sites. Mine monitoring staff were instructed in the use of the method.

Effective transfer of technology should take place by distribution of this report, or a condensed version explaining the method, to mine monitoring personnel.

APPENDIX B

"Saltmaster" Calculation Sheet

Saltmaster Spreadsheet - for Calculation of Stream Discharge by Salt Slug Injection by G. Whitley								
Date		Stream				Discharge	#DIV/0!	cms
time		Party						
Sample	cond	dif		Geoff Kite 1994				
1		0		L1	natural conductivity			
2		0		L2	recorded conductivity			
3		0		t	sample time in seconds			
4		0		Ms	mass of salt kg			
5		0		Cs	conductivity of 1 gram NaCl in 1 m3 water uS/c			
6		0		where				
7		0		Q=(1000*Ms*Cs)/t*sum(L2-L1)				
8		0						
9		0		width m		estimate		
10		0		depth m		estimate		
11		0		area m2	0	calculate		
12		0		mix length Lm	0	calculate		
13		0		velocity m/s		estimate		
14		0		cond uS/cm		calculate		
15		0		salt needed k	0.00	calculate		
16		0		salt used kg		actual		
17		0						
18		0						
19		0						
20		0						
21		0						
22		0						
23		0						
24		0						
25		0						
26		0						
27		0		Time interval		seconds		
28		0		Q flow cms	0	0		
29		0		#DIV/0!	0			
30		0	preparation					
31		0	conductivity meter, stopwatch, measuring tape, calculater					
32		0	salt in 1 kilo bags, mixing bucket					
33		0						
34		0	stream reach					
35		0	no loss or gain of water					
36		0	turbulent flow for mixing					
37		0						
38		0	measure background stream temperature and conductivity c5					
39		0	measure width and depth g14, g15					
40		0	measure distance between dosing and sampling greater than g16					
41		0	measure/estimate velocity g17					
42		0	dissolve g18 kg salt in water 200 g per liter					
43		0	pour salt into stream at time zero					

APPENDIX C

Raw Data

Date	26.01.99	Stream	Wolf Creek T1 26.01.99			Discharge	0.08533	cms
time	15:29:00	Party	Withers/Nordin			metered	0.072	
						Mix L	93.5m	
Sample	Conductivity	dif						
1	201	0						
2	220	19						
3	235	34						
4	262	61						
5	272	71						
6	271	70						
7	265	64						
8	257	56						
9	251	50						
10	247	46						
11	246	45						
12	242	41						
13	239	38						
14	230	29						
15	226	25						
16	224	23		salt used kg	1.08	actual		
17	221	20						
18	220	19						
19	217	16						
20	215	14						
21	214	13						
22	213	12						
23	211	10						
24	210	9						
25	210	9						
26	209	8						
27	208	7		Time interval	30	seconds		
28	208	7		Q flow cms	2170.8	848		
29	207	6		0.085330189	25440			
30	206	5						
31	206	5						
32	205	4						
33	205	4						
34	204	3						
35	204	3						
36	203	2						
37	203	2						
38	202	1						
39	202	1						
40	201	0						

Date	260199	Stream	Wolf Creek T 2 26.02.99			Discharge	0.076111	cms
time	16:01:25	Party	Withers, Nordin			metered	0.072	
						Mix L	93.5m	
Sample	cond	dif		Geoff Kite 1994				
1	203	0		203	natural conductivity			
2	218	15		L2	recorded conductivity			
3	230	27		15	sample time in seconds			
4	250	47		1.0417	mass of salt kg			
5	271	68		2	conductivity of 1 gram NaCl in 1 m3 water uS/c			
6	294	91		where				
7	307	104		Q=(1000*Ms*Cs)/t*sum(L2-L1)				
8	318	115						
9	322	119		width m	3	estimate		
10	322	119		depth m	0.1	estimate		
11	317	114		area m2	0.3	calculate		
12	309	106		mix length Lm	137	calculate		
13	302	99		velocity m/s	0.15	estimate		
14	291	88		cond uS/cm	203	calculate		
15	280	77		salt needed k	2.07	calculate		
16	275	72		salt used kg	1.0417	actual		
17	266	63						
18	260	57						
19	254	51						
20	249	46						
21	243	40						
22	239	36						
23	235	32						
24	232	29						
25	230	27						
26	226	23						
27	224	21		Time interval	15	seconds		
28	222	19		Q flow cms	2093.817	1834		
29	221	18		0.076111123	27510			
30	219	16						
31	218	15						
32	216	13						
33	214	11						
34	213	10						
35	211	8						
36	210	7						
37	210	7						
38	209	6						
39	208	5						
40	207	4						
41	207	4						
42	206	3						
43	205	2						
44	205	2						
45	204	1						
46	203	0						

Date	260199	Stream	Wolf Creek Trial 3 26.01.99			Discharge	0.077067	cms
time	16:01:25	Party	Withers, Nordin			metered	0.072	
						Mix L	93.5m	
Sample	cond	dif		Geoff Kite 1994				
1	201	0		201	natural conductivity			
2	211	10		L2	recorded conductivity			
3	219	18		15	sample time in seconds			
4	225	24		0.467	mass of salt kg			
5	234	33		2	conductivity of 1 gram NaCl in 1 m3 water uS/cm			
6	240	39		where				
7	244	43		Q=(1000*Ms*Cs)/t*sum(L2-L1)				
8	247	46						
9	248	47		width m	3	estimate		
10	247	46		depth m	0.1	estimate		
11	246	45		area m2	0.3	calculate		
12	244	43		mix length Lm	137	calculate		
13	241	40		velocity m/s	0.15	estimate		
14	238	37		cond uS/cm	201	calculate		
15	235	34		salt needed k	2.05	calculate		
16	232	31		salt used kg	0.467	actual		
17	229	28						
18	226	25						
19	224	23						
20	223	22						
21	221	20						
22	220	19						
23	218	17						
24	217	16						
25	216	15						
26	214	13						
27	213	12		Time interval	15	seconds		
28	212	11		Q flow cms	938.67	812		
29	211	10		0.077066502	12180			
30	210	9						
31	210	9						
32	209	8						
33	208	7						
34	207	6						
35	207	6						
36								
37								

27.01.99	Stream	Wolf Creek Trial 4 27.01.99			Discharge	0.071747	cms
12:42:00	Party	Withers/ Nordin			metered	0.067	
					Mix L	93.5m	
cond	dif		Geoff Kite 1994				
203	0		203	natural conductivity			
207	4		L2	recorded conductivity			
213	10		15	sample time in seconds			
220	17		0.5713	mass of salt kg			
227	24		2	conductivity of 1 gram NaCl in 1 m3 water uS/cm			
240	37		where				
245	42		Q=(1000*Ms*Cs)/t*sum(L2-L1)				
252	49						
258	55		width m	3	estimate		
260	57		depth m	0.1	estimate		
270	67		area m2	0.3	calculate		
265	62		mix length Lm	137	calculate		
260	57		velocity m/s	0.15	estimate		
255	52		cond uS/cm	203	calculate		
252	49		salt needed k	2.17	calculate		
249	46		salt used kg	0.5713	actual		
245	42						
239	36						
235	32						
232	29						
231	28						
229	26						
226	23						
225	22						
222	19						
221	18						
219	16		Time interval	15	seconds		
218	15		Q flow cms	1148.313	1067		
217	14		0.071747142	16005			
216	13						
215	12						
214	11						
213	10						

27.01.99	Stream	Wolf Creek Trial 5 27.01.99			Discharge	0.072549	cms
13:12:00	Party	Withers/ Nordin			metered	0.067	cms
					Mix L	93.5	m
cond	dif		Geoff Kite 1994				
203	0		203	natural conductivity			
206	3		L2	recorded conductivity			
213	10		30	sample time in seconds			
220	17		0.2144	mass of salt kg			
223	20		2	conductivity of 1 gram NaCl in 1 m3 water uS/cm			
224	21		where				
222	19		Q=(1000*Ms*Cs)/t*sum(L2-L1)				
220	17						
218	15		width m	3	estimate		
215	12		depth m	0.1	estimate		
214	11		area m2	0.3	calculate		
212	9		mix length Lm	137	calculate		
210	7		velocity m/s	0.15	estimate		
210	7		cond uS/cm	202	calculate		
208	5		salt needed kg	2.06	calculate		
208	5		salt used kg	0.2144	actual		
207	4						
206	3						
205	2						
205	2						
205	2						
205	2						
205	2						
204	1						
204	1						
204	1						
203	0		Time interval	30	seconds		
			Q flow cms	430.944	198		
			0.072549495	5940			

Date	27.01.99	Stream	Wolf Creek Trial 6 27.01.99			Discharge	0.070384	cms
time	13:41`	Party	Withers/ Nordin			metered	0.067	cms
						Mix L	93.5m	
Sample	cond	dif		Geoff Kite 1994				
1	203	0		203	natural conductivity			
2	208	5		L2	recorded conductivity			
3	221	18		30	sample time in seconds			
4	239	36		0.4935	mass of salt kg			
5	253	50		2	conductivity of 1 gram NaCl in 1 m3 water uS/cn			
6	259	56		where				
7	257	54		Q=(1000*Ms*Cs)/t*sum(L2-L1)				
8	250	47						
9	242	39		width m	3	estimate		
10	235	32		depth m	0.1	estimate		
11	230	27		area m2	0.3	calculate		
12	226	23		mix length Lm	137	calculate		
13	222	19		velocity m/s	0.15	estimate		
14	220	17		cond uS/cm	203	calculate		
15	216	13		salt needed k	2.07	calculate		
16	214	11		salt used kg	0.5221	actual		
17	213	10						
18	211	8						
19	210	7						
20	209	6						
21	208	5						
22	207	4						
23	206	3						
24	205	2						
25	205	2						
26	205	2						
27	204	1		Time interval	30	seconds		
28	204	1		Q flow cms	1049.421	497		
29	204	1		0.070383702	14910			
30	204	1						
31	203	0						
32								
33								
34								
35								
36								
37								
38								
39								
40								
41								
42								
43								
44								

Date	27.01.99	Stream	Wolf Creek T 7 27.01.99			Discharge	0.066964	cms
time	14:23:00	Party	Withers/ Nordin			metered	0.067	cms
						Mix L	307.5m	
Sample	cond	dif		Geoff Kite 1994				
1	203	0		203	natural conductivity			
2	205	2		L2	recorded conductivity			
3	208	5		30	sample time in seconds			
4	211	8		1.852	mass of salt kg			
5	216	13		2.14	conductivity of 1 gram NaCl in 1 m3 water uS/c			
6	221	18		where				
7	228	25		Q=(1000*Ms*Cs)/t*sum(L2-L1)				
8	235	32						
9	243	40		width m	3	estimate		
10	257	54		depth m	0.1	estimate		
11	260	57		area m2	0.3	calculate		
12	266	63		mix length Lm	137	calculate		
13	271	68		velocity m/s	0.15	estimate		
14	274	71		cond uS/cm	203	calculate		
15	277	74		salt needed k	2.07	calculate		
16	280	77		salt used kg	1.852	actual		
17	279	76						
18	277	74						
19	275	72						
20	272	69						
21	270	67						
22	265	62						
23	261	58						
24	257	54						
25	253	50						
26	249	46						
27	245	42		Time interval	30	seconds		
28	241	38		Q flow cms	3722.52	1853		
29	239	36		0.066963842	55590			
30	237	34						
31	235	32						
32	235	32						
33	233	30						
34	233	30						
35	230	27						
36	230	27						
37	228	25						
38	228	25						
39	227	24						
40	225	22						
41	223	20						
42	223	20						
43	221	18						
44	220	17						
45	218	15						
46	216	13						

Date	27.01.99	Stream	Wolf Creek T 8 27.01.99,				Discharge	0.069404	cms
time	14:37:00	Party	Withers/ Nordin				metered	0.067	cms
							Mix L	307.5m	
Sample	cond	dif		Geoff Kite 1994					
1	203	0		203	natural conductivity				
2	204	1		L2	recorded conductivity				
3	207	4		30	sample time in seconds				
4	215	12		1.852	mass of salt kg				
5	217	14		2.14	conductivity of 1 gram NaCl in 1 m3 water uS/c				
6	226	23		where					
7	228	25		Q=(1000*Ms*Cs)/t*sum(L2-L1)					
8	239	36							
9	247	44		width m	3	estimate			
10	259	56		depth m	0.1	estimate			
11	266	63		area m2	0.3	calculate			
12	272	69		mix length Lm	137	calculate			
13	275	72		velocity m/s	0.15	estimate			
14	278	75		cond uS/cm	203	calculate			
15	280	77		salt needed k	2.07	calculate			
16	283	80		salt used kg	2.1132	actual			
17	281	78							
18	280	77							
19	277	74							
20	274	71							
21	275	72							
22	272	69							
23	268	65							
24	264	61							
25	259	56							
26	253	50							
27	248	45		Time interval	30	seconds			
28	245	42		Q flow cms	4247.532	2040			
29	241	38		0.069404118	61200				
30	239	36							
31	237	34							
32	237	34							
33	235	32							
34	237	34							
35	235	32							
36	234	31							
37	234	31							
38	232	29							
39	230	27							
40	229	26							
41	225	22							
42	225	22							
43	223	20							
44	222	19							
45	219	16							
46	218	15							

Date	27.01.99	Stream	Wolf Creek T 9 27.01.99			Discharge	0.07213	cms
time	15:33:00	Party	Withers/ Nordin			metered	0.067	cms
						Mix L	214m	
Sample	cond	dif		Geoff Kite 1994				
1	203	0		203	natural conductivity			
2	205	2		L2	recorded conductivity			
3	210	7		15	sample time in seconds			
4	214	11		0.93456	mass of salt kg			
5	220	17		2	conductivity of 1 gram NaCl in 1 m3 water uS/c			
6	228	25		where				
7	235	32		Q=(1000*Ms*Cs)/t*sum(L2-L1)				
8	242	39						
9	250	47		width m	3	estimate		
10	254	51		depth m	0.1	estimate		
11	256	53		area m2	0.3	calculate		
12	259	56		mix length Lm	137	calculate		
13	257	54		velocity m/s	0.15	estimate		
14	256	53		cond uS/cm	203	calculate		
15	253	50		salt needed k	2.07	calculate		
16	250	47		salt used kg	0.9463	actual		
17	246	43						
18	240	37						
19	238	35						
20	234	31						
21	230	27						
22	228	25						
23	224	21						
24	221	18						
25	219	16						
26	216	13						
27	215	12		Time interval	30	seconds		
28	214	11		Q flow cms	1902.063	879		
29	211	8		0.072129807	26370			
30	210	7						
31	209	6						
32	208	5						
33	208	5						
34	207	4						
35	207	4						
36	206	3						
37	205	2						
38	205	2						
39	204	1						
40	204	1						
41	204	1						
42	203	0						
43								
44								
45								
46								

Date	25.02.99	Stream	Rose Creek R7 T1				Discharge	0.10701	cms
time	11:51	Party	Nordin/Withers/Denholm				MixLength	62.5m	
Sample		dif		Geoff Kite 1994					
1	302	0		L1	natural conductivity				
2	310	8		L2	recorded conductivity				
3	326	24		t	sample time in seconds				
4	328	26		Ms	mass of salt kg				
5	327	25		Cs	conductivity of 1 gram NaCl in 1 m3 water uS/cm				
6	323	21		where					
7	319	17		Q=(1000*Ms*Cs)/t*sum(L2-L1)					
8	315	13							
9	312	10		width m		estimate			
10	309	7		depth m		estimate			
11	308	6		area m2	0	calculate			
12	306	4		mix length Lm	0	calculate			
13	306	4		velocity m/s		estimate			
14	305	3		cond uS/cm	302	calculate			
15	304	2		salt needed k	0.29	calculate			
16	304	2		salt used kg	0.2811	actual			
17	303	1							
18	303	1							
19	303	1							
20	303	1							
21	302	0							
22									
23									
24									
25									
26									
27									
28									
29									
30									
31				Time interval	30	seconds			
32				Q flow cms	565.011	176			
33				0.107009659	5280				
34									
35									
36									
37									
38									
39									
40									
41									
42									
43									
44									
45									
46									

Date	25.02.99	Stream	Rose Creek R7T2 25.02.99			Discharge	0.106654	cms
time	12:08	Party	Nordin/Withers/Denholm			MixLength	62.5m	
Sample		dif		Geoff Kite 1994				
1	302	0		L1	natural conductivity			
2	309	7		L2	recorded conductivity			
3	317	15		t	sample time in seconds			
4	322	20		Ms	mass of salt kg			
5	323	21		Cs	conductivity of 1 gram NaCl in 1 m3 water uS/cm			
6	322	20		where				
7	319	17		Q=(1000*Ms*Cs)/t*sum(L2-L1)				
8	316	14						
9	313	11		width m		estimate		
10	310	8		depth m		estimate		
11	308	6		area m2	0	calculate		
12	307	5		mix length Lm	0	calculate		
13	306	4		velocity m/s		estimate		
14	305	3		cond uS/cm	231	calculate		
15	304	2		salt needed kg	0.00	calculate		
16	303	1		salt used kg	0.24992	actual		
17	303	1						
18	303	1						
19	303	1						
20	302	0						
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31				Time interval	30	seconds		
32				Q flow cms	502.3392	157		
33				0.106653758	4710			
34								
35								
36								
37								
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44								
45								
46								

Date	26.02.99	Stream	CVD Seepage X11 T3 26.02.99			Discharge	0.02028	cms
time	9:18	Party	Nordin/Withers/Denholm			MixLength	38.0m	
Sample		dif		Geoff Kite 1994				
1	1733			L1	natural conductivity			
2	2110	377		L2	recorded conductivity			
3	2890	1157		t	sample time in seconds			
4	3490	1757		Ms	mass of salt kg			
5	3570	1837		Cs	conductivity of 1 gram NaCl in 1 m3 water uS/c			
6	3320	1587		where				
7	2920	1187		Q=(1000*Ms*Cs)/t*sum(L2-L1)				
8	2540	807						
9	2310	577		width m		estimate		
10	2170	437		depth m		estimate		
11	2020	287		area m2	0	calculate		
12	1924	191		mix length Lm	0	calculate		
13	1828	95		velocity m/s		estimate		
14	1796	63		cond uS/cm	231	calculate		
15	1769	36		salt needed k	0.00	calculate		
16	1760	27		salt used kg	1.05548	actual		
17	1749	16						
18	1744	11						
19	1742	9						
20	1735	2						
21	1734	1						
22	1733	0						
23								
24								
25								
26								
27								
28								
29								
30								
31				Time interval	10	seconds		
32				Q flow cms	2121.5148	10461		
33				0.020280229	104610			
34								
35								
36								
37								
38								
39								
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44								
45								
46								

Date	25.02.99	Stream	Rose Creek R7 T4 25.02.99			Discharge	0.106886	cms
time		Party	Nordin/Withers/Denholm			MixLength	62.5m	
Sample		dif		Geoff Kite 1994				
1	303	0		L1	natural conductivity			
2	310	7		L2	recorded conductivity			
3	328	25		t	sample time in seconds			
4	343	40		Ms	mass of salt kg			
5	354	51		Cs	conductivity of 1 gram NaCl in 1 m3 water uS/cm			
6	356	53		where				
7	353	50		Q=(1000*Ms*Cs)/t*sum(L2-L1)				
8	345	42						
9	337	34		width m		estimate		
10	328	25		depth m		estimate		
11	323	20		area m2	0	calculate		
12	317	14		mix length Lm	0	calculate		
13	314	11		velocity m/s		estimate		
14	312	9		cond uS/cm		calculate		
15	309	6		salt needed k	0.00	calculate		
16	308	5		salt used kg	0.64929	actual		
17	306	3						
18	306	3						
19	306	3						
20	305	2						
21	305	2						
22	304	1						
23	304	1						
24	303							
25								
26								
27								
28								
29								
30								
31				Time interval	30	seconds		
32				Q flow cms	1305.0729	407		
33				0.106885577	12210			
34								
35								
36								
37								
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44								
45								
46								

Date	25.02.99	Stream	Rose Creek Diversion Canal X10 T1			Discharge	0.119371	cms
time	15:55	Party	Nordin/Withers/Denholm			MixLength	89.3m	
Sample		dif		Geoff Kite 1994				
1	336	0		L1	natural conductivity			
2	339	3		L2	recorded conductivity			
3	341	5		t	sample time in seconds			
4	345	9		Ms	mass of salt kg			
5	345	9		Cs	conductivity of 1 gram NaCl in 1 m3 water uS/c			
6	345	9		where				
7	345	9		Q=(1000*Ms*Cs)/t*sum(L2-L1)				
8	344	8						
9	344	8		width m		estimate		
10	342	6		depth m		estimate		
11	342	6		area m2	0	calculate		
12	342	6		mix length Lm	0	calculate		
13	341	5		velocity m/s		estimate		
14	341	5		cond uS/cm	231	calculate		
15	340	4		salt needed k	0.00	calculate		
16	339	3		salt used kg	0.1942	actual		
17	339	3						
18	339	3						
19	339	3						
20	338	2						
21	337	1						
22	337	1						
23	337	1						
24	336	0						
25								
26								
27								
28								
29								
30								
31				Time interval	30	seconds		
32				Q flow cms	390.342	109		
33				0.119370642	3270			
34								
35								
36								
37								
38								
39								
40								
41								
42								
43								
44								
45								
46								

Date	25.02.99	Stream	Rose Creek Diversion Canal X10 T2			Discharge	0.119692	cms
time	12:58	Party	Nordin/Withers/Denholm			MixLength	89.3m	
Sample		dif		Geoff Kite 1994				
1	336	0		L1	natural conductivity			
2	342	6		L2	recorded conductivity			
3	346	10		t	sample time in seconds			
4	352	16		Ms	mass of salt kg			
5	356	20		Cs	conductivity of 1 gram NaCl in 1 m3 water uS/c			
6	362	26		where				
7	365	29		Q=(1000*Ms*Cs)/t*sum(L2-L1)				
8	366	30						
9	365	29		width m		estimate		
10	362	26		depth m		estimate		
11	357	21		area m2	0	calculate		
12	355	19		mix length Lm	0	calculate		
13	354	18		velocity m/s		estimate		
14	352	16		cond uS/cm	231	calculate		
15	350	14		salt needed k	0.00	calculate		
16	349	13		salt used kg	0.67885	actual		
17	348	12						
18	346	10						
19	345	9						
20	345	9						
21	344	8						
22	343	7						
23	342	6						
24	341	5						
25	340	4						
26	340	4						
27	339	3						
28	339	3						
29	339	3						
30	338	2						
31	338	2		Time interval	30	seconds		
32	337	1		Q flow cms	1364.4885	380		
33	337	1		0.119691974	11400			
34	336	0						
35								
36								
37								
38								
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Date	26.02.99	Stream	CVD Seepage X11 T3 26.02.99			Discharge	0.02028	cms
time	9:18	Party	Nordin/Withers/Denholm			MixLength	38.0m	
Sample		dif		Geoff Kite 1994				
1	1733			L1	natural conductivity			
2	2110	377		L2	recorded conductivity			
3	2890	1157		t	sample time in seconds			
4	3490	1757		Ms	mass of salt kg			
5	3570	1837		Cs	conductivity of 1 gram NaCl in 1 m3 water uS/cm			
6	3320	1587		where				
7	2920	1187		Q=(1000*Ms*Cs)/t*sum(L2-L1)				
8	2540	807						
9	2310	577		width m		estimate		
10	2170	437		depth m		estimate		
11	2020	287		area m2	0	calculate		
12	1924	191		mix length Lm	0	calculate		
13	1828	95		velocity m/s		estimate		
14	1796	63		cond uS/cm	231	calculate		
15	1769	36		salt needed kg	0.00	calculate		
16	1760	27		salt used kg	1.05548	actual		
17	1749	16						
18	1744	11						
19	1742	9						
20	1735	2						
21	1734	1						
22	1733	0						
23								
24								
25								
26								
27								
28								
29								
30								
31				Time interval	10	seconds		
32				Q flow cms	2121.5148	10461		
33				0.020280229	104610			
34								
35								
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Date	26.02.99	Stream	Seepage X11 T4 26.02.99			Discharge	0.021312	cms
time		Party	Nordin/Withers/Denholm			MixLength	44.0m	
Sample		dif		Geoff Kite 1994				
1	1733	0		L1	natural conductivity			
2	1851	118		L2	recorded conductivity			
3	2240	507		t	sample time in seconds			
4	2490	757		Ms	mass of salt kg			
5	2600	867		Cs	conductivity of 1 gram NaCl in 1 m3 water uS/cm			
6	2590	857		where				
7	2470	737		Q=(1000*Ms*Cs)/t*sum(L2-L1)				
8	2270	537						
9	2150	417		width m		estimate		
10	2020	287		depth m		estimate		
11	1940	207		area m2	0	calculate		
12	1880	147		mix length Lm	0	calculate		
13	1831	98		velocity m/s		estimate		
14	1792	59		cond uS/cm		calculate		
15	1768	35		salt needed kg	0.00	calculate		
16	1759	26		salt used kg	0.60289	actual		
17	1750	17						
18	1742	9						
19	1737	4						
20	1733	0						
21								
22								
23								
24								
25								
26								
27								
28								
29								
30								
31				Time interval	10	seconds		
32				Q flow cms	1211.8089	5686		
33				0.021312151	56860			
34								
35								
36								
37								
38								
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Date	26.02.99	Stream	Seepage X11 T5 26.02.9			Discharge	0.020933	cms
time	10:00	Party	Nordin/Withers/Denholm					
Sample		dif		Geoff Kite 1994				
1	1733	0		L1	natural conductivity			
2	1967	234		L2	recorded conductivity			
3	2270	537		t	sample time in seconds			
4	2470	737		Ms	mass of salt kg			
5	2370	637		Cs	conductivity of 1 gram NaCl in 1 m3 water uS/c			
6	2260	527		where				
7	2130	397		Q=(1000*Ms*Cs)/t*sum(L2-L1)				
8	2020	287						
9	1913	180		width m		estimate		
10	1859	126		depth m		estimate		
11	1824	91		area m2	0	calculate		
12	1788	55		mix length Lm	0	calculate		
13	1756	23		velocity m/s		estimate		
14	1745	12		cond uS/cm	231	calculate		
15	1743	10		salt needed k	0.00	calculate		
16	1738	5		salt used kg	0.40231	actual		
17	1734	1						
18	1734	1						
19	1734	1						
20	1734	1						
21	1734	1						
22	1733	0						
23								
24								
25								
26								
27								
28								
29								
30								
31				Time interval	10	seconds		
32				Q flow cms	808.6431	3863		
33				0.020933034	38630			
34								
35								
36								
37								
38								
39								
40								
41								
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43								
44								
45								
46								

Date	26.02.99	Stream	Seepage X11 T6 26.02.99			Discharge	0.021395	cms
time		Party	Nordin/Withers/Denholm					
Sample		dif		Geoff Kite 1994				
1	1733	0		L1	natural conductivity			
2	1897	164		L2	recorded conductivity			
3	2240	507		t	sample time in seconds			
4	2510	777		Ms	mass of salt kg			
5	2600	867		Cs	conductivity of 1 gram NaCl in 1 m3 water uS/c			
6	2510	777		where				
7	2350	617		Q=(1000*Ms*Cs)/t*sum(L2-L1)				
8	2220	487						
9	2040	307		width m		estimate		
10	1936	203		depth m		estimate		
11	1868	135		area m2	0	calculate		
12	1825	92		mix length Lm	0	calculate		
13	1790	57		velocity m/s		estimate		
14	1765	32		cond uS/cm		calculate		
15	1756	23		salt needed k	0.00	calculate		
16	1749	16		salt used kg	0.53987	actual		
17	1738	5						
18	1734	1						
19	1734	1						
20	1734	1						
21	1734	1						
22	1734	1						
23	1734	1						
24	1733							
25								
26								
27								
28								
29								
30								
31				Time interval	10	seconds		
32				Q flow cms	1085.1387	5072		
33				0.02139469	50720			
34								
35								
36								
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Date	18.03.99	Stream	SilvertipWQ22 T1 18.03.99			Discharge	0.035749	cms
time	17:17	Party	Nordin/Withers/Lange/Love					
Sample	cond	dif		Geoff Kite 1994				
1	337	0		L1	natural conductivity			
2	345	8		L2	recorded conductivity			
3	356	19		t	sample time in seconds			
4	370	33		Ms	mass of salt kg			
5	394	57		Cs	conductivity of 1 gram NaCl in 1 m3 water uS/c			
6	403	66		where				
7	400	63		Q=(1000*Ms*Cs)/t*sum(L2-L1)				
8	395	58						
9	388	51		width m	0.5	estimate		
10	381	44		depth m	0.05	estimate		
11	376	39		area m2	0.025	calculate		
12	370	33		mix length Lm	40	calculate		
13	366	29		velocity m/s	1	estimate		
14	361	24		cond uS/cm	337	calculate		
15	357	20		salt needed k	0.08	calculate		
16	354	17		salt used kg	0.17234	actual		
17	351	14						
18	349	12						
19	347	10						
20	345	8						
21	344	7						
22	343	6						
23	342	5						
24	341	4						
25	341	4						
26	340	3						
27	340	3		Time interval	15	seconds		
28	339	2		Q flow cms	346.4034	646		
29	339	2		0.035748545	9690			
30	339	2						
31	339	2						
32	338	1						
33	338	1						
34	338	1						
35	338	1						
36	337	0						

Date	18.03.99	Stream	Silvertip WQ22 T2 18.03.99			Discharge	0.035145	cms
time	17:30	Party	Withers/Nordin/Lange/Love					
Sample	cond	dif		Geoff Kite 1994				
1	337	0		L1	natural conductivity			
2	350	13		L2	recorded conductivity			
3	364	27		t	sample time in seconds			
4	379	42		Ms	mass of salt kg			
5	390	53		Cs	conductivity of 1 gram NaCl in 1 m3 water uS/cn			
6	399	62		where				
7	403	66		Q=(1000*Ms*Cs)/t*sum(L2-L1)				
8	402	65						
9	400	63		width m	0.5	estimate		
10	391	54		depth m	0.05	estimate		
11	384	47		area m2	0.025	calculate		
12	380	43		mix length Lm	40	calculate		
13	374	37		velocity m/s	1	estimate		
14	369	32		cond uS/cm	337	calculate		
15	364	27		salt needed k	0.08	calculate		
16	361	24		salt used kg	0.2072	actual		
17	357	20						
18	354	17						
19	352	15						
20	350	13						
21	348	11						
22	346	9						
23	345	8						
24	344	7						
25	343	6						
26	342	5						
27	341	4		Time interval	15	seconds		
28	340	3		Q flow cms	416.472	790		
29	340	3		0.035145316	11850			
30	340	3						
31	339	2						
32	339	2						
33	339	2						
34	338	1						
35	338	1						
36	338	1						
37	338	1						
38	338	1						
39	337	0						
40								
41								
42								
43								
44								
45								
46								

Date	18.03.99	Stream	Silvertip WQ22 T3 18.03.99			Discharge	0.031187	cms
time	17:50	Party	Nordin/Withers/Lange/Love					
Sample	cond	dif		Geoff Kite 1994				
1	337	0		L1	natural conductivity			
2	351	14		L2	recorded conductivity			
3	365	28		t	sample time in seconds			
4	382	45		Ms	mass of salt kg			
5	393	56		Cs	conductivity of 1 gram NaCl in 1 m3 water uS/cm			
6	402	65		where				
7	406	69		Q=(1000*Ms*Cs)/t*sum(L2-L1)				
8	405	68						
9	402	65		width m	1	estimate		
10	398	61		depth m	0.2	estimate		
11	393	56		area m2	0.2	calculate		
12	386	49		mix length Lm	112	calculate		
13	380	43		velocity m/s	1	estimate		
14	373	36		cond uS/cm	100	calculate		
15	369	32		salt needed kg	0.56	calculate		
16	364	27		salt used kg	0.1969	actual		
17	360	23						
18	356	19						
19	354	17						
20	350	13						
21	348	11						
22	346	9						
23	345	8						
24	344	7						
25	342	5						
26	341	4						
27	340	3		Time interval	15	seconds		
28	340	3		Q flow cms	395.769	846		
29	340	3		0.03118747	12690			
30	339	2						
31	339	2						
32	339	2						
33	338	1						
34	338	1						
35	338	1						
36	338	1						
37	337							
38								
39								
40								
41								
42								
43								
44								
45								
46								

Date	18.03.99	Stream	Silvertip WQ22 T4 18.03.99			Discharge	0.035318	cms
time	18:15	Party	Nordin/Withers/Lange/Love					
Sample	cond	dif		Geoff Kite 1994				
1	337	0		337	natural conductivity			
2	366	29		L2	recorded conductivity			
3	378	41		t	sample time in seconds			
4	382	45		Ms	mass of salt kg			
5	399	62		Cs	conductivity of 1 gram NaCl in 1 m3 water uS/cm			
6	421	84		where				
7	422	85		Q=(1000*Ms*Cs)/t*sum(L2-L1)				
8	405	68						
9	402	65		width m	1	estimate		
10	398	61		depth m	0.04	estimate		
11	397	60		area m2	0.04	calculate		
12	384	47		mix length Lm	50	calculate		
13	382	45		velocity m/s	1	estimate		
14	378	41		cond uS/cm	100	calculate		
15	372	35		salt needed kg	0.18	calculate		
16	369	32		salt used kg	0.2438	actual		
17	365	28						
18	355	18						
19	350	13						
20	352	15						
21	349	12						
22	347	10						
23	344	7						
24	343	6						
25	340	3						
26	340	3						
27	339	2		Time interval	15	seconds		
28	339	2		Q flow cms	490.038	925		
29	339	2		0.035318054	13875			
30	338	1						
31	338	1						
32	338	1						
33	338	1						
34	337	0						
1								
2								
3								
4								
5								
6								
7								
8								
9								

APPENDIX D

Evaluation

of Effect on

Invertebrates

Salt Dilution Slug Injection Method

Evaluation of Salt Dilution Slug Injection Method on a Stream Invertebrate Community

Prepared by D. Davidge

Background

As part of Laberge Environmental Services' field trials and methods development for using the "Salt Slug Injection Method" to estimate total discharge in winter under ice low flow conditions in Yukon streams, the Yukon office of Environmental Protection (Environment Canada) attempted to evaluate the effect, if any, the salt has on the aquatic invertebrate community within the stream being measured. In order to determine if there is any impact from adding a concentrated salt solution to a freshwater stream, invertebrate drift was measured before and during a typical Salt Slug Injection test, as outlined by Laberge Environmental Services. The evaluation took place at the Ibex River site in an open water channel on 05-May-1999. Following is a description of the methods used and the results of this evaluation.

Methods

The effects of a measured salt solution added to a small stream during winter conditions was evaluated by estimating the density of drift aquatic invertebrates /m^3 of water within the stream. Density estimates of drift aquatic invertebrates was determined before and during a typical salt slug injection test.

Figure 1 Drift Nets

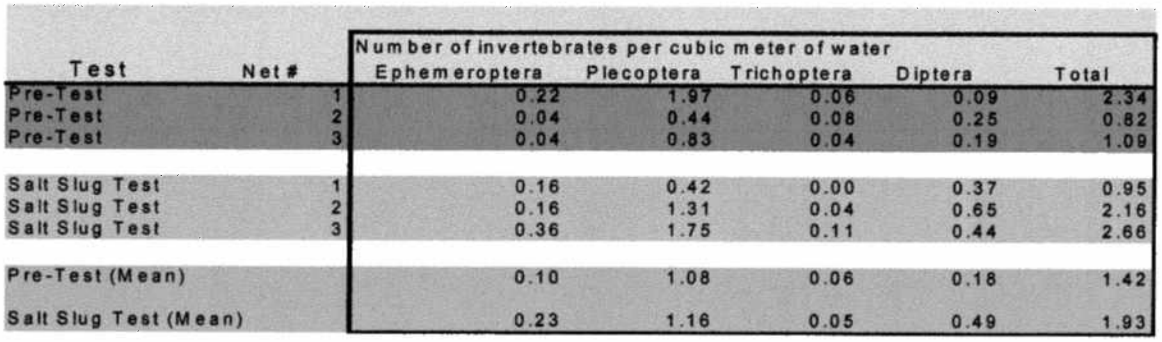
A series of three 363 um mesh nets were deployed at a suitable location at the Ibex River test site (See figure 1). Each net was secured to ensure it would remain stationary during the test. Invertebrate density/m^3 of water was calculated based on the number of individuals captured in the net, the cross-sectional area of the wetted net opening, the duration the net was deployed and the average stream velocity. The velocity of the stream flow was measured at surface, mid depth and near bottom at each of the net locations to obtain an average velocity for each net location. Stream depth at the net sample site ranged from 0.2m to 0.4m. Average velocity was 0.31m/sec. The salt concentration (xx?gm/l dissolved) was introduced approximately 75m upstream of the sample site.

Invertebrate drift samples were collected and placed in 1 litre plastic bottles and preserved with a 10% formalin solution. Invertebrates were sorted from each sample, counted and identified to major groups : Ephemeroptera (may flies), Plecoptera (stone flies), Trichoptera (caddies flies) and Diptera (black flies and midges).

Results

Table 1 summarizes the data collected. Stone flies were found to be the dominant group in each sample collected. The may fly, caddice fly and black fly/midge groups were represented in most of the samples but in much lower numbers. Total numbers of individuals per cubic meter of water ranged from 0.82 to 2.34 in the Pre-test samples and from 0.95 to 2.66 during the Salt Slug Injection test.

TABLE 1: Salt Slug Injection Methods - Aquatic Invertebrate Drift Survey



Test	Net #	Number of invertebrates per cubic meter of water Ephemeroptera	Plecoptera	Trichoptera	Diptera	Total
Pre-Test	1	0.22	1.97	0.06	0.09	2.34
Pre-Test	2	0.04	0.44	0.08	0.25	0.82
Pre-Test	3	0.04	0.83	0.04	0.19	1.09
Salt Slug Test	1	0.16	0.42	0.00	0.37	0.95
Salt Slug Test	2	0.16	1.31	0.04	0.65	2.16
Salt Slug Test	3	0.36	1.75	0.11	0.44	2.66
Pre-Test (Mean)		0.10	1.08	0.06	0.18	1.42
Salt Slug Test (Mean)		0.23	1.16	0.05	0.49	1.93

Conclusions

The aquatic invertebrate drift collected during the salt slug injection test is slightly higher in numbers of individuals per cubic meter of water than what was found during the pre-test sampling. This difference, however, is not significant enough to suggest the salt solution is directly responsible. Since the salt slug injection is typically a one time only event on any given day, the concentrations being specified by the trial tests is not considered to have any lasting negative impact on the benthic community.