Specific Conductance Method for In Situ Estimation of Total Dissolved Solids

Teja Singh and Y. P. Kalra

A contribution submitted to the JOURNAL on Mar. 20, 1974, by Teja Singh, res. scientist, and Y. P. Kalra, head, Central Soils Lab.; both of the Northern Forest Res. Centre, Canadian Forestry Svce., Dept. of the Envir., Edmonton, Alberta, Canada.

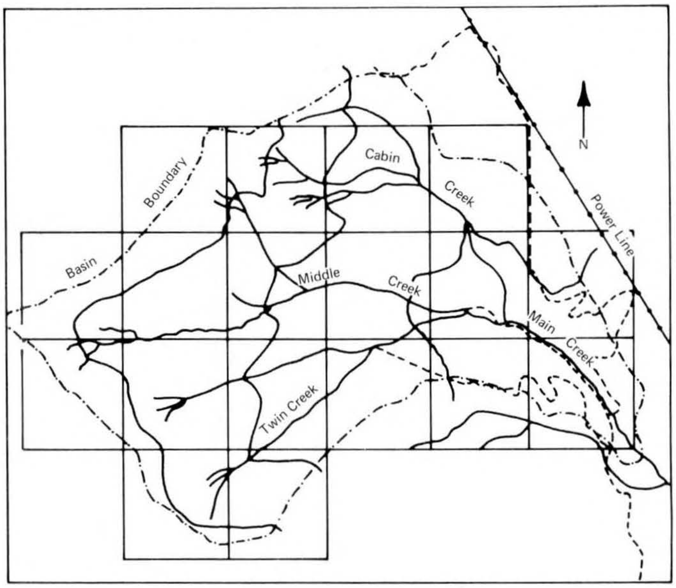

Fig. 1. Marmot Creek Basin, Alberta, Canada

There are two methods that are commonly used for determining total dissolved solids in water. This article proposes another method—determination by means of electrical conductance measurement. An excellent relationship was discovered between specific conductance and total dissolved solids of mountain streams.

A national water-quality data system (NAQUADAT) is currently in use in Canada for storing and retrieving water-quality data collected and analyzed by the Canada Dept. of the Envir. A detailed description of the system and its capability is provided by Demayo[1] and by Peters and Demayo.[2]

The analyses presented in this article pertain to the Marmot experimental watershed[3] situated in the Rocky Mountains of Alberta, Canada. A map of the watershed (Fig. 1) shows the three subbasin creeks (Cabin, Middle, and Twin). These join to form the main Marmot Creek, which is a tributary to the Kananaskis River. Samples for water quality were taken periodically at the gaging sites. Samples of Kananaskis River water were collected at the bridge crossing before Marmot Creek joins it. Samples were also taken at the cirque on Middle Creek to provide comparisons of water quality parameters above the timberline portion of the stream.

The total dissolved solids in waters are ordinarily determined by two methods. In the residue-on-evaporation method,[4] solids are dried to a constant weight at a specified temperature. In the calculation method,[5] all the constituents are determined separately and are added after conversion into forms in which they would normally occur in an anhydrous residue. These methods have limitations, however. In the first method much of the partly volatile substances may be lost. The second method is very lengthy.

Specific conductance indicates the total concentration of the ionized constituents in the samples. Although close correlation between specific conductance and total dissolved solids is not likely to be established in every instance,[4] a direct relationship exists in many streams.[6]

The determination of conductance offers many advantages in regard to precision, rapidity, simplicity, availability of reliable portable instruments, and *in situ* analysis. The present study was conducted to investigate the feasibility of calculating the concentration of total dissolved solids from the specific conductance data. If steady relationships would be established, then the results of monitoring specific conductance could be used as input into a computer to obtain a comparable record of total dissolved solids concentrations for assessing treatment effects on experimental watersheds.

Methods

Specific conductance was determined with a platinum-electrode-type conductivity meter. Total concentration of soluble salts was determined from the following formula after filtration through a 0.45-μm membrane filter and according to methods described by Traversy:[7]

$$\text{Total solids} = \text{Na} + \text{K} + \text{Si} + \text{Cl} + \text{SO}_4 + \text{F} + 0.6\,(\text{total alkalinity}) + \text{NO}_3 + \text{NO}_2 + \underset{0.393}{\cancel{1.607}}\,\text{Ca} + 0.243\,(\text{total hardness})$$

TABLE 1

*Data Summary for Specific Conductance**
From Jan. 1, 1969, to Jan. 2, 1972

Creek	Samples	Range		Median
		Low	High	
Marmot basin				
Marmot, main	45	191	462	366
Middle	43	156	386	339
Twin	43	140	349	306
Cabin	42	253	530	413
Middle, at cirque	28	90	479	322
Main river				
Kananaskis	41	244	333	300

*In micromhos per centimeter at 25C

TABLE 2

*Data Summary for Total Dissolved Solids**
From Jan. 1, 1969, to Jan. 2, 1973

Creek	Samples	Range		Median
		Low	High	
Marmot basin				
Marmot, main	42	105	270	203
Middle	42	82	210	189
Twin	39	76	186	163
Cabin	40	139	252	230
Middle, at cirque	25	47	215	169
Main river				
Kananaskis	38	128	188	165

*In milligrams per litre

TABLE 3

Relationship of Specific Conductance
*to Total Dissolved Solids**

Creek	Pairs *n*	Least Squares Estimates		Correlation Coefficient *r*
		a	*b*	
Marmot, main	42	− 3.9142	0.5598	0.9455
Middle	42	−11.9392	0.5884	0.9837
Twin	39	1.5733	0.5305	0.9645
Cabin	40	24.3207	0.4858	0.8854
Middle, at cirque	25	7.7546	0.5212	0.9413
Kananaskis River	38	−23.0942	0.6257	0.9501

*$Y = a + bX + e$, where Y is total dissolved solids in milligrams per litre; X is specific conductance in micomhos per centimeter; and e is the unobservable random error

TABLE 4

Relationship of Specific Conductance
*to Total Dissolved Solids**

Creek	Pairs *n*	Least Squares Estimate *b*	Correlation Coefficient *r*
Marmot, main	42	0.5487	0.9453
Middle	42	0.5517	0.9817
Twin	39	0.5359	0.9645
Cabin	40	0.5463	0.8784
Middle, at cirque	25	0.5461	0.9401
Kananaskis River	38	0.5491	0.9429

*$Y = bX + e$, where Y is total dissolved solids in milligrams per litre; X is specific conductance in micomhos per centimeter; and e is the unobservable random error

Results and Discussion

Tables 1 and 2 provide a summary of the specific conductance (μmho/cm) and total dissolved solids (mg/l) measurements. Tables 3 and 4 give the least squares estimates of model parameters relating total dissolved solids to specific conductance.

Although the estimates of a and b in Table 3 provide linear lines of best fit, theoretically, specific conductance is nearly zero when total dissolved solids are absent. The intercept a should therefore be zero or nearly so. From this consideration the simple models of Table 4 are theoretically preferable and have more realistic physical significance.

A simple straight line relationship, $Y = bX$ (where Y represents total dissolved solids and X represents specific conductance), instead of the regression model presented in Table 4, has been used by some investigators. In this equation, b represents the conversion factor or ratio of the two measurements. These ratios will have different values according to the nature of ions and their concentrations. For the natural waters studied by Hem,[8] the value was found to be from 0.54 to 0.96. From the studies pertaining to quality of irrigation waters, this value has been reported to be 0.65 ± 0.1 by Rainwater and Thatcher,[5] and to be 0.64 by Richards.[9] A ratio of 0.74 has been reported by Bochkarev and Nikolaeva[10] for the mean conductance and soluble constituents of water samples of a river.

The random component e in the models in Table 4 represents the unpredictable fluctuations in experimental data. The statistical models obtained by adding such a component to a deterministic relationship are more realistic than the simple ratios. The results also provide a measure of the goodness of fit as shown by the correlation coefficients listed in Table 4.

The least squares estimates of the ratios for each stream investigated in the present study are nearly the same (0.54–0.55). With a minor exception in the case of Middle Creek at cirque, all the natural waters show similarities in the proportion of main cations and anions as indicated by the computer data summaries.

The results demonstrate an excellent relationship between specific conductance and total dissolved solids of mountain streams. The electrical conductance models established in the experiment can be conveniently used as an alternative to the usual lengthy procedure of determining total dissolved solids by the addition of individual ions.

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