

Relationship between conductivity and analysed composition in a large set of natural surface-water samples, Queensland, Australia

V.H. McNeil · M.E. Cox

Abstract The relationship between Total Dissolved Ions (TDI) and conductivity is established in around 34000 samples collected from rivers, streams and dams in Queensland since the 1960s. These data are extremely variable in content, reliability and periodicity of sampling. The data were sorted into useable modules, and their statistical distribution was examined. The median ratios of TDI/Conductivity obtained for different salinity ranges were between 0.59 and 0.72, with normal variability ranging from below 0.35 to greater than 1.00, particularly at lower salinities. The data set used has sufficient sample numbers and areal distribution per increment to give reasonable reliability within the conductivity range of 50–1000 μScm^{-1} . A table has been developed that enables selection of conversion factors from conductivity to salinity (as TDI) which could be used to predict TDI from future conductivity measurements from the same surface water population.

Key words Freshwaters · Salinity · Conductivity · TDI

Introduction

Background

One of the most important tools for evaluating water quality and character in a catchment is a detailed knowledge of the ranges and trends in salinity of natural water. Although measurements are simple, effective assessment

requires intensive measurement of the parameter in a reliable and consistent manner with respect to location, time and hydrological condition.

Salinity represents the majority of the dissolved constituents in the water. Various terms are used and salinity can be measured in several ways, although these are not exactly comparable:

1. Total Dissolved Ions (TDI): this is the total number of ions in solution, whether they are dissociated or not. It is defined by Hart (1974) as the sum of the major ions in the water expressed in mg l^{-1} . In most surface waters these include the cations Na^+ , K^+ , Ca^{2+} , and Mg^{2+} , and the anions Cl^- and HCO_3^- , with SO_4^{2-} occasionally being significant.
2. Total Soluble Salts (TSS): this can be considered the same as TDI.
3. Total Dissolved Solids (TDS): this is also referred to as “filterable residue” and is the concentration of dissolved substances in water, and includes mineral and organic matter, whether or not this is in ionic form (Helmer 1987). This term therefore also includes SiO_2 and is expressed in mg l^{-1} .
4. Conductivity: this is the ability of a solution to conduct an electric current. It is not only dependent on the concentration of dissociated salts and dissolved gases (Pelkie and others 1992), but also on colloidal suspensions. Consequently, conductivity is affected by temperature, pressure and rate of flow, but it is not affected by dissolved silica or undissociated ions such as H_2CO_3 which do not carry an electric charge. Conductivity for most natural waters is measured in μScm^{-1} .

The salinity measure which is most useful in hydrological studies and for catchment managers is TDI, because it can be used to measure mass transport of salts. Conductivity, however, can be measured much more conveniently. Several general ratios are commonly used to convert between these two measurements, but our assessment of large data bases has shown that there is sufficient variation, especially at low salinities, to advocate the development of ratios suitable for individual populations of water analyses.

The aim of this investigation is to establish the relationship between TDI and conductivity in a very large set of water chemistry data from highly variable environments in Queensland, Australia. The relationship established could then be used to predict TDI from future conductivity measurements for certain populations.

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Factors determining conductivity in aqueous solutions

Conductivity is extensively discussed in a range of hydrogeological textbooks, in physical and electrical chemistry texts such as Hibbert (1993), and in studies of natural water chemistry such as Hem (1985) and Stumm and Morgan (1996). A number of general principles are described here. The effect of dissolved electrolytes on conductivity depends on the concentration, valence and rate of movement of each ionic species. Rate of movement is in turn dependent on size and charge as well as ion-ion and ion-solvent interactions. The mobilities of H^+ and OH^- in an aqueous solution are extremely high because the charge is carried by exchange of protons between neighbouring solute ions. For other ions, electrical migration occurs as a slow drift of ions towards electrodes, which is superimposed on much more rapid thermal movements (Crow 1988). As concentration increases, these processes become more significant, and tend to reduce the mobility of the ions. Reduction in mobility with increasing concentration means that the rate at which conductivity rises with increasing TDI will not be linear. In fact, the rate at which conductivity rises will diminish as TDI increases, and this rate will be dependent on the balance of ions in solution.

In addition, the rate of conductivity increase as a function of TDI differs between strong and weak electrolytes. This is because undissociated molecules cannot contribute to the conductance of a solution. Typical relationships between conductivity and concentration in single salt solutions were reported by USDA (1954) for a wide range of conductivities. Solutions with common anions, and with cations of equal charge showed the greatest similarity in electrical behaviour, as further confirmed by Serra and Sola (1986) for Ca^{2+} and Mg^{2+} . Colloidal and suspended matter may also contribute to measured values of water conductivity, and Tadros (1987) noted that a solid dispersed in a liquid will most likely bear a charge. There are a variety of processes which can bring this about. One such process is the capacity of clays to exchange their adsorbed cations without alteration to the clay's structure, whereby the transfer of a lower valency cation will result in a negative charge on the particle. In addition to this, the ions H^+ and OH^- have a high affinity for particle surfaces. Another such process is that of phosphate ions (PO_4^-) chemisorbing strongly to common minerals such as hematite and gibbsite. As a consequence, under most natural conditions it is extremely unlikely that the sum of negative charges on the particle will equal the sum of positive charges in aqueous solutions.

Conductivity is measured directly, using some form of electrodes connected to a meter. These instruments are known as conductivity meters, or as salinometers in some contexts. These instruments vary in terms of sensitivity, especially under extreme temperatures (Asakura and others 1989) and also with regard to solution salinity (Grimmer and others 1983), maintenance, and drift caused by surface reactions on the electrodes. The type of

electrode is also important, in addition to its sensitivity. Measurements are also influenced by movement of either the electrodes or the solution. Difficulties associated with conductivity meters, in general, can be traced to surface degradation of the material coating the plates (Munoz and others 1986), and to rapid changes in flow, temperature and salinity to which the instruments may not be equally sensitive (e.g. Horne and Toole 1980; Topham and Perkin 1984). Also some older instruments were difficult to read, owing to confusing units or scales. Although newer and higher quality instruments can counteract many of these effects, older data may not be regarded as being of the same standard, particularly if the measuring instrument and personnel are unknown.

Previous studies of conversion factors

Conductivity has been used, either generally or specifically, to estimate salinity (TDI or TDS) in natural waters since the 1970s, for example, the studies of Singh and Kalra (1975) and Lystrom and others (1978). VIRA (1969) recommended a conversion ratio of 0.64. Hem (1985) quotes a study concerning samples from a single site on the Gila River in Arizona, where a factor of 0.59 of conductivity was used to estimate TDS with an accuracy of about $\pm 100 \text{ mg l}^{-1}$ in a range of 250–3250 mg l^{-1} . The same figure was established for Queensland alluvial groundwaters of average salinity by V. McNeil (unpub. data 1973). Hem (1985) also reviewed other case studies of natural waters that gave conversion factors of 0.54–0.96, but with most falling between 0.55 and 0.75. Day and Nightingale (1984) determined a relationship based on regression analysis between TDS and conductivity for Californian groundwater. The ratio of dissolved conductive material to conductivity ranged from 0.527 to 0.597 for waters of between 106 and 2050 μScm^{-1} , with a precision of about 4–30 mg l^{-1} after allowance was made for the measured mass of silica.

The Practical Salinity Scale 1978, which can be used to estimate the salt content of seawater by means of conductivity, assumes a ratio of 0.82 (IEEE 1980; Lewis 1981). This ratio is based on conductivity measurements of potassium chloride and seawater, which would be expected to show similar electrical behaviour (Poisson 1981). The scale is required to be accurate to $\pm 1 \text{ mg l}^{-1}$ with a precision of $\pm 0.3 \text{ mg l}^{-1}$ for conductivities of between 2000 and 42000 μScm^{-1} . A correction factor was found necessary for lower conductivities (Hill and others 1986). However, it is pointed out that this scale is only applicable to waters which have major ions in the same proportions as those of seawater.

An example of variable ratios between measured conductivity and analyzed TDI is given by two different subartesian groundwater types from southeast Queensland (Table 1). Both types have very similar TDI ranges of between 1500 mg l^{-1} and 5000 mg l^{-1} TDI. However Type B, which is hard and dominated by bicarbonate, is relatively lower in conductivity than Type A, which has a high proportion of sodium chloride. The difference between the

Table 1
Mean composition of TDI in two groundwater types

Water type		A	B
Number of samples		934	296
Mean conductivity μScm^{-1}		4118	3361
Mean TDI mg l^{-1}		2651	3057
Percent Cations	Na^+	44	84
	Ca^{2+}	19	6
	Mg^{2+}	37	11
Percent Anions	Cl^-	75	33
	HCO_3^-	20	66
	Other	5	1
TDI/conductivity		0.64	0.61

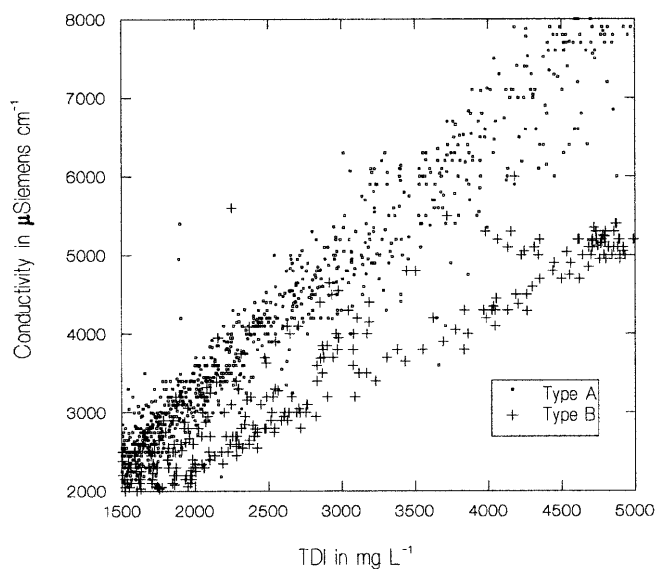


Fig. 1

Relationship of conductivity to TDI in alluvial groundwaters of differing composition summarised in Table 1. Type A are largely of Na-Cl and Na, Mg-Cl, and Type B tend to be Na- HCO_3 in composition

two types, which is accentuated at higher salinity levels, is shown on Fig. 1.

Setting of Queensland investigation

Queensland climatic conditions

The state of Queensland, where the data were collected, is a large and diverse land area, extending in latitude from 19°S to 29°S , and from 138°E to 154°E in longitude. A cordillera known as the Great Dividing Range runs down much of the east coast. The climate is subtropical to

tropical, with fairly even temperatures averaging between $22\text{--}24^\circ\text{C}$ in July and $25\text{--}28^\circ\text{C}$ in February. Temperatures, however, often get appreciably hotter in the central and western parts of the state. Rainfall is strongly seasonal, and much of the state is semi-arid, although there are patches of rainforest near the coastal ranges. Except for occasional tropical cyclones, rainfall usually occurs as sporadic localised storms of high intensity, and abnormally wet years are often separated by long droughts. In most areas, pan evaporation greatly exceeds precipitation (Gentilli 1971).

Streams draining the eastern side of the Great Dividing Range have relatively short, steep catchments, with moderate to high rainfall, typically over 2000 mm/year in the far north, to about 1000–1500 mm/year in the south. Three major river systems, the Burdekin, Fitzroy and Burnett, have cut through the range, but the bulk of the state's drainage flows to the north and southwest. These western catchments (see Fig. 2) are mostly extensive, dry, and heavily weathered, and drainage systems tend to be of braided or anastomosing form, with networks of lakes or waterholes.

As a result of these factors, Queensland surface water represents a wide variety of chemical environments.

Description of the data set

The available data consist of about 34000 analyses collected from rivers, streams and dams in Queensland since the 1960s. The average number of samples per site is around 70, with typically about four per year. In virtually all cases the analyses represent determinations made on water samples returned to the laboratory. These data are extremely variable in content, reliability and periodicity of sampling, but most include: conductivity, TDI, TDS, the anions Cl^- , SO_4^{2-} , HCO_3^- , and cations Na^+ , K^+ , Ca^{2+} , and Mg^{2+} which with SiO_2 provide the bulk of the dissolved constituents. In addition, pH, alkalinity (usually as HCO_3^-) Fe, Mn and a number of other trace elements are included, but their reliability is considered to be very poor. All stream samples are collected from properly constructed gauging stations, and reliable flow measurements are also available.

The data are stored in the Queensland Department of Natural Resources Surface Water Data Base, which uses the HYDSYS data base package, developed by Hydsys Pty. Ltd. of Canberra, Australia for hydrological data. Recent analyses are transferred from the laboratory in electronic form, but earlier records were transcribed from various hard copy formats, and some transcription errors took place during this process. Virtually all of the water samples were analyzed at the Queensland Government Chemical Laboratory which is NATA (National Association of Testing Authorities) registered, but obsolete sampling techniques and long transportation and storage reduced the integrity of the older data. The earliest analyses from the 1950s and early 1960s were computed as hypothetical compounds based on dry residue, and do not correspond precisely with modern analyses.

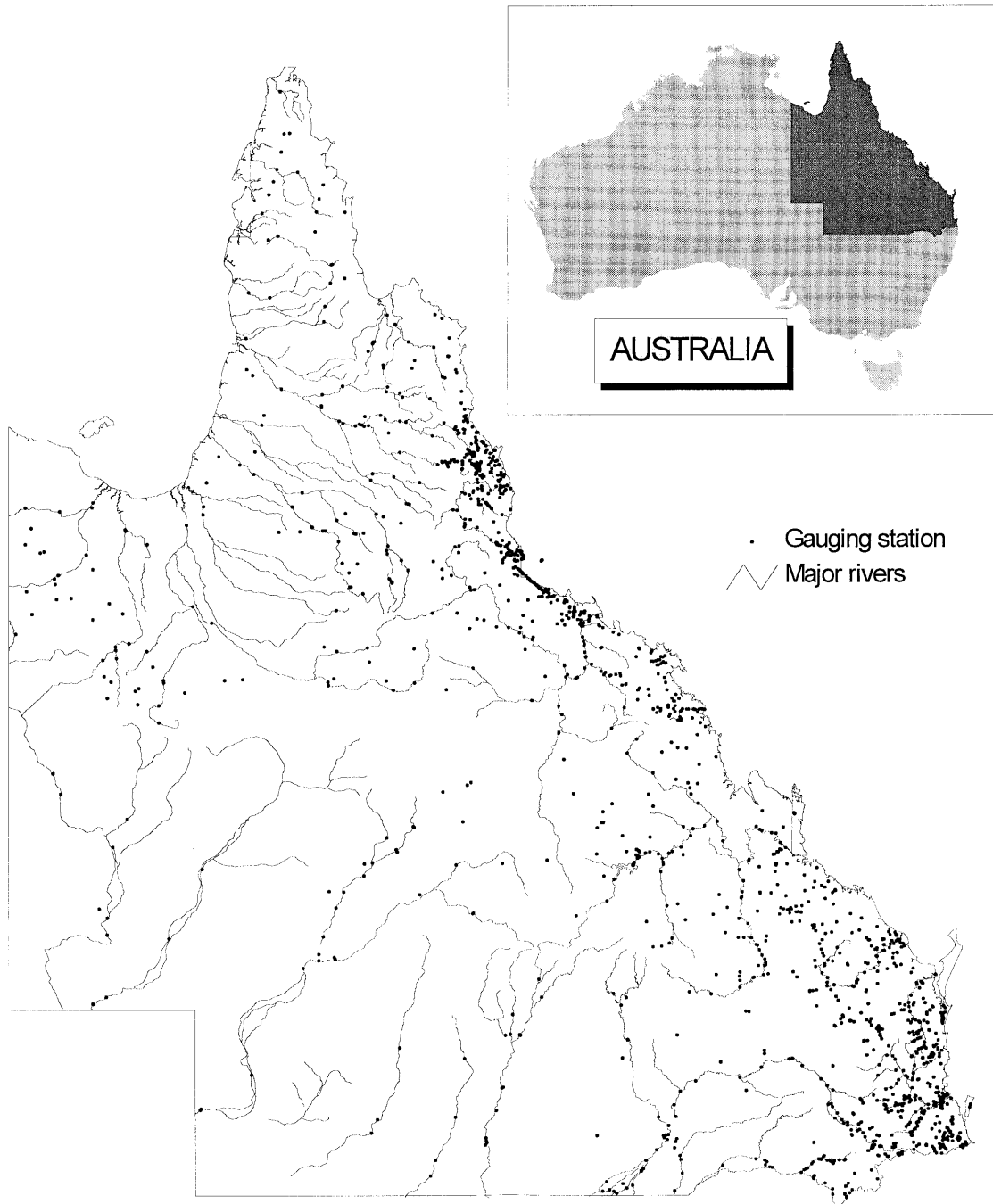


Fig. 2

Distribution of surface water measuring sites in Queensland from which data in this study were collected. Multiple data sets were taken at all locations

Approach to data assessment

Methods of sorting data

A number of problems were experienced in dealing with a data set of this nature. Problems included validation of the raw data, sorting it into useable modules, examina-

tion of the statistical distribution, and the selection of robust methods of analyses which allow for sampling irregularities. Statistical analysis was carried out using the SYSTAT statistical and graphical package, which supports large data files. Initial validation consisted of calculating the percent equivalents of the ionic constituents and rejecting poorly balanced or incomplete analyses. TDI and TDS were also calculated and compared to previously recorded values to ensure that typographical errors were eliminated.

The TDI values of the validated data were considered sufficiently accurate to use for bulk estimation of TDI/con-

ductivity, but many outliers still existed in the conductivity data. It was assumed that most of these were due to inaccurately measured or recorded readings, but their removal had to be carried out by statistical means, as there were no comparative chemical checks. Values of TDI in natural waters do not usually show a normal distribution, but in a data set of this size, small increments of TDI contain large numbers of samples. The mean and standard deviation of the sample TDI defines the distribution of salinity within that increment, provided the range is sufficiently small for the distribution to be approximately normal.

The data were then sorted by TDI and divided into bunches of 1500 samples, starting with the lowest value of TDI. Each bunch was subjected to standard tests for normality of the TDI distribution. These included the detrended PLOT test (Gnanadesikan 1977); the measure of skewness (*S*) for symmetry; and the kurtosis measure (*K*) for peakedness (Wilkinson 1990). The means and medians of the bunches were also calculated and compared as a further check.

Statistical approach

As there were no comparative tests available to validate conductivity data, a statistical technique was employed to exclude outliers resulting from errors in measurement or transcription. This was based on the box plot developed by Tukey (1977) and Velleman and Hoaglin (1981). The median conductivity of each bunch was calculated, then the 25th and 75th percentiles, referred to as “hinges”. These hinges enclose 50% of the samples in the bunch, but this is not sufficient to characterise the wide range of

conductivity that typically occurs within a fairly narrow range of TDI. Therefore, outer boundaries described by Tukey (1977) as “fences” were then calculated. These are roughly equivalent to the mean ± 3 SD in a normal distribution, and enclose 99.4% of the samples in each bunch. When plotted on a log scale, the upper and lower boundaries contain sufficient data to ensure that the vast majority of correctly measured conductivities from the population are included. The mean was also plotted to define the most probable values (Fig. 3).

A corresponding table and plot (Table 2; Fig. 4) were constructed to establish the relationship between conductivity and chloride, in case the chloride had a stronger influence on conductivity than did TDI.

Samples from each bunch were rejected if they did not fall within the established boundaries. The remaining data were then used to calculate the TDI/conductivity ratio. For internal comparison, the maximum, minimum and mean TDI/conductivity ratios for each bunch were plotted against the mean TDI (Fig. 5). The acceptable data were then sorted into increments, and ratios were calculated in a format which could be used to predict TDI from future conductivity measurements from the same surface water population (Table 3).

To compare ratios determined, the expression suggested by VIRA (1969):

$$\sqrt{\text{TDI} + 2.5077 + 0.6678} \\ = \sqrt{\text{Conductivity} + (\text{Conductivity} * 0.0009148)}$$

was tested with other predictive models, using the means of the original bunches and the NONLIN Module in SYS-TAT. This approach was to check the validity of the ex-

Table 2

Summary of statistical tests on chloride data in bunches of 1500

Bunch	Cl mg l ⁻¹							Cond Fences μScm^{-1}	
	Min	Max	Median	Mean	SD	S	K	Lower	Upper
1	0.1	25	8.0	8.6	3.92	1.20	1.79	19	96
2	1.3	34	10	12	5.23	1.34	1.84	52	111
3	0.7	40	13	14	6.52	1.07	1.51	63	138
4	1.0	53	16	17	8.80	1.29	2.50	70	176
5	2.5	66	17	20	11.82	1.26	1.66	98	205
6	1.3	81	19	22	13.98	1.32	2.00	115	257
7	0.9	91	24	26	14.60	1.19	1.94	150	286
8	1.8	92	30	30	14.46	0.83	1.36	170	330
9	3.0	115	36	37	16.96	0.72	1.12	200	376
10	2.7	125	44	45	18.50	0.68	1.32	227	425
11	3.0	135	51	52	22.26	0.67	1.31	262	470
12	4.7	165	63	63	25.86	0.30	0.48	286	560
13	2.6	195	78	76	30.56	0.05	0.29	320	640
14	2.9	205	91	88	34.73	-0.23	-0.09	370	720
15	3.4	280	110	104	44.86	-0.15	0.08	420	850
16	2.5	290	130	123	58.29	-0.36	-0.53	470	990
17	4.5	320	173	162	69.55	-0.53	-0.41	540	1200
18	6.0	420	235	229	76.93	-0.33	-0.34	680	1500
19	53.0	900	370	373	139.4	0.31	0.06	910	2650
20	155.0	14200	1180	1542	1326	4.83	35.34	Not calc.	Not calc.

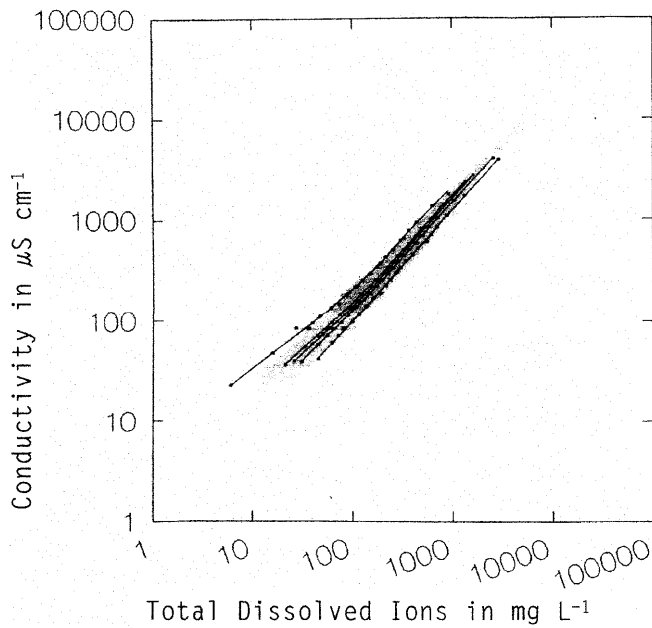


Fig. 3

Comparison of TDI in mg l^{-1} with measured conductivity in $\mu\text{S cm}^{-1}$ for Queensland surface water using a log/log plot. Actual data are plotted in grey. Lines join the following points for each bunch: median-2SD (\cong lower conductivity fence), median-SD (\cong 25th percentile), median, median + SD (\cong 75th percentile), median + 2SD (\cong upper conductivity fence)

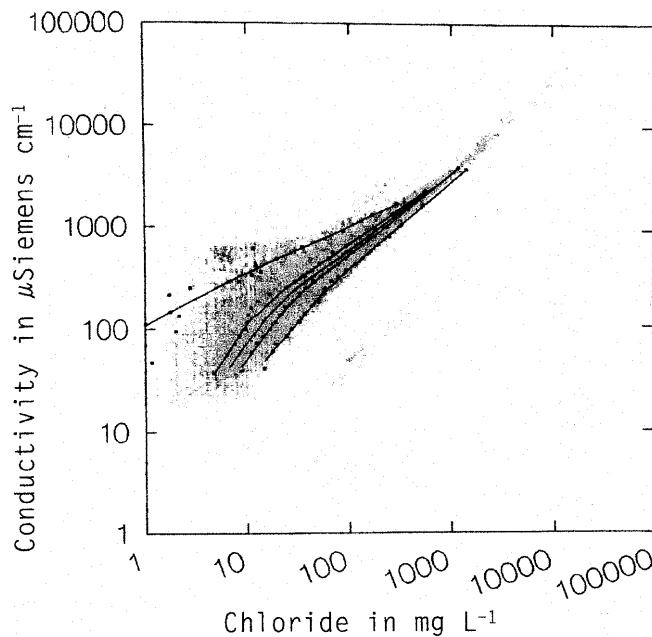


Fig. 4

Comparison of Cl^- in mg l^{-1} with measured conductivity in $\mu\text{S cm}^{-1}$ for Queensland surface waters using a log/log plot. Actual data are plotted in grey. Lines join the following points for each bunch: median-2SD (\cong lower conductivity fence), median-SD (\cong 25th percentile), median, median + SD (\cong 75th percentile), median + 2SD (\cong upper conductivity fence)

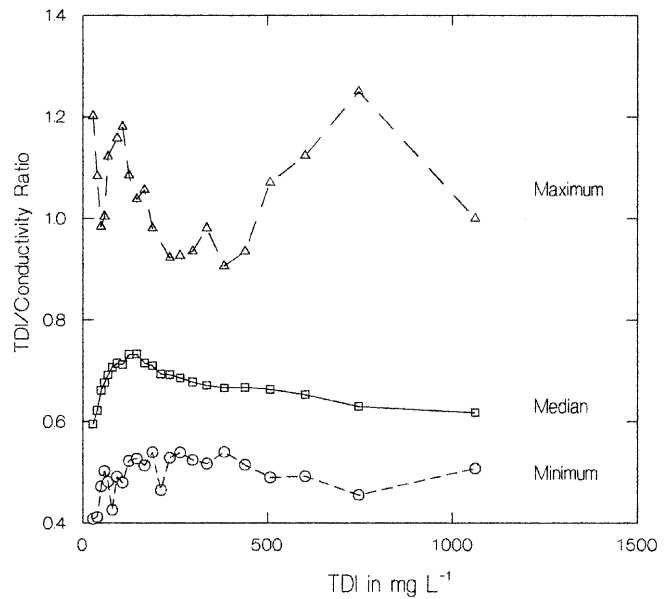


Fig. 5

Ratios of TDI/conductivity compared to TDI (mg l^{-1}) for maximum, minimum and median ratios for Queensland surface waters

pression, or to substitute a more suitable one for this population.

Results

The statistical results for TDI (Table 4) show reasonably normal distributions over the entire data set, except in the case of the final high salinity bunch. This bunch contained only 299 samples, but represented a very wide range of salinities, and therefore no attempt was made to calculate the TDI/conductivity ratio for this group. Comparison of the conductivity with the TDI on a log scale (Fig. 3) indicates that the rise of log conductivity with log TDI is slightly non-linear, and that the degree of variance decreases as salinity increases.

A comparison of conductivity/chloride (Fig. 4) with conductivity/TDI (Fig. 3) indicates that it is more appropriate to interpret conductivity in terms of TDI than chloride concentration, because chloride shows appreciably less correlation particularly at low salinities. Although the median only varies between 0.59 and 0.72, the actual range can vary from as low as 0.5 to greater than 1.0. It should be noted that the median of the ratio does not trend in a constant direction as TDI rises. Instead, it falls briefly at very low salinities ($\text{TDI} < 50 \text{ mg l}^{-1}$) increases steeply to a TDI of around 200 mg l^{-1} , then gradually decreases with increasing salinity.

When the VIRA (1969) model was tested on the bunch means, it gave a reasonable fit at very low salinities but

Table 3

Ratios of TDI/conductivity for rivers and streams in Queensland

Conductivity range μScm^{-1}	Number of Analyses	Usual ratios of TDI to Conductivity (outliers excluded)			
		Minimum	Mean	Maximum	Median
10– 20	18	0.49	0.80	2.33	0.68
20– 30	176	0.35	0.73	1.90	0.70
30– 40	537	0.38	0.68	1.17	0.65
40– 50	755	0.34	0.67	1.24	0.66
50– 60	832	0.35	0.69	1.11	0.67
60– 70	938	0.32	0.69	1.07	0.68
70– 80	1184	0.36	0.70	1.02	0.69
80– 90	1079	0.41	0.70	0.98	0.69
90– 100	972	0.41	0.71	1.07	0.70
100– 200	5799	0.44	0.72	1.06	0.72
200– 300	3552	0.48	0.71	1.01	0.71
300– 400	2829	0.49	0.69	0.89	0.69
400– 500	2186	0.45	0.68	0.93	0.67
500– 600	1693	0.50	0.68	0.99	0.67
600– 700	1262	0.49	0.67	0.89	0.66
700– 800	977	0.48	0.66	0.90	0.65
800– 900	753	0.47	0.65	0.84	0.64
900–1000	715	0.47	0.64	0.88	0.63
1000–2000	2131	0.35	0.62	0.85	0.61
2000–3000	292	0.51	0.59	0.86	0.59
3000–4000	64	0.25	0.59	0.73	0.58
4000–5000	10	0.54	0.59	0.69	0.60

Table 4

Summary of statistical tests on TDI data in bunches of 1500

Bunch	TDI mg l^{-1}							Cond Fences μScm^{-1}	
	Min	Max	Median	Mean	SD	S	K	Lower	Upper
1	11.63	46.40	34.52	33.92	8.18	-0.42	-0.71	19	96
2	46.40	62.10	54.89	54.63	4.46	-0.11	-1.19	52	111
3	62.12	79.00	70.40	70.42	4.93	-0.01	-1.25	63	138
4	79.00	97.60	88.01	88.07	5.38	0.03	-1.16	70	176
5	97.63	118.0	107.2	107.5	5.91	0.05	-1.19	98	205
6	118.0	143.2	130.5	130.5	7.37	-0.01	-1.22	115	257
7	143.2	166.5	154.5	154.6	6.75	0.04	-1.17	150	286
8	166.6	190.4	178.1	178.3	6.77	0.03	-1.17	170	330
9	190.4	213.7	202.5	202.5	6.77	-0.08	-1.19	200	376
10	213.8	239.5	226.2	226.5	7.38	0.04	-1.18	227	425
11	239.5	269.2	253.2	253.7	8.59	0.08	-1.20	262	470
12	269.2	305.3	286.2	286.6	10.45	0.06	-1.22	286	560
13	305.3	345.8	325.4	325.2	11.62	0.02	-1.20	320	640
14	345.8	396.2	368.9	370.1	14.62	0.12	-1.19	370	720
15	396.2	457.0	425.9	425.9	17.58	0.04	-1.22	420	850
16	457.1	533.0	491.9	492.9	22.11	0.12	-1.20	470	990
17	533.0	640.1	581.1	583.2	30.98	0.14	-1.19	540	1200
18	640.2	820.5	716.1	720.7	50.85	0.23	-1.10	680	1500
19	820.6	1539	985.8	1037	181.3	0.89	-0.13	910	2650
20	1540	25715	2457	3184	2401	4.60	32.21	Not calc.	Not calc.

increasingly over-estimated the TDI as the conductivity rose. A much more satisfactory relationship was obtained for the Queensland surface water data by plotting the log of TDI versus the log of conductivity (Fig. 6), and fitting a cubic expression to the plot. This equation is:

$$\log \text{TDI} = 0.154 (\log \text{cond})^3 - 1.22 (\log \text{cond})^2 + 4.12 (\log \text{cond}) - 2.76$$

The reasons for this apparent relationship are not fully clear, but are probably related to the areal distribution of anions as described in the discussion.

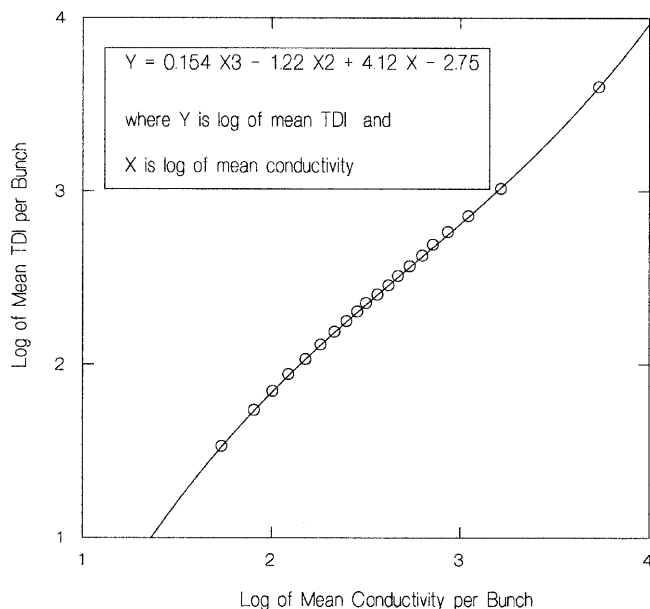


Fig. 6 Log of conductivity μScm^{-1} compared to the log of TDI in mg l^{-1} fitted to a cubic power series curve

Table 3 has been developed for prediction of TDI (effective salinity) from conductivity measurement. This table has sufficient numbers of samples and areal distribution per increment to give reasonable reliability within the conductivity range of $50\text{--}1000 \mu\text{Scm}^{-1}$. The most suitable conversion factor to use is the median values. These range from $0.65\text{--}0.72$ up to $800 \mu\text{Scm}^{-1}$, over which they are in the range of $0.58\text{--}0.64$

Discussion

An important factor in the ratio between conductivity and salinity is the relative abundances of the major dissolved ions. The relative percentages of chloride and bicarbonate for each bunch are shown in Fig. 7. These two species represent the majority of the anions, with sulfate and nitrate making occasional important contributions. Assessment of the composition of waters also shows a systematic regional variation. Fig. 7 clearly shows the inverse nature of Cl^- and HCO_3^- content, in particular in lower salinity ($100\text{--}250 \text{mg l}^{-1}$) and higher salinity ($>500 \text{mg l}^{-1}$) surface waters. Very low salinity ($<100 \text{mg l}^{-1}$) chloride-rich waters are sourced from northeast Queensland coastal streams, which have short, steep catchments and high rainfall. Streams in western Queensland are higher both in salinity and bicarbonate, because the prevailing winds blow overland, and because the rainfall has more contact with accumulated terrestrial salts. As the salinity rises above 100mg l^{-1} TDI, the abundance and proportion of chloride increases.

Conclusion

Although conductivity is often the only practical method for intensive monitoring of salinity variation, the results of this investigation verify that it is not a precise surrogate for TDI, particularly in waters of variable composition. This is in agreement with conclusions of Hem (1985).

Fig. 7 shows the strong relationship between the TDI/conductivity ratio and anionic composition, however, it is clear from Fig. 4 that the relative proportions of these anions are not a reliable predictor of the ratio. The conductivity predicted the chloride content less accurately than the TDI, particularly at low salinities.

The median ratios of TDI/conductivity obtained from the surface water data base were between 0.59 and 0.72 , which compares well with previous studies. However, the normal variability ranges from below 0.35 to greater than 1.00 , particularly at lower salinities. Low salinity waters often represent high flows, which carry the bulk of the salt load, despite a lower concentration.

The most effective use can be made of conductivity measurements at a particular gauging station if they are calibrated by frequent analyses of TDI at all stages of flow. This is especially important in large or complex catchments, because the source of the water may not be the same for similar flows but at different times.

Alternatively, a range of dissolved ion concentrations, rather than a single figure may be quoted to represent a conductivity measurement. This range should be calcu-

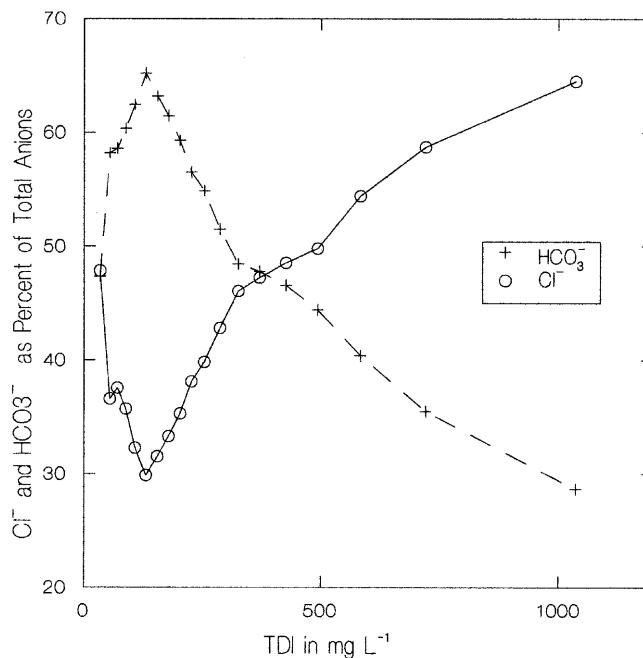


Fig. 7 Median percentages of Cl^- and HCO_3^- compared to salinity as TDI, all in mg l^{-1}

lated from as wide a sample as possible from the source population. A major outcome of this study is the development of a table (Table 3) that enables the selection of an appropriate conversion factor from conductivity to salinity (as TDI) for Queensland surface waters. Internal tests show that this is also appropriate for surface waters in other parts of Australia.

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