Application of CCME Procedures for Deriving Site-Specific Water Quality Guidelines for the CCME Water Quality Index

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Since its development in 2001, the Canadian Council of Ministers of the Environment (CCME) Water Quality Index (WQI) has established itself as a valuable tool for communicating ambient water quality data. Due to the high natural background levels of particular parameters in water bodies throughout the country it is often necessary to use Site-Specific Water Quality Guidelines (SS-WQGs) as opposed to generic national Water Quality Guidelines (WQGs) or provincial Water Quality Objectives (WQOs) in the CCME WQI model to obtain truly representative rankings. SS-WQGs have only been developed for a limited number of ambient water quality sites and this has been a major hurdle to the widespread use and acceptance of the CCME WQI. This paper presents the adaptation and implementation of an existing CCME-approved SS-WQGs derivation method called the background concentration (BC) procedure into a Site-Specific Water Quality Index (SS-WQI) calculator and tool. It discusses the application of the SS-WQI calculator to compute water quality indices for five pristine ambient water quality sites in Newfoundland and Labrador. The effects of using five different BC-based SS-WQGs (mean; median; mean ± one standard deviation; mean ± two standard deviations; 90th and 10th percentile) are examined. The paper also discusses the challenges and benefits of using this methodology and provides recommendations for further testing.

Key words: site-specific water quality guidelines, water quality index, CCME, SS-WQI calculator, background concentration procedure, Newfoundland and Labrador

Introduction

The communication and reporting of ambient water quality data to the average person without compromising the technical integrity of the data has always been a challenging task. However, reporting of water quality to Canadians has been made easier in recent years by the development and availability of the Canadian Council of Ministers of the Environment (CCME) Water Quality Index (WQI).

The CCME WQI was developed with the intent of providing a tool for simplifying the reporting of water quality data (CCME 2001). It is a tool that provides meaningful summaries of water quality data that are useful to technical and policy individuals as well as the general public interested in water quality results. As a summary tool, it provides a broad overview of water quality data and is not intended to be a substitute for detailed analysis of water quality data.

The province of British Columbia was the first to develop and apply a WQI, with a number of other jurisdictions and institutions applying some form of an index to water quality data prior to the development of the CCME WQI. In 1997, the CCME WQI Technical Sub-

committee was formed to assess the various approaches already in use and subsequently formulate a CCME WQI that could be used nationally. Since its formulation, the CCME WQI has been applied successfully to several ambient water quality data sets from across Canada and is being used to communicate ambient water quality data in several provinces (CCME 2001; Khan et al. 2004).

The application of the CCME WQI requires Water Quality Guidelines (WQGs) or Water Quality Objectives (WQOs). The model essentially consists of three measures of variance from selected WQGs or WQOs (scope, frequency, amplitude) that combine to produce a value between 0 and 100 that represents the overall water quality. The use of appropriate WQGs or WQOs in the CCME WQI is critical to the computation of representative and accurate water quality indices.

Most applications of the CCME WQI to date have used national WQGs and other provincial WQOs. There are many pristine water bodies throughout the country where, due to the high (or low depending on the parameter) natural background levels of particular parameters (such as colour, pH, turbidity, metals), there is a need to revise the national WQGs to reflect the naturally high (or low) background concentrations that are specific to these water bodies. Sometimes even for water bodies that are impacted by anthropogenic activities there is a need to

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derive site-specific WQGs for those parameters that are naturally higher (or lower) (not due to the anthropogenic activity in these impacted bodies). The computation of Site-Specific Water Quality Guidelines (SS-WQGs) is generally an involved intensive process. Consequently, SS-WQGs have been developed for only a limited number of ambient water quality sites. This unavailability of SS-WQGs for many ambient water quality monitoring sites has been a major hurdle to the widespread use and acceptance of the CCME WQI for these sites.

For use with the CCME WQI there is a need for a procedure or methodology that could screen water quality data to flag parameters that are candidates for revised SS-WQGs and then compute numerical SS-WQGs for just those parameters based on the water quality data for the site.

The CCME WQI

The formulation of the WQI as described in the Canadian Water Quality Index 1.0 – Technical Report is as follows (CCME 2001):

The measure for scope is F_1. This represents the extent of water quality guideline non-compliance over the time period of interest.

$$F_1 = \left(\frac{\text{Number of failed variables}}{\text{Total number of variables}} \right) \times 100 \qquad (1)$$

The measure for frequency is F_2. This represents the percentage of individual tests that do not meet objectives ("failed tests").

$$F_2 = \left(\frac{\text{Number of failed tests}}{\text{Total number of tests}} \right) \times 100 \qquad (2)$$

The measure for amplitude is F_3. This represents the amount by which failed test values do not meet their objectives. This is calculated in three steps:

Step 1 - Calculation of Excursion

Excursion is the number of times by which an individual concentration is greater than (or less than, when the objective is a minimum) the objective.

When the test value must not exceed the objective:

$$\text{excursion}_i = \left(\frac{\text{Failed Test Value}_i}{\text{Objective}_j} \right) - 1 \qquad (3)$$

When the test value must not fall below the objective:

$$\text{excursion}_i = \left(\frac{\text{Objective}_j}{\text{Failed Test Value}_i} \right) - 1 \qquad (4)$$

Step 2 - Calculation of Normalized Sum of Excursions

The normalized sum of excursions, *nse*, is the collective amount by which individual tests are out of compliance. This is calculated by summing the excursions of individual tests from their objectives and dividing by the total number of tests (both those meeting objectives and those not meeting objectives).

$$nse = \frac{\sum\limits_{i=1}^{n} \text{excursion}_i}{\text{Number of tests}} \qquad (5)$$

Step 3 - Calculation of F3

F_3 is calculated by an asymptotic function that scales the normalized sum of the excursions from objectives to yield a range from 0 to 100.

$$F_3 = \left(\frac{nse}{0.01nse + 0.01} \right) \qquad (6)$$

The WQI is then calculated as:

$$\text{WQI} = 100 - \left(\frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732} \right) \qquad (7)$$

The WQI values are then converted into rankings by using the categorization scheme presented in Table 1.

Deriving Numerical Site-Specific Water Quality Guidelines

SS-WQGs as defined by the Canadian Council of Resource and Environment Ministers (CCREM 1987) are numerical concentrations or narrative statements that establish the conditions required to address sensitivities in specific areas.

The 2002 CCME report "Guidance on the Site-Specific Application of Water Quality Guidelines in Canada: Procedures for Deriving Numerical Water Quality Objectives" recommends four specific procedures for deriving SS-WQGs in Canada:

- background concentration (BC) procedure
- recalculation procedure
- water effect ratio (WER) procedure, and
- resident species (RS) procedure.

As described by CCME (2002), in the BC procedure the natural background concentrations or level of a contaminant in water at the site are used to define acceptable water quality conditions for the site. The SS-WQGs developed using the BC procedure may be established by setting the SS-WQGs to be equal to the BC or equal to a

TABLE 1. CCME WQI categorization schema

Rank	WQI value	Description
Excellent	95–100	Water quality is protected with a virtual absence of threat or impairment; conditions very close to natural or pristine levels; these index values can only be obtained if all measurements are within objectives virtually all of the time.
Good	80–94	Water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels.
Fair	65–79	Water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels.
Marginal	45–64	Water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels.
Poor	0–44	Water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels.

value slightly above the BC (CCME 2002). Different statistics can be used to represent the natural BC of a parameter in water. Some statistics listed in CCME (2002) include the median, mean plus and minus two standard deviations, and the 90th and 10th percentile.

The recalculation procedure for a site involves the screening of the species data set used to formulate WQGs or WQOs to eliminate those species that are not resident at the site. Using this screened species database, SS-WQGs for the site are then recalculated using the same procedure that was used to calculate the generic WQGs or WQOs.

As described by CCME (2002), the WER procedure is a three-step procedure. In the first step, acute or short-term chronic toxicity tests are conducted with indicator or resident species using both site water and laboratory water. In the second step, the toxicological results of step 1 are used to determine the WER, which is the ratio of the toxicity of the substance in water from the site to its toxicity in laboratory water. In the last step, the calculated WER is then used directly to convert the generic WQGs or WQOs to SS-WQGs.

The RS procedure for a site is a very accurate method and requires compiling and generating a complete toxicity data set for each substance using site water and resident species. This data set is then used to calculate the SS-WQGs for the substance at the site.

Numerical SS-WQGs derived from all four procedures can be used in conjunction with the CCME WQI to incorporate the effect of SS-WQGs in the WQI ranking. However, as is evident from the brief description of each procedure presented above, the WER and RS procedures are relatively intensive procedures and do not lend themselves to any significant degree of automation. The recalculation procedure is not a complicated procedure but it also does not lend itself to any significant degree of automation. In contrast, the BC procedure is a statistical procedure which can be adapted and computed in an automated fashion in the CCME WQI calculator.

Development of the SS-WQI Calculator

To develop a Site-Specific Water Quality Index (SS-WQI) calculator, the BC procedure was implemented as presented in Fig. 1 into an existing coding of the CCME WQI calculator developed by the Newfoundland and Labrador Department of Environment and Conservation.

In the SS-WQI calculator the user may enter generic national WQGs, provincial WQOs or SS-WQGs computed using the recalculation procedure, WER procedure or RS procedure as the guidelines to be used in the computation of the CCME WQI. However, in the absence of SS-WQGs, an automated SS-WQGs routine can be invoked in the calculator to apply the BC procedure as outlined in Fig. 1. The user chooses a statistics builder module in the SS-WQI calculator to specify the statistic that is to be used as the BC statistic. The BC statistic can be one of the following:

- mean
- median
- standard deviation
- any formula built from a combination of the mean, median and standard deviation (e.g., mean ± two standard deviations)
- any desired percentile value.

The computation of the mean, median and standard deviation are straightforward statistical procedures. However, a review of literature indicates that percentiles can be calculated in a number of methods. In the SS-WQI calculator, the percentiles are calculated using Statistical Analysis Software (SAS) method 4. Equation 8 gives the equation for the SAS method 4 as described by Journet (1999). Other statistical software like Minitab and Statistical Package for the Social Sciences (SPSS) for percentiles use the same method.

$$y = (1 - g)*x(j) + g*x(j + 1), \quad (8)$$
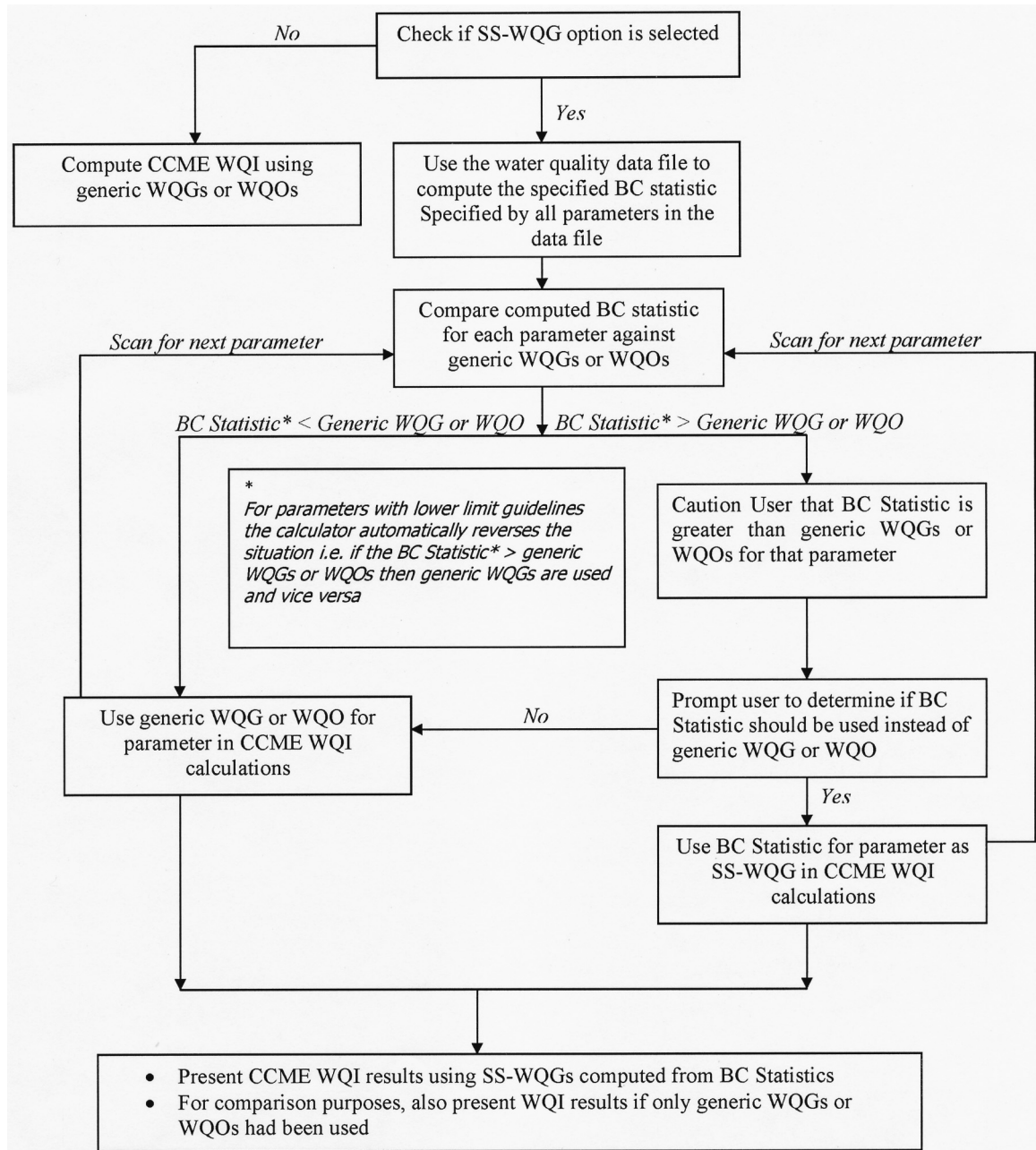where $(n + 1)*p = j + g$ [and $x(n + 1)$ is taken to be $x(n)$]

Fig. 1. Methodology for implementing background concentration (BC) procedure in SS-WQI calculator.

where y is the percentile associated with p; p is the p-th percentile to be calculated; n is the number of observations in the data set; x is the ordered values of a data set; g is the decimal part of n*p; and j is the integer part of n*p.

There are a number of other methods developed for the calculation of percentiles. The SAS method 5 (based on the empirical distribution function) and Microsoft Excel method as described by Journet (1999) are presented in equations 9 and 10, respectively.

$$0.5 * [x_{(j)} - x_{(j+1)}] \quad \text{if } g = 0$$
$$x_{(j+1)} \quad \text{if } g > 0 \quad (9)$$

where $n*p = j + g$; p is the p-th percentile to be calculated; x is the ordered values of a data set; g is the decimal part of n*p; and j is the integer part of n*p.

$$y = (1 - g)*x(j + 1) + g*x(j + 2), \text{ where } (n - 1)*p = j + g$$
$$[\text{and } x(0) \text{ is taken to be } x(1)] \quad (10)$$

where y is the percentile associated with p; p is the p-th percentile to be calculated; n is the number of observations in the data set; x is the ordered values of a data set; g is the decimal part of n*p; and j is the integer part of n*p.

The SS-WQI calculator uses the water quality data file provided for the CCME WQI computation to calculate the BC statistic for each parameter in the water quality data file. If the BC statistic for a parameter is less stringent than the corresponding generic WQGs or WQOs specified, the calculator cautions and prompts the user to determine if the BC statistic should be used. A less stringent BC statistic would be one that has a higher numerical value than the WQG or WQO for an upper limit or conversely a smaller numerical value for a lower guideline. Professional judgment must be used to determine if the BC statistic will be accepted over the generic WQGs or WQOs. If the user decides to accept the BC statistic the calculator internally replaces the WQGs or WQOs. The calculator then proceeds to scan the next parameter until all parameters have been scanned and the user has been cautioned and prompted about all parameters whose BC statistic is less stringent than the generic WQGs or WQOs.

When all parameters have been scanned, the calculator computes the CCME WQI using the BC statistics for the specified parameters and the generic WQGs or WQOs for the remaining parameters. For comparison purposes, the calculator also presents the water quality indices if only the generic WQGs or WQOs had been used for all parameters.

Application of the SS-WQI Calculator

The SS-WQI calculator was used to compute site-specific water quality indices and generic water quality indices using CCME's "Canadian Water Quality Guidelines for the Protection of Aquatic Life" (CCME 2003) for five pristine ambient water quality sites sampled under the Canada-Newfoundland Water Quality Monitoring Agreement. The effects of using five different BC-based SS-WQGs (mean, median, mean ± one standard deviation, mean ± two standard deviations, 90th and 10th percentile), for parameters whose natural background levels do not meet the CCME aquatic water quality guidelines, on the CCME WQI scores and rankings were examined. A BC-based SS-WQG of mean ± one standard deviation assigns the mean plus one standard deviation for the upper limit and mean minus one standard deviation as the lower limit, where appropriate.

All sites selected had at least 30 water quality samples to ensure that there was no effect on the BC statistics due to small sample sizes. Brief descriptions of the five sites are presented in Table 2. Table 3 presents the parameters that had a BC that is less stringent than the CCME aquatic water quality guidelines for each of the different BC-based SS-WQGs. It is important to note that the aluminum, copper and lead guidelines have been adjusted for each site due to dependence on hardness (copper and lead), pH and DOC (aluminum), as recommended by CCME Protection of Aquatic Life Guidelines (CCME 2003). It also presents the SS-WQGs that were adopted for each site.

It is evident from Table 3 that the parameters requiring SS-WQGs vary from site to site. The BC statistic selected to represent the natural BC concentration also has a bearing on which parameters require SS-WQGs.

TABLE 2. Description of the five pristine sites studied

	South West Brook	*Lomond River*	*Isle aux Mort River*	*Grey River*	*Eagle River*
Drainage area (km^2)	39.9	264	205	1340	8390
Main channel length (km)	11.7	40.8	35.6	85.8	218
Mean stream gradient (%)	0.278	0.83	1.37	0.47	0.22
Elevation drop (m)	90	340	488	400	480
Mean annual precipitation (mm)	1100	1300	1350	1550	950
Mean annual runoff (mm)	920	1000	2100	1400	750
Population	None	203 permanent, ~900 seasonal	10–20 (seasonal estimate)	50 (seasonal estimate)	0–20 (seasonal estimate for outfitters camp)
General description	Headwaters southeast of Terra Nova River and flows through Terra Nova National Park.	Headwaters drain heavily forested reaches of Long Range highlands.	Headwaters stretch north. River flows from the highlands of the Long Range barrens along a steep, narrow river valley.	Altered watershed with a dam. The headwaters extend north up to the reservoir dam.	Headwaters south of Lake Melville in Labrador.

TABLE 3. BC-based SS-WQGs with corresponding CCME aquatic water quality guidelines for the five pristine sites studied

BC statistic	Parameter	South West Brook SS-WQG	South West Brook CCME[a]	Lomond River SS-WQG	Lomond River CCME[a]	Isle aux Mort River SS-WQG	Isle aux Mort River CCME[a]	Grey River SS-WQG	Grey River CCME[a]	Eagle River SS-WQG	Eagle River CCME[a]
Mean	Al	0.205	0.198	—	—	—	—	—	—	0.281	0.101
	Fe	0.6	0.3	—	—	—	—	—	—	1.0	0.3
	Cu	—	—	—	—	0.006	0.002	—	—	0.004	0.002
	Cr	—	—	—	—	—	—	—	—	0.002	0.001
Median	Al	0.199	0.198	—	—	—	—	—	—	0.140	0.101
	Fe	0.6	0.3	—	—	—	—	—	—	0.6	0.3
	Cu	—	—	—	—	0.002	0.002	—	—	0.003	0.002
	Cr	—	—	—	—	—	—	—	—	0.002	0.001
Mean ± 1 St. dev.	DO	9.2	9.4	—	—	—	—	—	—	—	—
	Al	0.261	0.198	—	—	0.163	0.137	0.148	0.137	0.541	0.101
	Fe	0.9	0.3	—	—	—	—	—	—	1.6	0.3
	Pb	0.001	0.001	—	—	—	—	—	—	—	—
	Cr	—	—	—	—	0.001	0.001	0.002	0.001	0.003	0.001
	Cu	—	—	—	—	0.014	0.002	0.002	0.002	0.007	0.002
Mean ± 2 St. dev.	DO	7.1	9.4	8.4	9.4	—	—	—	—	8.3	9.4
	Al	0.317	0.198	—	—	0.201	0.137	0.177	0.137	0.800	0.101
	Cu	0.003	0.002	0.003	0.002	0.022	0.002	0.003	0.002	0.010	0.002
	Pb	1.2	0.3	—	—	—	—	—	—	2.2	0.3
	Fe	0.002	0.001	—	—	—	—	—	—	—	—
	Cr	—	—	—	—	0.002	0.001	0.002	0.001	0.003	0.001
90th Percentile	DO	8.6	9.4	9.4	9.4	—	—	—	—	9.0	9.4
	Al	0.267	0.198	—	—	0.192	0.137	0.156	0.137	0.767	0.101
	Fe	0.9	0.3	—	—	—	—	—	—	2.1	0.3
	Cr	—	—	—	—	0.002	0.001	0.003	0.001	0.003	0.001
	Cu	—	—	—	—	0.026	0.002	0.003	0.002	0.008	0.002

[a]CCME guidelines for aluminum, copper and lead have been adjusted on a site-specific basis due to dependence on hardness (copper and lead), pH and DOC (aluminum).

For South West Brook, as the BC statistic is changed from "mean" to "mean ± one standard deviation" and then to "mean ± two standard deviations" the number of parameters with SS-WQGs goes up from 2 to 4 and then to 5. On the other hand, for Lomond River, as the BC statistic is changed from "mean" to "mean ± one standard deviation" and then to "mean ± two standard deviations" the number of parameters with SS-WQGs goes from 0 to 0 and then up to 2.

Table 4 shows a tabular comparison of the CCME WQI values using the different SS-WQGs and the CCME aquatic water quality guidelines. The effect of using SS-WQGs on the CCME WQI score is very site specific and dependent on the statistic used to represent the natural BC. The effect of using different SS-WQGs can be understood more clearly by examining their effect on the three measures of variance (F1, F2, F3) that constitute the CCME WQI. Table 4 presents a comparison of F1, F2, F3, CCME WQI scores and rankings.

For South West Brook and Lomond River there is limited variation in the CCME WQI scores when using different SS-WQGs. For Lomond River, there is little change in the F1, F2 and F3 factors to make a difference in the WQI scores. The use of mean ± two standard deviations and 90th and 10th percentile guidelines for South West Brook slightly affects the F1 and F2 factors. For Isle aux Morts River, the effect of using different SS-WQGs is more distinct. Use of the mean ± two standard deviations and 90th and 10th percentile guidelines affects F1, and to a lesser degree F2 and F3. For Grey River, the effects of different SS-WQGs is not evident for the mean, median, and mean ± one standard deviation guidelines but there is marked change in the CCME WQI scores when the mean ± two standard deviations and 90th and 10th percentile guidelines are used. Use of the mean ± two standard deviations and 90th and 10th percentile guidelines strongly affects F1. The improvement in the CCME WQI scores is primarily due to the vastly decreased number of variables (scope) that fail when using the mean ± two standard deviations and 90th and 10th percentile guidelines. A similar marked increase in the CCME WQI scores is seen when the mean ± two standard deviations and 90th and 10th percentile guidelines are used for Eagle River. Use of the mean ± two standard deviations and 90th and 10th percentile guidelines strongly affects F1, F3 and to a lesser degree F2. The improvement in the CCME WQI scores is primarily due to the vastly decreased number of variables (scope)

TABLE 4. Comparison of WQI scores and rankings for the five pristine sites studied

Water body name	BC statistic	Using SS-WQGs with CCME aquatic WQ guidelines					Using only CCME aquatic WQ guidelines				
		F1	F2	F3	WQI score	WQI ranking	F1	F2	F3	WQI score	WQI ranking
South West Brook	Mean	50	17	4	69	Fair	50	23	11	68	Fair
	Median	50	18	4	69	Fair					
	Mean ± 1 St. dev.	50	12	2	70	Fair					
	Mean ± 2 St. dev.	50	9	1	71	Fair					
	90th Percentile	50	10	2	70	Fair					
Lomond River	Mean	29	2	1	83	Good	29	2	1	83	Good
	Median	29	2	1	83	Good					
	Mean ± 1 St. dev.	29	2	1	83	Good					
	Mean ± 2 St. dev.	29	2	0	83	Good					
	90th Percentile	29	2	1	83	Good					
Isle aux Mort River	Mean	31	35	6	73	Fair	31	36	12	72	Fair
	Median	31	36	11	72	Fair					
	Mean ± 1 St. dev.	31	32	4	74	Fair					
	Mean ± 2 St. dev.	23	31	3	77	Fair					
	90th Percentile	8	30	3	82	Good					
Grey River	Mean	33	26	4	75	Fair	33	26	4	75	Fair
	Median	33	26	4	75	Fair					
	Mean ± 1 St. dev.	33	26	3	75	Fair					
	Mean ± 2 St. dev.	17	24	3	83	Good					
	90th Percentile	8	24	3	85	Good					
Eagle River	Mean	46	17	4	71	Fair	46	22	17	69	Fair
	Median	46	17	8	71	Fair					
	Mean ± 1 St. dev.	46	14	1	72	Fair					
	Mean ± 2 St. dev.	8	11	1	92	Good					
	90th Percentile	8	11	1	92	Good					

that failed, the reduced amplitude of failure, and to a lesser degree the reduced frequency of failure when using the mean ± two standard deviations and 90th and 10th percentile guidelines.

In general, for the pristine ambient water bodies tested, the CCME WQI scores and ranks obtained by using the CCME aquatic water quality guidelines, mean, median and mean ± one standard deviation SS-WQGs are in the same range. Depending on the site being analyzed, the CCME WQI scores and ranks computed using the mean ± two standard deviations and 90th and 10th percentile SS-WQGs had the potential to deviate significantly from the remaining WQI scores and ranks.

Challenges and Benefits

A methodology for computing site-specific water quality indices using water quality data from a site has been successfully implemented in a SS-WQI calculator as demonstrated in this paper. The applicability of the CCME WQI model will be significantly improved by the ability to derive SS-WQGs.

There are, however, some challenges that need to be addressed in the application of this methodology. The BC procedure is not based on biological effects data (CCME 2002) and from the review of different procedures for deriving numerical SS-WQGs presented earlier, it is also clear that the BC procedure is not the most extensive and accurate method of deriving SS-WQGs. Another challenge is the absence of a "standard" against which to evaluate SS-WQGs derived using the BC procedure. SS-WQGs being derived using other procedures have a scientific basis in that they are based on biological effects data but SS-WQGs derived using the BC procedure vary based on the statistic that is used to define the background concentration. So for the computation of the CCME WQI, it is important to use SS-WQGs derived from the other procedures where possible. This is particularly important if there is any reason to suspect that the BC procedure for a parameter does not account for the sensitivity range of resident species or there are factors present that potentially influence the bioavailability of contaminants. When SS-WQGs derived from the other procedures are not available, SS-WQGs derived using the BC procedure is an excellent alternative to inappropriate generic WQGs or WQOs. It can also be used on an interim basis while SS-WQGs are being derived using other procedures.

Since the SS-WQGs derived using the BC procedure can vary based on the BC statistic used, regulatory authorities will need to evaluate and recommend a BC statistic for their respective jurisdictions or project areas. The choice of which BC statistic is to be used to represent the background concentration would need to be based on further testing of the different BC derived

SS-WQGs on sites where SS-WQGs derived using other biological effects-based procedures are available.

The current implementation is primarily addressed at sites where naturally occurring high concentrations of parameters invoke the need to adjust the WQGs or WQOs to reflect the high background concentrations. When using the SS-WQI calculator, it is very important to be sure that the high concentration levels are naturally occurring and are not associated with anthropogenic activities.

This implementation is aimed at pristine water bodies. The application of the BC procedure to water bodies where water quality has been impacted by anthropogenic activities should be attempted with extreme caution. It can be applied at impacted ambient water quality sites to selectively generate SS-WQGs for those parameters that are at elevated levels due to non-anthropogenic conditions. This requires suitable professional judgment in the selection of parameters, as there is the potential to inaccurately rank impacted sites as being better than they should be ranked.

The accuracy of some statistics (e.g., percentiles) used to represent the BC of a parameter is dependent on the sample size used to compute the statistic. This factor should be considered when applying the BC procedure for sites that have small water quality data sets. It is important to ensure that the water quality data being used is representative of the site and does not have any obvious bias (e.g., all samples were collected in one season of the year).

The SS-WQI calculator is also a tool for screening sites that have a need for SS-WQGs. It can also identify candidate parameters where SS-WQGs are required by flagging all parameters whose natural concentrations are above the generic WQGs or WQOs. By studying the effect of different BC statistics on the CCME WQI scores, one can also gauge the sensitivity of a site to different SS-WQGs. This information can be used to prioritize sites (and within each site the parameters) that need to have SS-WQGs derived by using more accurate methods.

As demonstrated in this paper, the SS-WQI calculator is also an excellent tool for analyzing the effect of adopting different statistics to describe the BC water quality conditions. As demonstrated, the final choice of which BC statistic is used to derive SS-WQGs can have a significant impact on the CCME WQI scores for some sites. It is important to understand all factors at play before any one statistic is chosen to represent the water quality data at a site.

Conclusions and Recommendations

By adapting the BC procedure for deriving numerical SS-WQGs, an easy-to-use SS-WQI calculator has been developed. The development of the SS-WQI calculator will address an ever-growing need to incorporate SS-WQGs in the computation of the CCME WQI for sites where natu-

rally occurring high concentrations of certain parameters invoke the need to revise generic WQGs or WQOs.

As with any tool, the SS-WQI calculator is based on a number of assumptions and is most reliable when applied within its design domain. The SS-WQI calculator is particularly relevant for ambient water quality sites that have naturally occurring high levels of certain parameters. Its use can be extended to other impacted ambient water quality sites if appropriate caution is exercised to generate SS-WQGs for only those parameters that are elevated for non-anthropogenic conditions.

Being essentially a statistical-based tool it requires a good water quality data set that is free of any significant sampling or statistical bias to be applied. It is not intended as a replacement for the process of deriving SS-WQGs using other numerical derivation procedures such as the recalculation, WER and RS procedures. The computation of SS-WQGs using these procedures is often not feasible for practical, economic, resource, temporal or site-specific reasons. The BC procedure is a practical tool for deriving SS-WQGs that account for the naturally high concentrations in ambient water bodies that impact water quality indices.

The calculator is also an excellent tool for screening sites that have a need for SS-WQGs, and for identifying candidate parameters at these sites for deriving SS-WQGs.

The SS-WQI was applied to five pristine ambient water quality sites and the effects of using five different BC-based SS-WQGs (mean, median, mean ± one standard deviation, mean ± two standard deviations, 90th and 10th percentile) were studied. It highlights that the effect of using SS-WQGs on the CCME WQI score and ranking is very site specific and is very dependent on the statistic used to represent the natural BC. Careful thought must be placed on selecting a BC statistic for each site.

This paper only discusses the pilot level application of the SS-WQI calculator to five pristine sites. The results of this application clearly highlight that there is insufficient information at this point to conclude which of the five BC statistics presented is most appropriate. To decide which BC statistic of the five presented is most appropriate, the SS-WQI calculator needs to be tested and applied further on other data sets that already have SS-WQGs, derived using other biological effects-based procedures. These SS-WQGs derived using other biological effects-based procedures can be used as a benchmark to evaluate the BC statistics presented in this paper.

To gain a better understanding of its applicability, the SS-WQI calculator requires further testing on semi-impacted and impacted ambient water quality sites.

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