PPWB WATER QUALITY MONITORING REVIEW

PHASE 2: BEAVER, RED DEER (at the Alberta-Saskatchewan Boundary), SOUTH SASKATCHEWAN, CHURCHILL, SASKATCHEWAN, AND CARROT RIVERS

Prepared for the PPWB
Committee on Water Quality

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1.0 INTRODUCTION

1.1 Background

The Prairie Provinces Water Board (PPWB) was formed in 1948 when the governments of Canada, Manitoba, Saskatchewan and Alberta signed the Prairie Provinces Water Board Agreement. In 1969 these same parties entered into the Master Agreement on Apportionment and in 1989, Schedule E of this Agreement defined the mandate of the PPWB Water Quality Program as being to *"foster and facilitate interprovincial water quality management among the parties that encourages the protection and restoration of the aquatic environment"*. The primary objectives of the Water Quality Program (PPWB 1991) are to:

1. Promote a preventative and proactive approach to interprovincial water quality management.
2. Promote the protection and restoration of the aquatic environment.
3. Promote an ecosystem approach to the management of interprovincial waters.
4. Recognize the effect of quantity on the quality of water for the effective management of interprovincial waters.
5. Promote compatible water quality objectives for the effective management of interprovincial waters.

In order to satisfy these objectives the PPWB's Committee on Water Quality (COWQ) established a Water Quality Monitoring Program on major interprovincial streams. The objectives of the Monitoring Program (PPWB 1991) form a subset of the larger water quality program. These objectives are to:

1. Describe the quality of the aquatic ecosystems at the interprovincial boundary and identify the presence, absence and abundance of toxic substances, and other physical, chemical and biological attributes of transboundary waters.
2. Provide evidence of changes in trends in the concentration of chemical and physical substances, and in the biological integrity of the aquatic ecosystem.
3. Assess the achievement of water quality objectives, other water quality indicators and other water quality goals.
4. Maintain a scientifically credible data and information base on the quality of transboundary waters.

Data collection was initiated in 1974 and, with the recent addition of the Cold River, the number of transboundary river reaches currently monitored has expanded to twelve (Figure 1). The COWQ annually reports to the PPWB on general water quality and excursions to specific objectives at each of the monitored reaches and, less frequently (approximately every five years), examines long-term trends in water quality variables (Dunn 1995a, b).

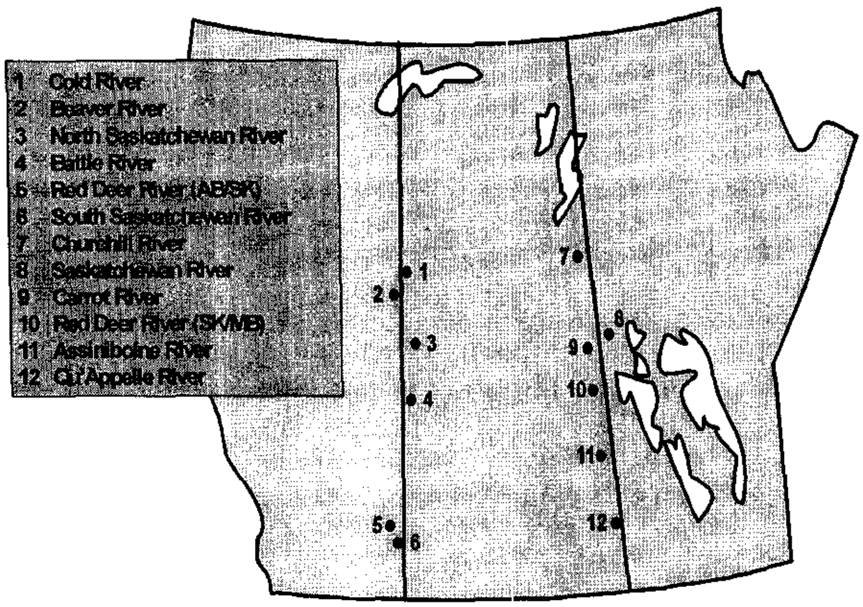

Figure 1. Location of PPWB Interprovincial Water Quality Monitoring Sites.

In light, of recent changes to the PPWB Water Quality Monitoring Program and because of changing funding pressures, the COWQ has chosen to undertake a comprehensive review of its current monitoring program. The purpose of this report is to provide background information and recommendations to facilitate the COWQ's discussions. It is also hoped that this report will help to ensure that the PPWB continues to meet its mandate in the most cost effective manner possible and that the data collected provide ecologically relevant information allowing for a characterization and assessment of environmental trends and current condition within each of the PPWB's twelve transboundary river reaches.

1.2 Objectives

This report builds on Cash (1998) which provided a general review of the PPWB Water Quality Monitoring Program and more specific recommendations regarding changes to the current monitoring programs along the Qu'Appelle and North Saskatchewan rivers. The objective of this series of reports is to provide a starting point for discussions concerning a response to several important changes that have occurred since the establishment of the PPWB Water Quality Monitoring Program in the mid-1970s. First, recent and predicted changes in funding availability serve to emphasize the need to conduct environmental monitoring in the most cost effective manner possible and to ensure there is a high return of information for each dollar invested. Second, the field of environmental monitoring is a rapidly evolving one, and this review represents an opportunity to incorporate recent advances in the theory, practice and interpretation of aquatic monitoring into the PPWB Water Quality Program. Finally, and perhaps most importantly, the current PPWB database now spans a period of over two decades and provides an excellent foundation for the quantitative and statistically rigorous assessment of trends. This database further provides the context within which monitoring efforts can be reviewed and refocused so as to identify and concentrate on the most ecologically relevant components of the ecosystem. It can also be used to ensure that those components are monitored on the spatial and temporal scales most appropriate to satisfy the PPWB mandate.

The specific objective of this report is to expand on Cash (1998) and inputs received from COWQ members to expand the review to six additional PPWB monitoring sites including the: (1) Beaver, (2) Red Deer (at the Alberta-Saskatchewan boundary), (3) South Saskatchewan, (4) Churchill, (5) Saskatchewan, and (6) Carrot rivers. The remaining PPWB monitoring reaches will be dealt with in the final phase of this review.

The report will not attempt to summarize or re-analyze data presented in PPWB excursion or trend reports. Rather, it will provide a general ecological assessment of the current Monitoring Program and provide recommendations where appropriate. Specific examples will be used to better illustrate the arguments provided. Cash (1998) provides the basis for the approach taken in this review as well as a more detailed discussion of certain key issues, including: (i) the ecosystem approach to environmental monitoring and the need for the development of ecosystem-specific monitoring programs; (ii) an overview of issues relating to the current PPWB Monitoring Program; and (iii) an overview of issues relating to statistical techniques for trend analysis in the PPWB Monitoring Program.

2.0 GENERAL ISSUES

As discussed in the previous section, Cash (1998) provides the basic rational employed in this review and the reader is directed to that report for a fuller justification of the recommendations provided here. It is also important to note that many of the recommendations in this report will be similar to those previously provided for the Qu'Appelle and North Saskatchewan rivers. This is to be expected given the nature of the PPWB Monitoring Program and the general similarity of many of the monitoring reaches. Although some recommendations (e.g., incorporation of benthic invertebrate sampling) are common to most or all monitoring reaches, the final decision to accept or reject the recommendation should be based on the results of pilot studies in some subset of reaches and the feasibility of applying it in any given reach.

In the following sections a brief update will be provided on specific issues raised in Phase 1 of this review and identified by the COWQ as being important to the overall Monitoring Program.

2.1 Nutrients

The appropriateness of current nutrient objectives has been identified as perhaps the most important issue facing the PPWB Monitoring Program. Current PPWB nutrient objectives, where they exist, are based largely on objectives and guidelines from other jurisdictions and may not be appropriate for prairie rivers that naturally experience high levels of phosphorous. The situation is further complicated by the fact that while the response (in terms of changes in primary productivity) to nutrient additions is fairly well understood in many lentic systems the same is not true in lotic systems. This is the case not only in Prairie Canada, but on a global basis as well.

The development of appropriate nutrient objectives for the PPWB Monitoring Program involves two distinct steps: (1) The empirical relationship between nutrient availability and primary production must be defined. In other words, the measurement endpoint (e.g., total phosphorous) should be predictive of the ecological consequence (e.g., algal production). (2) Decisions must be taken as to what constitutes "acceptable" levels of primary production within the monitoring reaches. This is partly an ecological issue but must also incorporate the public's aesthetic sense of what levels of primary productivity are deemed acceptable.

To address the first step the COWQ has approached Dr. Patricia Chambers of Environment Canada's National Water Research Institute to review spatial and temporal patterns in nutrients and algal abundance in Alberta rivers (Carr and Chambers 1998). The study was constrained by the availability of both nutrient and primary productivity data collected at that same time and at several sites along a length of river. However, the available data suggests that total phosphorous levels below 0.012mg/L will limit periphyton growth to "modest" (< 50mg/m^2 chlorophyll *a*) levels and that levels >0.030mg/L were often associated with periphyton chlorophyll *a* concentrations > 150mg/m^2. The authours point out that this empirical relationship should be tested further, and refined before it is used to set objectives and that public consultation should be undertaken to determine what constitutes "acceptable" levels of periphyton.

Despite these caveats, and despite the observed spatial (basin to basin) and temporal (season to season) variability in the empirical relationship, this approach holds a great deal of promise in so far as it attempts to relate directly nutrient objectives to levels of primary production. The challenge is to better define the relationship between total phosphorous and primary production and to determine what constitutes an acceptable level of periphyton growth. These issues will form the basis of a COWQ workshop to be held in early March 1999. It is hoped that the results of the workshop can be incorporated into the recommendations of this report.

2.2 Rapid Bioassessment of Benthic Invertebrate Community Structure

In the first phase of this review it was recommended that the PPWB evaluate the benthic macroinvertebrate community present at the Qu'Appelle and North Saskatchewan river monitoring sites on annual basis using rapid bioassessment techniques. Worldwide, benthic invertebrates are the most widely studied and employed biological indicator of aquatic systems and the advantages of using benthic macroinvertebrates have been well documented (see summaries in Plafkin *et al.* 1989; Rosenberg and Resh 1993) and include the fact that: (i) they are a diverse and widely distributed group that can be found in virtually all aquatic ecosystems; (ii) because they are relatively sessile, they integrate, and are representative of, conditions present in the area in which they are sampled; (iii) they are sensitive to a wide variety of environmental stresses (both natural and anthropogenic) and show a wide variety of responses to such stress; (iv) with some notable exceptions (e.g., Chironomidae, Oligochaeta) the taxonomy of benthic macroinvertebrates is generally well understood.

Once incorporated into the PPWB Monitoring Program temporal trends in community structure should be analyzed and related to general measures of water quality. Rapid bioassessment techniques have the advantage of being relatively inexpensive and can provide information on community structure in a timely fashion; however, changes in community structure detected using these techniques would have to be verified and further explored using more traditional methods

The recommendation was accepted by the COWQ in the final report but unfortunately, there was no opportunity to initiate a pilot study to investigate the feasibility of the approach in 1998. It is hoped that such a study could be undertaken in 1999.

2.3 Water Quality Index

In the review of the Qu'Appelle and North Saskatchewan Monitoring Programs it was recommended that the PPWB adopt the water quality index currently being developed by the CCME. The index is based on a consideration of three factors:

1. $\mathbf{F_1}$, the number of excursions to the objectives
2. $\mathbf{F_2}$, the frequency of excursions to the objectives
3. $\mathbf{F_3}$, the magnitude of the excursions.

that are combined to produce a single value (between 1 and 100) that describes water quality.

In January 1997 the Canadian Council of Ministers of the Environment (CCME) Water Quality Task Group, in cooperation with the CCME State of the Environment Task Group undertook to examine and, if necessary, modify the BC index with a view to creating a national water quality index that could be adopted by all provinces and territories. That work is currently underway and is making use of some PPWB data in testing modified versions of the index. A variation of the BC index has already been employed by the Province of Manitoba in its State of the Environment Report (Manitoba Environment 1997) and more recently Alberta (Wright *et al.* 1998) has modified the index for use in agricultural streams and is currently interested in formally testing its utility in assessing long-term trends in larger river systems (K. Saffran, pers. comm.).

Unlike some earlier indices, the basic BC formulation captures all key components of water quality, is easily calculated, and is sufficiently flexible that it can be applied in a variety of situations. The index can be very useful in tracking water quality changes at a given site over time. However, because both the variables and objectives that feed into the index will vary across sites, it is not an appropriate tool for comparing among sites, except in so far as comparing their ability to meet a defined use (e.g., recreation, irrigation, protection of aquatic life, etc.).

The water quality index is a simple and powerful way to draw general conclusions concerning water quality and could greatly enhance the PPWB's ability to communicate its results to both managers and the general public. Use of this index in the Prairie provinces as well as other Canadian jurisdictions would also serve to standardize the way in which the results of water quality monitoring could be communicated.

It must be stressed however, that the index is a technique used to report on water quality analyses and does not replace the need to analyze individual variables and trends. Any use of the index should be accompanied by narrative descriptions explaining the underlying causes of the calculated index values. It should also be noted that because the index is based on only those variables for which objectives exist, its utility to the PPWB will be largely constrained by the availability and appropriateness of such objectives.

3.0 PROPOSED CHANGES TO THE CURRENT MONITORING PROGRAM FOR THE BEAVER RIVER AT THE ALBERTA-SASKATCHEWAN BOUNDARY

3.1 Overview

The PPWB monitoring station on the Beaver River is located immediately upstream of the Alberta-Saskatchewan Boundary. There are approximately 14,500 km^2 of drainage area upstream of the monitoring station accounting for about 25% of the total drainage area of the Beaver River. The flow of the Beaver River is unregulated and flows are considered to be largely natural.

The portion of the drainage upstream of the monitoring station is primarily used as a recreational area. Principal water users in this part of the basin include local municipalities and some industry (e.g., oil sands industry), recreation and habitat for fish and wildlife (see Dunn 1995a for a more detailed description of the river basin). The PPWB Water Quality Monitoring site on the Beaver River is located at "Beaver River at Beaver Crossing".

An analysis of long-term trends in water quality in the Beaver River suggests that the majority of measured variables show few systematic trends over time. Parametric (linear regression) and non-parametric (Kendall Tau, Spearman Trend, Van Belle) tests revealed that concentrations of 11 water quality variables significantly decreased over the period of measurement. These variables included: NO2+NO3, total nitrogen, dissolved oxygen, sulphate, alpha-BHC, potassium, cooper, zinc, total coliforms, mercury, and daily discharge. (Dunn1995a). The same statistical trend analysis revealed that seven variables, TDS, conductivity, pH, sodium, chloride, calcium, and, alkalinity showed a positive trend in concentration over the same period.

Regardless of trend direction, rates of change were low and excursions to objectives rare. For these reasons, none of the detected trends were considered to be of management concern.

In addition, to the variables described above, manganese, iron and fecal coliforms were identified as deserving special attention in several PPWB Excursion Reports. Although no trend is apparent, for any of these variables occasional excursions to PPWB objectives (0.2mg/L. for manganese, 1.0mg/L for iron, and 100/100ml for fecal coliform) have been noted. In the case of manganese and iron, excursions are thought to be reflective of natural conditions (possibly groundwater influences) rather human activity and are not of immediate concern.

Although not measure recently (i.e., 1995-1999), historical fecal coliform counts have a median value of 6/100 ml, well below the PPWB guideline, and exceeded guidelines only four times in 17 years (Dunn 1995a). These data suggest that fecal coliforms are not of immediate concern in the Beaver River. Furthermore, as discussed in Cash (1998), the use of fecal coliforms as a measurement endpoint in these systems may not provide the most appropriate indicator of bacterial contamination.

In summary, the Beaver River is currently (1997-1999) monitored on a monthly basis. Monitored variables include nitrogen, phosphorous, carbon, NFR, pH, temperature, conductivity, dissolved oxygen, major ions, boron, heavy metals, mercury, and aluminum. The only variable currently identified as being of potential concern in this reach is fecal coliforms, but they have not been measured in recent years

3.2 Recommendations

The following recommendations are based on an examination of available data and a consideration of the issues discussed in earlier sections of this report and Cash (1998). Any changes to the Monitoring Program should be carefully evaluated and, if necessary, adapted based on new information and internal "feedback loops"

3.2.1 **It is recommended that the PPWB collect water samples from the Beaver River on a monthly basis every other year and quarterly in intervening years.** Given the lack of excursions to objectives or trends of management concern, such a change in sampling frequency will not significantly alter the ability to analyze trends or detect excursions in this reach.

3.2.2 **It is recommended that the PPWB undertake a review of current objectives associated with water quality variables measured in the Beaver River and that, where objectives are needed, they be developed.** As discussed in Cash (1998), the lack of objectives is a major impediment to the interpretation of the collected data and to the assessment of overall health or condition. Objectives also form the basis of any water quality index that might be applied to the PPWB data.

3.2.3 **It is recommended that the PPWB consider the need to control for other influences (e.g., discharge, hardness, sediment load, diurnal variability, etc.) when analyzing trends and establishing objectives.** Such a consideration may necessitate the control of certain covariates in trend analysis or the development of a number of condition-dependent objectives for some variables.

3.2.4 **It is recommended that (contingent upon the results of a pilot study) the PPWB evaluate the benthic macroinvertebrate community present at the Beaver River monitoring site on an annual basis using the rapid bioassessment techniques outlined in this report.** Worldwide, benthic invertebrates are the most widely studied and employed biological indicator of aquatic systems and should be incorporated into the PPWB Monitoring Program. Trends in community structure should be analyzed and related to general measures of water quality.

3.2.5 **It is recommended that the PPWB examine the feasibility of measuring primary productivity (periphyton and/or epiphyton) measured at the Beaver River monitoring site.** Measures of primary productivity, though not feasible in all locations, would link directly measured nutrient levels and their immediate affect on biota. This data would also assist efforts to improve nutrient objectives and should be directly linked to the work being conducted by Dr. P. Chambers (NWRI) for the PPWB.

3.2.6 **It is recommended that the PPWB explore the possibility of measuring sediment quality within the Beaver River monitoring site.** Sediments can serve as important sinks for a variety of contaminants. Sediments form an important compartment within the aquatic ecosystem and can have a strong influence on aquatic quality.

3.2.7 **It is recommended that the PPWB continue to periodically (every five years) analyze trends in water quality and biota measured at the Beaver River monitoring site.** Trend analysis is essential to the Monitoring Program but given the data already collected, an analysis every five years should be sufficient to detect changes in trends and identify potential concerns. Where appropriate, advances in statistical trend analysis and related software should be incorporated in this exercise.

3.2.8 **It is recommended that the PPWB monitor major ions at the Beaver River monitoring site on a quarterly basis only.** Major ions concentrations in this reach are consistently well below objectives and need not be measured monthly.

3.2.9 **It is recommended that the PPWB undertake a review of all nutrient objectives with a view to establishing objectives more appropriate for rivers in Prairie Canada.** The importance of nutrient levels in determining ecological function in these systems has long been recognized by the PPWB, as has the possible inappropriateness of current nutrient guidelines. These issues are the subject of ongoing study conducted by Dr. P. Chambers (DOE) and sponsored, in part, by the PPWB.

3.2.10 **It is recommended that the PPWB cease routine monitoring of dissolved oxygen at the Beaver River monitoring site.** Statistical analyses suggest a very slight negative trend in dissolved oxygen concentrations at this site. However, excursions from the PPWB guideline (6.0 mg/L) are very rare. More importantly, dramatic diurnal variation in dissolved oxygen values are common in these systems and single monthly measures probably hold little value. If measures of dissolve oxygen are required during certain periods (e.g., late winter, under ice) they should be collected on a temporal scale (e.g., hourly, every ten minutes) adequate to characterize the variation.

3.2.11 **It is recommended that the PPWB cease monitoring mercury and chromium in the water column at the Beaver River site.** Mercury and chromium levels in the water column are difficult to measure and interpret. The PPWB now monitors these variables in a more appropriate medium (i.e., fish tissue).

3.2.12 **It is recommended that the PPWB cease monitoring dissolved boron at the Beaver River site.** Long-term trend analysis fails to suggest any trend in boron concentration and the fact that concentrations have never approached the PPWB objective (5.0 mg/L) suggest there is little value in continuing to monitor boron at this site.

3.2.13 It is recommended that the PPWB cease monitoring total coliforms in favour of monitoring fecal coliforms and *Escherichia coli.* Because total coliforms is a poor indicator of sewage contamination it has been replaced in many jurisdictions by fecal coliforms. *E. coli* possess the added advantage of being a superior indicator of gastrointestinal illness. A shift toward monitoring fecal coliforms and *E. coli* would also make PPWB data more comparable to that collected downstream in Manitoba.

3.2.14 It is recommended that the PPWB adopt the water quality index currently being developed by the CCME and the province of Alberta as a means by which the results of water quality assessments can be communicated to managers and the general public. As discussed above, the index is already in use, or is being tested, by each of the Prairie Provinces. Adoption of the index would improve the PPWB's ability to report on water quality trends and facilitate the exchange of information among agencies.

4.0 PROPOSED CHANGES TO THE CURRENT MONITORING PROGRAM FOR THE RED DEER RIVER AT THE ALBERTA-SASKATCHEWAN BOUNDARY

4.1 Overview

The Red Deer River originates east of Lake Louise, and travels approximately 650 km through south central Alberta before joining the South Saskatchewan River 18km east of the Alberta-Saskatchewan boundary. The river has a gross drainage area of 44,683 km^2 and its flow is regulated by the Dickson Dam, located upstream of the city of Red Deer.

Most of the basin is sparsely populated but the river does flow through several population centers including the city of Red Deer (1996 population 60,075) and the town of Drumheller (1996 population 6,587). There are no major water users that withdraw water from the Red Deer River, however, the river does supply a number of municipalities in the basin as well as some industries. Adequate supplies are also required to maintain Sylvan and Buffalo Lakes. Other uses include recreation and habitat for fish and wildlife (see Dunn 1995a for a more detailed description of the river basin). The PPWB Water Quality Monitoring site on the Red Deer River is located at Bindloss, Alberta.

As with other PPWB monitoring sites, an analysis of long-term trends in water quality in the Red Deer River suggests that the majority of measured variables show few systematic trends over time. Parametric (linear regression) and non-parametric (Kendall Tau, Spearman Trend, Van Belle) tests revealed that concentrations of nine water quality variables significantly decreased over the period of measurement. These variables included: TDS, NO2+NO3, total nitrogen, sodium, magnesium, sulphate, alpha-BHC, calcium, and total coliforms (Dunn1995a). The same statistical trend analysis revealed that pH values showed a positive trend over the same period. A number of other variables (manganese, iron, mercury, lead, turbidity, fecal coliforms, daily discharge, 2,4,5-T and 2.4-D also appeared to display long-tern trends but these were an artifact of changes to detection limits/methodologies over the course of data collection.

Regardless of direction, rates of change for all significant trends were low and excursions to objectives rare. For these reasons, none of the detected trends were considered to be of management concern.

In addition, to the variables described above, copper, fecal coliforms, iron and lead were identified as deserving special attention in several PPWB Excursion Reports. Although no trend is apparent for any of these variables occasional excursions to the PPWB objectives (0.004mg/L. for copper, 100/100ml for fecal coliform, 0.3mg/L for iron, and 0.007mg/L for lead) have been noted. It is thought that excursions in the cooper and lead are reflective of the geology of the lower Red Deer drainage, and more specifically, of the Bearpaw formation and the badlands (Anderson 1996). Lead excursions are quite rare (only one excursion in the last three years) and may also reflect the underlying geology of the area.

Fecal coliform counts have, typically exceeded the PPWB guideline in 1-3 months of the year. These excursions to objectives are probably a consequence of local (i.e., downstream of

Drumheller) impacts including municipal discharge, irrigation return flows, livestock and wildlife (Anderson 1996).

In summary, the Red Deer River is currently (1997-1999) monitored on a monthly basis. Monitored variables include nitrogen, phosphorous, carbon, NFR, pH, temperature, conductivity, dissolved oxygen, major ions, boron, heavy metals, mercury, and aluminum. Bacteria are monitored during the seven open water months. Variables of potential concern include copper, iron, lead, and fecal coliforms. Metal excursions are thought to be reflective of local geography but, at least in the case of copper, are quite common. AEP is expected to produce a report on excursions in this reach in 1999.

4.2 Recommendations

The following recommendations are based on an examination of available data and a consideration of the issues discussed in earlier sections of this report and Cash (1998). Any changes to the Monitoring Program should be carefully evaluated and, if necessary, adapted based on new information and internal "feedback loops"

4.2.1 **It is recommended that the PPWB undertake a review of current objectives associated with water quality variables measured in the Red Deer River and that, where objectives are needed, they be developed.** As discussed in Cash (1998), the lack of objectives is a major impediment to the interpretation of the collected data and to the assessment of overall health or condition. Objectives also form the basis of any water quality index that might be applied to the PPWB data.

4.2.2 **It is recommended that the PPWB consider the need to control for other influences (e.g., discharge, hardness, sediment load, diurnal variability, etc.) when analyzing trends and establishing objectives.** Such a consideration may necessitate the control of certain covariates in trend analysis or the development of a number of condition-dependent objectives for some variables.

4.2.3 **It is recommended that (contingent upon the results of a pilot study) the PPWB evaluate the benthic macroinvertebrate community present at the Red Deer River monitoring site on an annual basis using the rapid bioassessment techniques outlined in this report.** Worldwide, benthic invertebrates are the most widely studied and employed biological indicator of aquatic systems and should be incorporated into the PPWB Monitoring Program. Trends in community structure should be analyzed and related to general measures of water quality.

4.2.4 **It is recommended that the PPWB examine the feasibility of measuring primary productivity (periphyton and/or epiphyton) measured at the Red Deer River monitoring site.** Measures of primary productivity, though not feasible in all locations, would link directly measured nutrient levels and their immediate affect on biota. This data would also assist efforts to improve nutrient objectives and should be directly linked to the work being conducted by Dr. P. Chambers (NWRI) for the PPWB..

4.2.5 **It is recommended that the PPWB explore the possibility of measuring sediment quality within the Red Deer River monitoring site.** Sediments can serve as important sinks for a variety of contaminants. Sediments form an important compartment within the aquatic ecosystem and can have a strong influence on aquatic quality.

4.2.6 **It is recommended that the PPWB continue to periodically (every five years) analyze trends in water quality and biota measured at the Red Deer River monitoring site.** Trend analysis is essential to the Monitoring Program but given the data already collected, an analysis every five years should be sufficient to detect changes in trends and identify potential concerns. Where appropriate, advances in statistical trend analysis and related software should be incorporated in this exercise.

4.2.7 **It is recommended that the PPWB monitor major ions at the Red Deer River monitoring site on a quarterly basis only.** There are no objectives for major ions in this monitoring reach, however, measure levels are well below the objectives for other reaches and show no significant positive trends suggesting they need not be need not be measured monthly.

4.2.8 **It is recommended that the PPWB undertake a review of all nutrient objectives with a view to establishing objectives more appropriate for rivers in Prairie Canada.** The importance of nutrient levels in determining ecological function in these systems has long been recognized by the PPWB, as has the possible inappropriateness of current nutrient guidelines. These issues are the subject of ongoing study conducted by Dr. P. Chambers (DOE) and sponsored, in part, by the PPWB.

4.2.9 **It is recommended that the PPWB cease routine monitoring of dissolved oxygen at the Red Deer River monitoring site.** Statistical analyses do not suggest any trend in dissolved oxygen concentrations and while there is no PPWB objective for dissolved oxygen in this reach measured values rarely drop below the Alberta guideline (6.5 mg/L). More importantly, dramatic diurnal variation in dissolved oxygen values are common in these systems and single monthly measures probably hold little value. If measures of dissolve oxygen are required during certain periods (e.g., late winter, under ice) they should be collected on a temporal scale (e.g., hourly, every ten minutes) adequate to characterize the variation.

4.2.10 **It is recommended that the PPWB cease monitoring mercury and chromium in the water column at the Red Deer River site.** Mercury and chromium levels in the water column are difficult to measure and interpret. The PPWB now monitors these variables in a more appropriate medium (i.e., fish tissue).

4.2.11 **It is recommended that the PPWB cease monitoring dissolved boron at the Red Deer River site.** Long-term trend analysis fails to suggest any trend in boron concentration and the fact that concentrations have never approached the PPWB objective (5.0 mg/L) suggest there is little value in continuing to monitor boron.

4.2.12 **It is recommended that the PPWB cease monitoring total coliforms in favour of monitoring fecal coliforms and *Escherichia coli*.** Because total coliforms is a poor indicator of sewage contamination it has been replaced in many jurisdictions by fecal coliforms. *E. coli* possess the added advantage of being a superior indicator of gastrointestinal illness. A shift toward monitoring fecal coliforms and *E. coli* would also make PPWB data more comparable to that collected downstream in Manitoba.

4.2.13 **It is recommended that the PPWB adopt the water quality index currently being developed by the CCME as a means by which the results of water quality assessments can be communicated to managers and the general public.** As discussed above, the index is already in use, or is being tested, by each of the Prairie Provinces. Adoption of the index would improve the PPWB's ability to report on water quality trends and facilitate the exchange of information among agencies.

5.0 PROPOSED CHANGES TO THE CURRENT MONITORING PROGRAM FOR THE SOUTH SASKATCHEWAN RIVER AT THE ALBERTA-SASKATCHEWAN BOUNDARY

5.1 Overview

The South Saskatchewan River originates at the confluence of the Bow and Oldman rivers, approximately 30 km west of Medicine Hat, Alberta. Collectively, the Bow, Oldman and Red Deer rivers, and that portion of the South Saskatchewan River contained within Alberta have a gross drainage area of 110,700 km^2 , approximately 20% of the land area of Alberta. The South Saskatchewan River is regulated downstream of the Alberta-Saskatchewan boundary by the Gardiner Dam and upstream of the boundary by numerous irrigation and power projects along the Oldman and Bow rivers. The human population within the Alberta portion of the drainage approaches 1,000,00, with the largest concentrations in the cities of Calgary, Lethbridge and Medicine Hat (1996 census: 768,082; 63,053, and 46,783, respectively). Irrigation is the major consumptive use of water within the basin, and nutrient enrichment from municipal sewage has been an historical problem, particularly on the Bow River, downstream of Calgary (see Dunn 1995a for a more detailed description of the river basin). The PPWB Water Quality Monitoring site on the South Saskatchewan River is located along Highway #41 in Alberta.

As with other PPWB monitoring sites, an analysis of long-term trends in water quality in the South Saskatchewan River suggests that the majority of measured variables show few systematic trends over time. Parametric (linear regression) and non-parametric (Kendall Tau, Spearman Trend, Van Belle) tests revealed that six water quality variables significantly decreased in concentration over the period of measurement. These variables included: total nitrogen, total dissolved phosphorus, total phosphorus, alpha-BHC, calcium, and cooper (Dunn1995a). The same statistical trend analysis revealed that four variables, including, turbidity, boron, pH, and chloride showed a positive trend in concentration over the same period. A number of other variables (including manganese, iron, mercury, lead, and 2,4,5-T) also appeared to display long-tern trends in concentration, but these were an artifact of changes to detection limits/methodologies over the course of data collection.

Regardless of direction, rates of change for all significant trends were low and excursions to objectives rare. For these reasons, none of the detected trends were considered to be of management concern.

The only exception to this pattern was total phosphorus. Although there is no PPWB objective for total phosphorous in the South Saskatchewan River, and despite a negative long-term trend in this variable, phosphorous, and associated eutrophication continue to be an issue in this basin.

As discussed above, Carr and Chambers (1998) suggest total phosphorous levels below 0.012mg/L will limit periphyton growth to "modest" (< 50mg/m^2 chlorophyll *a*) levels and that levels >0.030mg/L were often associated with periphyton chlorophyll *a* concentrations > 150mg/m^2. Measured total phosphorous measured at the South Saskatchewan River monitoring is rarely below 0.012mg/L and is frequently in excess of 0.03mg/L. Clearly further work is required to develop an appropriate phosphorous guideline for this monitoring reach.

In summary, the South Saskatchewan River is currently (1997-1999) monitored on a monthly basis. Monitored variables include nitrogen, phosphorous, carbon, NFR, pH, temperature, conductivity, dissolved oxygen, major ions, boron, heavy metals, mercury, and aluminum. Bacteria are monitored during the seven open water months and fish are sampled every five years for metals, chlorinated phenolics, dioxins/furans, and OC's/PCBs. At this time, the only variable of concern in the Monitoring Program for this site is total phosphorous. However, given upstream developments and agricultural changes it would seem wise to continue fairly intensive monitoring on this reach.

5.2 Recommendations

The following recommendations are based on an examination of available data and a consideration of the issues discussed in earlier sections of this report and in Cash (1998). Any changes to the Monitoring Program should be carefully evaluated and, if necessary, adapted based on new information and internal "feedback loops"

5.2.1 **It is recommended that the PPWB undertake a review of current objectives associated with water quality variables measured in the South Saskatchewan River and that, where objectives are needed, they be developed.** As discussed in Cash (1998), the lack of objectives is a major impediment to the interpretation of the collected data and to the assessment of overall health or condition. Objectives also form the basis of any water quality index that might be applied to the PPWB data.

5.2.2 **It is recommended that the PPWB consider the need to control for other influences (e.g., discharge, hardness, sediment load, diurnal variability, etc.) when analyzing trends and establishing objectives.** Such a consideration may necessitate the control of certain covariates in trend analysis or the development of a number of condition-dependent objectives for some variables.

5.2.3 **It is recommended that the PPWB continue monitoring fish condition and tissue contaminant levels in the South Saskatchewan River on a five year cycle.** Fish collected for contaminant analysis should also be assessed for general condition. Fish captured, but not collected for contaminant analysis, should also be assessed for general condition prior to release.

5.2.2 **It is recommended that (contingent upon the results of a pilot study) the PPWB evaluate the benthic macroinvertebrate community present at the South Saskatchewan River monitoring site on an annual basis using the rapid bioassessment techniques outlined in this report.** Worldwide, benthic invertebrates are the most widely studied and employed biological indicator of aquatic systems and should be incorporated into the PPWB Monitoring Program. Trends in community structure should be analyzed and related to general measures of water quality.

5.2.3 **It is recommended that the PPWB examine the feasibility of measuring primary productivity (periphyton and/or epiphyton) measured at the South Saskatchewan River monitoring site.** Measures of primary productivity, though not feasible in all locations, would link directly measured nutrient levels and their immediate affect on biota. This data would also assist efforts to improve nutrient objectives and should be directly linked to the work being conducted by Dr. P. Chambers (NWRI) for the PPWB.

5.2.4 **It is recommended that the PPWB explore the possibility of measuring sediment quality within the South Saskatchewan River monitoring site.** Sediments can serve as important sinks for a variety of contaminants. Sediments form an important compartment within the aquatic ecosystem and can have a strong influence on aquatic quality.

5.2.5 **It is recommended that the PPWB continue to periodically (every five years) analyze trends in water quality and biota measured at the South Saskatchewan River monitoring site.** Trend analysis is essential to the Monitoring Program but given the data already collected, an analysis every five years should be sufficient to detect changes in trends and identify potential concerns. Where appropriate, advances in statistical trend analysis and related software should be incorporated in this exercise.

5.2.6 **It is recommended that the PPWB monitor major ions at the South Saskatchewan River monitoring site on a quarterly basis only.** Measured levels of major ions are show no trend and are consistently low, suggesting they need not be measured monthly.

5.2.7 **It is recommended that the PPWB undertake a review of all nutrient objectives with a view to establishing objectives more appropriate for rivers in Prairie Canada.** The importance of nutrient levels in determining ecological function in these systems has long been recognized by the PPWB, as has the possible inappropriateness of current nutrient guidelines. These issues are the subject of ongoing study conducted by Dr. P. Chambers (DOE) and sponsored, in part, by the PPWB.

5.2.8 **It is recommended that the PPWB cease routine monitoring of dissolved oxygen at the South Saskatchewan River monitoring site.** Statistical analyses do not suggest any trend in dissolved oxygen concentrations and excursions to the Alberta guideline (6.5 mg/L) are very rare. More importantly, dramatic diurnal variation in dissolved oxygen values are common in these systems and single monthly measures probably hold little value. If measures of dissolve oxygen are required during certain periods (e.g., late winter, under ice) they should be collected on a temporal scale (e.g., hourly, every ten minutes) adequate to characterize the variation.

5.2.9 **It is recommended that the PPWB cease monitoring mercury and chromium in the water column at the South Saskatchewan River site.** Mercury and chromium levels in the water column are difficult to measure and interpret. The PPWB now monitors these variables in a more appropriate medium (i.e., fish tissue).

5.2.10 **It is recommended that the PPWB cease monitoring dissolved boron at the South Saskatchewan River site.** Long-term trend analysis indicate a slight positive trend in boron concentrations, however even the highest recorded concentrations fail to come within an order of magnitude of the PPWB objective (5.0 mg/L). These data suggest there is little value in continuing to monitor boron.

5.2.11 **It is recommended that the PPWB cease monitoring total coliforms in favour of monitoring fecal coliforms and *Escherichia coli*.** Because total coliforms is a poor indicator of sewage contamination it has been replaced in many jurisdictions by fecal coliforms. *E. coli* possess the added advantage of being a superior indicator of gastrointestinal illness. A shift toward monitoring fecal coliforms and *E. coli* would also make PPWB data more comparable to that collected downstream in Manitoba.

5.2.12 **It is recommended that the PPWB adopt the water quality index currently being developed by the CCME as a means by which the results of water quality assessments can be communicated to managers and the general public.** As discussed above, the index is already in use, or is being tested, by each of the Prairie Provinces. Adoption of the index would improve the PPWB's ability to report on water quality trends and facilitate the exchange of information among agencies.

6.0 PROPOSED CHANGES TO THE CURRENT MONITORING PROGRAM FOR THE CHURCHILL RIVER AT THE SASKATCHEWAN-MANITOBA BOUNDARY

6.1 Overview

The Churchill River originates as the Beaver River in eastern Alberta and flows eastward for over 1,600 km before entering Hudson's Bay, draining a total area of 299,000 km^2. Flow in the Churchill River is controlled by structures located at Reindeer lake and Lac La Ronge. Population densities within this area are low (approximately 50,000 people in the entire basin) and municipal/industrial requirements for water are minimal. However, the control structure at Reindeer does serve to significantly redistribute monthly flows which serves to dampen the hydrograph (see Dunn 1995b for a more detailed description of the river basin). The PPWB Water Quality Monitoring site on the Churchill River is located near the outlet of Wasawakasik Lake.

In general, water quality at the Churchill monitoring station has been consistently high. As with other PPWB monitoring sites, an analysis of long-term trends in water quality in the Churchill River suggests that the majority of measured variables show few systematic trends over time. Parametric (linear regression) and non-parametric (Kendall Tau, Spearman Trend, Van Belle) tests revealed that 15 water quality variables showed a significant negative trend in concentration over the period of measurement. These variables included: TDS, conductivity, NO2+NO3, total nitrogen, dissolved oxygen, sodium, magnesium, alpha-BHC, potassium, calcium, alkalinity, cooper, zinc, total coliforms and daily discharge (Dunn 1995b). The same statistical trend analysis that only turbidity displayed a significant positive trend over the same period. A number of other variables (manganese, iron, mercury, and lead) also appeared to display long-tern trends but these were an artifact of changes to detection limits/methodologies over the course of data collection.

Regardless of direction, rates of change for all significant trends were low and excursions to objectives rare. For these reasons, none of the detected trends were considered to be of management concern. Similarly, the annual PPWB Excursion Studies have failed to identify any issues of management concern at this station.

In summary, the Churchill River is currently (1997-1999) monitored on a quarterly basis. Monitored variables include nitrogen, phosphorous, carbon, NFR, pH, temperature, conductivity, dissolved oxygen, major ions, boron, heavy metals, mercury, and aluminum. Fish are sampled every five years for metals, chlorinated phenolics, dioxins/furans, and OC's/PCBs. At this time, there are no variables of concern in the Monitoring Program for this site.

6.2 Recommendations

The following recommendations are based on an examination of available data and a consideration of the issues discussed in earlier sections of this report and in Cash (1998). Any changes to the Monitoring Program should be carefully evaluated and, if necessary, adapted based on new information and internal "feedback loops"

6.2.1 **It is recommended that the PPWB continue to monitor the Churchill River on a quarterly basis.** Although the Churchill River represents an important component in the PPWB monitoring network, the lack of excursions or trends of management concern indicate that such a change in sampling frequency will not significantly alter the ability to analyze trends or detect excursions in this reach.

6.2.2 **It is recommended that the PPWB undertake a review of current objectives associated with water quality variables measured at the Churchill River monitoring site and that, where objectives are needed, they be developed.** As discussed in Cash (1998), the lack of objectives is a major impediment to the interpretation of the collected data and to the assessment of overall health or condition. Objectives also form the basis of any water quality index that might be applied to the PPWB data.

6.2.3 **It is recommended that the PPWB consider the need to control for other influences (e.g., discharge, hardness, sediment load, diurnal variability, etc.) when analyzing trends and establishing objectives.** Such a consideration may necessitate the control of certain covariates in trend analysis or the development of a number of condition-dependent objectives for some variables.

6.2.4 **It is recommended that the PPWB continue monitoring fish condition and tissue contaminant levels in the Churchill River on a five year cycle.** Fish collected for contaminant analysis should also be assessed for general condition. Fish captured, but not collected for contaminant analysis, should also be assessed for general condition prior to release.

6.2.5 **It is recommended that (contingent upon the results of a pilot study) the PPWB evaluate the benthic macroinvertebrate community present at the Churchill River monitoring site every second year using the rapid bioassessment techniques outlined in this report.** Worldwide, benthic invertebrates are the most widely studied and employed biological indicator of aquatic systems and should be incorporated into the PPWB Monitoring Program. Trends in community structure should be analyzed and related to general measures of water quality.

6.2.6 **It is recommended that the PPWB explore the possibility of measuring sediment quality within the Churchill River monitoring site.** Sediments can serve as important sinks for a variety of contaminants. Sediments form an important compartment within the aquatic ecosystem and can have a strong influence on aquatic quality.

6.2.7 **It is recommended that the PPWB continue to periodically (every five years) analyze trends in water quality and biota measured at the Churchill River monitoring site.** Trend analysis is essential to the Monitoring Program but given the data already collected, an analysis every five years should be sufficient to detect changes in trends and identify potential concerns. Where appropriate, advances in statistical trend analysis and related software should be incorporated in this exercise.

6.2.8 **It is recommended that the PPWB undertake a review of all nutrient objectives with a view to establishing objectives more appropriate for rivers in Prairie Canada.** The importance of nutrient levels in determining ecological function in these systems has long been recognized by the PPWB, as has the possible inappropriateness of current nutrient guidelines. These issues are the subject of ongoing study conducted by Dr. P. Chambers (DOE) and sponsored, in part, by the PPWB.

6.2.9 **It is recommended that the PPWB cease routine monitoring of dissolved oxygen at the Churchill River monitoring site.** Statistical analyses suggest a slight negative trend in dissolved oxygen concentrations but there are no excursions to the PPWB guideline (6.5 mg/L) and no issue of concern. More importantly, dramatic diurnal variation in dissolved oxygen values are common in these systems and single monthly measures probably hold little value. If measures of dissolve oxygen are required during certain periods (e.g., late winter, under ice) they should be collected on a temporal scale (e.g., hourly, every ten minutes) adequate to characterize the variation.

6.2.10 **It is recommended that the PPWB cease monitoring mercury and chromium in the water column at the Churchill River site.** Mercury and chromium levels in the water column are difficult to measure and interpret. The PPWB now monitors these variables in a more appropriate medium (i.e., fish tissue).

6.2.11 **It is recommended that the PPWB cease monitoring dissolved boron at the Churchill River site.** Long-term trend analysis fails to suggest any trend in boron concentration and the fact that concentrations have never approached the PPWB objective (5.0 mg/L) suggest there is little value in continuing to monitor boron.

6.2.12 **It is recommended that the PPWB adopt the water quality index currently being developed by the CCME as a means by which the results of water quality assessments can be communicated to managers and the general public.** As discussed above, the index is already in use, or is being tested, by each of the Prairie Provinces. Adoption of the index would improve the PPWB's ability to report on water quality trends and facilitate the exchange of information among agencies.

7.0 PROPOSED CHANGES TO THE CURRENT MONITORING PROGRAM FOR THE SASKATCHEWAN RIVER AT THE SASKATCHEWAN-MANITOBA BOUNDARY

7.1 Overview

The Saskatchewan River originates at the confluence of the North and South Saskatchewan rivers, near Prince Albert, Saskatchewan and (after passing through the Cumberland Delta) at The Pas, Manitoba, has a gross drainage area of 347,627 km^2 . Flow in the Saskatchewan River is controlled by the existence of reservoirs located along the North and South Saskatchewan rivers (particularly Lake Diefenbaker) as well as storage in Codette and Tobin lakes. The effect of these structures is to reduce overall flow in certain years and to dampen the hydrograph in all years. Population densities within this area are fairly low and agriculture remains the most significant activity in the area. Water uses in the area include irrigation, municipal and industrial uses and instream use by power plants (see Dunn 1995b for a more detailed description of the river basin). The PPWB Water Quality Monitoring site on the Saskatchewan River is located near its confluence with the Carrot River.

As with other PPWB monitoring sites, an analysis of long-term trends in water quality in the Saskatchewan River suggests that the majority of measured variables show few systematic trends over time. Parametric (linear regression) and non-parametric (Kendall Tau, Spearman Trend, Van Belle) tests revealed that nine water quality variables showed a significant negative trend in concentration over the period of measurement. These variables included: NO2+NO3, total nitrogen, magnesium, alpha-BHC, potassium, iron, total coliforms, daily discharge, and 2,4-D (Dunn 1995b). The same statistical trend analysis that only total alkalinity displayed a significant positive trend over the same period. Two other variables (manganese and 2,4,5-T) also appeared to display long-tern trends but these were an artifact of changes to detection limits/methodologies over the course of data collection.

Regardless of direction, rates of change for all significant trends were low and excursions to objectives rare. For these reasons, none of the detected trends were considered to be of management concern.

As with the South Saskatchewan River, although there is no detectable trend for concentrations of total phosphorous, measurements are frequently higher than the PPWB objective (0.05 mg/L) and usually above the critical values (0.012mg/L and 0.03 mg/L, identified by Carr and Chambers (1998) for Alberta rivers. As discussed above, there is a need to assess the appropriateness of current objectives for total phosphorous in all PPWB monitoring reaches.

In summary, the Saskatchewan River is currently (1997-1999) monitored on a monthly basis. Monitored variables include nitrogen, phosphorous, carbon, NFR, pH, temperature, conductivity, dissolved oxygen, major ions, boron, heavy metals, mercury, and aluminum and bacteria. Fish are sampled every five years for metals, chlorinated phenolics, dioxins/furans, and OC's/PCBs. At this time the only variable of concern in the Monitoring Program for this site is total phosphorous. However, given upstream developments and agricultural changes it would seem wise to continue fairly intensive monitoring on this reach.

7.2 Recommendations

The following recommendations are based on an examination of available data and a consideration of the issues discussed in earlier sections of this report. Any changes to the Monitoring Program should be carefully evaluated and, if necessary, adapted based on new information and internal "feedback loops"

7.2.1 **It is recommended that the PPWB undertake a review of current objectives associated with water quality variables measured in the Saskatchewan River and that, where objectives are needed, they be developed.** As discussed above and in Cash (1998) the lack of objectives is a major impediment to the interpretation of the collected data and to the assessment of overall health or condition. Objectives also form the basis of any water quality index that might be applied to the PPWB data.

7.2.2 **It is recommended that the PPWB consider the need to control for other influences (e.g., discharge, hardness, sediment load, diurnal variability, etc.) when analyzing trends and establishing objectives.** Such a consideration may necessitate the control of certain covariates in trend analysis or the development of a number of condition-dependent objectives for some variables.

7.2.3 **It is recommended that the PPWB continue monitoring fish condition and tissue contaminant levels in the Saskatchewan River on a five year cycle.** Fish collected for contaminant analysis should also be assessed for general condition. Fish captured, but not collected for contaminant analysis, should also be assessed for general condition prior to release. Fish should be collected in Round Lake only if conditions in the lake adequately represent those observed in the mainstem.

7.2.4 **It is recommended that (contingent upon the results of a pilot study) the PPWB evaluate the benthic macroinvertebrate community present at the Saskatchewan River monitoring site on an annual basis using the rapid bioassessment techniques outlined in this report.** Worldwide, benthic invertebrates are the most widely studied and employed biological indicator of aquatic systems and should be incorporated into the PPWB Monitoring Program. Trends in community structure should be analyzed and related to general measures of water quality.

7.2.5 **It is recommended that the PPWB examine the feasibility of measuring primary productivity (periphyton and/or epiphyton) measured at the Saskatchewan River monitoring site.** Measures of primary productivity, though not feasible in all locations, would link directly measured nutrient levels and their immediate affect on biota. These data would also assist efforts to improve nutrient objectives and should be directly linked to the work being conducted by Dr. P. Chambers (NWRI) for the PPWB.

7.2.6 **It is recommended that the PPWB explore the possibility of measuring sediment quality within the Saskatchewan River monitoring site.** Sediments can serve as important sinks for a variety of contaminants. Sediments form an important compartment within the aquatic ecosystem and can have a strong influence on aquatic quality.

7.2.7 **It is recommended that the PPWB continue to periodically (every five years) analyze trends in water quality and biota measured at the Saskatchewan River monitoring site.** Trend analysis is essential to the Monitoring Program but given the data already collected, an analysis every five years should be sufficient to detect changes in trends and identify potential concerns. Where appropriate, advances in statistical trend analysis and related software should be incorporated in this exercise.

7.2.8 **It is recommended that the PPWB monitor major ions at the Saskatchewan River monitoring site on a quarterly basis only.** Measured levels of major ions are show no trend and are consistently low, suggesting they need not be measured monthly.

7.2.9 **It is recommended that the PPWB undertake a review of all nutrient objectives with a view to establishing objectives more appropriate for rivers in Prairie Canada.** The importance of nutrient levels in determining ecological function in these systems has long been recognized by the PPWB, as has the possible inappropriateness of current nutrient guidelines. These issues are the subject of ongoing study conducted by Dr. P. Chambers (DOE) and sponsored, in part, by the PPWB.

7.2.10 **It is recommended that the PPWB cease routine monitoring of dissolved oxygen at the Saskatchewan River monitoring site.** Statistical analyses do not suggest any trend in dissolved oxygen concentrations and excursions to the PPWB guideline (6.5 mg/L) are very rare. More importantly, dramatic diurnal variation in dissolved oxygen values are common in these systems and single monthly measures probably hold little value. If measures of dissolve oxygen are required during certain periods (e.g., late winter, under ice) they should be collected on a temporal scale (e.g., hourly, every ten minutes) adequate to characterize the variation.

7.2.11 **It is recommended that the PPWB cease monitoring mercury and chromium in the water column at the Saskatchewan River site.** Mercury and chromium levels in the water column are difficult to measure and interpret. The PPWB now monitors these variables in a more appropriate medium (i.e., fish tissue).

7.2.12 **It is recommended that the PPWB cease monitoring dissolved boron at the Saskatchewan River site.** Long-term trend analysis fails to suggest any trend in boron concentration and the fact that concentrations have never approached the PPWB objective (5.0 mg/L) suggest there is little value in continuing to monitor boron.

7.2.13 It is recommended that the PPWB cease monitoring total coliforms in favour of monitoring fecal coliforms and *Escherichia coli*. Because total coliforms is a poor indicator of sewage contamination it has been replaced in many jurisdictions by fecal coliforms. *E. coli* possess the added advantage of being a superior indicator of gastrointestinal illness. A shift toward monitoring fecal coliforms and *E. coli* would also make PPWB data more comparable to that collected downstream in Manitoba.

7.2.14 It is recommended that the PPWB adopt the water quality index currently being developed by the CCME as a means by which the results of water quality assessments can be communicated to managers and the general public. As discussed above, the index is already in use, or is being tested, by each of the Prairie Provinces. Adoption of the index would improve the PPWB's ability to report on water quality trends and facilitate the exchange of information among agencies.

8.0 PROPOSED CHANGES TO THE CURRENT MONITORING PROGRAM FOR THE CARROT RIVER AT THE SASKATCHEWAN-MANITOBA BOUNDARY

8.1 Overview

The Carrot River originates in north eastern Saskatchewan and flows eastward, south of the Saskatchewan River until it joins it the vicinity of The Pas Manitoba. The Carrot River has a gross drainage area of 12, 591 km^2, and while unregulated, drainage projects (Waterhen Lake, Waterhen Marsh) and overflow from the Saskatchewan River during high water events adds to the flow of the Carrot River. The area is lightly populated (approximately 10,000 people) and the primary activities are agriculture and forestry. Water uses in the area are minimal (see Dunn 1995b for a more detailed description of the river basin). The PPWB Water Quality Monitoring site on the Carrot River is located near its confluence with the Saskatchewan River.

As with other PPWB monitoring sites, an analysis of long-term trends in water quality in the Carrot River suggests that the majority of measured variables show few systematic trends over time. Parametric (linear regression) and non-parametric (Kendall Tau, Spearman Trend, Van Belle) tests revealed that 11 water quality variables showed a significant negative trend in concentration over the period of measurement. These variables included: NO2+NO3, total nitrogen, NFR, magnesium, sulphate, alpha-BHC, calcium, copper, zinc, total coliforms, and daily discharge 2,4-D (Dunn 1995b). No measure variables show a positive trend in concentration over the same period.

Several other variables (mercury, lead, 2,4,5-T, and 2,4-D) also appeared to display long-tern trends but these were an artifact of changes to detection limits/methodologies over the course of data collection.

Regardless of direction, rates of change for all significant trends were low and excursions to objectives rare. For these reasons, none of the detected trends were considered to be of management concern.

Although there is no detectable trend for concentrations of total phosphorous in the Carrot River, measurements are frequently higher than the PPWB objective (0.05 mg/L) and usually above the critical values (0.012mg/L and 0.03 mg/L, identified by Carr and Chambers (1998) for Alberta rivers. As discussed above, there is a need to assess the appropriateness of current objectives for total phosphorous in all PPWB monitoring reaches.

In summary, the Saskatchewan River is currently (1997-1999) monitored on a monthly basis for nitrogen, phosphorous, carbon, NFR, pH, temperature, conductivity, dissolved oxygen. Major ions, boron, heavy metals, mercury, and aluminum are measured every other month and bacteria are measured in each of the six ice-free months. At this time the only variable of concern in the Monitoring Program for this site is total phosphorous.

8.2 Recommendations

The following recommendations are based on an examination of available data and a consideration of the issues discussed in earlier sections of this report. Any changes to the Monitoring Program should be carefully evaluated and, if necessary, adapted based on new information and internal "feedback loops"

8.2.1 **It is recommended that the PPWB collect water samples from the Carrot River on a monthly basis every other year and quarterly in intervening years.** Given the lack of excursions to objectives or trends of management concern, such a change in sampling frequency will not significantly alter the ability to analyze trends or detect excursions in this reach.

8.2.2 **It is recommended that the PPWB undertake a review of current objectives associated with water quality variables measured in the Carrot River and that, where objectives are needed, they be developed.** As discussed above and in Cash (1998), the lack of objectives is a major impediment to the interpretation of the collected data and to the assessment of overall health or condition. Objectives also form the basis of any water quality index that might be applied to the PPWB data.

8.2.3 **It is recommended that the PPWB consider the need to control for other influences (e.g., discharge, hardness, sediment load, diurnal variability, etc.) when analyzing trends and establishing objectives.** Such a consideration may necessitate the control of certain covariates in trend analysis or the development of a number of condition-dependent objectives for some variables.

8.2.4 **It is recommended that (contingent upon the results of a pilot study) the PPWB evaluate the benthic macroinvertebrate community present at the Carrot River monitoring site on an annual basis using the rapid bioassessment techniques outlined in this report.** Worldwide, benthic invertebrates are the most widely studied and employed biological indicator of aquatic systems and should be incorporated into the PPWB Monitoring Program. Trends in community structure should be analyzed and related to general measures of water quality.

8.2.5 **It is recommended that the PPWB examine the feasibility of measuring primary productivity (periphyton and/or epiphyton) measured at the Carrot River monitoring site.** Measures of primary productivity, though not feasible in all locations, would link directly measured nutrient levels and their immediate affect on biota. These data would also assist efforts to improve nutrient objectives.

8.2.6 **It is recommended that the PPWB explore the possibility of measuring sediment quality within the Carrot River monitoring site.** Sediments can serve as important sinks for a variety of contaminants. Sediments form an important compartment within the aquatic ecosystem and can have a strong influence on aquatic quality.

8.2.7 **It is recommended that the PPWB continue to periodically (every five years) analyze trends in water quality and biota measured at the Carrot River monitoring site.** Trend analysis is essential to the Monitoring Program but given the data already collected an analysis every five years should be sufficient to detect changes in trends and identify potential concerns.

8.2.8 **It is recommended that the PPWB monitor major ions at the Carrot River monitoring site on a quarterly basis only.** Measured levels of major ions are show no trend and are consistently low, suggesting they need not be measured monthly.

8.2.9 **It is recommended that the PPWB undertake a review of all nutrient objectives with a view to establishing objectives more appropriate for rivers in Prairie Canada.** The importance of nutrient levels in determining ecological function in these systems has long been recognized by the PPWB, as has the possible inappropriateness of current nutrient guidelines. These issues are the subject of ongoing study conducted by Dr. P. Chambers (DOE) and sponsored, in part, by the PPWB.

8.2.10 **It is recommended that the PPWB cease routine monitoring of dissolved oxygen at the Carrot River monitoring site.** Statistical analyses do not suggest any trend in dissolved oxygen concentrations and excursions to the PPWB guideline (6.5 mg/L) are very rare. More importantly, dramatic diurnal variation in dissolved oxygen values are common in these systems and single monthly measures probably hold little value. If measures of dissolve oxygen are required during certain periods (e.g., late winter, under ice) they should be collected on a temporal scale (e.g., hourly, every ten minutes) adequate to characterize the variation.

8.2.11 **It is recommended that the PPWB cease monitoring mercury and chromium in the water column at the Carrot River site.** Mercury and chromium levels in the water column are difficult to measure and interpret. The PPWB now monitors these variables in a more appropriate medium (i.e., fish tissue).

8.2.12 **It is recommended that the PPWB cease monitoring dissolved boron at the Carrot River site.** Long-term trend analysis fails to suggest any trend in boron concentration and the fact that concentrations have never approached the PPWB objective (5.0 mg/L) suggest there is little value in continuing to monitor boron.

8.2.13 **It is recommended that the PPWB cease monitoring total coliforms in favour of monitoring fecal coliforms and *Escherichia coli*.** Because total coliforms is a poor indicator of sewage contamination it has been replaced in many jurisdictions by fecal coliforms. *E. coli* possess the added advantage of being a superior indicator of gastrointestinal illness. A shift toward monitoring fecal coliforms and *E. coli* would also make PPWB data more comparable to that collected downstream in Manitoba.

8.2.14 It is recommended that the PPWB adopt the water quality index currently being developed by the CCME as a means by which the results of water quality assessments can be communicated to managers and the general public. As discussed above, the index is already in use, or is being tested, by each of the Prairie Provinces. Adoption of the index would improve the PPWB's ability to report on water quality trends and facilitate the exchange of information among agencies.

9.0 LITERATURE CITED

Carr, G.M, and P.A. Chambers, 1998. Spatial and temporal patterns in nutrients and algal abundance in Alberta Rivers. NWRI Report No. 98-225. 96p.

Cash, K.J. 1998. PPWB Water Quality Monitoring Review Phase 1: Qu'Appelle and North Saskatchewan rivers. PPWB Report No. 144. 30p.

Dunn, G.W. 1995a. Trends in water quality variables at the Alberta/Saskatchewan boundary. Prepared for the Committee on Water Quality, March 1995.

Dunn, G.W. 1995b. Trends in water quality variables at the Saskatchewan/Manitoba boundary. Prepared for the Committee on Water Quality, March 1995.

Manitoba Environment. 1997. State of the environment report for Manitoba, 1997.

Marmorek, D. R., T. M. Berry, P. Bunnel, D. P. Bernard, W.A. Kurz, C. L. Murray, K. Paulig, and L. Sully. 1992. Towards an ecosystem approach in British Columbia: Results of a workshop on ecosystem goals objectives, December 7 to 9, 1992. Prepared by ESA Ltd., Vancouver BC for Environment Canada, British Columbia Ministry of Environment, Lands and Parks, and British Columbia Ministry of Forests. Fraser River Action Plan 193-16. 77p.

Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughes. 1989. Rapid bioassessment protocols for use in streams and rivers. Benthic macroinvertebrates and fish. EPA/444/4-89-001. Office of Water Regulation and Standards, US Environmental Protection Agency, Washington, DC.

Prairie Province Water Board Report. 1991. Water quality procedures manual. Prairie Province Water Board Report No. 110, October 1991.

Province of British Columbia. 1996. British Columbia water quality status report. BC Environment. Water Quality Branch. April 1996.

Rosenberg, D. M., and V. H. Resh. 1993. Introduction to freshwater biomonitoring and benthic macroinvertebrates. In: Rosenberg, D. M., V. H. Resh (eds.), Freshwater biomonitoring and benthic macroinvertebrates. Chapman and Hall, New York.

Wright, C.R., K.A. Saffran, A.-M. Anderson, D. Neilson, N. MacAlpine, and S. Cooke. 1998. A water quality index for agricultural streams in Alberta. Draft Report.