

**DISINFECTION BY-PRODUCTS IN THE  
WABAMUN LAKE WATER TREATMENT  
PLANT-TREATED WATER AND  
WABAMUN LAKE,  
JULY 2002 TO MARCH 2003**





**Disinfection By-Products In The Wabamun Lake  
Water Treatment Plant–Treated Water And  
Wabamun Lake,  
July 2002 To March 2003**

*Prepared by:*

**Richard Casey, M.Sc.  
Limnologist**

Science and Standards Branch  
Alberta Environment

September 2003

Pub. No: T/715

ISBN: 0-7785-3036-1 (Printed Edition)

ISBN: 0-7785-3037-x (On-Line Edition)

Web Site: <http://www3.gov.ab.ca/env/info/infocentre/publist.cfm>

Any comments, questions, or suggestions regarding the content of this document may be directed to:

Environmental Monitoring and Evaluation Branch

Alberta Environment

10<sup>th</sup> Floor, Oxbridge Place

9820 – 106<sup>th</sup> Street

Edmonton, Alberta T5K 2J6

Phone: (780) 427-6278

Fax: (780) 422-6712

Additional copies of this document may be obtained by contacting:

Information Centre

Alberta Environment

Main Floor, Great West Life Building

9920 – 108<sup>th</sup> Street

Edmonton, Alberta T5K 2M4

Phone: (780) 944-0313

Fax: (780) 427-4407

Email: [env.infocent@gov.ab.ca](mailto:env.infocent@gov.ab.ca)

## SUMMARY

Several studies were initiated in 2002 to address concerns related to a fish kill and metal levels in sediments from Wabamun Lake. This study was conducted by Alberta Environment to determine the occurrence and temporal and spatial variability of disinfection by-products (DBPs) in treated water from the Wabamun Lake Water Treatment Plant (WL-WTP), at sites in the vicinity of the treated water discharge, and at other sites further away within the lake. This report provides the findings of the sampling program.

Results of the program (from July 2002 to March 2003) showed that various DBPs were present in the treated water pumped to the lake. Many of these DBPs were also found in the receiving canal (RC). The highest DBP concentrations in the lake samples occurred at this site. A small number of DBPs were present at lake sites closest ( $\leq 100$  m) to the canal mouth.

Aldehydes were the only group of DBPs commonly found at the other lake sites. Formaldehyde and acetaldehyde were the main aldehydes found. These compounds may occur naturally in the environment (e.g., due to forest fires and irradiation of humic acids). Some aldehydes were at higher concentrations in the treated water and RC, compared to the lake samples, indicating the treated water is a potential source of aldehydes to the lake. Overall, the concentrations of aldehydes in Wabamun Lake were comparable to data from other studies in rivers. No comparable data for aldehydes in Alberta lakes are available.

There was no pronounced difference in the concentrations of DBPs in Wabamun Lake over the three seasons (summer, fall, and winter) sampled. These sample periods included a broad range of water quality, lake conditions (e.g., ice cover), and WL-WTP operating conditions.

Comparisons of the DBP concentrations in the lake to water quality guidelines and toxicity data, mostly from a US-EPA ecotoxicological database (ECOTOX), indicated:

1. Chloroform concentrations in the RC and two lake samples close to the canal opening (0.6 to 8.5  $\mu\text{g/L}$ ) were close to or greater than the CCME *interim* water quality guideline for the protection of freshwater aquatic life (1.8  $\mu\text{g/L}$ ).
2. Based on the available toxicity data for other DBPs, the concentrations of haloacetic acids, aldehydes, and chlorate in the lake were lower than the toxicity-endpoints or concentrations where effects occurred. No toxicity data were found for other DBPs detected at the RC site (i.e., one haloketone and chloral hydrate).
3. Concentrations of chloroform and toluene (not a DBP) were less than the CCME water quality guidelines for livestock water.

Mixtures of DBPs (e.g., aldehydes) were present at lake sites during the study. Using the toxicity information available, it was not possible to evaluate the potential effects of mixtures of DBPs, if any, on freshwater biota in Wabamun Lake. But the results of a recent study did not appear to indicate a major impact from the WL-WTP discharge on the zoobenthos communities in the lake.

# TABLE OF CONTENTS

<b>SUMMARY</b> .....	<b>i</b>
<b>LIST OF TABLES</b> .....	<b>iii</b>
<b>LIST OF FIGURES</b> .....	<b>iii</b>
<b>LIST OF APPENDICES</b> .....	<b>iii</b>
<b>ACKNOWLEDGEMENTS</b> .....	<b>iv</b>
<b>1.0 INTRODUCTION</b> .....	<b>1</b>
<b>2.0 METHODS</b> .....	<b>2</b>
2.1 Study Design and Sites .....	2
2.2 Field and Laboratory Methods.....	2
<b>3.0 RESULTS AND DISUSSION</b> .....	<b>6</b>
3.1 Design of the Sampling Program.....	6
3.2 Detailed Results.....	6
3.2.1 Quality Assurance Data .....	6
3.2.2 Spatial Patterns of DBPs and Other Volatile Organic Compounds.....	6
3.2.3 DBP Concentrations and Temporal Patterns .....	7
3.3 Comparisons of DBP Concentrations to Water Quality Guidelines and <b>Toxicity Data</b> .....	17
3.3.1 Chloroform.....	17
3.3.2 Haloacetic Acids .....	18
3.3.3 Aldehydes .....	18
3.3.4 Remaining DBPs and Toluene.....	18
3.3.5 Mixtures of DBPs and Toxicity on Aquatic Biota.....	19
<b>4.0 CONCLUSIONS</b> .....	<b>20</b>
<b>5.0 LITERATURE CITED</b> .....	<b>22</b>

## LIST OF TABLES

Table 1	Sampling program for disinfection by-products at Wabamun Lake, July 2002 to March 2003 .....	3
Table 2	Trihalomethanes and other volatile organic compounds in the WL-WTP1 treated water and Wabamun Lake, July 2002 to March 2003 .....	8
Table 3	Haloacetic acids in the WL-WTP1 treated water and Wabamun Lake, July 2002 to March 2003 .....	10
Table 4	Haloketones, haloacetonitriles and other disinfection by-products in the WL-WTP1 treated water and Wabamun Lake, July 2002 to March 2003 .....	11
Table 5	Aldehydes in the WL-WTP1 treated water and Wabamun Lake, July 2002 to March 2003 .....	12
Table 6	Chlorinated phenols in the WL-WTP1 treated water and Wabamun Lake, July 2002 to March 2003 .....	13

## LIST OF FIGURES

Figure 1	Features in the Wabamun Lake watershed and sample sites for disinfection by-products .....	4
----------	--	---

## LIST OF APPENDICES

Appendix A	The quality assurance (QA) data associated with the DBP program .....	25
------------	---	----

## **ACKNOWLEDGEMENTS**

I am grateful to several Alberta Environment staff who provided assistance in completing the report. They include: Bridgette Halbig for technical support (compiling data, preparation of graphics, and formatting the report); Kim Westcott for conducting the searches of the ECOTOX database; Anne-Marie Anderson, Leigh Noton, Kim Westcott, and Leanne Zrum for helpful comments on the report. The samples were collected by technical staff of the Monitoring Branch, Alberta Environment, namely: Chris Ware, John Willis, and Brain Jackson. I also thank Grant Prill and Dave Humphries of the Alberta Research Council, and John Paran and Inni Rashid of EPCOR Water Services Inc. who provided additional information with respect to their analytical protocols and quality assurance data.

## 1.0 INTRODUCTION

The Wabamun Lake Water Treatment Plant (WL-WTP1) was built in 1977 by TransAlta Utilities Limited (TAU). The plant was designed to mitigate the cumulative and ongoing (annual) effects of TAU activities within the lake watershed (mining and power plants) on the lake level. The WL-WTP1 is used to treat water from the Sundance cooling pond and to pump the treated water to the lake (at a maximum volume of  $16 \times 10^6 \text{ m}^3$  per year). The cooling pond water is made up of water pumped from the North Saskatchewan River, and wastewaters and plant-site runoff from the Highvale mine and Sundance power plant. A second treatment plant (WL-WTP2), with similar treatment processes to WL-WTP1, was constructed and started operation in mid-2002 to provide additional treated water to the lake (up to  $8 \times 10^6 \text{ m}^3$  per year).

Chlorination and ozonation treatments are used in both the WL-WTP1 and WL-WTP2. These treatment processes can produce various halogenated and non-halogenated compounds, known as disinfection by-products (DBPs), in the final treated water pumped to the lake. Disinfection by-products include trihalomethanes (THMs), other halogenated volatile organic compounds, haloacetic acids, haloacetonitriles, haloketones, chlorinated phenols, aldehydes, chloral hydrate, chloropicrin, total residual chlorine (TRC), bromate, chlorate, and chlorite. Various DBPs are found at low concentrations in the WL-WTP1 treated water pumped to Wabamun Lake (Casey 2003). However, the actual presence or potential fate and effects of DBPs in the lake (if present) had not been investigated.

Determining the levels and potential effects of some DBPs in surface waters are somewhat limited by the development or availability of analytical methods in some cases and incomplete published information on the effects of DBPs on freshwater biota. For example, there are few water quality guidelines available to evaluate the potential effects of DBPs on freshwater aquatic life in Alberta (Alberta Environment 1999; and see Section 3.3 for further details). This may be because the original development of water quality guidelines for DBPs has focussed on the evaluation of effects on humans (due to exposure via drinking water), rather than on aquatic life. The circumstances at Wabamun Lake are unique where large volumes of treated water (equivalent to drinking water quality) are pumped directly to the lake rather than into a drinking water distribution system.

Alberta Environment initiated a sampling program in July 2002 to determine the occurrence and temporal and spatial variability of DBP concentrations in the WL-WTP1 treated water, at sites in the vicinity of the combined WL-WTP1 and WL-WTP2 treated water discharge, and at other sites further away within the lake basins. This report provides the findings of the program.

## 2.0 METHODS

### 2.1 Study Design and Sites

Samples of the WL-WTP1 treated water and at eight sites in Wabamun Lake were taken during three seasons (summer, fall, and winter), beginning in July 2002 (Table 1; Figure 1). For each season, two sets of samples were taken at each site on separate dates, one-week apart (Table 1). Each of the two sample sets were analysed for different DBPs. This was necessary because the analytical laboratory was unable to analyse all DBPs in the same week when samples were collected. Storage of samples can lead to degradation or transformation of DBPs in the sample containers.

Treated water from the WL-WTP1 and WL-WTP2 enters Wabamun Lake in a combined discharge pipe at the beginning of a canal to the lake, north of the Sundance power plant (Figure 1). The lake site closest to the treated water discharge is in the canal, referred to as the receiving canal (RC). The RC site is about 180 m from the discharge pipe and about 130 m from the canal opening to the lake. About half of the remaining lake sites were close to the RC opening (Figure 1). Depending on the sample date, three or four samples were taken in the area surrounding the RC mouth (Table 1; Figure 1). The three sites sampled in July (ECO, NCO, and WCO) were located about 75 m apart and 100 m from the RC opening (Figure 1). In October, the four sites sampled (CO1, CO2, CO3, and CO4) were closer to the RC opening, about 5 m from each of the RC embankments (Figure 1). The remaining lake sites (Sundance Bay, East Basin, and West Basin profile sites) were at established sample sites (Figure 1). These sites are used in the long-term water quality monitoring program at Wabamun Lake conducted by Alberta Environment (Casey 2003).

### 2.2 Field and Laboratory Methods

Methods and materials used in the DBP sampling program followed the field and laboratory protocols outlined in *Water Quality Sampling Methods* (Alberta Environment 2002).

Two types of samples were taken in the sampling program. The WL-WTP1 treated water was sampled as a grab (or discrete) sample; the sample containers were filled with the WL-WTP1 treated water, which flows continuously from a tap inside the plant. The treated water was normally sampled after it was cooled by the cooling towers; this is the final treated water pumped to Wabamun Lake. On one occasion, however, the treated water sample was sampled before the cooling towers (Table 1). Grab or composite samples were taken at the lake sites (Table 1; Figure 1). Top and bottom grabs were taken at the RC site to determine if there are differences in DBP concentrations in the water column due to physical and chemical processes (e.g., thermal stratification, volatilization) in the canal. Top grabs were taken  $\leq 30$  cm below the water surface and bottom grab samples were taken about 30 cm above the lake bottom. Water depth at the RC site was  $< 2$  m. Most of the remaining lake samples were integrated composite samples of the water column allowing an overall measure of DBP concentrations at each site (Table 1). The grab and composite samples were taken using a sample container secured in a weighted under-ice sampler (Alberta Environment 2002).

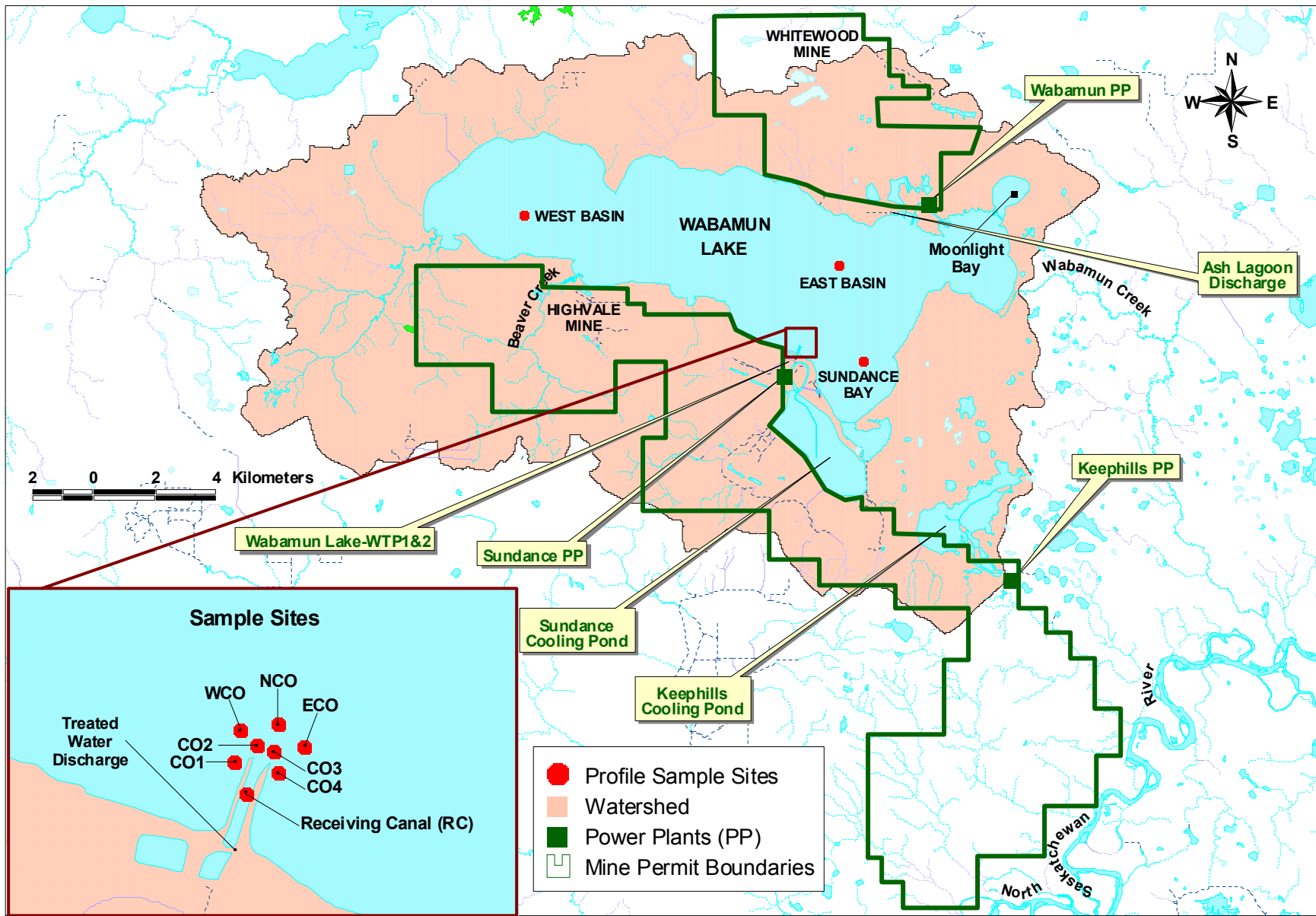
**Table 1 Sampling program for disinfection by-products at Wabamun Lake, July 2002 to March 2003**

Sample Sites (see Figure 1)	Summer 2002		Fall 2002		Winter 2003	
	10 July	16 July	21 Oct	28 Oct	4 Mar	11 Mar
<b>WL-WTP1 Treated Water</b>	Grab *	Grab	Grab	Grab	Grab	Grab
<b>Receiving Canal (RC)</b>	Top-Grab Bottom-Grab	Top-Grab Bottom-Grab	Top-Grab Bottom-Grab	Top-Grab Bottom-Grab	Composite	-----
<b>ECO</b>	Top-Grab	Top-Grab				
<b>NCO</b>	Top-Grab	Top-Grab				
<b>WCO</b>	Top-Grab	Top-Grab				
<b>CO4</b>			Composite	-----		
<b>CO3</b>			Composite	-----		
<b>CO2</b>			Composite	-----		
<b>CO1</b>			Composite	-----		
<b>East Basin Profile (EBP)</b>	Top-Grab	Top-Grab	Composite	Composite	Composite	Composite
<b>Sundance Bay Profile (SBP)</b>	-----	-----	Composite	Composite	Composite	Composite
<b>West Basin Profile (WBP)</b>	Top-Grab	Top-Grab	-----	-----	Composite	Composite

Notes:

See Figure 1 for location of sites; additional details on site codes and locations are in Section 2.1

Grab \* = sample taken before the cooling towers (instead of after the towers; Section 2.2)



Alberta Environment

Figure 1 Features in the Wabamun Lake watershed and sample sites for disinfection by-products

The following DBPs were analysed by the water laboratories of EPCOR Water Services Inc., Edmonton: trihalomethanes (THMs), other volatile organic compounds (VOCs) (including halogenated compounds), haloacetic acids, haloacetonitriles, halo ketones, chlorinated phenols, aldehydes, chloral hydrate, chloropicrin, total residual chlorine (TRC), bromate, chlorate, and chlorite. Most compounds were analysed using gas chromatography or gas chromatography-mass spectrometry. Ion chromatographic methods were used for bromate, chlorate, and chlorite and an amperometric method was used for TRC. Method detection limits for most DBPs were  $\leq 1$   $\mu\text{g/L}$ . Exceptions were for TRC ( $<0.01$   $\text{mg/L}$ ), chlorate/chlorite ( $<0.02$   $\text{mg/L}$ ), bromate ( $<0.005$   $\text{mg/L}$ ), and some haloacetic acids and pentachlorophenol ( $<0.3$   $\mu\text{g/L}$ ).

Quality assurance (QA) data associated with the sampling program included duplicate splits of some samples of the WL-WTP1 treated water and at the RC site. These split samples were analysed for VOCs (including THMs) at the EPCOR laboratories and Trace Organics Laboratory at the Alberta Research Council (ARC), Vegreville. The ARC and EPCOR laboratories also provided some additional in-house QA data for the analysis of VOCs and aldehydes in laboratory “blank” water (see Appendix A for further details). Field blanks were not taken in the DBP program because of limited resources and the relatively high cost of analysing all DBPs in a single sample.

## 3.0 RESULTS AND DISCUSSION

### 3.1 Design of the Sampling Program

Modifications to the sampling program were necessary due to restrictions on the availability of analytical laboratory services (Section 2.0) and unforeseen circumstances. Temporary shut-down of one or both WL-WTPs (pumping treated water to the lake) occurred during sampling on one date each in the fall and winter sampling events. This resulted in no samples being taken at the lake sites close to the receiving canal (RC) on 28 October and at the RC site on 11 March (Table 1). In addition, the daily volumes of treated water pumped to the lake from both the WL-WTP1 and WL-WTP2 varied throughout the study period, due to operational conditions. Thus, the daily volumes or potential loads of DBPs (concentration x volume per day) from each plant to the lake was variable during the study.

### 3.2 Detailed Results

This Section includes a detailed description of the spatial and temporal patterns of DBPs in the samples. Comparisons of the results to other data and information in the scientific literature, when readily available, are also provided.

In the following text, the *treated water* data refer to those collected for the *WL-WTP1 treated water* alone. The WL-WTP2 treated water was not sampled in this program. Water quality data for the lake sites, however, should be representative of the potential influences of treated water from both the WL-WTP1 and WL-WTP2 in the lake. This is because the two treated water sources are combined and discharged in the same pipe to the lake (i.e., 180 m from the RC site) (Figure 1).

#### 3.2.1 Quality Assurance Data

The quality assurance data associated with the sampling program showed two concerns with some results of the sampling program (details in Appendix A). In the case of chloroform, a potential bias of higher concentrations in the portions of the split samples analysed by another laboratory, independent of the one used in this study, was found. A review of factors which could be related to this bias (i.e., protocols for field collection, sample handling, and sample analysis) did not identify a clear reason for the bias (Appendix A). Overall, these results indicate that the chloroform concentrations presented in the report could be underestimated, but (if this occurred) it is unlikely to have had a strong effect on the conclusions of the study (Section 3.2.3).

With respect to aldehydes, half of the 14 aldehydes analysed in the samples were detected in the laboratory blank samples (Appendix A). These results indicate the possibility of low-level external contamination of samples by aldehydes (see Section 3.2.3 for further discussion).

#### 3.2.2 Spatial Patterns of DBPs and Other Volatile Organic Compounds

Various disinfection by-products (DBPs) were present in the treated water pumped to Wabamun Lake. These were: two trihalomethanes (THMs) (mostly chloroform), one other volatile

halogenated-methane compound (dichloromethane), three haloacetic acids, two haloketones, one haloacetonitrile, chloral hydrate, total residual chlorine (TRC), chlorate, and most aldehydes analysed in the samples (Tables 2, 3, 4, and 5). The remaining DBPs analysed in the sampling program (i.e., chloropicrin, bromate, chlorite, and all chlorinated phenols) were not found in the treated water or at any of the lake sites (Tables 4 and 6).

About 74% of the DBPs found in the treated water were also detected in the RC. These were: one THM (chloroform), two haloacetic acids, one haloketone, chloral hydrate, chlorate, and most aldehydes (Tables 2, 3, 4, and 5). A smaller number of these DBPs were detected at one or two of the lake sites close to RC opening (i.e., chloroform, one haloketone, chloral hydrate, chlorate, and most aldehydes) (Tables 2, 3, 4, 5, and 6). Aldehydes were the only DBPs found at many of the remaining lake sites, beyond the general vicinity of the RC (Table 5).

Some non-halogenated VOCs (toluene and xylene) and undetermined VOCs were present in the RC and lake, close to the canal opening, but they were not found in the treated water (Table 2). Toluene and xylene are not generally considered as DBPs. Concentrations of toluene and xylene (maximum concentrations = 0.6 and 1.1 µg/L, respectively) were equal to or close to the method detection limit (0.5 µg/L; Table 2). The presence of toluene and xylene in the vicinity of the RC may be due to contamination by gasoline combustion or leakage from motor boats operating in the area. A boat launch is located in the canal adjacent to the treated water discharge pipe.

### 3.2.3 *DBP Concentrations and Temporal Patterns*

#### Halogenated Volatile Organic Compounds

Chloroform (or trichloromethane) and dichlorobromomethane were the only THMs found in the samples (Table 2). Chloroform is often the main THM followed by dichlorobromomethane in chlorinated drinking water (Health Canada no date). Chloroform concentrations in the (WL-WTP1) treated water and at the RC site usually ranged from 1.1 µg/L to 8.5 µg/L, except for the highest recorded concentration of 48.9 µg/L in the 10-July sample (Table 2). The other halogenated VOCs found in the treated water (i.e., two halomethanes: bromodichloromethane and dichloromethane) were only detected in the 10-July treated water sample (Table 2). The highest chloroform concentrations and the only detections of other volatile halomethanes in the 10-July treated water sample might be because it was taken before the cooling towers rather than after the towers on this date (Table 1; Section 2.2). Loss of VOCs from the treated water might be expected as the water passes over the cooling towers. Volatilization is a major removal process of halomethanes in surface waters (CCME 1999a, 1999b, 1999c). Thus, the concentrations of VOCs and possibly other volatile DBPs (see below) in the 10-July treated water sample may not be representative of concentrations for these compounds in the final treated water pumped to the lake. The concentrations of all VOCs in the lake were usually less than the method detection limit (Table 2).

During the two remaining sample dates (in October and March), slightly higher chloroform concentrations occurred at the RC site compared to the (WL-WTP1) treated water (Table 2). This pattern may be due to the additional chloroform load in the WL-WTP2 treated water that

**Table 2 Trihalomethanes and other volatile organic compounds in the WL-WTP1 treated water and Wabamun Lake, July 2002 to March 2003**

Site	Sample Date	Chloro form µg/L	Bromo dichloro methane µg/L	Dibromo chloro methane µg/L	Bromo form µg/L	Total Trihalo methanes µg/L	Dichloro ethylene 1,1- µg/L	Dichloro methane µg/L	Dichloro ethylene, trans 1,2- µg/L	Dichloro ethylene, Cis 1,2- µg/L	Trichloro ethane 1,1,1- µg/L	Carbon Tetra chloride µg/L	Benzene µg/L	Trichloro ethylene µg/L
WL-WTP1	10- Jul-02	<b>48.9</b>	<b>2.8</b>	<0.5	<1.0	<b>51.7</b>	<3.0	<b>2.7</b>	<0.5	<0.5	<0.5	<1.0	<0.5	<0.5
WL-WTP1	21-Oct-02	<b>8.1</b>	<0.5	<0.5	<1.0	<b>1.3</b>	<3.0	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5	<0.5
WL-WTP1	4-Mar-03	<b>1.1</b>	<0.5	<0.5	<1.0	<b>1.1</b>	<3.0	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5	<0.5
RC-Top	10- Jul-02	<b>8.5</b>	<0.5	<0.5	<1.0	<b>8.5</b>	<3.0	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5	<0.5
RC-Bottom	10- Jul-02	<b>8.5</b>	<0.5	<0.5	<1.0	<b>8.5</b>	<3.0	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5	<0.5
RC-Top	21-Oct-02	<b>4.7</b>	<0.5	<0.5	<1.0	<b>4.7</b>	<3.0	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5	<0.5
RC-Bottom	21-Oct-02	<b>4.1</b>	<0.5	<0.5	<1.0	<b>4.1</b>	<3.0	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5	<0.5
RC-Composite	4-Mar-03	<b>1.6</b>	<0.5	<0.5	<1.0	<b>1.6</b>	<3.0	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5	<0.5
ECO	10- Jul-02	<0.5	<0.5	<0.5	<1.0	<1.0	<3.0	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5	<0.5
NCO	10- Jul-02	<0.5	<0.5	<0.5	<1.0	<1.0	<3.0	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5	<0.5
WCO	10- Jul-02	<b>0.6</b>	<0.5	<0.5	<1.0	<1.0	<3.0	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5	<0.5
CO4	21-Oct-02	<0.5	<0.5	<0.5	<1.0	<1.0	<3.0	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5	<0.5
CO3	21-Oct-02	<0.5	<0.5	<0.5	<1.0	<1.0	<3.0	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5	<0.5
CO2	21-Oct-02	<0.5	<0.5	<0.5	<1.0	<1.0	<3.0	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5	<0.5
CO1	21-Oct-02	<b>3.1</b>	<0.5	<0.5	<1.0	<b>3.1</b>	<3.0	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5	<0.5
EBP	10- Jul-02	<0.5	<0.5	<0.5	<1.0	<1.0	<3.0	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5	<0.5
EBP	21-Oct-02	<0.5	<0.5	<0.5	<1.0	<1.0	<3.0	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5	<0.5
EBP	4-Mar-03	<0.5	<0.5	<0.5	<1.0	<1.0	<3.0	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5	<0.5
SBP	21-Oct-02	<0.5	<0.5	<0.5	<1.0	<1.0	<3.0	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5	<0.5
SBP	4-Mar-03	<0.5	<0.5	<0.5	<1.0	<1.0	<3.0	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5	<0.5
WBP	10- Jul-02	<0.5	<0.5	<0.5	<1.0	<1.0	<3.0	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5	<0.5
WBP	4-Mar-03	<0.5	<0.5	<0.5	<1.0	<1.0	<3.0	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5	<0.5

Notes:

See Table 1 and Figure 1 for site codes and locations

**Table 2 Trihalomethanes and other volatile organic compounds in the WL-WTP1 treated water and Wabamun Lake, July 2002 to March 2003 (continued)**

Site	Sample Date	Dichloro propane 1,2- µg/L	Toluene µg/L	Tetra chloro ethylene µg/L	Chloro benzene µg/L	Ethyl benzene µg/L	Xylene 1,4- µg/L	Xylene 1,2- µg/L	Tetra chloro ethane 1,1,2,2- µg/L	Dichloro benzene 1,4- µg/L	Dichloro benzene 1,2- µg/L	Trichloro benzene 1,2,4- µg/L	Total Volatile Organics (NonTHM) µg/L	Total Volatile Organics (Unknown) µg/L
WL-WTP1	10- Jul-02	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5	<0.5	<0.5	<b>2.7</b>	<1.0
WL-WTP1	21-Oct-02	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5	<0.5	<0.5	<1.0	<1.0
WL-WTP1	4-Mar-03	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5	<0.5	<0.5	<1.0	<1.0
RC-Top	10- Jul-02	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5	<0.5	<0.5	<b>1.6</b>	<b>1.9</b>
RC-Bottom	10- Jul-02	<0.5	<b>0.6</b>	<0.5	<0.5	<0.5	<b>0.9</b>	<0.5	<1.0	<0.5	<0.5	<0.5	<b>2.6</b>	<b>2.5</b>
RC-Top	21-Oct-02	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5	<0.5	<0.5	<1.0	<1.0
RC-Bottom	21-Oct-02	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5	<0.5	<0.5	<1.0	<1.0
RC-Composite	4-Mar-03	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5	<0.5	<0.5	<1.0	<1.0
ECO	10- Jul-02	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5	<0.5	<0.5	<1.0	<1.0
NCO	10- Jul-02	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5	<0.5	<0.5	<1.0	<1.0
WCO	10- Jul-02	<0.5	<b>0.6</b>	<0.5	<0.5	<0.5	<b>0.6</b>	<0.5	<1.0	<0.5	<0.5	<0.5	<b>2.2</b>	<b>2.4</b>
CO4	21-Oct-02	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5	<0.5	<0.5	<b>1.0</b>	<1.0
CO3	21-Oct-02	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5	<0.5	<0.5	<1.0	<1.0
CO2	21-Oct-02	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5	<0.5	<0.5	<1.0	<1.0
CO1	21-Oct-02	<0.5	<0.5	<0.5	<0.5	<0.5	<b>1.1</b>	<b>0.5</b>	<1.0	<0.5	<0.5	<0.5	<b>3.1</b>	<1.0
EBP	10- Jul-02	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5	<0.5	<0.5	<1.0	<1.0
EBP	21-Oct-02	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5	<0.5	<0.5	<1.0	<1.0
EBP	4-Mar-03	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5	<0.5	<0.5	<1.0	<1.0
SBP	21-Oct-02	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5	<0.5	<0.5	<1.0	<1.0
SBP	4-Mar-03	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5	<0.5	<0.5	<1.0	<1.0
WBP	10- Jul-02	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5	<0.5	<0.5	<1.0	<1.0
WBP	4-Mar-03	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<1.0	<0.5	<0.5	<0.5	<1.0	<1.0

**Table 3 Haloacetic acids in the WL-WTP1 treated water and Wabamun Lake, July 2002 to March 2003**

Site	Sample Date	Monochloro acetic Acid µg/L	Bromo acetic Acid µg/L	Dichloro acetic Acid µg/L	Trichloro acetic Acid µg/L	Bromochloro acetic Acid µg/L	Dibromo acetic Acid µg/L	Bromo dichloro acetic Acid µg/L	Chloro dibromo acetic Acid µg/L	Tribromo acetic Acid µg/L	Total Haloacetic Acids µg/L
WL-WTP1	16-Jul-02	<2	<1	6.5	17.2	1.5	<1	<1	<3	<3	25.2
WL-WTP1	28-Oct-02	<2	<1	13.8	37.1	<1	<1	<1	<3	<3	50.9
WL-WTP1	4-Mar-03	<2	<1	5.3	8.4	<1	<1	<1	<3	<3	13.7
RC-Top	16-Jul-02	<2	<1	6.0	13.8	<1	<1	<1	<3	<3	19.8
RC-Bottom	16-Jul-02	<2	<1	6.6	13.8	<1	<1	<1	<3	<3	20.3
RC-Top	28-Oct-02	<2	<1	11.8	31.0	<1	<1	<1	<3	<3	42.8
RC-Bottom	28-Oct-02	<2	<1	12.1	31.6	<1	<1	<1	<3	<3	43.7
RC-Composite	4-Mar-03	<2	<1	4.4	6.9	<1	<1	<1	<3	<3	11.3
ECO	16-Jul-02	<2	<1	<1	<1	<1	<1	<1	<3	<3	<3
NCO	16-Jul-02	<2	<1	<1	<1	<1	<1	<1	<3	<3	<3
WCO	16-Jul-02	<2	<1	<1	<1	<1	<1	<1	<3	<3	<3
EBP	16-Jul-02	<2	<1	<1	<1	<1	<1	<1	<3	<3	<3
EBP	28-Oct-02	<2	<1	<1	<1	<1	<1	<1	<3	<3	<3
EBP	4-Mar-03	<2	<1	<1	<1	<1	<1	<1	<3	<3	<3
SBP	28-Oct-02	<2	<1	<1	<1	<1	<1	<1	<3	<3	<3
SBP	4-Mar-03	<2	<1	<1	<1	<1	<1	<1	<3	<3	<3
WBP	16-Jul-02	<2	<1	<1	<1	<1	<1	<1	<3	<3	<3
WBP	4-Mar-03	<2	<1	<1	<1	<1	<1	<1	<3	<3	<3

Notes:

See Table 1 and Figure 1 for site codes and locations

**Table 4 Haloketones, haloacetonitriles and other disinfection by-products in the WL-WTP1 treated water and Wabamun Lake, July 2002 to March 2003**

Site	Sample Date	Haloketones			Haloacetonitriles					Others					
		1,1-Dichloro-2-prop anone µg/L	1,1,1-Trichloro-2-prop anone µg/L	Total Halo ketones µg/L	Trichloro aceto nitrile µg/L	Dichloro aceto nitrile µg/L	Bromo chloro aceto nitrile µg/L	Dibromo aceto nitrile µg/L	Total Haloace tonitriles µg/L	Chloral Hydrate µg/L	Total Residual Chlorine mg/L	Bromate mg/L	Chloro picrin µg/L	Chlorite mg/L	Chlorate mg/L
WL-WTP1	10- Jul-02	<0.5	<b>1.5</b>	<b>1.5</b>	<0.5	<b>3.9</b>	<0.5	<0.5	<b>3.9</b>	<b>2.8</b>	<b>0.07</b>	<0.005	<0.5	<0.02	<b>0.09</b>
WL-WTP1	21-Oct-02	<b>0.8</b>	<b>1.8</b>	<b>2.5</b>	<0.5	<b>0.8</b>	<0.5	<0.5	<b>0.8</b>	<b>8.5</b>	<0.01	<0.005	<0.5	<0.02	<b>0.11</b>
WL-WTP1	4-Mar-03	<0.5	<b>1.0</b>	<b>1.0</b>	<0.5	<b>0.5</b>	<0.5	<0.5	<b>0.5</b>	<b>0.9</b>	nd	nd	<0.5	nd	nd
WL-WTP1	11-Mar-03	nd	nd	nd	nd	nd	nd	nd	nd	nd	<0.01	<0.005	<0.005	<0.005	<b>0.04</b>
RC-Top	10- Jul-02	<0.5	<b>0.8</b>	<b>0.8</b>	<0.5	<0.5	<0.5	<0.5	<0.5	<b>2.2</b>	<0.01	<0.005	<0.5	<0.02	<b>0.09</b>
RC-Bottom	10- Jul-02	<0.5	<b>0.7</b>	<b>0.7</b>	<0.5	<0.5	<0.5	<0.5	<0.5	<b>2.1</b>	<0.01	<0.005	<0.5	<0.02	<b>0.10</b>
RC-Top	21-Oct-02	<0.5	<b>1.2</b>	<b>1.2</b>	<0.5	<0.5	<0.5	<0.5	<0.5	<b>2.4</b>	<0.01	<0.005	<0.5	<0.02	<b>0.09</b>
RC-Bottom	21-Oct-02	<0.5	<b>1.0</b>	<b>1.0</b>	<0.5	<0.5	<0.5	<0.5	<0.5	<b>2.3</b>	<0.01	<0.005	<0.5	<0.02	<b>0.07</b>
RC-Composite	4-Mar-03	<0.5	<b>0.6</b>	<b>0.6</b>	<0.5	<0.5	<0.5	<0.5	<0.5	<b>0.6</b>	nd	nd	<0.5	nd	nd
ECO	10- Jul-02	<0.5	<b>0.7</b>	<b>0.7</b>	<0.5	<0.5	<0.5	<0.5	<0.5	<0.3	<0.01	<0.005	<0.5	<0.02	<0.02
NCO	10- Jul-02	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.3	<0.01	<0.005	<0.5	<0.02	<0.02
WCO	10- Jul-02	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.3	<0.01	<0.005	<0.5	<0.02	<0.02
CO4	21-Oct-02	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.3	<0.01	<0.005	<0.5	<0.02	<0.02
CO3	21-Oct-02	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.3	<0.01	<0.005	<0.5	<0.02	<0.02
CO2	21-Oct-02	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.3	<0.01	<0.005	<0.5	<0.02	<0.02
CO1	21-Oct-02	<0.5	<b>0.9</b>	<b>0.9</b>	<0.5	<0.5	<0.5	<0.5	<0.5	<b>1.3</b>	<0.01	<0.005	<0.5	<0.02	<b>0.02</b>
EBP	10- Jul-02	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.3	<0.01	<0.005	<0.5	<0.02	<0.02
EBP	21-Oct-02	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.3	<0.01	<0.005	<0.5	<0.02	<0.02
EBP	4-Mar-03	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.3	nd	nd	<0.5	nd	nd
EBP	11-Mar-03	nd	nd	nd	nd	nd	nd	nd	nd	nd	<0.01	<0.005	nd	<0.005	<0.005
SBP	21-Oct-02	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.3	<0.01	<0.005	<0.5	<0.02	<0.02
SBP	4-Mar-03	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.3	nd	nd	<0.5	nd	nd
SBP	11-Mar-03	nd	nd	nd	nd	nd	nd	nd	nd	nd	<0.01	<0.005	nd	<0.005	<0.005
WBP	10- Jul-02	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.3	<0.01	<0.005	<0.5	<0.02	<0.02
WBP	4-Mar-03	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.3	nd	nd	<0.5	nd	nd
WBP	11-Mar-03	nd	nd	nd	nd	nd	nd	nd	nd	nd	<0.01	<0.005	nd	<0.005	<0.005

Notes:

See Table 1 and Figure 1 for site codes and locations

nd = no data

**Table 5 Aldehydes in the WL-WTP1 treated water and Wabamun Lake, July 2002 to March 2003**

Site	Sample Date	Formaldehyde µg/L	Acetaldehyde µg/L	Propanal µg/L	2-Methyl Propanal µg/L	Butanal µg/L	3-Methyl Butanal µg/L	Pentanal µg/L	Hexanal µg/L	Heptanal µg/L	Octanal µg/L	Benzaldehyde µg/L	Nonanal µg/L	Glyoxal µg/L	Methyl Glyoxal µg/L	Total Aldehydes µg/L
WL-WTP1	16-Jul-02	21.4	24.6	1.2	<0.4	1.6	<0.4	1.2	2.1	7.6	3.4	<0.5	1.2	4.3	3.8	72.5
WL-WTP1	28-Oct-02	9.5	7.0	1.4	<0.4	1.3	<0.4	0.6	6.0	2.0	<0.4	<0.5	<0.5	3.3	3.1	34.2
WL-WTP1	11-Mar-03	6.3	12.0	<0.4	<0.4	3.2	<0.4	0.8	1.2	0.5	<0.4	<0.5	0.6	1.5	2.0	28.1
RC-Top	16-Jul-02	11.4	11.0	1.8	<0.4	2.7	<0.4	0.7	2.2	7.5	2.5	1.4	1.1	3.5	1.6	47.4
RC-Bottom	16-Jul-02	12.7	11.7	2.2	<0.4	3.1	<0.4	0.8	2.2	7.8	2.5	2.2	1.2	3.2	1.5	51.1
RC-Top	28-Oct-02	8.8	7.4	1.4	<0.4	1.1	<0.4	0.5	4.0	2.4	<0.4	<0.5	<0.5	2.1	1.6	29.1
RC-Bottom	28-Oct-02	7.6	5.9	1.2	<0.4	0.9	<0.4	0.5	3.9	1.4	<0.4	<0.5	<0.5	1.6	1.3	24.1
ECO	16-Jul-02	6.8	8.4	1.5	0.9	2.0	<0.4	<0.4	1.5	7.2	0.6	0.8	1.2	0.8	<0.4	31.8
NCO	16-Jul-02	6.7	7.8	1.6	1.0	2.1	<0.4	<0.4	2.0	7.2	0.5	0.7	1.2	0.9	<0.4	31.9
WCO	16-Jul-02	7.1	7.5	1.5	0.9	2.1	<0.4	<0.4	1.8	7.3	0.6	1.1	1.3	<0.4	<0.4	31.1
EBP	16-Jul-02	7.9	9.6	1.7	<0.4	2.4	<0.4	<0.4	1.8	7.3	0.6	1.0	1.1	1.0	<0.4	34.5
EBP	28-Oct-02	2.4	5.5	1.4	<0.5	0.6	<0.5	<0.4	2.5	<0.5	<0.4	<0.5	<0.5	<0.4	<0.4	12.4
EBP	11-Mar-03	1.7	5.7	<0.4	<0.4	1.6	<0.4	1.5	1.0	0.5	2.1	1.1	2.0	0.5	<0.4	17.7
SBP	28-Oct-02	2.2	6.2	1.4	<0.4	1.2	<0.4	<0.4	2.6	<0.4	<0.4	<0.5	<0.5	<0.4	<0.4	13.5
SBP	11-Mar-03	1.8	6.5	<0.4	<0.4	2.5	<0.4	2.1	1.5	0.6	1.3	1.0	1.0	0.7	<0.4	19.0
WBP	16-Jul-02	7.5	10.1	1.7	<0.4	2.3	<0.4	<0.4	2.0	7.2	<0.4	1.2	1.3	1.2	<0.4	34.5
WBP	11-Mar-03	1.9	5.9	<0.4	<0.4	2.3	<0.4	1.6	1.5	0.6	0.9	0.7	0.6	0.5	0.4	16.9
Laboratory "Blank" Water:																
Mean Concentration or <MDL		1.3	2.8	<0.4	<0.4	1	<0.4	0.9	3.2	<0.4	<0.4	<0.5	0.7	0.5	<0.4	

Notes:

See Table 1 and Figure 1 for site codes and locations

Laboratory "blank" water data are from Appendix A: Table B

**Table 6 Chlorinated phenols in the WL-WTP1 treated water and Wabamun Lake, July 2002 to March 2003**

Site	Sample Date	Chloro phenol, 2- µg/L	Methyl phenol, 2- µg/L	Methyl phenols, 3- & 4- µg/L	Di methyl phenol, 2,4- µg/L	Di chloro phenol, 2,4- µg/L	Di chloro phenol, 2,6- µg/L	4-Chloro-3-methyl-phenol µg/L	Tri chloro phenol, 2,3,5- µg/L	Tri chloro phenol, 2,4,6- µg/L	Tri chloro phenol, 2,4,5- µg/L	Tri chloro phenol, 2,3,4- µg/L	Tri chloro phenol, 2,3,6- µg/L	Tetra chloro phenol, 2,3,5,6- µg/L	Tetra chloro phenol, 2,3,4,5- µg/L	Tetra chloro phenol, 2,3,4,6- µg/L	Tri chloro phenol, 3,4,5- µg/L	Penta chloro phenol µg/L
WL-WTP1	16-Jul-02	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<3
WL-WTP1	21-Oct-02	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<3
WL-WTP1	11-Mar-03	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<3
RC-Top	16-Jul-02	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<3
RC-Bottom	16-Jul-02	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<3
RC-Top	21-Oct-02	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<3
RC-Bottom	21-Oct-02	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<3
ECO	16-Jul-02	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<3
NCO	16-Jul-02	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<3
WCO	16-Jul-02	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<3
CO4	21-Oct-02	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<3
CO3	21-Oct-02	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<3
CO2	21-Oct-02	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<3
CO1	21-Oct-02	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<3
EBP	16-Jul-02	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<3
EBP	21-Oct-02	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<3
EBP	11-Mar-03	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<3
SBP	21-Oct-02	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<3
SBP	11-Mar-03	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<3
WBP	16-Jul-02	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<3
WBP	11-Mar-03	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<3

Notes:

See Table 1 and Figure 1 for site codes and locations

could have influenced chloroform concentrations at the RC site. The water quality of the WL-WTP2 treated water was expected to be similar to that of the WL-WTP1, because the same major treatment processes (chlorination and ozonation) were used in both plants. For example, the concentration ranges of various DBPs in treated water from the WL-WTP1 and WL-WTP2 were similar in July and August 2002 (TAU 2002a, 2002b).

As noted above (Section 3.2.1), the QA data indicated chloroform concentrations analysed in the samples of this program could have been underestimated. If this was the case, it appears that this potential bias would not have had a strong effect on the conclusions related to the chloroform data presented above. Based on the split sample data, the maximum chloroform concentration was 8.5 µg/L in the portions of the splits analysed by the laboratory used for the results reported above, compared to a maximum of 12.9 µg/L in the portions analysed by the second laboratory (Appendix A: Table A).

The chloroform concentrations in Wabamun Lake (excluding data in the immediate vicinity of the treated water discharge) appear to be comparable to those from Canadian rivers. Chloroform concentrations in river data from four provinces (Alberta, British Columbia, Ontario, and Quebec) showed a median value of <0.2 µg/L with 95<sup>th</sup> and 99<sup>th</sup> percentiles of <1 and 2.94 µg/L, respectively (n = 984; method detection limits for these data were ≤1 µg/L) (Environment Canada 2001a). In one Alberta study, chloroform was found at a maximum concentration of 4 µg/L in the Athabasca River, 21 km downstream of a combined pulp mill and municipal effluent (Noton and Shaw 1989). Highest chloroform concentrations in these studies were associated with discharges of chlorinated wastewaters (Noton and Shaw 1989; Environment Canada 2001a). The highest chloroform concentrations in Wabamun Lake were in the RC (maximum = 8.5 µg/L) due to proximity of the discharge. Chloroform data for other lakes are not available.

#### Other DBPs Excluding Aldehydes

Concentrations of the remaining DBPs (excluding aldehydes) in the samples showed similar overall patterns to the halomethanes. These compounds were at highest concentrations in the treated water or RC samples and some DBPs were at highest concentrations or only detected in the 10-July treated water sample. Concentrations of the two dominant haloacetic acids (trichloroacetic acid and dichloroacetic acid) in the treated water and RC ranged from 4.4 to 37.1 µg/L; on each sample date, the concentrations were often slightly higher in the treated water (Table 3). Highest haloacetic acid concentrations occurred in October (maximum concentration = 37.1 µg/L for trichloroacetic acid), compared to the other sample dates (Table 3). Similar or higher concentrations of trichloroacetic acid and dichloroacetic acid can occur in Canadian drinking waters. For example, in a national survey of treated drinking water, haloacetic acid concentrations ranged from 10 to 100 µg/L with an average of less than 50 µg/L; trichloroacetic acid and dichloroacetic acid were the dominant haloacetic acid species in drinking waters (Health Canada no date).

Concentrations of the main haloketone in the treated water and RC (1,1,1, trichloro-2-propanone) ranged from 0.6 to 1.8 µg/L (Table 4). This haloketone was also detected at two lake sites close to the RC; these concentrations (0.7 and 0.9 µg/L) were slightly above the method detection limit

(0.5 µg/L) (Table 4). Concentrations of the only haloacetonitrile found in all samples (dichloroacetonitrile) ranged from 0.5 to 3.9 µg/L in the treated water; the highest concentrations occurred in the 10-July sample (Table 4). Higher concentrations of haloacetonitriles, up to 40 µg/L, may occur in treated drinking waters; data for haloketones were not available (Health Canada no date). Chloral hydrate concentrations ranged from 0.6 to 8.5 µg/L in the treated water and RC, and chlorate concentrations varied from 0.04 to 0.11 mg/L in the same samples (Table 4). Both chloral hydrate and chlorate were only detected once (on 21 October) at the same lake site, close to the RC opening (concentrations = 1.3 µg/L and 0.02 mg/L, respectively) (Table 4). Chloral hydrate may be found in treated drinking water at up to 100 µg/L with a mean of 10 µg/L (Health Canada no date). Total residual chlorine (TRC) was found once in the 10-July treated water sample, at 0.07 mg/L (Table 4). No data for the concentrations of chlorate and TRC in drinking water were available (Health Canada no date).

### Aldehydes

As noted already (Section 3.2.1), external contamination of samples by some aldehydes is a possibility based on the QA data. However, comparisons of the mean concentrations of aldehydes in the laboratory blanks to individual concentrations in the field samples indicates that aldehydes were usually lower in the blanks than in the treated water and lake samples (Table 5). These findings indicate that external contamination by aldehydes only partly explains the concentrations observed in the lake samples. Potential sources of aldehydes in Wabamun Lake include the WL-WTP treated water and natural processes.

In contrast to the other DBPs, most aldehydes present in the treated water were also often found at many of the lake sites (Table 5). Concentrations of individual aldehydes in the treated water ranged from the method detection limits (MDLs = <0.4 or <0.5 µg/L) to 24.6 µg/L; while aldehyde concentrations varied from the MDLs to 12.7 µg/L in the lake samples (Table 5). Formaldehyde and acetaldehyde were the dominant aldehydes on most individual sample dates (Table 5). Similar to the halomethanes, concentrations of some aldehydes (e.g., acetaldehyde and formaldehyde) in the 10-July treated water sample may be biased high, compared to other dates (Table 5). For example, volatilization along with biodegradation and other processes are considered to be important processes affecting the fate of acetaldehyde in surface waters (Environment Canada 2001b). In general, the concentrations of individual aldehydes in the treated water and lake samples were often similar (with overlapping concentration ranges); this was especially evident in October and March.

Although the concentration ranges of aldehydes in the treated water and lake samples often overlapped, some aldehydes (e.g., methyl glyoxal, glyoxal, pentanal, and formaldehyde) were frequently at higher concentrations, or they were primarily detected in the treated water and RC samples, compared to the other lake sites throughout the sampling program (Table 5). This pattern indicates that the treated water is a potential source of these aldehydes to the lake. In contrast, two aldehydes (2-methyl propanal and benzaldehyde) were not found in the treated water (or laboratory blank water), but they were present in the lake (range in concentrations <0.4 or 0.5 to 2.2 µg/L) (Table 5). Only one of the aldehydes analysed (3-methyl butanal) was not found in any of the samples (or in the laboratory blank water) (Table 5).

Formaldehyde and acetaldehyde may be formed by various natural processes, such as forest fires and irradiation of humic acids (e.g., components of dissolved organic carbon) in water, and thus they can occur naturally in the environment (Environment Canada 2001a and 2001b; Kieber *et al.* 1990). In surface waters, both compounds may undergo biodegradation and in the case of acetaldehyde, residence time in water may be affected by environmental conditions, such as temperature, wind speed, water currents, and ice cover (Environment Canada 2001a, 2001b). Ambient data for the concentrations of formaldehyde and acetaldehyde in Canadian surface waters appear to be primarily from rivers. In an Alberta study, formaldehyde concentrations in raw water from the North Saskatchewan River (at the Rosedale Water Treatment Plant, Edmonton) were usually at low levels, with a mean of 1.2 µg/L and a maximum of 9.0 µg/L between March 1989 and January 1990 (Huck *et al.* 1990). In the same study, acetaldehyde concentrations were higher with a mean concentration of 8 µg/L and a maximum of 31 µg/L in the river from March to October 1989; lowest concentrations of acetaldehyde and formaldehyde (<1 µg/L) occurred in the winter (Huck *et al.* 1990).

In other studies of raw water sources in Ontario with varying sampling periods, formaldehyde concentrations ranged from <1 to 8.4 µg/L in the Detroit and Ottawa rivers and a mean of 1.1 µg/L was found in the Grand River (Anderson *et al.* 1994). In the same studies, acetaldehyde concentrations varied from no detections (i.e., <0.9 µg/L) in the Grand River, one detection at 5.9 µg/L in the Ottawa River, and detections of 1.4 and 114 µg/L in the Detroit River (Anderson *et al.* 1994). Direct comparison of these data to Wabamun Lake data are not possible without the original data, however, the concentrations are similar in both datasets. No data are available for the ambient concentrations of aldehydes in Alberta lakes. These data would be helpful in providing perspective on the concentrations of aldehydes present in other lake basins with varying geological characteristics, land uses, and potential sources or emissions of aldehydes.

#### Overall Temporal Pattern in DBP Concentrations

Various studies have documented seasonal variation in the concentrations of different DBPs which are likely related to the levels of precursors of DBP formation (e.g., organic carbon and its chemical components) and environmental conditions. In one study, higher THM concentrations in the Ohio River were associated with higher algal production and algal senescence in the river (Jack *et al.* 2002). In another study, Huck *et al.* (1990) documented higher concentrations of aldehydes (especially acetaldehyde) in the North Saskatchewan River during spring run-off and major rainfall events, while levels of these compounds were lower in the winter following river freeze-up.

The Wabamun Lake sample periods (summer, fall and winter) included a broad range of seasonal water quality characteristics, lake conditions (including ice cover), and WL-WTP operating conditions which may have influenced DBP levels in the lake. Based on the lake samples, there does not appear to be a pronounced difference in the concentrations of major DBP groups among the seasons sampled in the study. Using the treated water data to evaluate temporal patterns is hindered by the potential bias associated with the 10-July sample. However, in comparison to these data, other monthly samples of the WL-WTP1 treated water (collected by TransAlta Utilities Ltd.; TAU) over relatively long period (from 1998 to 2001), showed a similar range of concentrations for major DBP groups (i.e., for total THMs, total haloacetic acids, total

haloacetonitriles, total haloketones, and chloral hydrate) in both sets of data (the TAU data are summarised in Casey 2003: Table 12). As noted above, DBP concentrations appear to be similar in the WL-WTP1 and WL-WTP2 treated waters.

### Vertical Distribution of DBPs in the Water Column

Based on the small amount of data comparing samples taken at the top and bottom of the water column at the same site and date (i.e., samples taken at the RC site on 10 July and 21 October), there did not appear to be any major difference in the concentrations of individual DBPs at the site, although the depth difference was small (maximum water depth at the RC site was <2 m) (Tables 2, 3, 4, and 5). The RC site was chosen to examine this pattern because the highest DBP concentrations were expected at this site, closest to the treated water discharge to the lake.

### **3.3 Comparisons of DBP Concentrations to Water Quality Guidelines and Toxicity Data**

Water quality guidelines for use in Alberta (Alberta Environment 1999) and scientific literature may be used to evaluate the potential effects of DBPs found in Wabamun Lake. Currently, there are only two water quality guidelines for the protection of freshwater aquatic life for the chemical compounds detected in the lake samples. These guidelines were developed for chloroform and toluene by the Canadian Council of Ministers of the Environment (CCME) (Alberta Environment 1999). Only one of these compounds, chloroform, is a DBP. Water quality guidelines for agricultural uses were also used to evaluate potential effects of the compounds found in the lake. These guidelines only exist for chloroform and toluene in livestock water; there are no relevant guidelines for irrigation uses (Alberta Environment 1999).

Data on the toxicity of DBPs on freshwater biota used in the following evaluation were mostly obtained from searches of the ecotoxicology database maintained by the U.S. Environmental Protection Agency (US-EPA) (ECOTOX database). The ECOTOX database contains information on lethal, sub-lethal, and residue effects of a wide range of chemical compounds on biota including freshwater plants and animals. In these studies, toxicity effects or endpoints are often defined as LC<sub>50</sub> and EC<sub>50</sub> values. The LC<sub>50</sub> is the median lethal concentration which is a statistically estimated concentration where 50% of the test organisms die. The EC<sub>50</sub> is the effective concentration where 50% of the test organisms show a specified non-lethal response examined in the study. The ECOTOX database was searched for individual chemicals found in the Wabamun Lake samples.

#### *3.3.1 Chloroform*

During the Wabamun lake study, chloroform concentrations in the RC and two lake samples, taken near the canal opening (0.6 to 8.5 µg/L), were close to or greater than the chloroform *interim* water quality guideline of 1.8 µg/L (Table 2)(Alberta Environment 1999). Of the toxicity studies used to develop the CCME water quality guideline, the lowest observed effect was for deformities in embryos of a spring peeper (or chorus frog) species at 18 µg/L (CCME 1999a). The remaining toxicity studies showed acute and chronic effects of chloroform on various freshwater invertebrates, vertebrates, and blue-green algae at much higher concentrations;

various toxicity endpoints ranged from 270 to 185,000 µg/L (CCME 1999a). The chloroform water quality guideline is defined as *interim* because there was incomplete toxicity information required for the development of a *full* guideline (CCME 1999a, 1999b). Other toxicity studies support the finding that amphibians are the most sensitive group of freshwater biota to chloroform and other halomethanes (CCME 1999a; CCME 1999b; CCME 1999c; Environment Canada 2001a; ECOTOX data).

All chloroform concentrations in Wabamun Lake were less than the CCME water quality guideline for livestock water (100 µg/L) (Alberta Environment 1999). This guideline is based on adopting the interim Canadian drinking water guideline concentration because insufficient data were available to derive one for livestock water (Alberta Environment 1999).

### 3.3.2 *Haloacetic Acids*

Information on the toxicity of haloacetic acids indicated that trichloroacetic acid and dichloroacetic acid showed toxic effects (often LC<sub>50</sub> endpoints in each study) on a range of biota at concentrations of parts per million (1 mg/L = 1 x 10<sup>-6</sup>) (ECOTOX database). These concentrations were well above those observed for trichloroacetic acid and dichloroacetic acid in the RC (range of concentrations for both compounds = 4.4 to 31.6 µg/L; i.e., parts per billion, 1 µg/L = 1 x 10<sup>-9</sup>), the only lake site where these compounds were detected. Some studies showed effects at parts per billion for some aquatic taxa, however, citations to the original source of these data were not available (in the ECOTOX database) to allow an evaluation of the relevance of these studies and results.

### 3.3.3 *Aldehydes*

Toxicity data were available for various aldehydes observed in Wabamun Lake. In general, toxicity of aldehydes were usually found at higher concentrations than those observed in the lake. Of major freshwater groups, invertebrates appeared to be most sensitive to formaldehyde (i.e., a species of seed shrimp, or Ostracoda, 96-hour EC<sub>50</sub> = 0.36 mg formaldehyde/L), although there was a wide range of toxicity endpoint concentrations in the studies (Environment Canada 2001a). In comparison, toxicity data for acetaldehyde, showed fathead minnows were the most sensitive organism (96-hour LC<sub>50</sub> = 30.8 mg/L (Environment Canada 2001b). Based on the toxicity endpoints in the ECOTOX database, toxic effects of various aldehydes found in the Wabamun Lake samples (i.e., for formaldehyde, acetaldehyde, propanal, butanal, and glyoxyl) are likely to occur at concentrations of mg/L; these concentrations are well above those observed in the lake.

### 3.3.4 *Remaining DBPs and Toluene*

Limited information is available on the effects of chlorate on freshwater biota. In one Alberta study, the survival of five freshwater insect species (belonging to four different orders of Insecta) were not affected by chlorate concentrations ranging from 0.5 to 50 mg/L in the laboratory (Doddall *et al.* 1997). The LC<sub>50</sub> for a freshwater zooplankton species (Crustacea: *Daphnia magna*) was 3,162 mg/L (Doddall *et al.* 1997). In another Canadian study, Perrin and Bothwell (1992) found that chlorate additions of up to 0.5 mg/L did not affect growth rates or taxonomic

composition of flowing-water diatoms in experimental flumes. Based on these toxicity results, chlorate concentrations in the Wabamun Lake samples (maximum = 0.10 mg/L) would not appear to be toxic to these freshwater invertebrates. No chlorate toxicity data were available for freshwater fish.

No toxicity data were found for other DBPs (i.e., one haloketone and chloral hydrate) which were mostly detected at the RC site. Concentrations of toluene in the RC and outside the canal (maximum = 0.6 µg/L) were less than the CCME water quality guidelines for the protection of freshwater aquatic life (2.0 µg/L) and livestock water (24 µg/L) (Alberta Environment 1999).

### 3.3.5 *Mixtures of DBPs and Toxicity on Aquatic Biota*

Mixtures of DBPs were present at all sites during the study. For example, several DBPs were found in the RC and vicinity, and mixtures of aldehydes were present at all lake sites. Using the toxicity information available, it was not possible to evaluate the potential effects of mixtures of DBPs, if any, on freshwater biota in Wabamun Lake. However, data on the zoobenthos (or benthic macroinvertebrate) communities in the lake can be used to evaluate potential impacts of DBPs on these important communities. Benthic macroinvertebrates are generally sedentary, living in or close to the bottom sediments.

A recent study of zoobenthos in Wabamun Lake examined the composition (taxonomic diversity) and abundances of these communities at several locations in the lake (Stantec 2003). Samples related to potential impacts from the WL-WTP discharge were taken at three sites: in the RC, an area close to the RC opening (which was also close to the water quality sites of the study), and a location, about 1 km to the north-west of the RC. This latter area was sampled to reflect reference or “background” conditions relative to the other sites.

Results of these samples indicated overall differences in the zoobenthos communities (i.e., taxa composition and abundances) among the three locations (Stantec 2003). Causes of these differences may be attributed to various factors, such as differences in the water quality and habitat conditions (e.g., substrate composition) at the three areas. Water quality in the RC was likely to be different from the other areas, especially compared to the most distant, background location. Compared to the rest of the lake, the water in the RC contained more DBPs or higher DBP concentrations (Section 3.2) and it would also have higher total dissolved solids concentrations, due to the WL-WTP discharge (Casey 2003). Detailed physical measurements of the substrate composition are not available (Stantec 2003) to allow a thorough analysis of habitat differences among the three areas. But differences in the abundance of macrophytes may have influenced the fauna at the locations (Stantec 2003). In comparison to the overall analysis of the zoobenthos communities, more detailed analysis of the zoobenthos data showed several similarities in the fauna among the three areas. For example, there were overlapping ranges of the mean number of taxa and mean densities of major zoobenthos groups among the locations (Stantec 2003). Overall, these results do not appear to indicate a major impact from the WL-WTP discharge on the zoobenthos communities.

## 4.0 CONCLUSIONS

Results of the sampling program (from July 2002 to March 2003) showed that various disinfection by-products (DBPs) analysed in the samples were present in the final (WL-WTP1) treated water pumped to Wabamun Lake. These DBPs were: two trihalomethanes (mostly chloroform), one other volatile halogenated-methane compound (dichloromethane), three haloacetic acids, two halo ketones, one haloacetonitrile, chloral hydrate, total residual chlorine (TRC), chlorate, and most aldehydes analysed in the samples.

Many of the DBPs present in the treated water were also found in the receiving canal (RC), 180 m from the combined discharge of treated water from the WL-WTP1 and WL-WTP2. The highest DBP concentrations in the lake samples occurred in the RC. This was likely due to the proximity of the treated water discharge, restricted mixing within the canal, and a relatively short time to allow volatilization to occur, compared to the rest of the lake. A smaller number of the DBPs found in the RC were also present at the lake sites closest (i.e.,  $\leq 100$  m) to the canal mouth.

Aldehydes were the only group of DBPs that were commonly found at the remaining lake sites, i.e., furthest away from the treated water discharge. Formaldehyde and acetaldehyde were the dominant aldehydes in the lake samples. These compounds may occur naturally in the environment (e.g., due to forest fires and irradiation of humic acids). Some aldehydes were at higher concentrations in the treated water and RC compared to the lake samples, which indicates the treated water is a potential source of aldehydes to the lake. Overall, the concentrations of aldehydes in Wabamun Lake were comparable to data from other studies of raw water sources for drinking waters, although these studies were restricted to rivers. No comparable data for aldehydes in Alberta lakes are available.

Overall, there was no pronounced difference in the concentrations of DBPs in Wabamun Lake over the three seasons (summer, fall, and winter) sampled. These sample periods included a broad range of water quality, lake conditions (including ice cover), and WL-WTP operating conditions which could have influenced DBP levels in the lake.

Comparisons of the DBP concentrations in Wabamun Lake to water quality guidelines and toxicity data, primarily from the US-EPA ECOTOX database, indicated:

1. Chloroform concentrations in the RC and two lake samples close to the canal opening (0.6 to 8.5  $\mu\text{g/L}$ ) were close to or greater than the CCME *interim* water quality guideline for the protection of freshwater aquatic life (1.8  $\mu\text{g/L}$ ). Of the toxicity studies used to develop the CCME water quality guideline, the lowest observed effect concentration was for deformities in embryos of a spring peeper (or chorus frog) species at 18  $\mu\text{g/L}$ .
2. Based on the available toxicity data for other DBPs, the concentrations of haloacetic acids, aldehydes, and chlorate in the lake were lower than the toxicity-endpoints (e.g.,  $\text{LC}_{50}$ ) or concentrations where effects occurred. No toxicity data were found for the remaining DBPs detected at the RC site (i.e., one halo ketone and chloral hydrate).

3. Chloroform and toluene concentrations were less than the CCME water quality guidelines for livestock water.

Mixtures of DBPs (e.g., aldehydes) were present at lake sites during the study. Using the toxicity information available, it was not possible to evaluate the potential effects of mixtures of DBPs, if any, on freshwater biota in Wabamun Lake. But data on the zoobenthos communities in the lake can be used to evaluate potential impacts of DBPs on these important communities. A recent Wabamun Lake study indicated overall differences in the zoobenthos communities at three locations related to potential effects of the WL-WTP discharge. However, more specific analysis of these data showed several similarities in the zoobenthos fauna among the three locations. The results do not appear to indicate a major impact from the WL-WTP discharge on the zoobenthos communities.

## 5.0 LITERATURE CITED

- Alberta Environment. 1999. Surface Water Quality Guidelines for Use in Alberta. November 1999. Environmental Sciences Division and Water Management Division, Edmonton, Alberta. Publication available at: <http://www.gov.ab.ca/env/protenf/publications/SurfWtrQual-Nov99.pdf>
- Alberta Environment. 2002. Water Quality Sampling Methods for Surface Waters. Prepared by Water Monitoring Group, Compliance Branch, Northern and Southern Regions, Regional Services, Edmonton, Alberta.
- Anderson, W.B., P.M. Huck, I.P. Douglas, J. Van Den Oever, B.C. Hutcheon, J.C. Fraser, S.Y. Jasim, R.J. Patrick, H.E. Donison and M.P. Uza. 1994. Ozone Byproduct Formation in Three Different Types of Surface Water. Presented at the 22nd Water Quality Technology Conference, November 6–10, 1994, San Francisco, California. Proc. Am. Water Works Assoc. 2(21): 871–908. Cited in Environment Canada, 2001b.
- APHA. 1998. Standard Methods for the Examination of Water and Wastewater. Prepared and published jointly by the American Public Health Association and American Water Works Association, and Water Environment Federation.
- Casey, R. 2003. Wabamun Lake Water Quality 1982 to 2001. Draft Report. Environmental Monitoring and Evaluation Branch & Science and Standards Branch, Environmental Assurance, Edmonton, Alberta. Publication available at the Alberta Government Information Centre: <http://www3.gov.ab.ca/env/info/infocentre/publist.cfm>
- CCME. 1999a. Canadian Water Quality Guidelines of the Protection of Aquatic Life: Halogenated Methanes: Trichloromethane (Chloroform). Published in Canadian Environmental Quality Guidelines, by Canadian Council of Ministers of the Environment, Winnipeg, Manitoba.
- CCME. 1999b. Canadian Water Quality Guidelines of the Protection of Aquatic Life: Halogenated Methanes: Tetrachloromethane (Carbon Tetrachloride). Published in Canadian Environmental Quality Guidelines, by Canadian Council of Ministers of the Environment, Winnipeg, Manitoba.
- CCME. 1999c. Canadian Water Quality Guidelines of the Protection of Aquatic Life: Halogenated Methanes: Dichloromethane (Methylene Chloride). Published in Canadian Environmental Quality Guidelines, by Canadian Council of Ministers of the Environment, Winnipeg, Manitoba.
- Dosdall, L.M., L.R. Goodwin, R.J. Casey, and L. Noton. 1997. The Effect of Ambient Concentrations of Chlorate on Survival of Freshwater Aquatic Invertebrates. Water Quality Research Journal of Canada 32: 839-854.

ECOTOX database. Access to the U.S.-E.P.A ecotoxicological database is available at:  
[http://www.epa.gov/ecotox/ecotox\\_home.htm](http://www.epa.gov/ecotox/ecotox_home.htm)

Environment Canada. 2001a. Chloroform. Priority Substance List Assessment Report. Co-published with Health Canada. Publication can be requested from Environment Canada through: <http://www.ec.gc.ca/substances/ese/eng/psap/final/main.cfm>

Environment Canada. 2001b. Acetaldehyde. Priority Substance List Assessment Report. Co-published with Health Canada. Publication can be requested from Environment Canada through: <http://www.ec.gc.ca/substances/ese/eng/psap/final/main.cfm>

Environment Canada. 2001c. Formaldehyde. Priority Substance List Assessment Report. Co-published with Health Canada. Publication can be requested from Environment Canada through: <http://www.ec.gc.ca/substances/ese/eng/psap/final/main.cfm>

Health Canada. No publication date. Chlorinated Disinfection By-Products (CDBPs). Prepared for the Chlorinated Disinfection By-Products (CDBP) Task Group. Publication is available at: [http://www.hc-sc.gc.ca/hecs-sesc/water/chlorinated\\_disinfection.htm](http://www.hc-sc.gc.ca/hecs-sesc/water/chlorinated_disinfection.htm)

Huck, P.M., W.B. Anderson, S.M. Rowley, and S.A. Daignault. 1990. Formation and Removal of Selected Aldehydes in a Biological Drinking-Water Treatment Process. *J. Water SRT – Aqua* 39 (5): 321-333.

Humphries, D., Senior Analyst, Alberta Research Council, Vegreville. Personal communication

Jack, J., T. Sellers, and P.A. Bukaveckas. 2002. Algal Production and Trihalomethane Formation Potential: An Experimental Assessment and Inter-River Comparison. *Canadian Journal of Fisheries and Aquatic Sciences* 59: 1482-1491.

Kieber, R.J., X. Zhou and K. Mopper. 1990. Formation of Carbonyl Compounds From UV-Induced Photodegradation of Humic Substances in Natural Waters: Fate of Riverine Carbon in the Sea. *Limnol. Oceanogr.* 35(7): 1503–1515. Cited in Environment Canada, 2001a and 2001b.

Noton, L.R., and R.D. Shaw. 1989. Winter Water Quality in the Athabasca River 1988 and 1989. Environmental Quality Monitoring Branch, Environmental Assessment Division, Alberta Environment, Edmonton.

Paran, J. EPCOR Water Services Inc., Edmonton. Personal communication.

Perrin, C.J. and M.L. Bothwell. 1992. Chlorate Discharges from Pulp Mills: An Examination of Effects on River Algal Communities. *Water Pollution Research Journal of Canada* 27: 473-485.

Rashid, I., Laboratory Analyst, EPCOR Water Services Inc., Edmonton. Personal communication.

Stantec Consulting Ltd. 2003. Benthic Invertebrate Assessment in Wabamun Lake, November 2002. Prepared for Alberta Environment, Edmonton.

TAU. 2002a. Wabamun Lake Water Treatment Facility Operating Approval No. 18528-00-03 Monthly Water Works Summary Report July 2002. Report submitted to Alberta Environment.

TAU. 2002b. Wabamun Lake Water Treatment Facility Operating Approval No. 18528-00-03 Monthly Water Works Summary Report August 2002. Report submitted to Alberta Environment.

## Appendix A The quality assurance (QA) data associated with the DBP program

The quality assurance (QA) data associated with the DBP program indicated variation in the dominant volatile organic compound (VOC) detected in the duplicate-split samples. Higher chloroform concentrations were consistently present in the sample portions analysed by ARC compared to EPCOR laboratories (Table A). The coefficient of variation (CV, equivalent to the standard deviation expressed as a percentage of the mean) may be used to provide a measure of precision for each pair of chloroform concentrations in the split samples. The CV values were very high for two split samples (66 and 80%) compared to the other samples (range of CV = 13 to 26%) (Table A). This consistent bias in the results may be attributed to various factors which could have influenced the results, including protocols associated with the field collection, sample handling, and sample analysis by the laboratories.

Review of these specific protocols has not identified a clear reason(s) for the bias. The review showed some consistent differences in the protocols, such as different sample preservatives and types of analytical instruments used by the two analytical laboratories. These differences, however, do not appear to be related to the bias based on the use of standard analytical protocols (i.e., those developed by APHA [1998] and US-EPA) and comparisons of some in-house QA data from each laboratory (e.g., statistical variability of measurements of samples at specific concentration ranges and percent recovery of spikes of chloroform). Also, routine analyses of VOCs in laboratory “blank” water (i.e., purified water to remove chemical contaminants, prepared by each laboratory) typically showed no VOCs detected in the samples (John Paran and Dave Humphries, personal communications). All analytical protocols used by both laboratories (excluding those for aldehydes) are accredited by the Canadian Association for Environmental Analytical Laboratories (CAEAL).

The only exception to the consistent pattern of higher VOC (i.e., chloroform) concentrations in sample splits analysed by one laboratory compared to the other was found for toluene that was detected at a slightly higher concentration in the sample-split analysed by EPCOR (Table A).

The remaining duplicate-split sample data showed three compounds (dichlorobromomethane, toluene, and benzene) were only detected in the portions analysed by ARC (Table A). This was due to a slightly lower method detection limit (MDL) used by the ARC laboratory (MDL = 0.1 µg/L), compared to the EPCOR laboratories (MDL = 0.5 µg/L). The three compounds were found at concentrations in between the two MDLs (i.e., >0.1 and <0.25 µg/L) (Table A).

Analyses of aldehydes in laboratory “blank” water by EPCOR laboratories (Section 2.2) showed that seven of the 14 aldehydes analysed were detected in the blank water associated with the Wabamun Lake samples (MDLs = 0.4 or 0.5 µg/L) (Table B). Four aldehydes (formaldehyde, acetaldehyde, butanal, and hexanal) were present in all three blank samples and they were generally found at concentrations up to 2.8 µg/L, with exception of one hexanal sample at 7.0 µg/L (Table B). Other aldehydes (i.e., pentanal, nonanal, and glyoxal) were present at concentrations up to 2.2 µg/L in one or two of the blanks (Table B). The EPCOR blank water was purified with various treatments in the following order: granulated activated carbon, reverse osmosis, ultra-violet light, reverse osmosis (on a smaller system), Zenon® purification system with carbon cartridges, Milli Q® purification system with ion exchange and carbon cartridges,

filtration, and ultra-violet light for two hours. Blank water is used as part of the analytical procedure, however, the contribution of the blank reagent water to the final sample volume is small, 5% of the sample volume. The aldehydes present in the blanks are likely to be derived from reagent water and not due to contamination from other sources, such as the analytical instrument, reagents, and glassware (Inni Rashid, personal communication). Overall, these results indicate the difficulty of excluding aldehydes from water, even after intense purification to eliminate potential contaminants. Comparing the data for aldehydes in the blank and lake samples (details in Section 3.2.3) indicates that the presence of various aldehydes in the lake samples may be partly due to external contamination of the samples.

**Table A Results of analyses of split samples analysed by the EPCOR and Alberta Research Council (ARC) laboratories, July 2002 to March 2003**

Site	Sample Date	Chloroform			Dichlorobromo-methane		Dibromochloro-methane		Bromoform		Toluene		Benzene	
		EPCOR	ARCV	CV (%)	EPCOR	ARCV	EPCOR	ARCV	EPCOR	ARCV	EPCOR	ARCV	EPCOR	ARCV
Receiving Canal-Top	10-Jul-02	<b>8.5</b>	<b>12.23</b>	25	<0.5	<b>0.18</b>	<0.5	<0.1	<1.0	<0.5	<0.5	<b>0.17</b>	<0.5	<0.1
Receiving Canal-Bottom	10-Jul-02	<b>8.5</b>	<b>12.35</b>	26	<0.5	<b>0.11</b>	<0.5	<0.1	<1.0	<0.5	<b>0.6</b>	<b>0.25</b>	<0.5	<b>0.15</b>
WL-WTP1 Treated Water	21-Oct-02	<b>8.1</b>	<b>9.72</b>	13	<0.5	<0.1	<0.5	<0.1	<1.0	<0.5	<0.5	<0.1	<0.5	<0.1
Receiving Canal-Top	21-Oct-02	<b>4.7</b>	<b>12.9</b>	66	<0.5	<0.1	<0.5	<0.1	<1.0	<0.5	<0.5	<0.1	<0.5	<0.1
Receiving Canal-Composite	4-Mar-03	<b>1.6</b>	<b>5.81</b>	80	<0.5	<b>0.14</b>	<0.5	<0.1	<1.0	<0.5	<0.5	<0.1	<0.5	<0.1

Notes:

CV = coefficient of variation (i.e., standard deviation expressed as a percentage of the mean)

**Table B Aldehydes in laboratory "blank" water analysed by EPCOR (see Section 2.2 for details)**

Sample Type	Sample Date	Formaldehyde µg/L	Acetaldehyde µg/L	Propanal µg/L	2-Methyl Propanal µg/L	Butanal µg/L	3-Methyl Butanal µg/L	Pentanal µg/L	Hexanal µg/L	Heptanal µg/L	Octanal µg/L	Benzaldehyde µg/L	Nonanal µg/L	Glyoxal µg/L	Methyl Glyoxal µg/L
Laboratory "Blank" Water	16-Jul-02	<b>1.3</b>	<b>4</b>	<0.4	<0.4	<b>0.9</b>	<0.4	<0.4	<b>1.6</b>	<0.4	<0.4	<0.5	<b>1.2</b>	<b>0.7</b>	<0.4
	28-Oct-02	<b>1.2</b>	<b>2.8</b>	<0.4	<0.4	<b>1.3</b>	<0.4	<0.4	<b>7</b>	<0.4	<0.4	<0.5	<0.5	<0.4	<0.4
	12-Mar-03	<b>1.5</b>	<b>1.5</b>	<0.4	<0.4	<b>0.7</b>	<0.4	<b>2.2</b>	<b>1.1</b>	<0.4	<0.4	<0.5	<b>0.7</b>	<b>0.7</b>	<0.4
Mean Concentration in Laboratory "Blank" Water		1.3	2.8			1.0		0.9	3.2				0.7	0.5	

Notes:

Mean concentrations calculations that include <MDL data are replaced by half of the MDL (i.e., <0.4 and <0.5 µg/L are replaced by 0.2 and 0.25 µg/L, respectively)