Halifax Harbour
Water Quality Monitoring Program
Quarterly Report #7

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DISCLAIMER

PREFACE

The Halifax Harbour Water Quality Monitoring Project (HHWQMP) is an ongoing project, part of the Halifax Harbour Solutions Project (HRM and JWEL, 2002). It commenced in June 2004, before any of the proposed sewage treatment changes were put into effect, and is slated to continue for a year following the commission of the final plant (June 2009). The project is based on weekly sampling at over 30 sites located from the Bedford Basin to the Outer Halifax Harbour. Water samples taken at 1m and 10m depths are analyzed for a range of parameters. In addition, continuous profiles of basic hydrographic properties (salinity, temperature and density), dissolved oxygen and fluorescence are collected. The sample and profile data are presented in weekly reports along with ancillary data including water level, wind, rainfall and other parameters. The weekly reports are generated as inserts into a binder (JWEL and COA, 2004). The detailed datasets are also archived to CD and provided to the client. A detailed description of the program is contained in the introduction section of the report binder.

The weekly data sets are reviewed on a quarterly basis (13 weeks). The main objective of the quarterly reports is to summarize and evaluate the weekly data sets in terms of water quality objectives and concerns. The quarterly report also provides an opportunity to review the effectiveness of various aspects of the program and recommend changes that will improve the program. Project reports and data are available on the Halifax Regional Municipality (HRM) website: http://www.halifax.ca/harboursol/waterqualitydata.html

The HHWQMP program involves an extensive network of personnel including boat operators, field technicians, laboratory technicians and their associated equipment and procedures. The study team also includes managers, oceanographers and water quality experts. The routines, procedures, report and data archive formats are evolving as the project proceeds. These are documented in the project report binder.

Table of Contents

List of Figures

List of Tables

1 Introduction

This quarterly report is a summary of Halifax Harbour Water Quality Monitoring Project (HHWQMP) data collected from 20 Dec 2005 to 14 Mar 2006 (weekly reports 79 to 91). The data for the period are discussed in terms of compliance/exceedance of applicable water quality guidelines (Halifax Harbour Task Force, 1990), and how they affect recommendations for program modification. An emphasis in this report is a continued assessment of the efficacy of the sampling program and of the potential introduction of systematic sampling bias in the data. This is a necessary step in the more detailed statistical analysis of the data that can occur subsequently. In this report, the data from the center of Bedford Basin (Station G2) is also compared with data collected at a nearby site by the Bedford Basin Phytoplankton Monitoring Program (BBPMP), a project involving scientists with the Department of Fisheries and Oceans at Bedford Institute of Oceanography. This report discusses just the seventh quarter. Every fourth quarterly report includes an annual summary of data and trends over the previous four quarters. In the interest of making the quarterly reports useful as a stand alone document, there is a significant amount of repetition of background information among the quarterly reports.

2 Weekly Reporting

The basic weekly report format is discussed in detail in the introduction of the project report binder and in Quarterly Report #1 (QR1, JWL and COA, 2004). Slight modifications and enhancements to the weekly reports continue to be made as experience dictates. In this quarter, reporting of the secchi depth on the DO and fluoresecnence contour plots began in the 3 Jan weekly report (week 81).

From time to time, errors are discovered in the weekly reports after they have been issued. In addition, the sampling program is modified periodically, necessitating changes in the weekly reports. An Errata/Changes section is included in the Introduction section of the report binder and is updated on a quarterly basis. This documents any issues which could affect the interpretation of the data, as well as documenting changes in the data collection or analysis.

3 Sampling Program

Survey sampling is conducted on a weekly basis from one of several vessels based at the Armdale Yacht Club. The details of the sampling program are discussed in the introduction section of the project report binder and QR#1. The locations of the 34 regular sampling sites are included for reference in Figure 1. Sampling involves the collection of continuous profile data and discrete water samples at 1 and 10m water depth. The level of analysis varies from site to site: CTD only (CTD only sites); CTD and coliform bacteria (Coliform stations); or CTD, Bacteria, and additional contaminant analysis (Chemistry stations). The additional sampling at the Chem sites occurs on a bi-weekly basis. In addition to the regular sites, Figure 1 includes a sample site in Dartmouth Cove, established in response to public concern. At this site, a 1m water sample and profile data are obtained. The water sample is analyzed for the full suite of parameters. This site is sampled once a month during the summer. A summary of the sampling and analysis schedules and relevant established criteria in place at the end of quarter seven (14 Mar 06) are in Table 1. There have been no changes to the sampling for this quarter. This table indicates that there are several analyses, including TOG and metals, which are now performed only for “supplemental samples”. The "supplemental sample" procedure that has been established allows water samples to be taken at additional sites, based on visual observations, at the discretion of the field team. The laboratory analysis on supplementary samples is made possible using funds saved from missed samples during the regular program. During this quarter, there were two missed Chem stations (at both 1 and 10m depths), for a total of four samples, and fourteen missed bacteria stations (1 and 10m depths), for a total of twenty-eight missed bacterial samples. These stations were missed due to environmental conditions (i.e. ice and weather), or conflicting harbour activities (i.e. diving operations). The specifics of the missed stations are described in the weekly reports. During this quarter, there were no supplemental samples taken.

3.1 Sampling Order

Sampling generally occurs on Tuesday, with Wednesday and Thursday as contingency days. Every week the sampling order is varied to minimize biasing the collected data with respect to known diurnal variations in sewage load and sunlight. A variable circuit is used that results in ‘quasi’ random sampling, subject to certain operational constraints. This procedure is discussed in QR#1. The sampling order for each week in the seventh quarter is presented in Table 2.

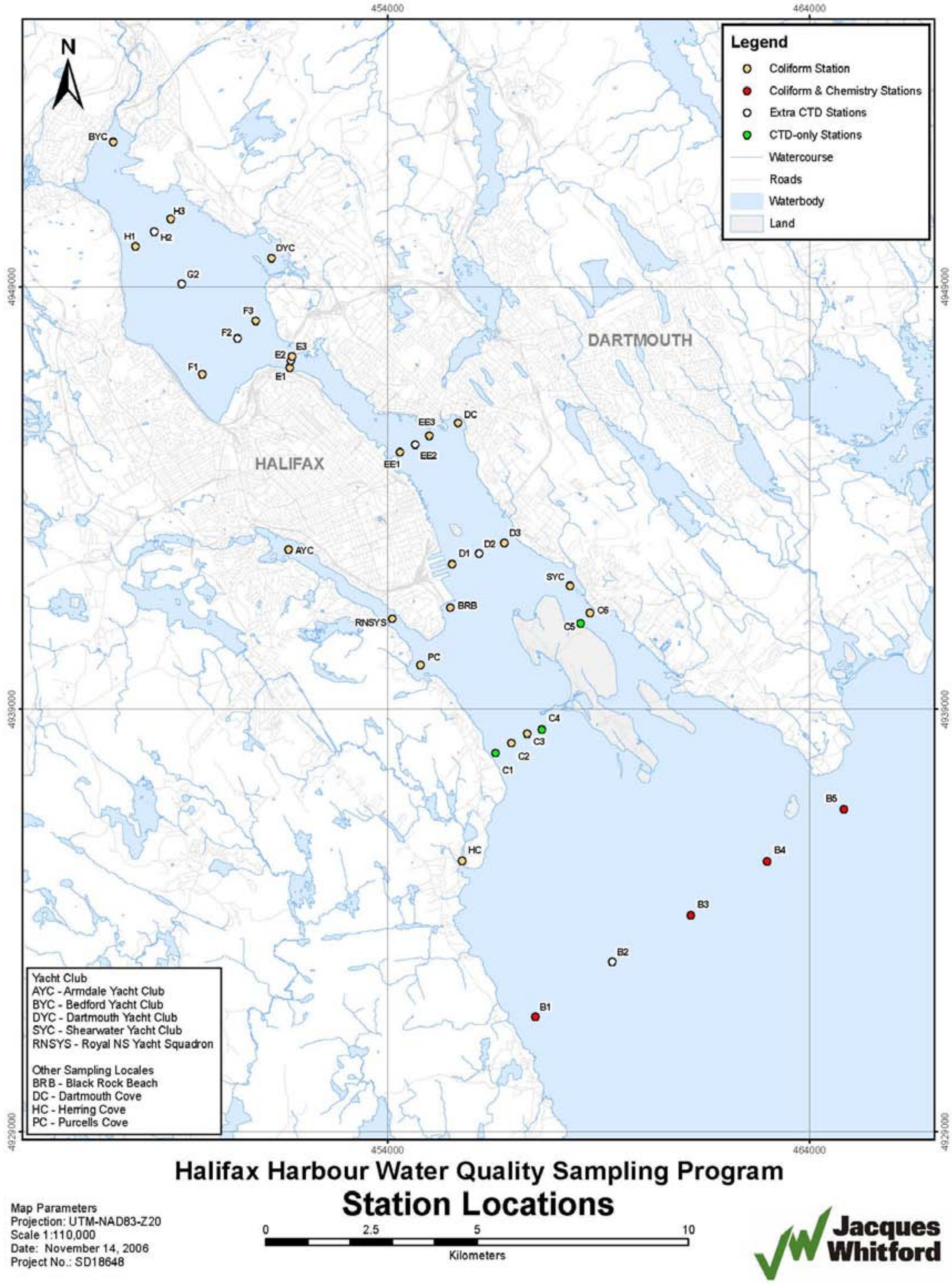


Figure 1. Halifax Inlet Sample Locations

Table 1. Summary of measured parameters as of 21 Mar 06.

	EQL		Harbour Task Force Guideline	Water Use Category	Sampling Stations (refer to Fig. 1)	Sampling frequency
	value	units				
Profile Data					All	weekly
Salinity	n/a	PSU	n/a	n/a		
Temperature	n/a	C°	n/a	n/a		
Chlorophyll *a*	n/a	ug/L	n/a	n/a		
Dissolved Oxygen	n/a	mg/L	8 7 6	SA SB SC		
Secchi depth	n/a	m	n/a	n/a		
Bacteria Samples					Bacteria + Chemical	weekly
Fecal Coliform	0	cfu/ 100mL	14 200	SA SB		
Chemical Samples						
CBOD	5	mg/L	none		Supplemental sites	unscheduled
Ammonia Nitrogen	0.05	mg/L	none		Chemical sites	bi-weekly
TSS	2.0	mg/L	<10% backgroun d	all	Chemical sites	bi-weekly
Total Oil and Grease	5	mg/L	10	all	Supplemental sites	unscheduled
Metal scan					Supplemental sites	unscheduled
Cadmium	3	ug/L	9.3	all		
Chromium	20	ug/L	50.0	all		
Copper	20	ug/L	2.9	all		
Lead	5	ug/L	5.6	all		
Manganese	20	ug/L	100.0	all		
Nickel	20	ug/L	8.3	all		
Zinc	50	ug/L	86.0	all		
Aluminum	100	ug/L	none			
Antimony	20	ug/L	none			
Arsenic	20	ug/L	none			
Barium	50	ug/L	none			
Beryllium	20	ug/L	none			
Bismuth	20	ug/L	none			
Boron	500	ug/L	none			
Cobalt	10	ug/L	none			
Lithium	20	ug/L	none			
Iron	500	ug/L	none			
Molybdenum	20	ug/L	none			
Selenium	50	ug/L	none			
Strontium	50	ug/L	none			
Thallium	1	ug/L	none			
Tin	20	ug/L	none			
Titanium	20	ug/L	none			
Uranium	1	ug/L	none			
Vanadium	20	ug/L	none			

Table 2. Sample collection order (green sites are CTD only)

Date	20-Dec-05	28-Dec-05	3-Jan-06	11-Jan-06	17-Jan-06	24-Jan-06	31-Jan-06	8-Feb-06	15-Feb-06	21-Feb-06	28-Feb-06	6-Mar-07	14-Mar-07
Survey	79	80	81	82	83	84	85	86	87	88	89	90	91
1	AYC	AYC	AYC	AYC	AYC	AYC	HC	HC	AYC	AYC	PC	HC	C1
2	RNSYS	RNSYS	RNSYS	RNSYS	RNSYS	RNSYS	C4	B2	RNSYS	RNSYS	C2	B2	C2
3	PC	PC	PC	PC	PC	PC	C3	C3	PC	PC	C1	D1	HC
4	C1	C1	EE1	C4	C1	EE1	C2	C4	EE1	BRB	HC	D2	B2
5	C2	C2	EE2	C3	C2	D1	C1	RNSYS	D1	D1	B2	EE1	C3
6	HC	BRB	D2	B2	BRB	BRB	BRB	C5	BRB	D2	C3	EE2	C4
7	B2	D1	D1	HC	D2	C2	D1	C6	C2	EE2	C4	E1	C5
8	C3	D2	BRB	C1	D1	C1	EE1	D1	C1	EE1	C5	E2	C6
9	C4	EE2	C2	C2	EE1	C3	E1	EE3	HC	C2	C6	F1	SYC
10	C6	EE1	C1	BRB	EE2	C4	F1	EE2	B2	C1	SYC	F2	D3
11	C5	E2	HC	D1	E1	C5	G2	E3	C3	HC	D3	G2	EE3
12	SYC	E1	B2	EE1	E2	C6	H1	E2	C4	B2	EE3	H2	E3
13	D2	F2	C3	E1	F2	SYC	BYC	F2	C5	C3	E3	H1	F3
14	D3	F1	C4	F1	F1	D3	H2	F3	C6	C4	F3	BYC	DYC
15	EE3	G2	C5	G2	G2	D2	H3	DYC	SYC	C5	H3	H3	H3
16	EE2	H1	C6	H1	H1	EE3	DYC	H3	D3	C6	BYC	F3	BYC
17	E3	H2	SYC	BYC	H2	EE2	F3	H2	D2	SYC	H2	E3	H1
18	E2	BYC	D3	H2	BYC	E3	F2	BYC	EE3	D3	H1	EE3	H2
19	F3	H3	EE3	H3	H3	E2	E3	H1	EE2	EE3	G2	D3	G2
20	F2	DYC	E3	DYC	DYC	F2	E2	G2	E3	E3	F1	SYC	F1
21	DYC	F3	F3	F3	F3	F3	EE2	F1	E2	F3	F2	BRB	F2
22	H3	E3	DYC	F2	E3	DYC	EE3	E1	F2	H3	E1	C6	E1
23	BYC	EE3	H3	E2	EE3	H3	D2	EE1	F3	BYC	E2	C5	E2
24	H2	D3	BYC	E3	D3	H2	D3	D3	DYC	H2	EE1	C4	EE1
25	H1	SYC	H2	EE2	SYC	BYC	SYC	D2	H3	H1	EE2	C3	EE2
26	G2	C6	H1	EE3	C6	H1	C6	SYC	H2	G2	D1	C2	D2
27	F1	C5	G2	D2	C5	G2	C5	BRB	BYC	F1	D2	C1	D1
28	E1	C4	F1	D3	C4	F1	PC	C2	H1	F2	BRB	PC	RNSYS
29	EE1	C3	F2	SYC	C3	E1	RNSYS	C1	G2	E1	RNSYS	RNSYS	AYC
30	D1		E1				AYC	PC	F1	E2	AYC	AYC	
31	BRB		E2					AYC	E1				

3.2 Sampling Bias

There are two issues regarding potential bias in the dataset. The first is the relative bias between sites—whether the statistics from one site can be compared with those from another site. The second is the absolute bias with respect to the environmental forcing, or how well the dataset represents typical conditions in the Harbour. Our sampling has operational constraints which introduce a morning/early afternoon bias to the entire dataset. It is impractical to address this fully, except to document it. The following section is a first look at potential bias with respect to time of day, water level, and rainfall during the seventh quarter.

3.2.1 Time of Day

Sewage flows have significant regular diurnal variations, which can affect the water quality in the harbour on short timescales. In addition to variations in sewage load, the most obvious diurnal variation is in sunlight. Sunlight is perhaps the major contributor to the die off of bacteria, and can have effects on other parameters, particularly chlorophyll (fluorescence) and dissolved oxygen. The short term variation in sewage load is primarily an issue in the Inner Harbour, relatively close to the outfalls, while sunlight affects the entire Harbour. In Halifax there is also a significant diurnal tidal component affecting water levels. This is considered in the subsequent section.

Figure 2 represents the sampling time at each site since the start of the program in June 2004. The data from the seventh quarter are shown in red. In this figure the sample sites are generally sorted from north to south. There are a few patterns that emerge, which have been documented previously. The stations at the north end of Bedford Basin have a smaller range of sampling times. This is because logistics dictates that the surveys never start or end in the Basin. In general, the range of sampling times increases with distance south, a function of travel time from the Armdale Yacht club in the Northwest Arm. Even if a site is sampled first, it still takes time to travel there. Given that sampling begins at the same time every week, these effects are unavoidable. Given the necessary operational constraints, the sampling scheme has resulted in a reasonably uniform distribution in the Inner Harbour (Section D through Section E), where diurnal fluctuations would likely be greatest.

The diagram also indicates that there is an early morning bias in the Outer Harbour Stations, a result of weather considerations. Each week, a primary and an alternate sampling route are provided to the field team. If the primary route has the Outer Harbour sampled early in the day, the alternate route will have it sampled late in the program. The decision on which route to take is made between the field team and the boat operator considering the weather forecast for the day. Wind, waves and visibility can limit operations in the Outer Harbour and since the wind and wave conditions tend to be worse in the afternoon, a morning bias is introduced. The diurnal variations in conditions in the

Outer Harbour are expected to be the least of any harbour region, so this bias is less significant.

In this quarter, there were some additional trends. There is a morning bias in this quarter's samples in the NW Arm. Due to transit time considerations, the Arm is sampled either first or last. There were eight of thirteen surveys that started in the Arm this quarter. There is no real reason for this. This is potentially of importance in the Southern Arm (PC and RNSYS) near the chain rock outfall and should be monitored more closely. The Inner Harbour is fairly well sampled but for E3, which was always sampled mid-day. A review of the sampling scheme reveals no reason for this, except random variation. The Outer Harbour morning bias is pretty strong this quarter. There is only one instance where sites B2 and HC were sampled after noon. This is likely a result of increasing wind conditions in winter, restricting operations in the Outer Harbour. The tendency to sample the Outer Harbour first has inevitably led to a less obvious afternoon bias to the Basin samples. The bias is based on safety considerations and is unavoidable.

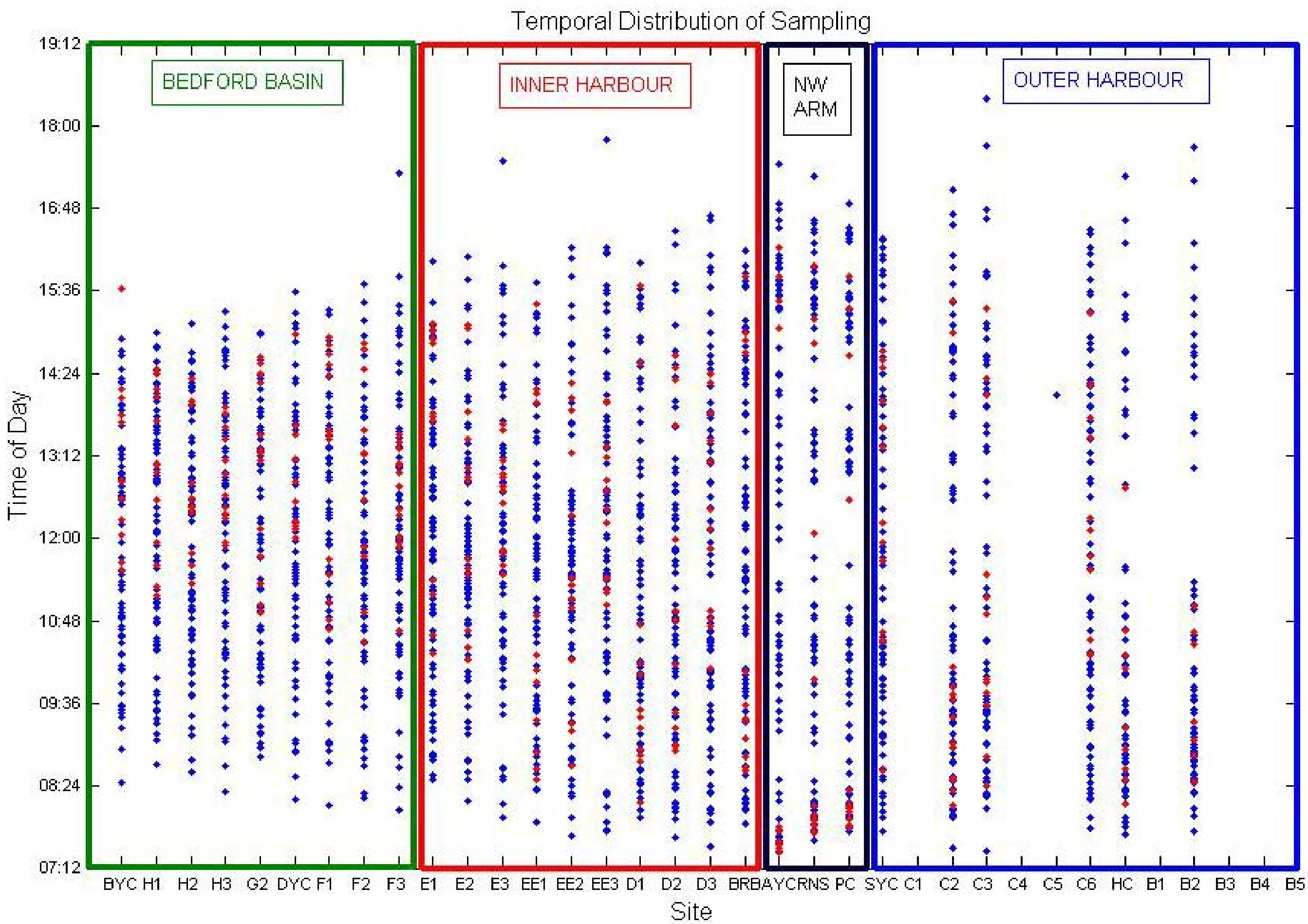


Figure 2. Temporal sampling distribution by site over entire program. Red markers denote points from this (seventh) quarter.

3.2.2 Water Levels

The water level at the time of sampling can affect the results. The two most obvious considerations are whether a particular sample was taken upstream or downstream (based on flood/ebb direction) from the nearest outfall, and the variation in initial dilution, caused by variations in submergence depth, from shallow outfalls. These are both issues primarily in the Inner Harbour.

Water level variations in the Harbour are caused by the tides and meteorological forcing. The meteorologically-induced changes are of longer period and, except in extreme storms, are much smaller in magnitude than the tides. Because of their longer duration their effect on Harbour flushing can be significant and their impact on water quality may warrant investigation in the future. Note that the tidal currents in the Harbour are, for the most part, not that strong and may be over ridden by local/regional meteorological effects (Hurlbut et al., 1990). This means, for example, that the surface current may not always be going out on a falling tide. However, the occurrence of surges is relatively random and the possibility of inducing a systematic sampling bias is small compared with that of the very regular higher frequency tides. The tides in Halifax Harbour are classified as semidiurnal, meaning that there are two high and two low tides in a day.

There is also a potential bias introduced by regular weekly sampling. Sampling which occurs on the same day every second week (i.e. the chemistry sampling) could occur at the same point in the fortnightly tidal cycle (i.e. the same tidal range). An initial assessment of the tidal signal in Halifax Harbour indicates that the fortnightly cycle is sufficiently irregular (i.e. the tides are sufficiently "mixed"), that this problem is unlikely, particularly given the variation in sampling day (Tuesday or Wednesday, sometimes Thursday). This issue will be monitored and may be revisited more rigorously at a later time.

The probability distribution of water level (above chart datum) as derived from the tide gauge at the Naval Dockyard in Halifax (CHS station 490) for the period December 2005 to March 2006 is shown in Figure 3**.** The red line connecting the bars is the baseline, recreated in each panel of Figure 4, against which water levels during sampling will be compared. The overall water level distribution is slightly bi-modal. The central minimum probability roughly corresponds to the mean tide level. However the distribution is actually relatively flat, between 0.6 m and 1.8 m. In an ideal situation each site would be sampled in a distribution similar to the overall distribution.

Figure 4 shows the distribution of water levels at each site at the time of sampling (blue bars) compared to the overall water level distribution for the quarter, derived above (red line). The sampling distributions show that given the relatively small number of samples, a relatively full range of water levels has been sampled at each site. There are some minor discrepancies. As opposed to last quarter, the higher water levels appear to be somewhat under-sampled in Bedford Basin. This is similar in the NW Arm. The C section samples have a slight high water bias. Inner Harbour is relatively well sampled with respect to water level.

The water level bias in Basin appears to be a function of the small sample size as this is opposite of last quarters trend, but is similar to the quarter before last. At any rate, this is unlikely an issue, as tidal currents in the Basin are very low (i.e. tidal excursions are small), and there are no large shallow water outfalls. The exception to this is the Fairview Cove Combined Sewer Overflow (CSO) which flows during large storms.

The Southern Arm (PC and RNSYS) water quality is affected by the trajectory of the plume from the Chain Rock outfall and further analysis of this data should take into account the water level bias.

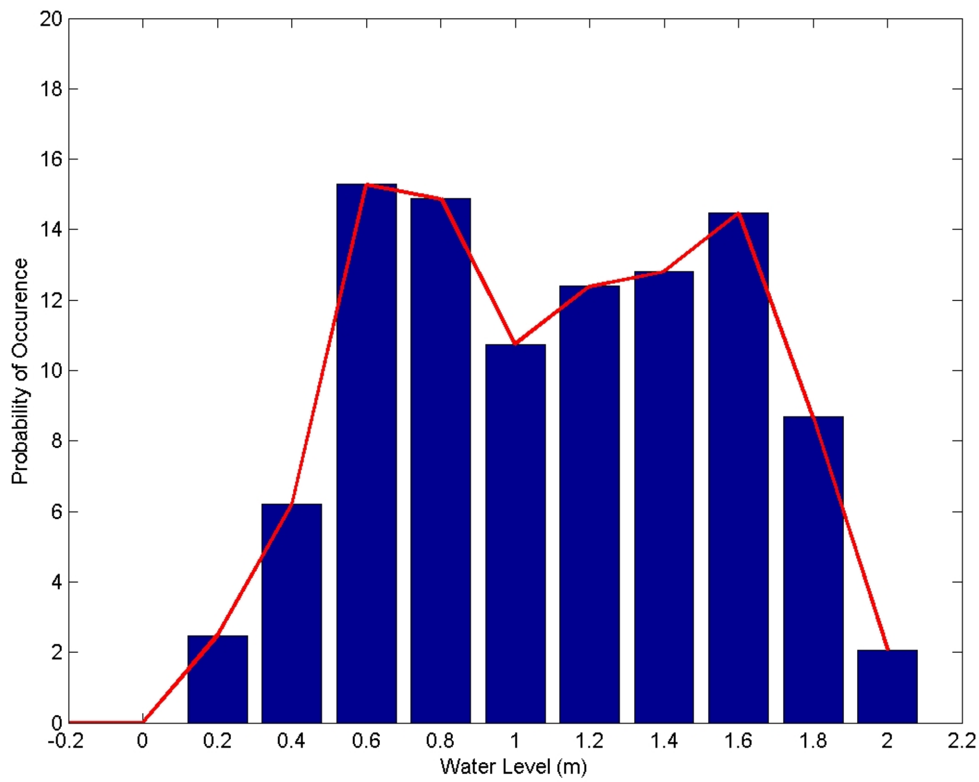


Figure 3. Probability distribution of water levels in Halifax, December 2005 to March 2006.

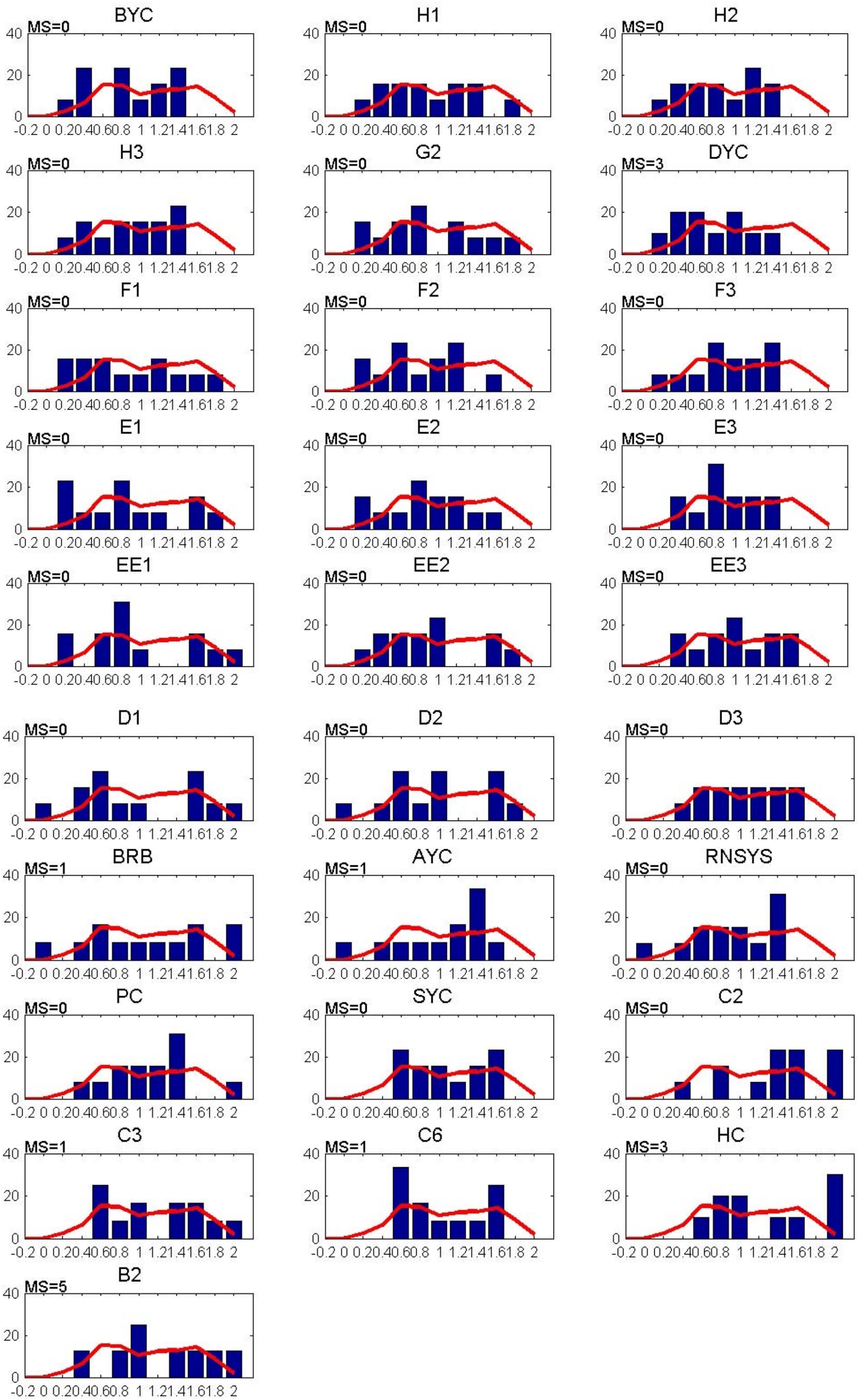


Figure 4. Water level distribution at each site during sampling 20 December 2005 to 14 March 2006. Note: MS = Missed samples

3.2.3 Precipitation

Rainfall affects both the sewage loads and the dynamics of the Harbour. Following a rain event, effluent flow increases in a combined sewage system; collected material in the sewage pipes can be flushed; and the Harbour, in response to the increased fresh water input, can become more stratified, enhancing estuarine circulation. The combination of increased flow and stratification can have a great effect on the near field behaviour of the plumes from the outfalls. These effects lag the rainfall by some time and persist for some period after the rain stops. The duration of the impact, of course, depends on the magnitude of the rain event and the condition of the watershed. For purposes of discussion we have, somewhat arbitrarily, selected a three day (72 hour) precipitation window for our analysis. The red line in Figure 5 depicts the probability distribution of precipitation integrated over the current and previous two days for this quarter (20 Dec 05 to 14 Mar 06). The blue bars on this plot represent a similar analysis performed for sampling days only. The plot indicates that our sampling has been reasonably representative with respect to precipitation, though there have been some large rainfall events missed. Over the entire period, about 40% of days had precipitation less than 5 mm in the 72 hour window. The sampling day distribution includes 47% of these “dry days”. We have over-sampled days with moderate precipitation (20-25 mm) and had no sampling days in the few high precipitation days (>30 mm).

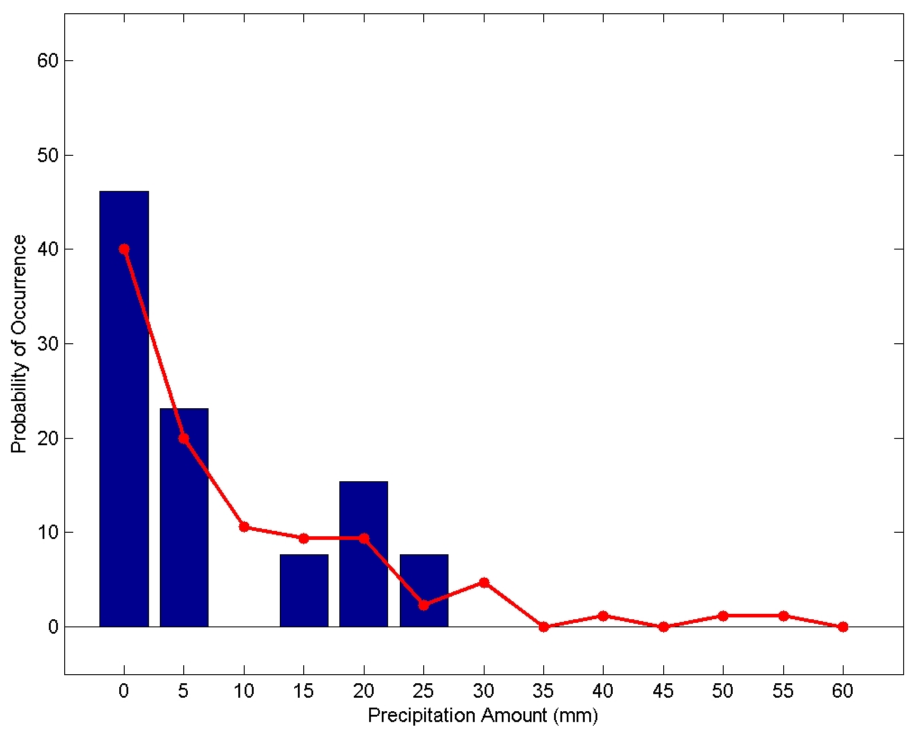


Figure 5. Probability distribution of cumulative 72 hour rainfall, 20 Dec 05 through 14 March 06

3.3 Program Changes

There have been no program changes this quarter.

3.4 Supplemental Samples

Based on recommendations from QR#2, a supplemental sample protocol has been instituted to take opportunistic samples of visible water quality features in the Harbour. These samples are acquired on a discretionary and exploratory basis when an interesting feature, such as a visible front or plume, is encountered. It is anticipated that these samples will have lower water quality than most normal samples. As such, the samples are processed for the full range of parameters specified at the beginning of the program, including parameters which have been eliminated from normal sampling due to lack of detection. During this quarter there were no supplemental samples.

3.5 Sampling Protocol

Sampling protocol/sample handling has been dictated by experience and specific lab directions. CTD casts are performed according to the manufacturer's recommendation and data analysis follows standard procedures. These protocols are documented in the project binder with weekly and quarterly reports.

4 Water Quality Results and Discussion

Results of the water quality sampling are discussed in the following sections with emphasis on compliance with water quality guidelines, and any need for modifications to the program.

4.1 Fecal Coliform

The Guidelines for Canadian Recreational Water Quality (GCRWQ) (Health and Welfare Canada 1992) evaluate the compliance with bacterial water quality criteria based on geometric mean. The geometric mean, G, of n values is defined as:

$$G(x_1, x_2, x_3, \ldots, x_n) = (x_1 \cdot x_2 \cdot x_3 \cdot \ldots \cdot x_n)^{1/n}$$

To compute geometric mean, some adjustments to the data are required. Zeros are not valid in the calculation, so ones (1's) are substituted for all zero values. The result of this is that there will be no zero counts reported at any site. An appropriate interpretation of a reported mean value of one, then, is that it is equivalent to "less than or equal to" one. Out of range values are reported by the lab as >10,000 in the units reflective of the resolution of the analysis being performed (see Out of Range Values section below and in

QR#1). For statistical purposes, these values are, relatively arbitrarily, replaced by 14,999. This is simply a number >10,000 which is easily identified.

Maps representing the geometric mean values over all samples for the seventh quarter are presented in Figure 6. In this figure, values in red exceed swimming guidelines (200 cfu/100 mL); values in blue exceed shellfishing guidelines (14 CFU/100 mL); and values in black indicate suitability for either activity. Separate maps are presented for the 1 and 10m samples. In the following discussion, it is helpful to refer to the station map in Figure 1.

For both the 1m and 10m samples, the geometric mean coliform values are high in the Inner Harbour. The magnitude of these values is similar to, but perhaps slightly lower than, last quarter. The spatial distributions at both depths are centered on the EE section, suggesting that the net effect of two layer flow in the Inner Harbour is not significant in this quarter. South of the Narrows, the maximum values at any site are in the 1m sample, while north of the Narrows the highest values are in the 10m sample (except BYC, at the mouth of the Sackville River). This relatively familiar distribution suggests a net "estuarine" flow with contaminated Inner Harbour water flowing in a lower layer into the Basin. The values in the Narrows (section E) are similar at both depths, again suggesting that the effect of the implied two layer flow is less in the Inner Harbour in this quarter than it has been in some others.

The geometric mean values exceeding the swimming guidelines occur in much of the Inner Harbour, which is classified SC, with no bacteria guidelines, and extend into the edges of adjacent "class SB" areas of the Outer Harbour and the Northwest Arm, where swimming levels are desired. Significantly, there were low, but quite consistently detectable levels all the way out to site B2. A more rigorous discussion of guideline exceedence follows.

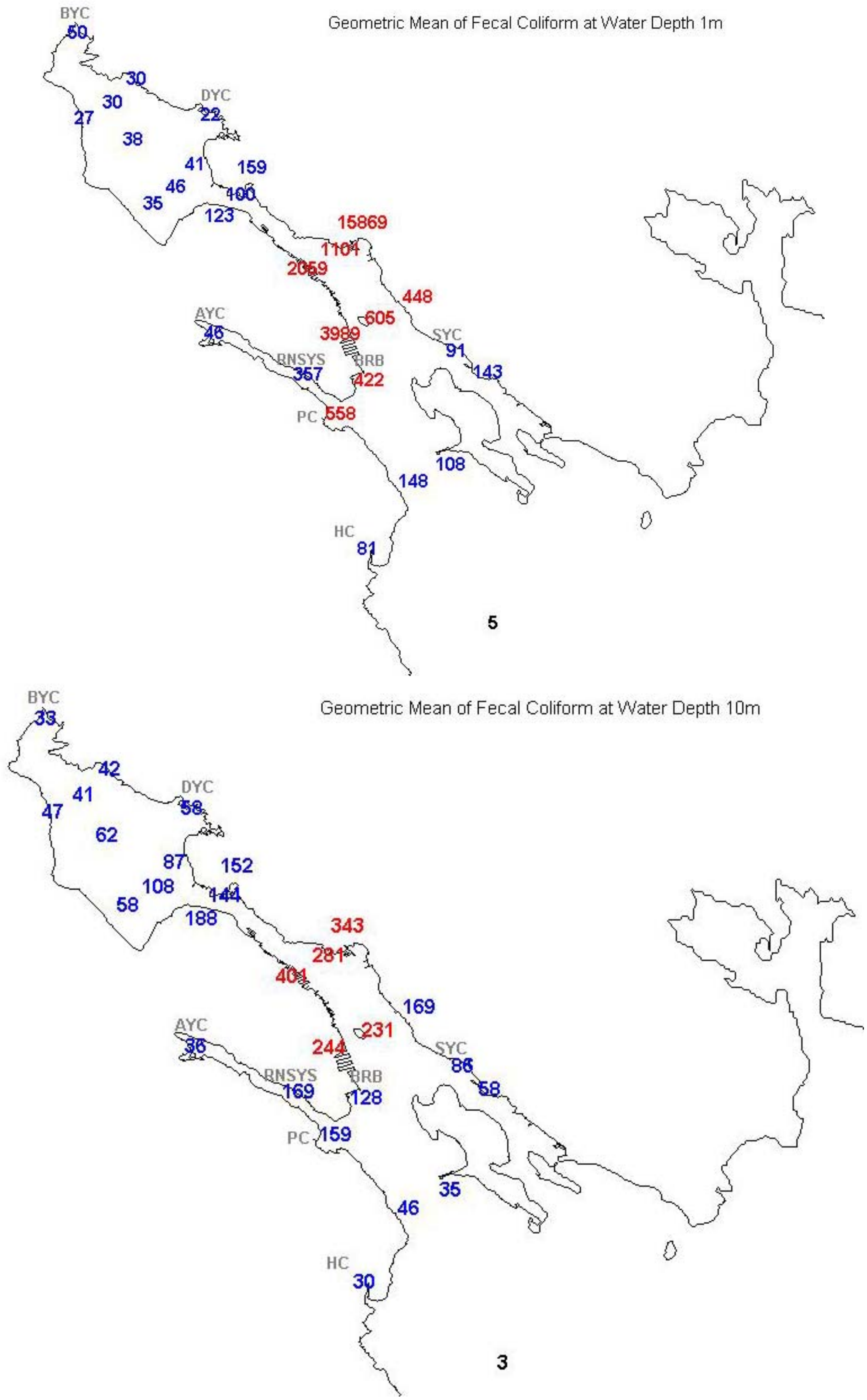


Figure 6. Fecal coliform geometric means (cfu/100mL), 20 Dec 05 to 14 Mar 06.

4.1.1 Guideline Exceedance

As presented in QR#1, the Harbour Task Force fecal coliform guidelines (Harbour Task Force, 1990) are interpreted using the methodology presented in the Guidelines for Canadian Recreational Water Quality (Health and Welfare Canada, 1992). The guidelines specify that in swimming areas, the geometric mean of at least five fecal coliform values taken within 30 days should not exceed 200 cfu/100mL, and any sample with values >400 cfu/100mL should trigger re-sampling. Our weekly sampling regime generally meets the criteria of five samples within 30 days.

Interpreting this procedure in our context results in a weekly assessment, at three levels:

1. ACCEPTABLE, defined as a geometric mean <200 cfu/100mL
2. QUESTIONABLE, geometric mean <200 cfu/100mL but one or more samples >400 cfu/100mL
3. UNACCEPTABLE, geometric mean >200 cfu/100mL.

If there are missed samples within the 30 day period, the analysis uses a reduced number of samples, rather than extending the time beyond thirty days. Tables 3 and 4 show the results of the analysis for the 1m and 10 m samples respectively. The tables represent the floating 30 day geometric mean and, in parentheses, the number of samples (max 5) used in the average. The values are colour coded to represent acceptable (green), questionable (yellow) and unacceptable (red) levels.

As seen in the tables below, for this quarter, the near surface water (1m) in the D and EE sections in Inner Harbour would be deemed unacceptable for primary body contact essentially all of the time. The distribution of sites with the highest fecal coliform counts reflects their proximity to major sewage outfalls: the EE section to the Peace Pavillion outfall, Historic Properties outfall, and many other smaller outfalls along the waterfront; site D1 to the Pier A outfall. Two of the largest outfalls in the Harbour are the Duffus St. and Tufts Cove outfalls on opposite sides of the Narrows 1-2 km south of the E section. While these are large sources quite close to the E sites, the effect of these outfalls on the E section depends greatly on the complex dynamics in the Narrows. As discussed above, in this quarter the overall geometric mean values (Figure 6) in the E section are not particularly high and are similar in both the 1 and 10m samples. Tables 3 and 4 indicate, however, that the probability of exceeding swimming guidelines (in the E section), as assessed here, is greater in the 10 m samples than the 1m samples.

In the Inner Harbour, the mean values at 10m are often “unacceptable”, and have a similar spatial distribution to those in the 1m samples, but with somewhat lower values. As discussed above, in the Basin the situation is reversed, with higher values in the 10m samples.

Table 3. 30 day geometric mean (number of samples) of 1m fecal coliform concentrations (CFU/100 ml).

	Outer Harbour				Eastern Pass.		Inner Harbour									
	B2	HC	C2	C3	C6	SYC	BRB	D1	D2	D3	EE1	EE2	EE3	E1	E2	E3
Survey79	12 (3)	199 (3)	330 (5)	390 (4)	184 (5)	164 (5)	851 (5)	3312 (5)	2522 (4)	889 (4)	4338 (5)	2174 (5)	8780 (3)	149 (5)	73 (4)	339 (4)
Survey80	12 (3)	199 (3)	288 (5)	283 (5)	264 (5)	160 (5)	473 (5)	4693 (5)	1531 (4)	718 (4)	3144 (5)	1930 (5)	10919 (4)	69 (5)	102 (5)	117 (4)
Survey81	14 (3)	124 (3)	414 (5)	315 (5)	239 (5)	183 (5)	568 (5)	4502 (5)	1524 (5)	899 (5)	2651 (5)	1527 (5)	13373 (4)	106 (5)	141 (5)	168 (5)
Survey82	5 (3)	60 (3)	298 (5)	231 (5)	154 (4)	160 (5)	459 (5)	4203 (5)	1767 (5)	819 (5)	2422 (5)	1956 (5)	15194 (4)	138 (5)	239 (5)	144 (5)
Survey83	5 (3)	60 (3)	230 (5)	203 (5)	197 (4)	270 (5)	333 (5)	5775 (5)	1121 (5)	799 (5)	2554 (5)	1789 (5)	12781 (5)	112 (5)	193 (5)	139 (5)
Survey84	12 (2)	93 (2)	175 (5)	186 (5)	229 (4)	276 (5)	503 (5)	8980 (5)	1237 (5)	1200 (5)	2062 (5)	1955 (5)	15417 (5)	231 (5)	150 (5)	174 (5)
Survey85	12 (2)	69 (3)	213 (5)	102 (5)	543 (4)	213 (5)	759 (5)	5463 (5)	1180 (5)	1224 (5)	1645 (5)	1489 (5)	16772 (5)	324 (5)	120 (5)	261 (5)
Survey86	16 (2)	86 (3)	158 (5)	136 (5)	818 (4)	265 (5)	410 (5)	4970 (5)	686 (5)	827 (5)	1479 (5)	946 (5)	12981 (5)	203 (5)	108 (5)	175 (5)
Survey87	6 (2)	54 (3)	117 (5)	93 (5)	525 (5)	127 (5)	437 (5)	3359 (5)	506 (5)	630 (5)	1135 (5)	703 (5)	10621 (5)	139 (5)	67 (5)	128 (5)
Survey88	4 (3)	75 (4)	109 (5)	63 (5)	274 (5)	72 (5)	417 (5)	2216 (5)	350 (5)	381 (5)	945 (5)	454 (5)	16023 (5)	84 (5)	63 (5)	152 (5)
Survey89	3 (4)	63 (5)	99 (5)	48 (5)	214 (5)	70 (5)	251 (5)	2274 (4)	187 (5)	218 (5)	790 (5)	323 (5)	20777 (5)	36 (5)	65 (5)	110 (5)
Survey90	3 (5)	56 (5)	90 (5)	66 (5)	72 (5)	45 (5)	178 (5)	6192 (4)	230 (5)	178 (5)	1353 (5)	280 (5)	16228 (5)	48 (5)	73 (5)	84 (5)
Survey91	1 (5)	43 (5)	62 (5)	28 (5)	24 (5)	13 (5)	201 (4)	2160 (4)	155 (5)	101 (5)	1320 (5)	359 (5)	25510 (5)	57 (5)	74 (5)	82 (5)

	Bedford Basin									Northwest Arm		
	F1	F2	F3	DYC	G2	H1	H2	H3	BYC	PC	RNSYS	AYC
Survey79	102 (5)	102 (5)	59 (5)	40 (5)	89 (5)	53 (5)	66 (5)	61 (5)	136 (5)	929 (4)	1098 (5)	185 (5)
Survey80	63 (5)	72 (5)	59 (5)	27 (5)	59 (5)	31 (5)	36 (5)	33 (5)	66 (5)	651 (4)	586 (5)	75 (5)
Survey81	70 (5)	93 (5)	81 (5)	40 (5)	80 (5)	57 (5)	59 (5)	55 (5)	111 (5)	724 (4)	357 (5)	45 (5)
Survey82	88 (5)	123 (5)	109 (5)	43 (5)	97 (5)	88 (5)	72 (5)	69 (5)	177 (5)	570 (4)	338 (5)	46 (5)
Survey83	77 (5)	139 (5)	150 (5)	45 (5)	106 (5)	81 (5)	83 (5)	99 (5)	129 (5)	514 (5)	174 (5)	40 (5)
Survey84	88 (5)	95 (5)	120 (5)	24 (5)	121 (5)	86 (5)	70 (5)	79 (5)	75 (5)	516 (5)	170 (5)	90 (5)
Survey85	58 (5)	70 (5)	97 (5)	24 (5)	90 (5)	68 (5)	53 (5)	61 (5)	41 (5)	683 (5)	276 (5)	177 (5)
Survey86	46 (5)	65 (5)	85 (5)	16 (5)	62 (5)	55 (5)	37 (5)	38 (5)	32 (5)	325 (5)	204 (5)	114 (5)
Survey87	30 (5)	37 (5)	43 (5)	8 (5)	37 (5)	29 (5)	24 (5)	21 (5)	16 (5)	513 (5)	164 (5)	98 (5)
Survey88	12 (5)	15 (5)	28 (5)	5 (4)	18 (5)	13 (5)	12 (5)	12 (5)	9 (4)	691 (5)	231 (5)	42 (5)
Survey89	11 (5)	19 (5)	33 (5)	9 (3)	16 (5)	15 (5)	15 (5)	17 (5)	17 (4)	681 (5)	91 (5)	14 (5)
Survey90	7 (5)	9 (5)	13 (5)	5 (2)	8 (5)	8 (5)	8 (5)	9 (5)	17 (4)	372 (5)	108 (5)	4 (5)
Survey91	7 (5)	9 (5)	7 (5)	3 (2)	5 (5)	3 (5)	6 (5)	6 (5)	15 (4)	577 (4)	347 (5)	5 (5)

Note: Red indicates exceedance of swimming criteria (geometric mean >200). Yellow denotes "questionable" water quality, resampling is indicated (mean < 200, but one or more samples >400). Green indicates compliance with criteria.

Table 4. 30 day geometric mean (number of samples) of 10m fecal coliform concentrations (CFU/100 mL).

	Outer Harbour				Eastern Pass.		Inner Harbour									
	B2	HC	C2	C3	C6	SYC	BRB	D1	D2	D3	EE1	EE2	EE3	E1	E2	E3
Survey79	4 (3)	41 (3)	55 (5)	52 (4)	38 (5)	36 (5)	92 (5)	167 (5)	476 (5)	114 (5)	285 (5)	201 (5)	184 (4)	290 (5)	133 (4)	318 (4)
Survey80	4 (3)	41 (3)	41 (5)	57 (5)	84 (5)	68 (5)	60 (5)	163 (5)	353 (5)	94 (5)	250 (5)	165 (5)	148 (4)	214 (5)	157 (5)	262 (5)
Survey81	6 (3)	54 (3)	45 (5)	94 (5)	151 (5)	138 (5)	93 (5)	273 (5)	383 (5)	125 (5)	334 (5)	183 (5)	162 (4)	325 (5)	220 (5)	307 (5)
Survey82	4 (3)	73 (3)	61 (5)	92 (5)	168 (4)	283 (5)	187 (5)	423 (5)	469 (5)	240 (5)	564 (5)	327 (5)	332 (4)	305 (5)	264 (5)	275 (5)
Survey83	4 (3)	73 (3)	67 (5)	113 (5)	215 (4)	341 (5)	194 (5)	509 (5)	511 (5)	326 (5)	429 (5)	393 (5)	319 (5)	282 (5)	235 (5)	228 (5)
Survey84	9 (2)	118 (2)	107 (5)	126 (5)	270 (4)	347 (5)	274 (5)	793 (5)	582 (5)	579 (5)	820 (5)	542 (5)	456 (5)	480 (5)	275 (5)	244 (5)
Survey85	9 (2)	62 (3)	104 (5)	83 (5)	206 (4)	272 (5)	356 (5)	826 (5)	631 (5)	529 (5)	677 (5)	542 (5)	489 (5)	429 (5)	229 (5)	275 (5)
Survey86	2 (2)	20 (3)	73 (5)	46 (5)	112 (4)	167 (5)	168 (5)	414 (5)	253 (5)	259 (5)	344 (5)	344 (5)	391 (5)	249 (5)	132 (5)	143 (5)
Survey87	1 (2)	14 (3)	59 (5)	36 (5)	85 (5)	97 (5)	141 (5)	214 (5)	123 (5)	163 (5)	229 (5)	195 (5)	383 (5)	159 (5)	85 (5)	87 (5)
Survey88	1 (3)	18 (4)	32 (5)	18 (5)	38 (5)	53 (5)	107 (5)	130 (5)	82 (5)	78 (5)	224 (5)	102 (5)	306 (5)	92 (5)	69 (5)	94 (5)
Survey89	1 (4)	16 (5)	20 (5)	15 (5)	37 (5)	63 (5)	73 (5)	106 (5)	74 (5)	105 (5)	204 (5)	92 (5)	326 (5)	44 (5)	52 (5)	76 (5)
Survey90	2 (5)	17 (5)	25 (5)	12 (5)	36 (5)	63 (5)	75 (5)	112 (5)	75 (5)	103 (5)	200 (5)	73 (5)	308 (5)	48 (5)	73 (5)	56 (5)
Survey91	2 (5)	20 (5)	23 (5)	10 (5)	26 (5)	56 (5)	108 (4)	120 (5)	69 (5)	93 (5)	426 (5)	123 (5)	481 (5)	62 (5)	123 (5)	77 (5)

	Bedford Basin									Northwest Arm		
	F1	F2	F3	DYC	G2	H1	H2	H3	BYC	PC	RNSYS	AYC
Survey79	84 (5)	168 (5)	104 (5)	82 (5)	101 (5)	60 (5)	45 (5)	78 (5)	26 (5)	213 (5)	162 (5)	58 (5)
Survey80	70 (5)	154 (5)	71 (5)	56 (5)	76 (5)	39 (5)	33 (5)	48 (5)	17 (5)	233 (5)	93 (5)	29 (5)
Survey81	134 (5)	195 (5)	136 (5)	81 (5)	118 (5)	73 (5)	69 (5)	85 (5)	30 (5)	371 (5)	127 (5)	32 (5)
Survey82	161 (5)	279 (5)	243 (5)	124 (5)	166 (5)	89 (5)	96 (5)	132 (5)	55 (5)	333 (5)	149 (5)	36 (5)
Survey83	138 (5)	224 (5)	254 (5)	112 (5)	176 (5)	144 (5)	147 (5)	159 (5)	83 (5)	242 (5)	111 (5)	34 (5)
Survey84	130 (5)	197 (5)	211 (5)	105 (5)	152 (5)	102 (5)	103 (5)	87 (5)	128 (5)	187 (5)	267 (5)	64 (5)
Survey85	122 (5)	195 (5)	222 (5)	88 (5)	142 (5)	95 (5)	83 (5)	65 (5)	84 (5)	246 (5)	380 (5)	75 (5)
Survey86	85 (5)	119 (5)	117 (5)	55 (5)	84 (5)	61 (5)	48 (5)	39 (5)	57 (5)	129 (5)	196 (5)	59 (5)
Survey87	59 (5)	82 (5)	69 (5)	34 (5)	55 (5)	43 (5)	27 (5)	21 (5)	29 (5)	138 (5)	219 (5)	58 (5)
Survey88	44 (5)	48 (5)	40 (5)	23 (4)	35 (5)	26 (5)	17 (5)	13 (5)	15 (4)	121 (5)	149 (5)	36 (5)
Survey89	41 (5)	47 (5)	37 (5)	25 (3)	34 (5)	32 (5)	21 (5)	20 (5)	13 (4)	94 (5)	79 (5)	18 (5)
Survey90	23 (5)	31 (5)	25 (5)	19 (2)	17 (5)	29 (5)	20 (5)	19 (5)	20 (4)	70 (5)	54 (5)	11 (5)
Survey91	18 (5)	39 (5)	32 (5)	11 (2)	17 (5)	18 (5)	17 (5)	14 (5)	14 (4)	90 (4)	140 (5)	12 (5)

Note: Red indicates exceedance of swimming criteria (geometric mean >200). Yellow denotes "questionable" water quality, resampling is indicated (mean < 200, but one or more samples >400). Green indicates compliance with criteria

There appears to be a distinct temporal trend in fecal coliform through the quarter in both the 1m and 10 m samples. In both, there is a general decrease in bacterial concentrations at most sites as the quarter progresses. Combining observations at both depths, the mean values go from a count of 13/25/18 sites (number of sites that are acceptable/questionable/unacceptable), at the start of the quarter, to 39/8/9 at the end. This is the opposite trend to last quarter and is likely at least in part due to the increase in sunlight, which contribute to the decay of FC bacteria (USEPA, 1985). The temporal trend is less obvious in sites intermittently affected by an outfall plume, most specifically EE3, D1, PC and RNSYS. In these cases bacteria decay can be a secondary process.

4.1.2 Out-of-Range Values

The adaptive lab procedure, using different fecal coliform detection ranges for different sites, developed as a result of previous recommendations, has reduced the number of out-of-range values significantly. For this quarter there were no out-of-range values. As a result of the out-of-range values experienced last quarter a seasonally adjusted scheme is under consideration.

4.2 Ammonia Nitrogen

The values obtained for this period are shown in Table 5. The laboratory "estimated quantification level" (EQL) for ammonia nitrogen is 0.05 mg/L. For the purpose of computing statistics, the EQL/2, or 0.025 mg/L was used for values below detection. Missed sample are excluded from the calculations.

Overall, in this quarter, 69% of samples had detectable levels of ammonium. Over time, there has been discussion of patterns in the data but the variability is large and the detectibility is marginal. It does appear that the highest values tend to occur in the Northern Inner Harbour and Southern Basin consistent with a sewage/runoff source. This is consistent with observations this period (Figure 7). In this quarter, the highest values and most number of detections occurred at site EE2. The values in the Narrows and Basin were on average all quite similar.

In this quarter, while there is week-to-week variability, it again seems random and there appears to be no definite temporal trend. The survey with the most consistently high values was 17 Jan (week 83), though there is no obvious reason for this. There does not appear to be a strong correlation with Ammonia concentrations and meteorological events/oceanographic conditions as is seen in the coliform data.

Table 5. Ammonia Nitrogen summary (mg/L)
Note: green highlights indicate values below detection limits (0.05 mg/L)

1m	B2	D2	EE2	E2	F2	G2	H2	mean	max
20-Dec-05	0.025	0.08	0.09	0.07	0.08	0.05	0.09	0.07	0.09
3-Jan-06	0.06	0.05	0.14	0.09	0.09	0.08	0.06	0.08	0.14
17-Jan-06	missed	0.07	0.09	0.15	0.11	0.09	0.13	0.11	0.15
31-Jan-06	missed	0.025	0.12	0.025	0.08	0.07	0.09	0.07	0.12
15-Feb-06	0.07	0.07	0.08	0.07	0.07	0.08	0.08	0.07	0.08
28-Feb-06	0.025	0.025	0.025	0.06	0.025	0.05	0.05	0.04	0.06
14-Mar-06	0.06	0.025	0.05	0.025	0.025	0.025	0.025	0.03	0.06
mean	0.05	0.05	0.09	0.07	0.07	0.06	0.08	0.07	
max	0.07	0.08	0.14	0.15	0.11	0.09	0.13		0.15

10m	B2	D2	EE2	E2	F2	G2	H2	mean	max
20-Dec-05	0.05	0.05	0.07	0.09	0.025	0.025	0.06	0.05	0.09
3-Jan-06	0.07	0.08	0.05	0.025	0.07	0.025	0.08	0.06	0.08
17-Jan-06	missed	0.1	0.08	0.09	0.09	0.12	0.07	0.09	0.12
31-Jan-06	missed	0.025	0.06	0.025	0.07	0.06	0.18	0.07	0.18
15-Feb-06	0.025	0.025	0.09	0.12	0.15	0.08	0.08	0.08	0.15
28-Feb-06	0.025	0.025	0.07	0.025	0.025	0.025	0.025	0.03	0.07
14-Mar-06	0.06	0.07	0.49	0.025	0.025	0.025	0.07	0.11	0.49
mean	0.05	0.05	0.13	0.06	0.07	0.05	0.08	0.07	
max	0.07	0.10	0.49	0.12	0.15	0.12	0.18		0.49

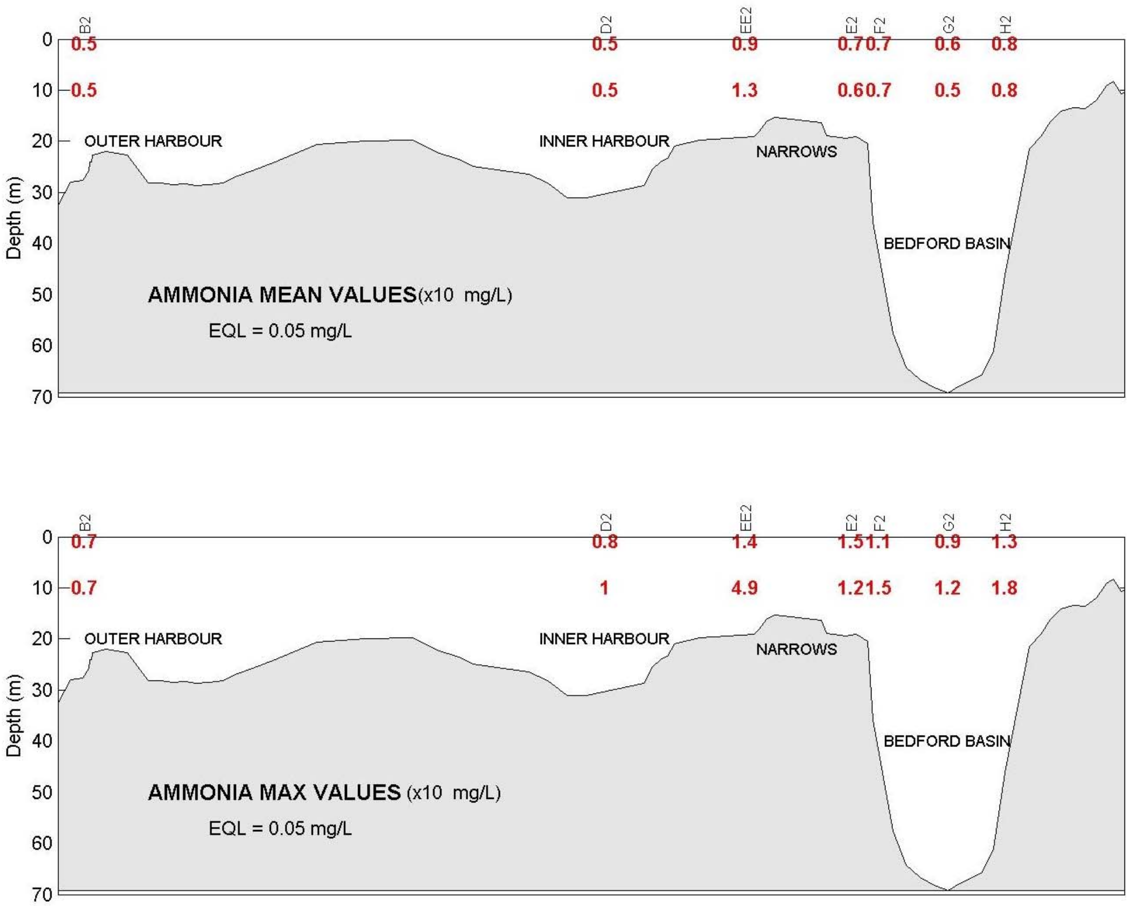


Figure 7. Mean and maximum value of ammonia nitrogen (X10 mg/L) over all seventh quarter samples

4.3 Carbonaceous Biochemical Oxygen Demand

There was no $CBOD_5$ analyses performed this quarter. Further to a recommendation in QR#2, $CBOD_5$ analysis ceased on 25 May 05, due to lack of detectable values. $CBOD_5$ analysis continues for supplemental samples, where there have been detectable values.

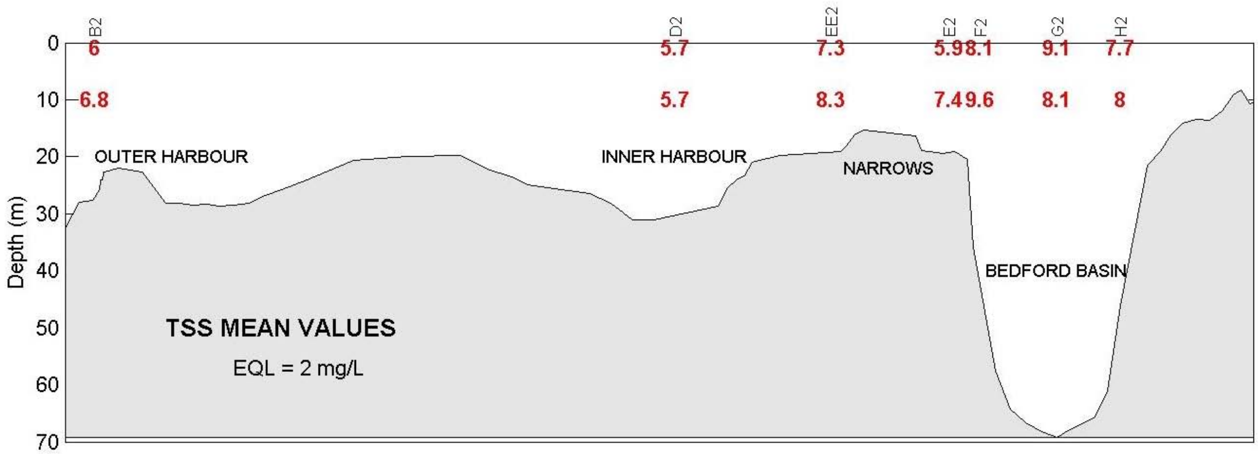
4.4 Total Suspended Solids

A summary of the TSS values for this quarter is shown in Table 6. There were no samples taken during the quarter that were below the EQL of 1 mg/L. As with total nitrogen, for samples below the detection limit, a value of one half the EQL (0.5 mg/L) is used for statistical purposes. Missed samples, of which there were four, are excluded from the calculations. In addition, the quarterly mean and max values are plotted on an along harbour bathymetric section in Figure 8. This quarter the average values were slightly lower than the previous quarter, generally in the range of 6-9 mg/L. There is no clear spatial pattern; however there is a definite increase in overall values in the last survey of the quarter (14 Mar, week 91). The average values increase consistently by about 50% to >11 mg/L. This survey also seems to mark the start of the spring phytoplankton bloom.

Table 6. Summary of TSS Data (mg/L)

1m	B2	D2	EE2	E2	F2	G2	H2	mean	max
20-Dec-05	9.0	6.0	5.0	7.0	6.0	8.0	5.0	6.6	9.0
3-Jan-06	4.0	7.0	8.0	5.0	6.0	9.0	8.0	6.7	9.0
17-Jan-06	missed	3.0	6.0	7.0	7.0	8.0	8.0	6.5	8.0
31-Jan-06	missed	3.0	4.0	7.0	11.0	9.0	7.0	6.8	11.0
15-Feb-06	4.0	3.0	6.0	6.0	5.0	7.0	6.0	5.3	7.0
28-Feb-06	5.0	6.0	9.0	5.0	8.0	9.0	7.0	7.0	9.0
14-Mar-06	8.0	12.0	13.0	4.0	14.0	14.0	13.0	11.1	14.0
mean	6.0	5.7	7.3	5.9	8.1	9.1	7.7	7.1	
max	9.0	12.0	13.0	7.0	14.0	14.0	13.0		14.0

10m	B2	D2	EE2	E2	F2	G2	H2	mean	max
20-Dec-05	5.0	4.0	6.0	7.0	8.0	7.0	6.0	6.1	8.0
3-Jan-06	8.0	4.0	10.0	6.0	10.0	6.0	10.0	7.7	10.0
17-Jan-06	missed	4.0	6.0	6.0	9.0	8.0	7.0	6.7	9.0
31-Jan-06	missed	7.0	6.0	6.0	14.0	8.0	9.0	8.3	14.0
15-Feb-06	4.0	4.0	5.0	7.0	6.0	8.0	7.0	5.9	8.0
28-Feb-06	7.0	7.0	9.0	7.0	11.0	9.0	7.0	8.1	11.0
14-Mar-06	10.0	10.0	16.0	13.0	9.0	11.0	10.0	11.3	16.0
mean	6.8	5.7	8.3	7.4	9.6	8.1	8.0	7.7	
max	10.0	10.0	16.0	13.0	14.0	11.0	10.0		16.0



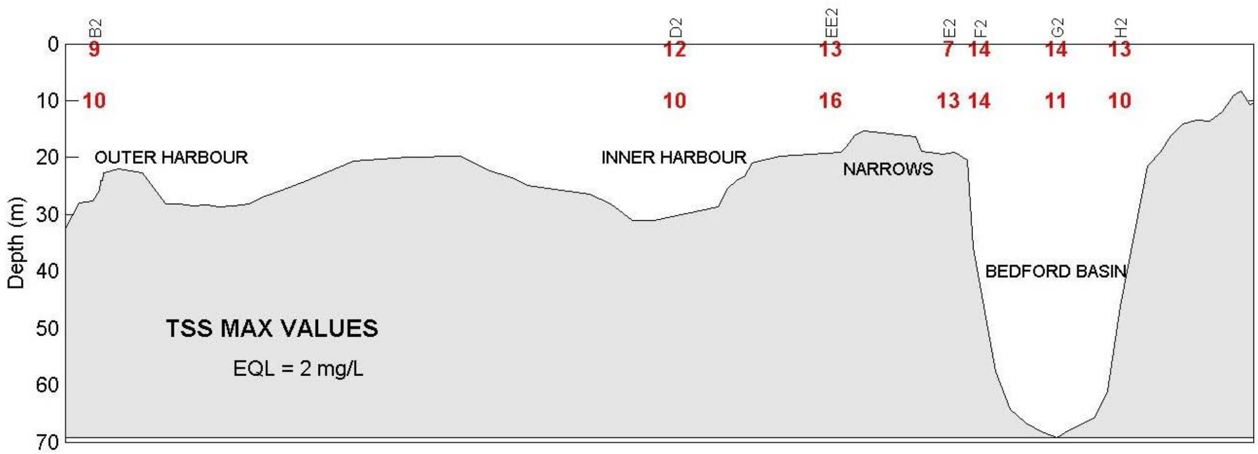


Figure 8. Mean and maximum values of total suspended solids (mg/L) over all seventh quarter samples.

4.5 Total Oils and Grease

Based on recommendations in Quarterly Report #5 regular sampling for Total Oil and Grease was discontinued on 23 Nov, survey 73. The analysis is retained for supplemental samples.

4.6 Metals

The low level metals scan was discontinued on 23 November (survey number 73). This was in response to recommendations made in Quarterly Report 4. The analysis was inadequately resolving metals concentrations in the harbour and an alternative procedure with higher resolution is being developed. Therefore, in this quarter metals there is no metals data.

4.7 Profile Data

The Bedford Basin Plankton Monitoring Program (BBPMP) is a long standing program of the Department of Fisheries and Oceans at the Bedford Institute of Oceanography. Starting in 1991, the program has collected a time series to record the weekly state of the plankton ecosystem in Bedford Basin. The purpose is to provide data to assess the environmental variability on weekly to decadal time scales. As part of the program, oceanographic profiles from the centre of Bedford Basin are collected on a weekly basis. The BBPMP data are available on their website: www.mar.dfo-mpo.gc.ca/science/ocean/BedfordBasin. The data consist of (among many other parameters) continuous profiles of temperature, salinity, fluorescence, and dissolved oxygen. The HHWQMP collects profiles of these variables at all sample stations to give a synoptic view of the oceanographic state of the harbour during the monitoring program. The spatial distribution of these parameters is discussed in the individual weekly survey reports.

The BBPMP sample site (*** coordinates) and the HHWQMP site G2 are very close to each other and are located near the deepest part of Bedford Basin. Both sites are sampled weekly, with similar, if not identical, Seabird CTDs (Conductivity Temperature and Depth profilers with additional sensors to measure dissolved oxygen and fluorescence). The HHWQMP samples on Tuesday, with contingency days on Wednesday or sometimes Thursday, while the BBPMP usually samples on Wednesday. The slight shifts in time and location are generally expected to create only minor variations in measured parameters. In the worst case, during an intrusive event where things change relatively rapidly, the two datasets might differ in the timing of the event by a week. The overlap of these two programs provides a good opportunity to inter-compare and further validate the collected data.

4.7.1 Temperature and Salinity

The HHWQMP and BBPMP temperature and salinity data from 1 Jan 06 until the end of the seventh quarter (mid March 06) are presented in Figures 9 and 10. As would be expected the temperature data for each of the two programs show a nearly perfect correspondence. The salinity data for this period also shows high degree of correspondence. Some of the fine detail of these plots varies, but this variation can mostly be reconciled by differences in contouring routines and perhaps, in some cases where change is relatively rapid, the difference in sampling day. The biggest difference is the rapid decrease in salinity at depth in the BBPMP at the very end of the quarter. This is not seen in the HHWQMP data. Whether this difference is real or not will become obvious when the next quarters data is added.

The main feature of these data sets is the freshwater melt/precipitation event noted in the week 86 (8 Feb 06) survey. This resulted in a relatively large flux of freshwater into the harbour, temporarily interrupting a trend of generally increasing salinity at the surface. This event resulted in quite high flushing in the harbour and though unusually high coliform levels in the harbour were not observed, elevated coliform levels were seen all the way to B2. The temperature data during this period is more complex as there is a slight warming period before the runoff event and subsequent cooling. This warming could have been forced by atmospheric temperatures. The minimum surface water temperature of something less than 1.5° C occurred around day 45-50.

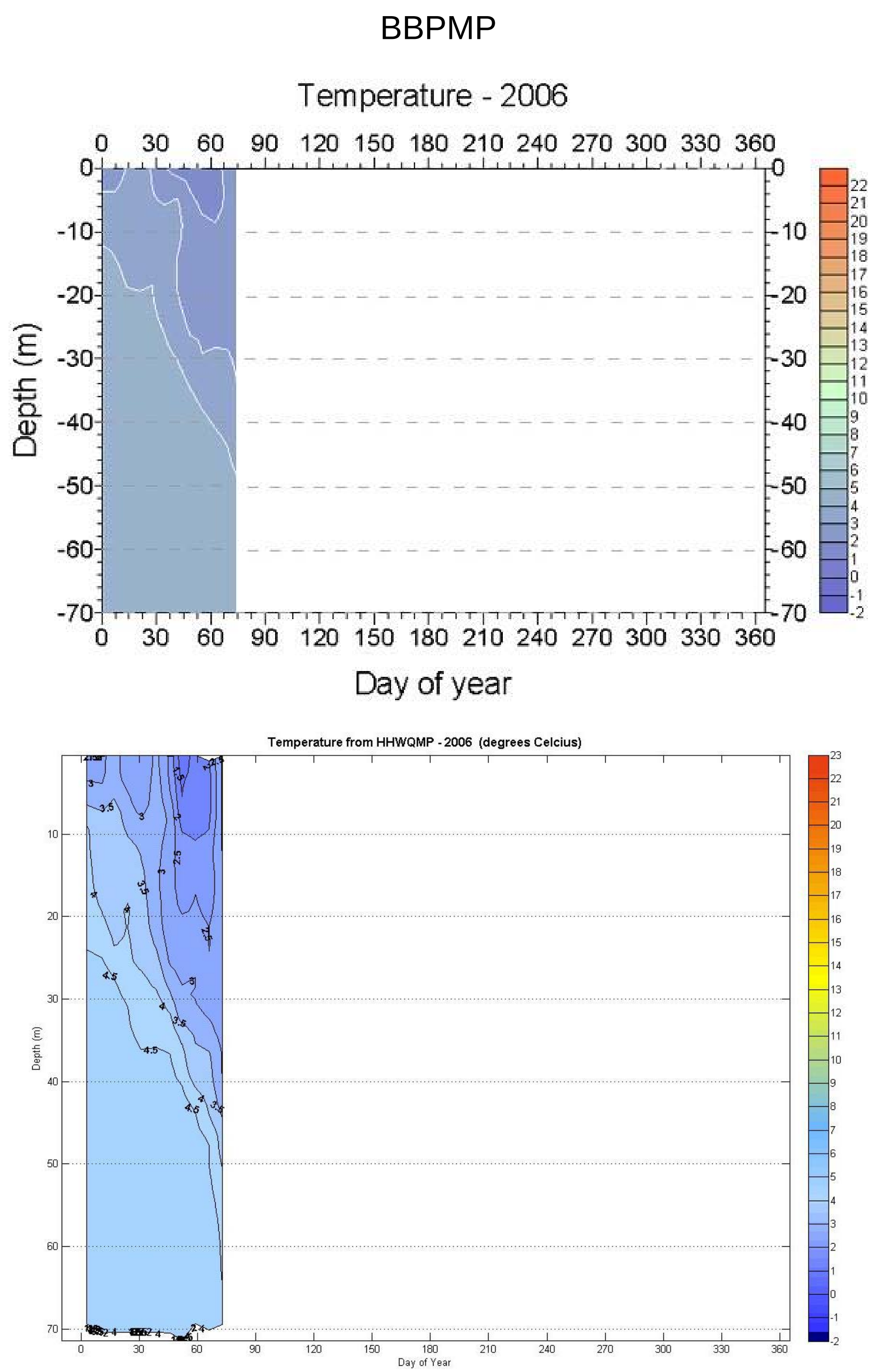


Figure 9. Comparison of BBPMP and HHWQMP temperature data from Station G2 (1 Jan to 14 Mar 06).

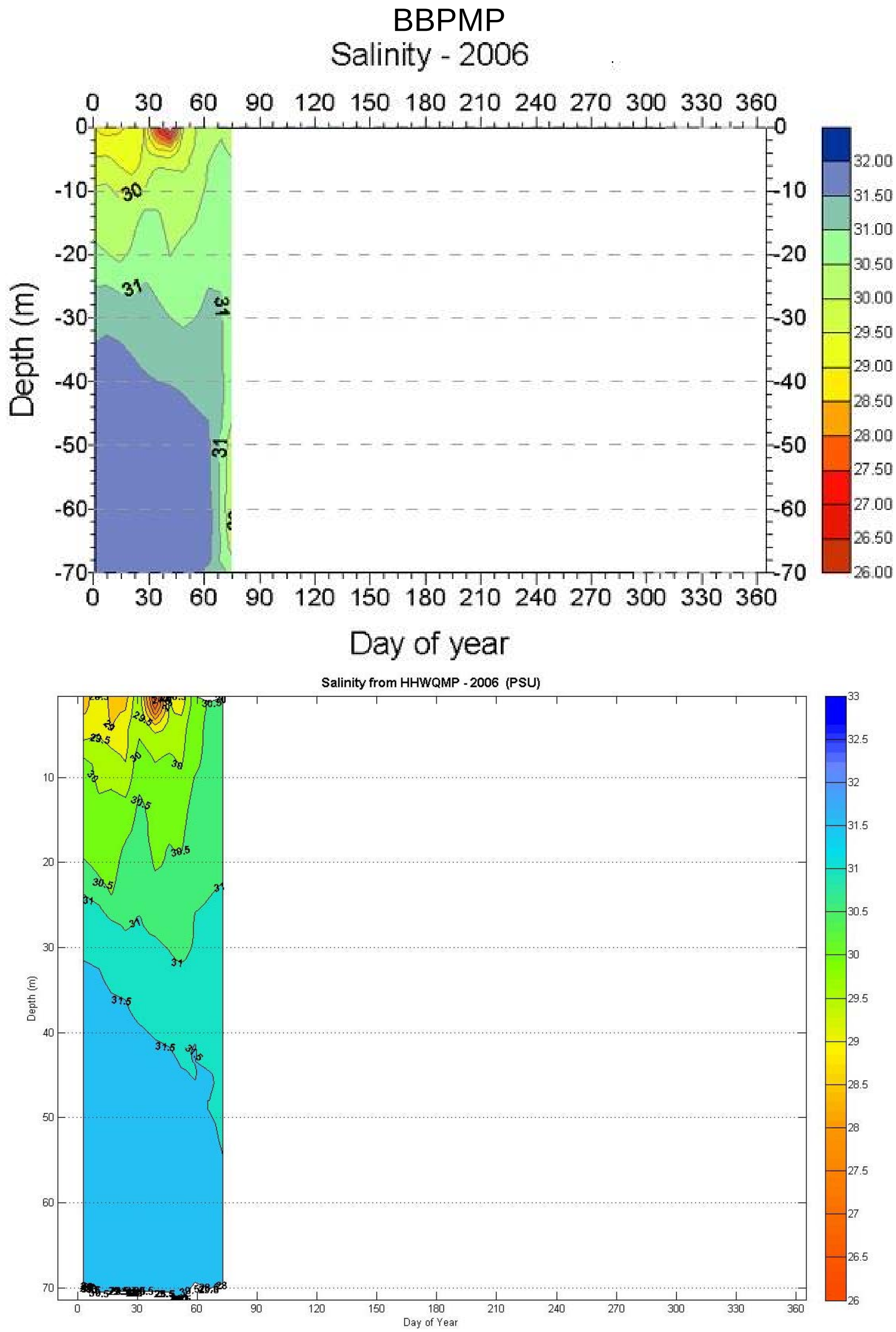


Figure 10. Comparison of BBPMP and HHWQMP salinity data from Station G2 (1 Jan to 14 Mar 06).

4.7.2 Fluorescence

The HHWQMP reported values of Chlorophyll *a* are un-calibrated, generated using the default values provided with the Seabird instrument software. As such, though the units are mg/m^3, they are really more of a measure of fluorescence than of a true measure of the mass concentration of phytoplankton. The conversion to biomass is highly dependant on many factors, including species and condition of plankton present, and is approximate even when fully calibrated with water samples. The fluorescence values can be useful when considered on a relative basis. This comparison is probably more valid within a survey, where conditions are more likely to be consistent over the harbour, than between surveys which occur under different conditions. The more separated in time, the more uncertain the comparison. Nonetheless, due to the large variability in natural plankton concentrations, the data provides useful information on the relative spatial and temporal variability of phytoplankton activity.

A comparison of HHWQMP fluorescence data with that of the BBPMP is presented in Figure 11. Note that BBPMP data is relative fluorescence presented without dimensions. Also, the BBPMP is presented on a variable scale, while the HHWQMP data is presented on a linear scale. These two factors dictate that the units and figure colours are not directly comparable. The general trends in the two data sets, however, are very similar.

The data indicate a period of low phytoplankton activity at the beginning of the quarter. After about day 30 there a short period of some activity, seemingly associated with the freshwater event discussed above. The spring bloom appears to have begun at the end of February and beginning of March (day 60+).

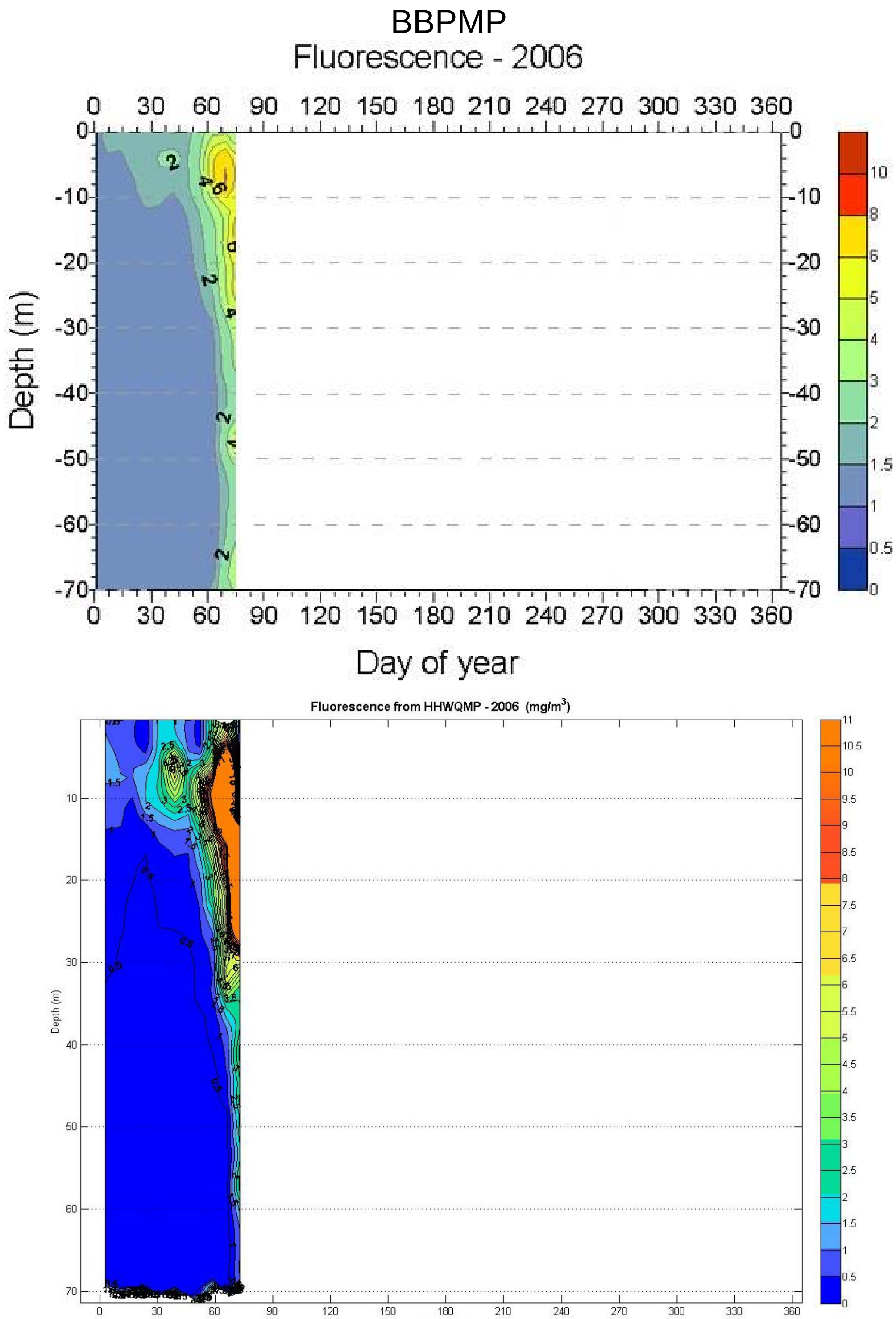


Figure 11. Comparison of BBPMP and HHWQMP fluorescence data from Station G2 (1 Jan to 14 Mar 2006).

4.7.3 Dissolved Oxygen

The dissolved oxygen data for this quarter are generally above the applicable use-specific (SA, SB and SC) guidelines. Overall, the DO levels have been quite uniform and increasing throughout the quarter from >7.0 mg/L at the start to 9-10 mg/L by the end. The usual exception is the Bedford Basin bottom water, which becomes oxygen deprived in its regular cycle of stagnation and renewal. Based on the weekly reports, at the start of the quarter, the minimum DO at the bottom of the Basin was approximately 5.5 mg/L, which is relatively high, due to a bottom water renewal in the previous quarter. This dropped through the quarter until it reached approximately 3.0 mg/L by week 89 (date) at which point it rebounded slightly, to approximately 3.5 mg/L, seemingly due to the influence of a mid-water intrusion noted in week 90. This trend, accounting for differences in units can be seen in the contour plots in Figure 12.

Figure 12 is a comparison of HHWQMP oxygen data with the BBPMP oxygen data from the beginning of the year to the end of this quarter (14 Mar 06). Note that the units for the HHWQMP plot are mL/L, rather than the mg/L, the units used in the weekly reports. These units correspond to the units of the published BBPMP data. The conversion factor from mg/L to mL/L is approximately 0.7. In this quarter, the two datasets show a high degree of correspondence. Aside from differences due to data presentation (i.e. contouring), there are only two real differences. The first is that the surface values in the HHWQMP data are lower (up to 0.5 mL/L) at higher near-surface values. This is opposite to the trend noted in previous quarters. The maximum contour in the HHWQMP plot is 6.5 mL/L, while the corresponding contour in the BBPMP plot is 7.0 mL/L. The values correspond nearly exactly deeper in the water column. The second difference is that the drop in DO levels between 20-30 m water depth in the last two weeks is not as evident in the HHWQMP as in the BBPMP data. This drop is consistent with displacement /mixing due to the minor intrusion noted in the weekly reports (report 89).

Dissolved oxygen sensors are relatively "finicky" sensors, which could explain some of the discrepancies. There are also procedures to “align” the data streams in the CTD to account for lag due to sensor position in the flow loop and instrument response time. This procedure can vary slightly from user to user and could also add to uncertainty. The sensors installed in CTDs are quite stable, however due to the nature of the CTD itself, they are very difficult to calibrate. Improved data quality can be achieved by adjusting the profile data a posteriori with independently determined high quality dissolved oxygen values from contemporaneous water samples. The BBPMP collects water samples for this purpose and analyzes them in the lab. This data can be used to adjust the profile data. For a period of time the water samples were collected and analyzed, but the presented data was not corrected. This seems to be remedied as of this quarter. The BBPMP data therefore now represents a more stable ground truth for the HHWQMP data. (Email sent to Bill Li). It is assumed that the previous BBPMP data that was removed from the web site will be returned when it is calibrated, allowing a comparison with previous HHWQMP data.

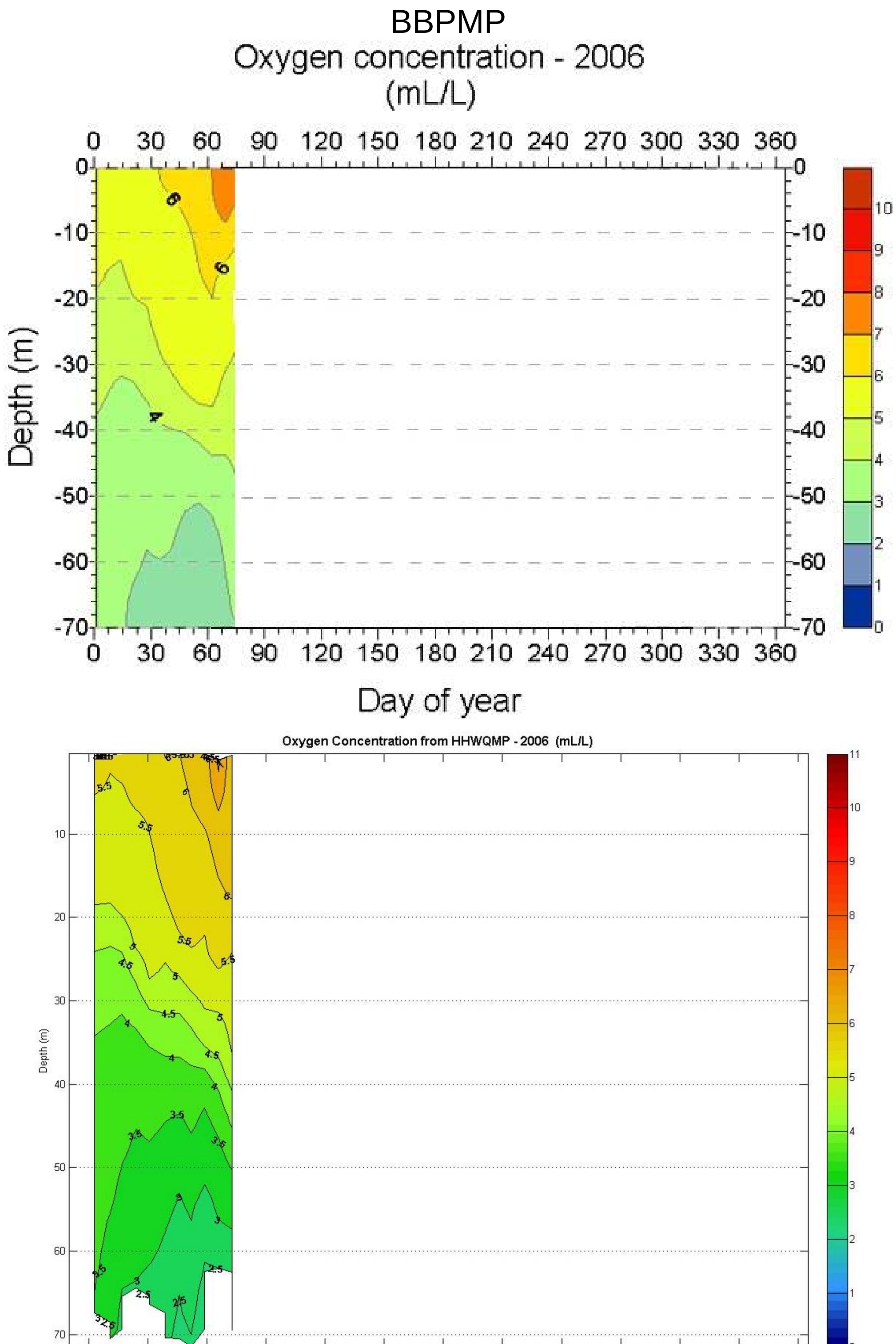


Figure 12. HHWQMP dissolved oxygen data from Station G2 (1 Jan to 14 Mar 06).

The importance of this data set has been discussed in previous reports. It is important that the data be appropriately quality controlled, and warrants continued attention.

4.8 Supplemental Samples

There were no supplemental samples taken this quarter.

5 Summary and Action Items

For each item, a brief statement of summary is provided along with any changes that occurred during the quarter, and action items resulting from discussions of the issues with the Harbour Solution Project Team. These items reflect issues arising in this quarter as well as issues carried forward from previous quarterly reports. Issues from previous reports are identified as "ongoing", and are listed with the number of the quarterly report in which they first occurred. These issues may include issues deferred until a later date, items in progress but not completed, or longer term items requiring continuing consideration.

5.1 Reporting

Weekly Reports

Summary Statement – The weekly report analysis/presentation has been refined and is essentially in final form. There may be periodic changes required to accommodate any changes in data collection.

Changes – In this quarter, reporting of the secchi depth on the DO and fluorescence contour plots began in the 3 Jan weekly report (week 81).

Action
Continued review/adjustment of reports to reflect program changes.

Quarterly Reports

Summary Statement – The Quarterly report discussion is limited to the data of that quarter. Every fourth Quarterly report includes a section reviewing the data over the last year. There remains a future reporting issue of comparison of data between years. The documentation of sampling/sample handling/lab procedures/ data analysis remains incomplete.

Changes – None

Action

1. Continued development of quarterly report content and format, with respect to project requirements.
2. Consideration of reporting implication of inter-annual data comparison.
3. Outstanding item (QR#1): Complete documentation of sampling and analysis methods along with QA/QC procedures for inclusion in the project binder.

5.2 Sampling Program

Summary Statement – Sampling continues as per the end of the sixth quarter. There is a potential bias being introduced in the NW Arm based on selection of sampling routes.

Changes –none

Action

1. Continued analysis of sampling scheme with respect to sample bias versus boat travel time with adjustment of scheduling to improve efficiency as dictated. Particularly with respect to sample scheduling in the NW Arm.
2. Continued consideration of modification to the analysis suite to include/improve/remove some parameters (see sections on measured parameters below).
3. Outstanding item (QR#3): Consider additional/or substituted sampling sites to address Herring Cove and/or recreational area issues. Note: Additional Herring Cove sampling sites have been instituted as of the writing of this report.

5.3 Water Quality Parameters

Fecal Coliform

Summary Statement – The existing variable sample resolution scheme resulted in no out-of-range values for this quarter. The previous quarter (Fall 05) was characterized by large FC contamination events and generally high fecal coliform values. While, based on experience to date, this seems characteristic of the Fall, this was the first time since variable by site analysis resolution was instituted that there were a significant number of out of range values. A seasonal shift might be justified.

The current CCME guidelines recommend enterococci over fecal coliform as a tracer of human waste contamination in salt water. There are several practical reasons for continuing to monitor fecal coliform including historical continuity, and consistency with WWTP monitoring procedures. The trend toward enterococci will likely continue and the monitoring program should recognize that at some level.

Changes - None.

Action

1. Outstanding: Evaluate the statistics of FC data from the start of the program in light of the data from quarter six and consider modifying the specified analysis resolution on a seasonal basis as appropriate.
2. Ongoing (QR#1): Consider inclusion of enterococci as an alternate and/or additional tracer.

Ammonia Nitrogen

Summary Statement – The data return for this quarter was 69%, which is consistent with previous quarters. Ammonia Nitrogen has consistently been present at levels that are is at or slightly above the detection limit of 0.05 mg/L. There are periodic higher measurements that are up to about 10 times the detection limit. Ammonia Nitrogen is an attractive tracer as it is routinely monitored in sewage treatment facilities and, therefore, has quantifiable source strength in sewage. Recognizing nitrogen as the key nutrient in marine systems, and the potential importance that nutrients have in the harbour oxygen dynamics, additional species of nitrogen continue to be considered for monitoring.

The BBPMP monitors nutrients at their site in Bedford Basin, including nitrate, silicate and phosphate; it is possible that the analysis of nitrate at an expanded number of sites could be included in the future.

Changes – None.

Action

1. Ongoing (QR#1): Consider monitoring more nitrogen species.
2. Continued discussions with BBPMP regarding cooperation in nutrient monitoring.

$CBOD_5$

Summary Statement – Based on recommendations in QR#2, $CBOD_5$ was dropped from regular analysis on 25 May 05. Until that time there was an insignificant number of regular samples with detectable $CBOD_5$ at the 5 mg/L level. $CBOD_5$ has been retained as a tracer for the supplemental sampling program

Changes – None

Action - None

Total Suspended Solids

Summary Statement – The TSS concentrations averaged 5-10 mg/L over the quarter, with no values below the reduced detection limit of 1 mg/L instituted last quarter.

Changes – None

Action – None

Total Oils and Grease

Summary Statement — Based on recommendations in QR # 5, Total Oils and Grease was dropped from regular analysis on 23 Nov 05, survey #75, due to lack of detection. It is retained in supplemental sample analysis.

Changes - None

Action – None

Metals

Summary Statement – Based on recommendations in QR # 2, the low resolution metals scan was dropped from regular analysis on 23 Nov 05, survey #75, due to lack of detection.

Changes – None

Action – Develop a modified sampling protocol for metals based on previously discussed modifications (QR#2, Section 4.6). This aim is to resolve the existing metals concentrations in the Harbour (Dalziel et al. 1989) at a resolution in time and space compatible with the scope of the project. Note: A modified metals sampling protocol has been instituted as of the writing of this report.

Fluorescence

Summary Statement - Uncalibrated fluorescence provides a relative measure of chlorophyll and hence phytoplankton activity throughout the Harbour, but the absolute quantification of phytoplankton mass requires lab analysis of water samples. The phytoplankton dynamics of the harbour is an important piece of the overall oxygen dynamics in the harbour. The BBPMP collects water samples at their site in Bedford Basin and performs the required lab analyses to extend the utility of the fluorescence data. Discussions are underway to investigate cooperation with the BBPMP to have chlorophyll analysis performed at selected HHWQMP sites throughout the Harbour.

Changes – None

Action – Ongoing (QR#3) Continue dialogue with BIO (BBPMP) to investigate procedures to enhance the utility of the HHWQMP data.

Dissolved Oxygen

Summary Statement – To date, including this quarter, oxygen levels as measured in the program, are generally high in surface waters, and chronically low in the deep water of Bedford Basin. This is consistent with the existing understanding that Bedford Basin is a fjord, in which depressed oxygen in bottom water is typical. The DO levels, except for the deep Basin water, generally meet the guidelines set by the Harbour Task Force (Halifax Harbour Task Force. 1990). However, in the previous quarter there was an extended period where the HHWQMP data have indicated that guidelines were exceeded in all areas classified SA or SB by the Harbour Task Force. There was a shorter period where the data indicated that the class SC guideline of 6 mg/L, which applies to the Inner Harbour, was exceeded at some levels in the water column.

In situ oxygen measurements are particularly sensitive to a variety of factors and there is some discrepancy between the HHWQMP profile data and data collected from other sources (i.e. other instruments deployed by HHWQMP), periodic water samples analyzed by Winkler titration, and the monitoring data of BBPMP in Bedford Basin. In general, the measured DO profiles have been somewhat lower than data obtained with other instruments and by Winkler titration; however there are significant uncertainties associated with those values as well. On the other hand, the HHWQMP data has corresponded reasonably well with the BBPMP data. In fact the HHWQMP data has general been a bit higher, than the BBPMP data. This quarter is the first where HHWQMP data is in some instances slightly lower than the BBPMP data. This likely reflects the fact that the BBPMP data is now corrected to reflect its ground truth samples (**** verify – e-mail has been sent to Bill Li). Given this uncertainty and the fact that dissolved oxygen is perhaps the most important indicator of the health of a water body, it is important to insure the quality of the collected data. If sewage load is contributing significantly to oxygen depression in the harbour it will be a critical parameter in future waste management decisions.

Changes – none

Action

1. Ongoing (QR#3) Continue dialogue with BIO (BBPMP) to coordinate sampling and maximize cross comparison of data for ground truth purposes.
2. Ongoing (QR#1) Consider alternate ground-truthing procedures, including Winkler titration or laboratory instruments.
3. Institute discussions with other parties (e.g. Dalhousie Oceanography) regarding potential calibration/verification procedures.

6 References

Dalziel, J.A., P.A. Yeats and D.H. Loring (1989). Dissolved and particulate trace metal distributions in Halifax Harbour, In: H.B. Nicholls (ed.), Investigations of Marine Environmental Quality in Halifax Harbour. Can. Tech. Rep. Fish. Aquat. Sci. 1693.

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Health and Welfare Canada (1992). Guidelines for Canadian Recreational Water Quality.

Hurlbut, S., A. Isenor, J.M. MacNeil and B. Taylor (1990). Residual Circulation in Halifax Inlet and its Impact on Water Quality, report prepared by ASA Consulting Ltd. for Nova Scotia Department of the Environment.

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