Halifax Harbour
Water Quality Monitoring Program
Quarterly Report #12

(March 28 to June 19, 2007**)**

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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 water quality surveys that include over 30 sites distributed from the Bedford Basin to the Outer Halifax Harbour. Water samples taken at 1 m and 10 m 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. From June 2004 to June 2006 the surveys were conducted weekly and from July 2006 onward, slightly modified surveys are conducted biweekly. The sample and profile data are presented in survey reports (weekly or biweekly, as appropriate) along with ancillary data including water level, wind, rainfall and other parameters. The reports are generated as inserts into a binder (JWEL and COA, 2004). Electronic copies of the reports and data files are also delivered to the client. A detailed description of the program is contained in the introduction section of the report binder.

The weekly/biweekly data sets are reviewed on a quarterly basis (13 weeks). The main objective of the quarterly reports is to summarize and evaluate the weekly/biweekly 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.

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1 Introduction

This quarterly report is a summary of Halifax Harbour Water Quality Monitoring Project (HHWQMP) data collected from 28 March to 19 June 2007 (surveys 126 to 132). The results of the individual surveys are documented in survey reports. In this report, 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. This report discusses just the twelfth quarter. Every fourth quarterly report includes an annual summary of data and trends over the previous four quarters. In the interest of making each quarterly report useful as a stand alone document, there is a significant amount of repetition of background information among the quarterly reports.

2 Reporting

The basic report format for both survey and quarterly reports 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 reports continue to be made as experience dictates. There have been no changes this quarter.

In earlier quarterly reports (up to Quarterly Report 8), the data from the center of Bedford Basin (Station G2) was compared with data collected at a nearby site by the Bedford Basin Phytoplankton Monitoring Program (BBPMP), a project of the Department of Fisheries and Oceans at Bedford Institute of Oceanography. The BBPMP discontinued the summary time series contour plots that were used for comparison purposes. The data is still available in the form of individual profile plots and time series plots at selected depths. Selected points from the BBPMP Dissolved Oxygen (DO) profiles are now compared with the HHWQMP DO for purposes of ground truthing. The time series contour plots of the HHWQMP data in the centre of the Basin are instructive in the description of longer term variability in the harbour and are continued in the annual summary discussions in every fourth quarterly report (See Appendix).

From time to time, errors are discovered in the reports after they have been issued. An Errata/Changes section is included in the Introduction section of the report binder and is updated on a quarterly basis. In addition to errors the Errata/Changes section documents the changes in the sampling program and reporting.

3 Sampling Program

Survey sampling is done on a biweekly basis as of July 2006. Sampling is conducted from one of several vessels, operated by Connors Diving Services Ltd., based at the Armdale Yacht Club. The details of the sampling program are discussed in the introduction section of the project report binder and Quarterly Report 1. The locations of the 34 regular sampling sites are included in Figure 1. These sites are a combination of historically occupied sites (Jordan, 1972), some project specific sites and identified recreational (yacht club/beach) sites. Sampling involves the collection of continuous profile data and discrete water samples at 1 and 10 m water depth. The level of analysis varies from site to site as depicted in Figure 1: CTD only (CTD only stations); CTD and coliform bacteria (Coliform stations); or CTD, Bacteria, and additional contaminant analysis (Chemistry stations). In addition to the regular sites, Figure 1 includes a sample site in Dartmouth Cove (DC), established in response to public concern. At this site, a 1 m 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. 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.

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.

3.1 Program Changes

There have been no program changes this quarter. A summary of the sampling and analysis schedules and relevant established criteria in place at the end of eleventh quarter (13 March 2007) are in Table 1. This table indicates that the carbonaceous biochemical oxygen demand ($CBOD_5$) and total oil and grease (TOG) analyses, discontinued from regular sampling due to lack detection, are now performed only for “supplemental samples”.

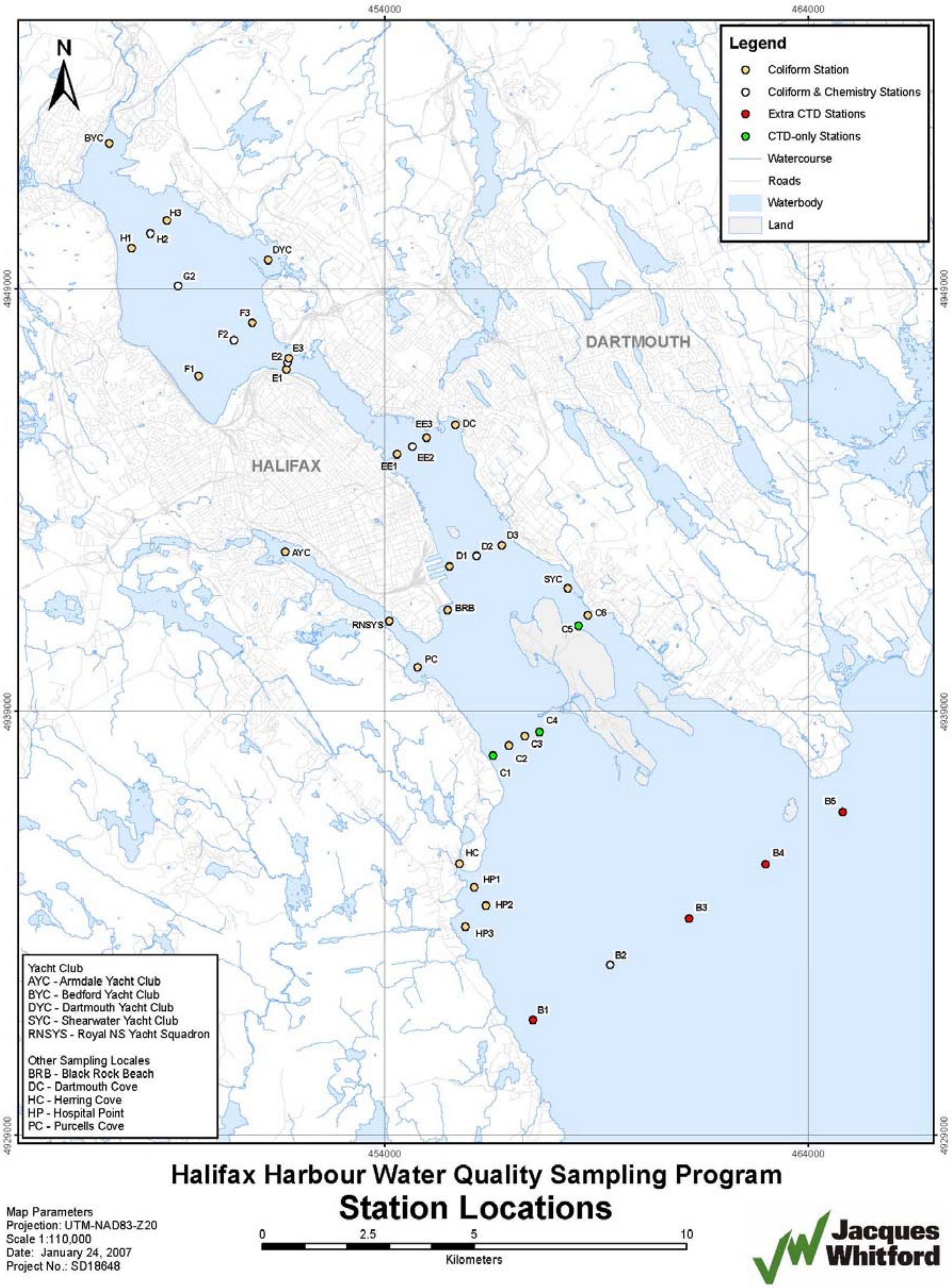


Figure 1. Halifax Inlet sample locations.

Table 1. Summary of measured parameters as of 19 June 2007.

	RDL		Harbour Task Force Guideline	Water Use Category	Sampling Stations (refer to Fig. 1)	Sampling frequency
	value	units				
Profile Data					All	biweekly
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	biweekly
Fecal Coliform	1	cfu/ 100mL	14 200 none	SA SB SC		
Chemical Samples						
CBOD	5	mg/L	none		Supplemental sites	unscheduled
Ammonia Nitrogen	0.05	mg/L	none		Chemical sites	bi-weekly
TSS	0.5	mg/L	<10% background	all	Chemical sites	bi-weekly
Total Oil and Grease	5	mg/L	10	all	Supplemental sites	unscheduled
Metal scan						bi-weekly
Cadmium	0.1	ug/L	9.3	all	Chemical sites	
Copper	0.1	ug/L	2.9	all	Chemical sites	
Lead	0.1	ug/L	5.6	all	Chemical sites	
Manganese	1	ug/L	100.0	all	Chemical sites	
Nickel	0.5	ug/L	8.3	all	Chemical sites	
Zinc	1	ug/L	86.0	all	Chemical sites	
Mercury	0.01	ug/L	0.025	all	Chemical sites	
Cobalt	0.1	ug/L	none		Chemical sites	
Iron	1	ug/L	none		Chemical sites	

3.2 Supplemental Samples

Based on recommendations from Quarterly Report 2, a supplemental sample protocol has been instituted to take opportunistic samples of visible water quality features in the Harbour, or to document unusual discharge conditions (e.g. bypass etc). These samples are acquired on a discretionary and exploratory basis when an interesting feature, such as a visible front, plume, or patch of visibly deteriorated water quality 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, in addition to the previously mentioned quasi-regular sample at DC (survey 132, 29 Jun 07), there was a supplemental sample of a visible feature at the Fairview Cove outfall.

3.3 Sampling Order

Sampling generally occurs on Tuesday, with Wednesday and Thursday as contingency days. Every survey 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 Quarterly Report 1. Wind, waves and visibility can limit operations in the Outer Harbour. 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. The sampling order for each survey in the twelfth quarter is presented in Table 2.

Also, Table 2 lists the missed stations and additional samples (described above) for each survey. During this quarter, the only missed station was B2. This was missed due to weather conditions in Survey 129 (8 May 07).

3.4 Data Return

In addition to the missed sites detailed above, there were other sporadic data losses generally associated with quality control issues that were discovered during data processing. These are discussed in the individual survey reports. All factors considered, the overall data return for the quarter is summarized in Table 3.

3.5 Sampling Bias

There are two issues regarding potential bias in the dataset. The first is the relative bias between sites, that is, 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 that 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 twelfth quarter.

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

Date	28-Mar-07	10-Apr-07	24-Apr-07	8-May-07	23-May-07	5-Jun-07	19-Jun-07
Survey	126	127	128	129	130	131	132
1	B2	EE3	AYC	D1	BRB	BRB	D3
2	HP3	EE2	RNSYS	EE1	D1	D1	EE3
3	HP2	D3	BRB	E1	D2	E1	F3
4	HP1	D2	D1	E3	EE1	E2	DYC
5	HC	SYC	D2	E2	EE2	E3	H3
6	C1	C6	EE1	F1	E1	F1	BYC
7	C2	C5	EE2	G2	E3	G2	H1
8	C3	C4	E3	H1	E2	H1	H2
9	C4	C3	E1	BYC	F1	BYC	G2
10	BRB	B2	E2	H3	F2	H2	F1
11	D1	HP3	F1	H2	G2	H3	F2
12	D2	HP2	F2	DYC	H1	DYC	E1
13	EE1	HP1	G2	F3	H2	F3	E3
14	EE2	HC	H1	F2	BYC	F2	E2
15	E3	C1	H2	EE3	H3	EE1	EE1
16	E1	C2	BYC	EE2	DYC	EE3	EE2
17	E2	BRB	H3	D3	F3	EE2	D1
18	F2	D1	DYC	D2	EE3	D2	BRB
19	F1	F1	F3	SYC	D3	D3	D2
20	G2	G2	EE3	C6	SYC	SYC	SYC
21	H1	H1	D3	C5	C6	C6	C6
22	H2	BYC	SYC	C4	C5	C5	C5
23	BYC	H3	C6	C3	C4	C3	C3
24	H3	H2	C5	HP3	C3	C4	C4
25	DYC	DYC	C4	HP2	B2	B2	B2
26	F3	F3	C3	HP1	HP3	HP3	HP3
27	EE3	F2	B2	HC	HP2	HP2	HP2
28	D3	E1	HP3	C1	HP1	HP1	HP1
29	SYC	E3	HP2	C2	HC	HC	HC
30	C6	E2	HP1	BRB	C1	C1	C2
31	C5	EE1	HC	PC	C2	C2	C1
32	PC	PC	C1	RNSYS	PC	PC	PC
33	RNSYS	RNSYS	C2	AYC	RNSYS	RNSYS	RNSYS
34	AYC	AYC	PC		AYC	AYC	AYC
No data				B2			
Supplemental			Fairview Cove				DC

Table 3. Quarter twelve data return.

Chemical	**Target**	**Achieved**	**Percent Return**
7 sites			
NH_3	98	96	
TSS	98	96	
Metal Suite	98	95	
Mercury	98	95	
Total	**392**	**382**	**97%**

Bacteria	**Target**	**Achieved**	
28 sites			
F Coliform	434	431	
Total	**434**	**431**	**99%**

Profiles	**Target**	**Achieved**	
31 sites			
C-T	238	230	
Dissolved Oxygen	238	230	
Chlorophyll	238	230	
Total	**714**	**690**	**97%**
All data records	**1540**	**1503**	**98%**

3.5.1 Time of Day

Sewage flows have significant regular diurnal variations that can affect the water quality in the Harbour on short timescales. In residential areas there are generally two flow peaks a day, the largest occurring in the morning, and the second in the evening. In systems with relatively short flow distances these generally occur around 0800 – 0900 and 2100. In commercial areas the flows are much more uniform during the day and low at night. 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, however 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 shows the sampling time at each site since the start of the program in June 2004. The data from the twelfth 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 that 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.

The diagram indicates that overall there has been an afternoon bias in the Outer Harbour Stations, a result of weather conditions this quarter. This creates a morning bias in the remainder of the data. This is strongest in the Basin and Narrows (section E). In the remainder of the Inner Harbour sampling is relatively uniformly distributed but all before 1330. The Northwest Arm that has a built in early morning/late afternoon bias had six of seven surveys in the late afternoon.

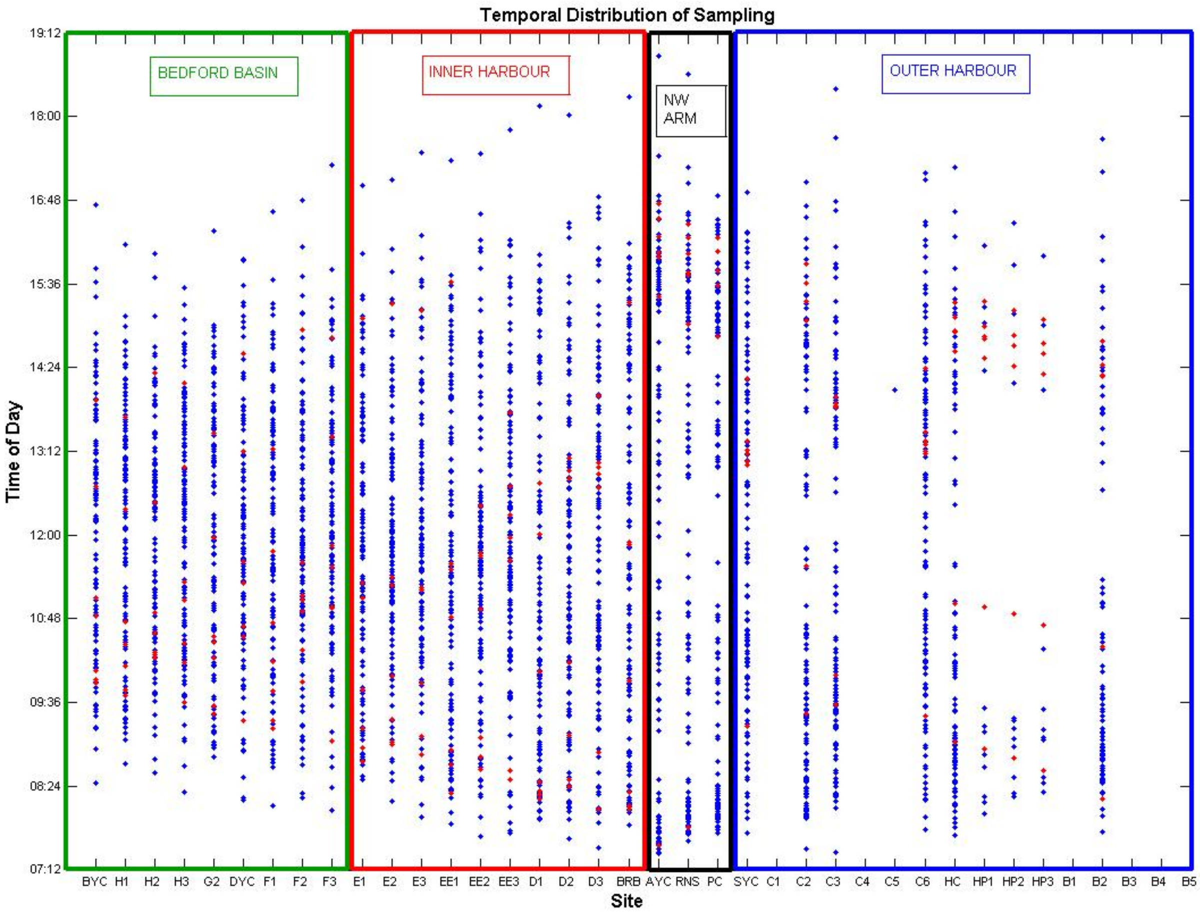


Figure 2. Temporal sampling distribution by site over entire program. Red markers denote points from 28 March to 19 June 2007.

3.5.2 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 shoreline 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 mostly of longer period and, except in large 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 overridden 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/biweekly sampling. Sampling that occurs on the same day every second week 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 March to June 2007 is shown in Figure 3. In an ideal situation each site would be sampled in a distribution similar to the overall baseline 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, as represented by the red line recreated from Figure 3.

This shows that for this quarter, in the Basin the water level distribution is relatively well represented. In the Inner Harbour the results are mixed with some site biased toward higher water levels and some toward lower water levels. In the Outer Harbour the distribution is relatively well sampled but the higher and lower levels are somewhat undersampled. Because sampling has been switched to bi-weekly, the number of samples in a quarter has been roughly halved. Therefore a somewhat deteriorated representation of the water level range is inevitable. If more detailed analysis is performed, particularly in the Inner Harbour where water level/tidal phase is more important, the analysis may have to include the tidal phase explicitly.

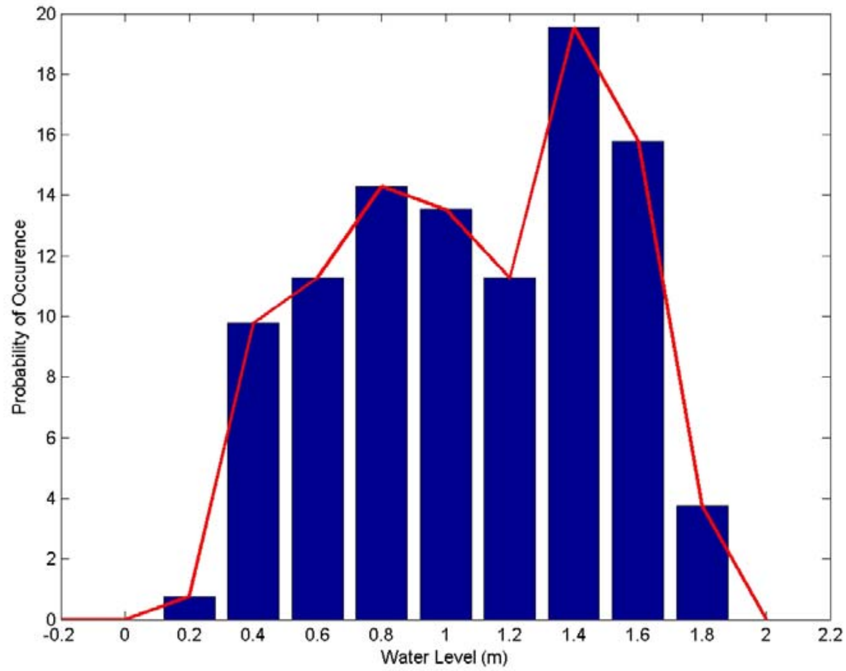


Figure 3. Probability distribution of water levels in Halifax, March to June 2007.

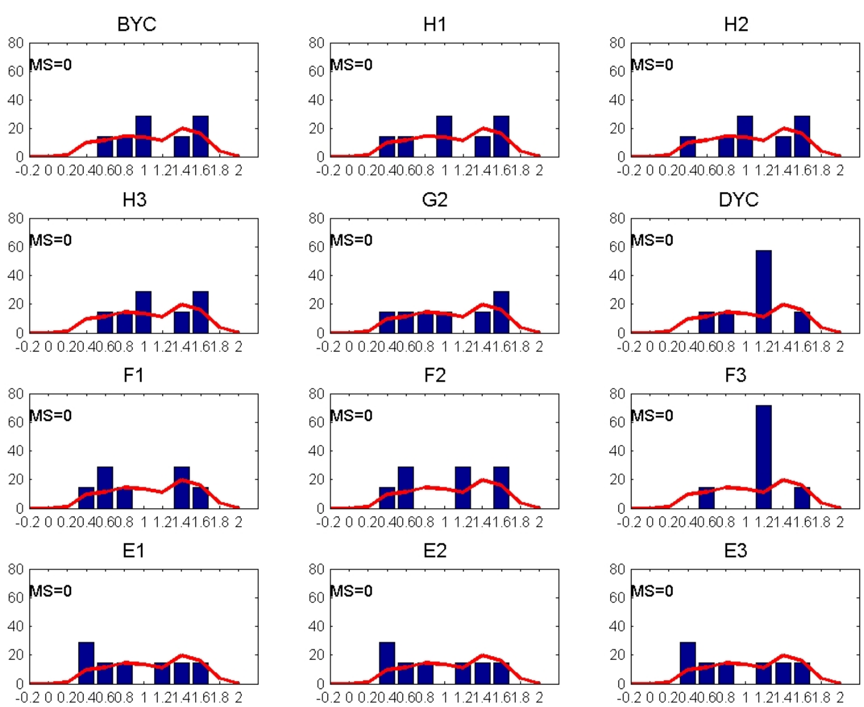


Figure 4a. Water level distribution at each site during sampling 28 March to 19 June 2007. Note: MS = Missed samples.

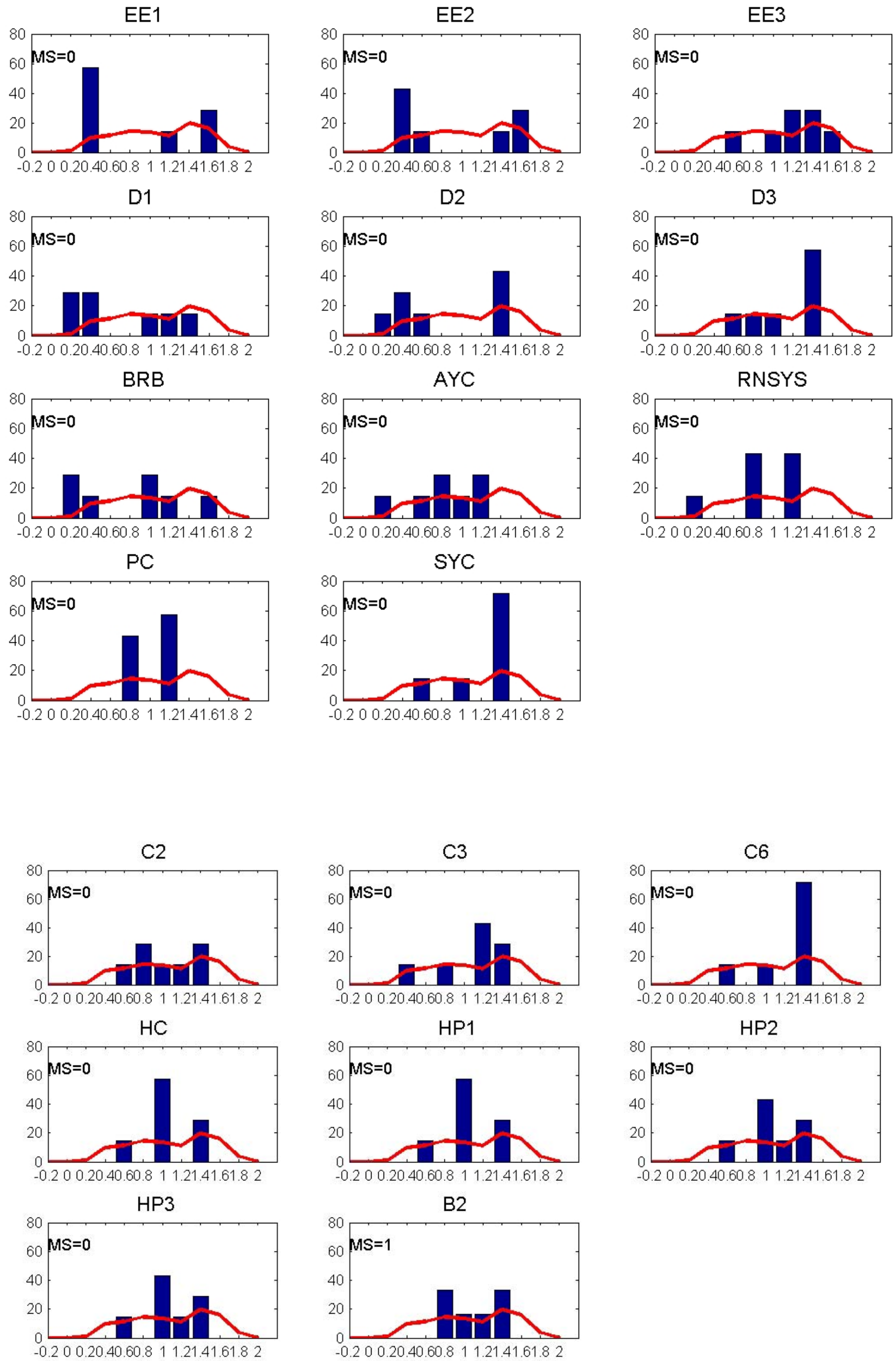


Figure 4b. Water level distribution at each site during sampling 28 March to 19 June 2007.
Note: MS = Missed samples.

3.5.3 Precipitation

Rainfall affects both the sewage loads and the dynamics of the Harbour. In a combined sewer system, like in Halifax, increased flow due to a rainfall event can mobilize material that has collected in the sewer pipes in low flow conditions resulting in quite high loads. Additionally, in response to the increased fresh water input, the harbour can become more stratified, enhancing estuarine circulation. The combination of increased flow and stratification can have a significant effect on the near field behaviour of the plumes from the outfalls. These effects lag the rainfall and persist for a period of time 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 (28 March to 19 June, 2007). The blue bars on this plot represent a similar analysis performed for sampling days only. The plot indicates that our sampling has been biased toward dry weather. Days with no precipitation for the previous 72 hours occurred 50% of the time but represent 70% of out sampling days. There was at least one event of 55mm that was not sampled.

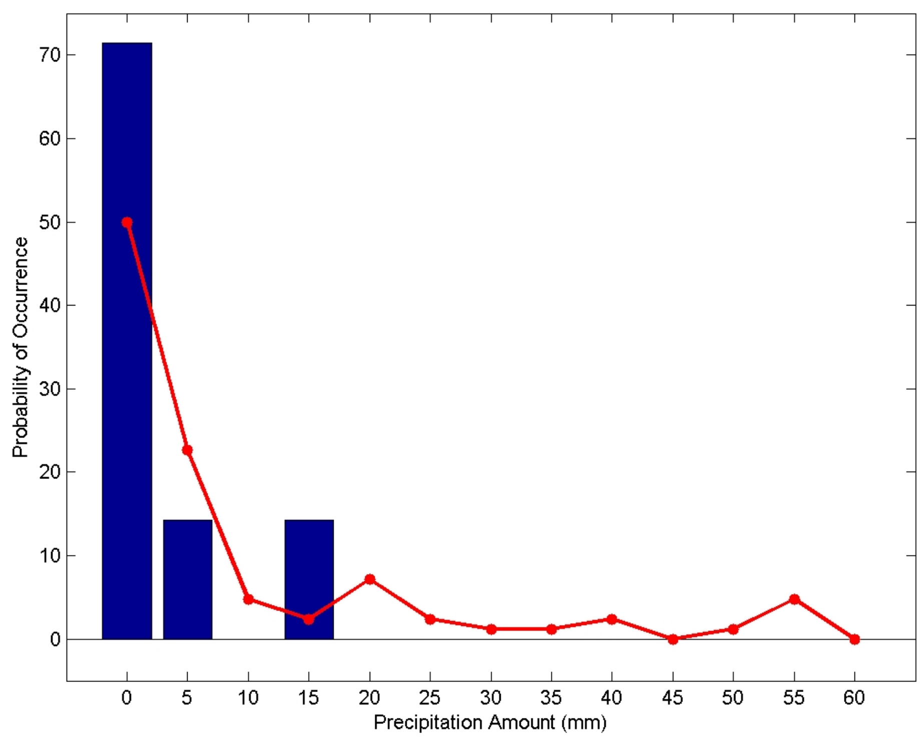


Figure 5. Probability distribution of cumulative 72 hour rainfall, 28 March to 19 June 2007.

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

4.1.1 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 are no out-of-range values.

4.1.2 Quarterly Means

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:

$$G(x_{1,}x_{2,}x_3,\ldots,x_n) = (x_1\cdot x_2\cdot x_3\cdot\ldots\cdot x_n)^{1/n}$$

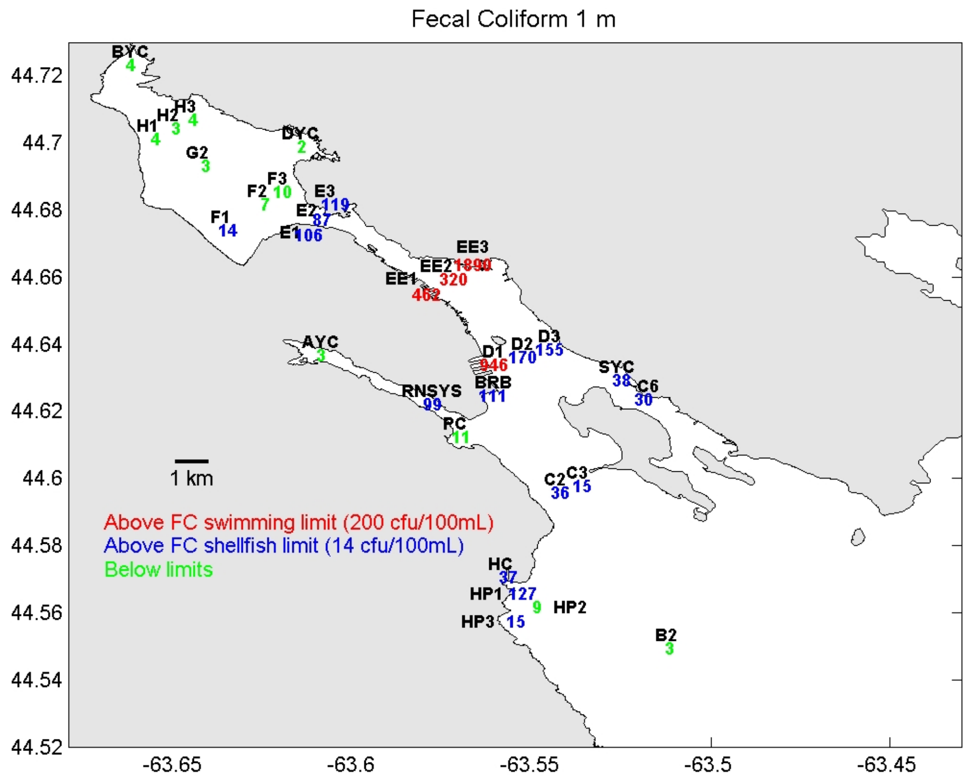
To compute geometric mean, some adjustments to the data are required. Zeros are not valid in the calculation, so ones (1's) are substituted for all zero values. The result of this is that there will be no zero counts reported at any site. An appropriate interpretation of a reported mean value of one, 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. For this analysis out of range values are replaced by 10,000.

Maps representing the geometric mean values over all samples for the twelfth 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 green indicate suitability for either activity. Separate maps are presented for the 1 and 10m samples.

For the 1 m samples, the mean coliform levels are relatively low with values greater than two hundred at only four sites in the Inner Harbour. In the 10m samples there are only two sites greater than two hundred. The center of the spatial distribution at 10m (between section E and EE) is shifted northward with respect to the center of the distribution at 1m (between section EE and D). This suggests a net estuarine flow (out at the surface, in at the bottom) for the quarter. This is consistent with increased freshwater input in the spring.

South of the Narrows, the maximum values at any site are generally in the 1 m sample. North of the Narrows, in the Bedford Basin, the highest values are as usual, generally in the 10 m sample. This relatively familiar distribution suggests contaminated Inner Harbour water flowing in a lower layer into the Basin. The pattern is not as robust as normal, perhaps due to the temporary diversion of sewage from the Duffus St. outfall in the Narrows to the outfall (CSO) in Fairview Cove. However, the effect of this diversion is not clearly evident in these distributions. The vertical concentration difference at F1, the site closest to the Fairview Cove outfall, is almost nonexistent, though the concentrations are quite low. The transition in the vertical distribution is quite far south, between sections E and EE.

The geometric mean values exceeding the swimming guidelines are limited to the Inner Harbour, where there are no Task Force guideline limits on bacteria. A more rigorous discussion of guideline exceedance follows.



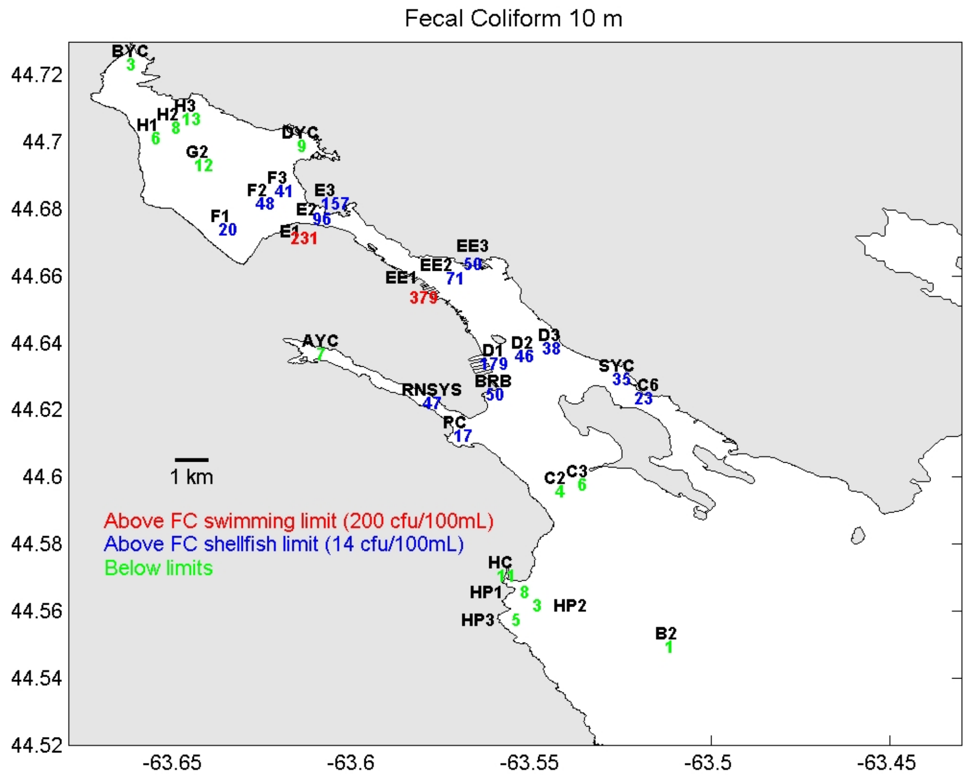


Figure 6. Fecal coliform geometric means (cfu/100mL) at 1m and 10m, 28 March to 19 June 2007.

4.1.3 Guideline Exceedance

As presented in Quarterly Report 1, the Harbour Task Force fecal coliform guidelines (Harbour Task Force, 1990) are interpreted using the methodology for swimming areas, presented in the Guidelines for Canadian Recreational Water Quality (Health and Welfare Canada, 1992). The recreational 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. This strictly applies only to areas classified SB (recreational) by the Task Force (Table 1). The implications for areas classified SA and SC are discussed subsequently. The original weekly sampling regimen resulted in five samples within 30 days and allowed a fairly rigorous application of this analysis. The change to biweekly sampling in quarter nine means that the data do not meet the criteria of five samples within 30 days. The analysis is continued using a three sample floating average to meet the 30 day window but sacrifice the five sample criteria. We feel that the analysis, though no longer a rigorous application of the criteria, remains instructive.

Interpreting this procedure in our context results in a biweekly 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.

In the following discussion the terms “acceptable”, “questionable” and “unacceptable” will refer to these primary contact levels and not the Harbour Task Force SA, SB and SC guidelines. These guidelines will be discussed subsequently.

Tables 4 and 5 show the results of the analysis for the 1 m and 10 m samples respectively. The tables represent the floating 30 day geometric mean and, in parentheses, the number of samples (max 3) used in the average. The values are colour coded to represent acceptable (green), questionable (yellow) and unacceptable (red) levels.

1 m Samples

As seen in the Table 4 below, for this quarter, the near surface water (1 m) at section EE and site D1 in Inner Harbour would be deemed “unacceptable” for primary body contact essentially all of the time. D2 and D3 are “unacceptable” for much of the time and BRB was “unacceptable” for the last two surveys. Interestingly there are few instances of “unacceptable” water quality at section E and not a single occurrence in the Basin. Other than this there is consistent "unacceptable" water quality in the last half of the quarter at site HP1. This suggests a northward flow from the Tribune Head outfall to the HP1 site.

Eastern Passage and the Northwest Arm have “acceptable” water quality throughout the quarter.

10 m Samples

Referring to Table 5, the 10m floating mean values for this quarter show “unacceptable” water quality at 10m only sporadically and but for one in the Basin, only in the Inner Harbour. There are some “unacceptable” values in section E and one at site F2, all further up-harbour than in the 1m samples. This is consistent with the pattern seen in the quarterly mean values.

Task Force Guidelines

Most of the sites that are regularly deemed unacceptable for swimming are in the Inner Harbour that is classified SC by the Halifax Harbour Task Force. There are no Task Force limits on bacteria in this area. The greatest number of Task Force guideline exceedances, normally occur in the class SB areas just outside the Inner Harbour; that is, in the southern Basin, Black Rock Beach and the Northwest Arm, particularly the PC and RNSYS sites. This quarter there are limited SB guideline exceedances and all but one are in the South at BRB and Section C. The Outer Harbour is the only region classified SA.

This has a lower requirement (14 cfu/100 mL) than the swimming criteria. The sites within the Task Force "Outer Harbour" boundaries are B2, HC and the HP section. HC (Herring Cove) seldom meets the SA criteria. The HP sites sometimes meet the SA guideline, but these sites are periodically affected by the plume from the Tribune Head outfall. This quarter, site B2 meets the SA criteria all of the time.

Table 4. 30 day geometric mean (number of samples) of 1 m fecal coliform concentrations (cfu/100 ml).

	Outer Harbour							Northwest Arm			Eastern Pass		Inner Harbour		
	B2	HP1	HP2	HP3	HC	C2	C3	PC	RNSYS	AYC	C6	SYC	BRB	D1	D2
Survey126	9 (3)	17 (3)	16 (3)	22 (3)	15 (3)	453 (3)	87 (3)	35 (3)	154 (3)	3 (3)	58 (3)	25 (3)	74 (3)	889 (3)	390 (3)
Survey127	13 (3)	36 (3)	24 (3)	22 (3)	15 (3)	403 (3)	152 (3)	10 (3)	65 (3)	1 (3)	14 (3)	38 (3)	66 (3)	1269 (3)	276 (3)
Survey128	6 (3)	148 (3)	14 (3)	4 (3)	28 (3)	92 (3)	29 (3)	7 (3)	22 (3)	3 (3)	16 (3)	68 (3)	49 (3)	1061 (3)	338 (3)
Survey129	2 (2)	585 (3)	4 (3)	4 (3)	25 (3)	11 (3)	4 (3)	3 (3)	34 (3)	2 (3)	8 (3)	24 (3)	22 (3)	818 (3)	118 (3)
Survey130	1 (2)	470 (3)	2 (3)	4 (3)	27 (3)	6 (3)	3 (3)	6 (3)	105 (3)	2 (3)	4 (3)	10 (3)	111 (3)	722 (3)	205 (3)
Survey131	1 (2)	582 (3)	7 (3)	11 (3)	50 (3)	4 (3)	3 (3)	6 (3)	93 (3)	3 (3)	38 (3)	33 (3)	364 (3)	293 (3)	99 (3)
Survey132	1 (3)	212 (3)	10 (3)	42 (3)	131 (3)	10 (3)	11 (3)	14 (3)	185 (3)	3 (3)	59 (3)	94 (3)	856 (3)	1166 (3)	108 (3)

	Inner Harbour							Bedford Basin								
	D3	EE1	EE2	EE3	E1	E2	E3	F1	F2	F3	DYC	G2	H1	H2	H3	BYC
Survey126	386 (3)	1813 (3)	193 (3)	4518 (3)	53 (3)	62 (3)	73 (3)	5 (3)	3 (3)	4 (3)	1 (2)	3 (3)	4 (3)	3 (3)	7 (3)	4 (3)
Survey127	463 (3)	842 (3)	231 (3)	2700 (3)	20 (3)	13 (3)	30 (3)	4 (3)	2 (3)	2 (3)	1 (2)	2 (3)	2 (3)	2 (3)	5 (3)	3 (3)
Survey128	247 (3)	394 (3)	393 (3)	770 (3)	19 (3)	12 (3)	35 (3)	9 (3)	4 (3)	4 (3)	1 (3)	2 (3)	3 (3)	2 (3)	3 (3)	1 (3)
Survey129	171 (3)	447 (3)	308 (3)	2002 (3)	119 (3)	77 (3)	137 (3)	14 (3)	4 (3)	15 (3)	1 (3)	2 (3)	1 (3)	1 (3)	1 (3)	1 (3)
Survey130	65 (3)	207 (3)	409 (3)	551 (3)	525 (3)	154 (3)	120 (3)	18 (3)	9 (3)	31 (3)	2 (3)	3 (3)	4 (3)	1 (3)	3 (3)	4 (3)
Survey131	44 (3)	290 (3)	408 (3)	2131 (3)	1570 (3)	400 (3)	277 (3)	59 (3)	16 (3)	27 (3)	3 (3)	7 (3)	6 (3)	3 (3)	3 (3)	9 (3)
Survey132	56 (3)	122 (3)	722 (2)	469 (2)	186 (3)	139 (3)	170 (3)	36 (3)	26 (3)	15 (3)	6 (3)	5 (3)	12 (3)	6 (3)	8 (3)	14 (3)

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 5. 30 day geometric mean (number of samples) of 10 m fecal coliform concentrations (cfu/100 mL).

	Outer Harbour							Northwest Arm			Eastern Pass		Inner Harbour		
	B2	HP1	HP2	HP3	HC	C2	C3	PC	RNSYS	AYC	C6	SYC	BRB	D1	D2
Survey126	2 (3)	14 (3)	4 (3)	10 (3)	10 (3)	14 (3)	7 (3)	59 (3)	95 (3)	7 (3)	33 (3)	65 (3)	70 (3)	128 (3)	36 (3)
Survey127	2 (3)	3 (3)	3 (3)	2 (3)	6 (3)	5 (3)	6 (3)	22 (3)	37 (3)	5 (3)	33 (3)	60 (3)	38 (3)	312 (3)	45 (3)
Survey128	1 (3)	2 (3)	2 (3)	1 (3)	4 (3)	2 (3)	4 (3)	8 (3)	20 (3)	8 (3)	33 (3)	27 (3)	14 (3)	349 (3)	45 (3)
Survey129	1 (2)	3 (3)	2 (3)	1 (3)	2 (3)	1 (3)	4 (3)	3 (3)	26 (3)	3 (3)	10 (3)	7 (3)	14 (3)	610 (3)	41 (3)
Survey130	1 (2)	4 (3)	2 (3)	2 (3)	5 (3)	2 (3)	2 (3)	3 (3)	18 (3)	3 (3)	7 (3)	7 (3)	35 (3)	123 (3)	24 (3)
Survey131	1 (2)	6 (3)	2 (3)	4 (3)	25 (3)	2 (3)	2 (3)	5 (3)	19 (3)	4 (3)	11 (3)	17 (3)	70 (3)	56 (3)	32 (3)
Survey132	1 (3)	13 (3)	5 (3)	13 (3)	72 (3)	3 (3)	7 (3)	22 (3)	44 (3)	11 (3)	42 (3)	96 (3)	123 (3)	73 (3)	64 (3)

	Inner Harbour							Bedford Basin								
	D3	EE1	EE2	EE3	E1	E2	E3	F1	F2	F3	DYC	G2	H1	H2	H3	BYC
Survey126	67 (3)	519 (3)	58 (3)	115 (3)	62 (3)	45 (3)	143 (3)	19 (3)	31 (3)	33 (3)	12 (2)	6 (3)	7 (3)	4 (3)	13 (3)	2 (3)
Survey127	42 (3)	304 (3)	44 (3)	41 (3)	76 (3)	52 (3)	93 (3)	10 (3)	27 (3)	18 (3)	6 (2)	3 (3)	4 (3)	4 (3)	8 (3)	1 (3)
Survey128	11 (3)	241 (3)	31 (3)	20 (3)	48 (3)	27 (3)	60 (3)	10 (3)	15 (3)	14 (3)	7 (3)	6 (3)	2 (3)	6 (3)	4 (3)	1 (3)
Survey129	24 (3)	168 (3)	57 (3)	41 (3)	322 (3)	53 (3)	65 (3)	6 (3)	17 (3)	18 (3)	3 (3)	3 (3)	1 (3)	3 (3)	2 (3)	1 (3)
Survey130	8 (3)	104 (3)	39 (3)	33 (3)	308 (3)	27 (3)	76 (3)	12 (3)	26 (3)	31 (3)	7 (3)	12 (3)	4 (3)	6 (3)	6 (3)	3 (3)
Survey131	39 (3)	218 (3)	93 (3)	103 (3)	1098 (3)	166 (3)	221 (3)	29 (3)	130 (3)	117 (3)	11 (3)	35 (3)	7 (3)	13 (3)	22 (3)	5 (3)
Survey132	35 (3)	625 (3)	111 (3)	26 (3)	621 (3)	366 (3)	418 (3)	71 (3)	200 (3)	115 (3)	24 (3)	114 (3)	20 (3)	41 (3)	88 (3)	13 (3)

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

4.2 Ammonia Nitrogen

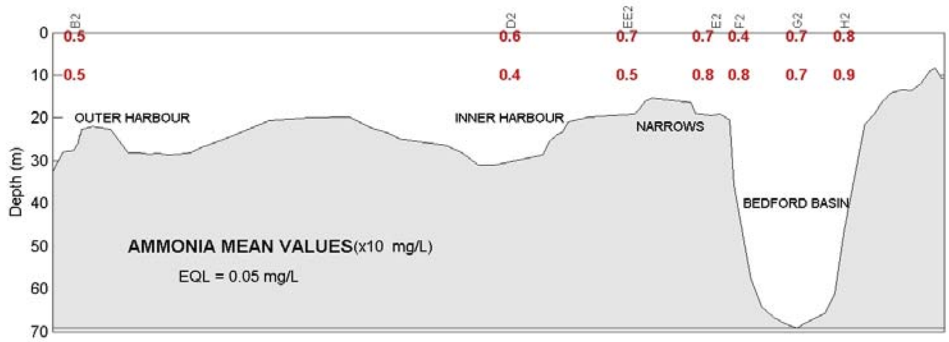
Ammonia nitrogen is an important component in the nutrient balance in an estuary, and in high concentrations has potential for toxic effects; however, there is currently no marine water quality guideline for ammonia (CCME, 1999). The values obtained for this period are shown in Table 6. In addition, the quarterly mean and max values are plotted by station in Figure 7. The laboratory "reportable detection limit" (RDL) for ammonia nitrogen is 0.05 mg/L. For the purpose of computing statistics, the RDL/2, or 0.025 mg/L was used for values below detection. Missed samples are excluded from the calculations.

Ammonia nitrogen has consistently been present at levels that are around the detection limit of 0.05 mg/L. In this quarter, at 1 m, 60 % of samples had detectable levels of ammonium and at 10 m, 65 % of samples had detectable levels. The mean value over the quarter is about 0.08 mg/L with a maximum observation of 0.17 mg/L. There is no clear spatial pattern except that the values tend to be lower in the Outer Harbour at site B2. In this quarter, while there is week-to-week variability, it again seems relatively random. One survey (127, 10 Apr 07) had no detectable values and one survey (132, 29 Jun 07) had values that were the quarterly maximum at every site. Overall, there does not appear to be a simple correlation between ammonia concentrations and meteorological events/oceanographic conditions, as is seen in the coliform data.

Table 6. Ammonia nitrogen summary (mg/L).
Note: green highlights indicate values below detection limits (0.05 mg/L). For statistics 0.025 mg/L was used for values below detection

1m	B2	D2	EE2	E2	F2	G2	H2	mean	max
126 (28 Mar 07)	0.07	0.06	0.07	0.06	ND	0.05	0.09	0.06	0.09
127 (10 Apr 07)	ND	ND	ND	ND	ND	ND	ND	ND	ND
128 (24 Apr 07)	ND	0.07	0.08	0.06	ND	0.07	ND	0.05	0.08
129 (8 May 07)	missed	0.06	0.07	0.07	ND	0.07	0.07	0.06	0.07
130 (23 May 07)	ND	ND	ND	ND	ND	0.09	ND	0.03	0.09
131 (5 Jun 07)	0.06	0.06	0.06	0.10	ND	0.05	0.14	0.07	0.14
132 (29 Jun 07)	0.09	0.10	0.13	0.16	0.14	0.14	0.16	0.13	0.16
mean	0.05	0.06	0.07	0.07	0.04	0.07	0.08	0.08	
max	0.09	0.10	0.13	0.16	0.14	0.14	0.16		0.16

10m	B2	D2	EE2	E2	F2	G2	H2	mean	max
126 (28 Mar 07)	0.06	ND	0.05	0.08	0.06	0.09	0.09	0.07	0.09
127 (10 Apr 07)	ND	ND	ND	ND	ND	ND	ND	ND	ND
128 (24 Apr 07)	ND	ND	ND	0.08	0.09	0.08	0.09	0.06	0.09
129 (8 May 07)	missed	0.06	0.05	0.09	0.08	0.10	0.13	0.09	0.13
130 (23 May 07)	ND	ND	0.06	0.09	0.08	ND	0.05	0.05	0.09
131 (5 Jun 07)	0.06	ND	ND	0.08	0.06	ND	0.07	0.05	0.08
132 (29 Jun 07)	0.10	0.11	0.10	0.14	0.14	0.15	0.17	0.13	0.17
mean	0.05	0.04	0.05	0.08	0.08	0.07	0.09	0.08	
max	0.10	0.11	0.10	0.14	0.14	0.15	0.17		0.17



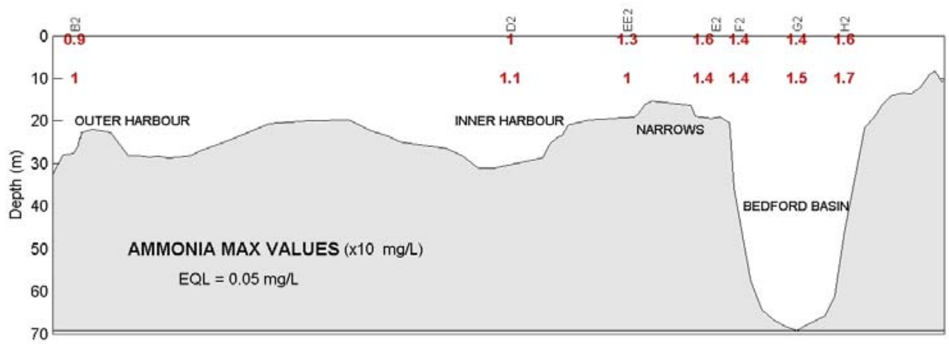


Figure 7. Mean and maximum values of ammonia nitrogen (X10 mg/L) over all twelfth quarter samples

4.3 Carbonaceous Biochemical Oxygen Demand

Further to a recommendation in Quarterly Report 2, $CBOD_5$ analysis for regular samples ceased on 25 May 2005, due to lack of detectable values. $CBOD_5$ analysis continues for supplemental samples, where there have been detectable values. Due to an oversight the supplementary sample this quarter was not analyzed for $CBOD_5$ so there were no $CBOD_5$ results this quarter.

4.4 Total Suspended Solids

A summary of the TSS values for this quarter is shown in Table 7. There were no samples that were below the RDL of 0.5 mg/L. The quarterly mean and max values are plotted by station in Figure 8. This quarter's site average values were in the range of 2.5-5.6 mg/L. The maximum values, by site, ranged from 4.3-10 mg/L. Overall, as with Ammonia, there does not appear to be a simple correlation between TSS concentrations and meteorological events/oceanographic conditions. There are occasional higher values that seem to be associated with more extreme events (e.g. storms, plankton blooms etc).

These events are generally identifiable visually and are usually documented in field notes. In this quarter all survey means were similar at about 4 mg/L, except for the final survey had an overall mean of about 2.3 mg/L.

Table 7. Summary of TSS data (mg/L).

1m	B2	D2	EE2	E2	F2	G2	H2	mean	max
126 (28 Mar 07)	4.3	7.1	3.6	2.8	4.0	10.0	10.0	6.0	10.0
127 (10 Apr 07)	2.5	4.7	4.0	2.2	5.2	4.5	4.9	4.0	5.2
128 (24 Apr 07)	3.9	1.7	2.9	5.6	6.7	3.4	5.2	4.2	6.7
129 (8 May 07)	missed	6.2	3.3	3.0	3.1	3.0	1.8	3.4	6.2
130 (23 May 07)	1.0	2.0	2.7	8.0	5.7	2.0	7.0	4.1	8.0
131 (5 Jun 07)	1.5	3.0	2.6	3.2	2.3	4.4	7.9	3.6	7.9
132 (29 Jun 07)	1.5	3.3	1.3	1.5	2.2	3.8	2.4	2.3	3.8
mean	2.5	4.0	2.9	3.8	4.2	4.4	5.6	3.9	
max	4.3	7.1	4.0	8.0	6.7	10.0	10.0		10.00

10m	B2	D2	EE2	E2	F2	G2	H2	mean	max
126 (28 Mar 07)	4.1	5.3	2.8	2.8	4.3	3.8	2.7	3.7	5.3
127 (10 Apr 07)	1.5	3.0	4.8	2.7	3.5	3.9	2.0	3.1	4.8
128 (24 Apr 07)	6.0	3.7	3.0	3.8	6.1	1.9	1.9	3.8	6.1
129 (8 May 07)	missed	1.6	2.6	2.2	2.7	9.3	7.3	4.3	9.3
130 (23 May 07)	2.0	1.0	4.0	0.9	2.0	5.3	6.0	3.0	6.0
131 (5 Jun 07)	2.0	6.5	6.9	5.0	4.2	7.9	5.7	5.5	7.9
132 (29 Jun 07)	1.6	1.7	3.2	2.6	2.6	1.9	2.2	2.3	3.2
mean	2.9	3.3	3.9	2.9	3.6	4.9	4.0	3.7	
max	6.0	6.5	6.9	5.0	6.1	9.3	7.3		9.3

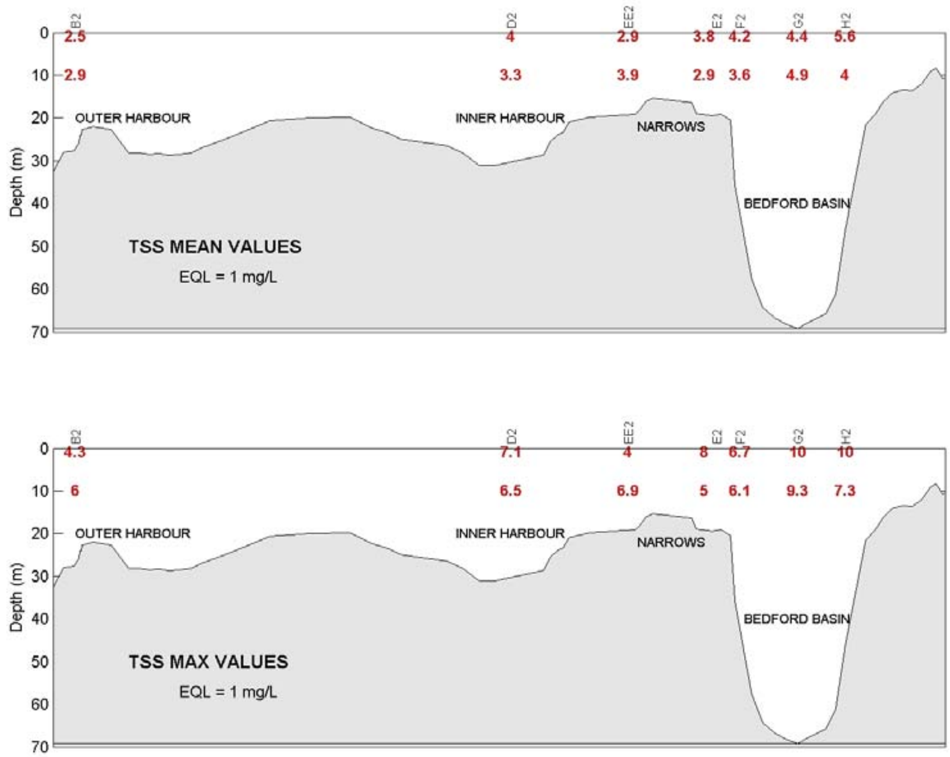


Figure 8. Mean and maximum values of total suspended solids (mg/L) over all twelfth quarter samples.

4.5 Total Oils and Grease

Based on recommendations in Quarterly Report 5 regular sampling for total oil and grease was discontinued in, survey 73 (23 November 06). The analysis is retained for supplemental samples. By oversight, the supplemental sample taken this quarter was not analyzed for TOG.

4.6 Metals

The results of the metals analysis are summarized in Figure 9. For this plot the non-detectable values are considered zero. Through the whole quarter there were two guideline exceedances. In survey 130 (23 May 07) a copper concentration of 4.0 µg/L was recorded in the 1m sample at site EE2. In the DC sample (1m) in survey 132 (29 Jun 07) a very high mercury concentration of 0.4 µg/L was measured. This sample also had a relatively very high value of zinc (68µg/L) that was below the guideline. (see section 4.8). Aside from these samples this plot shows that of the metals for which guidelines exist copper and manganese regularly have detectable levels. The scale on the zinc plot is misleading due to the single high value, zinc is regularly detectable with typical values about 3 µg/L. Lead and nickel are occasionally detectable, while cadmium was not detected. Iron is regularly detected, but has no guideline. Note that cobalt is also measured but has no guideline and is not regularly detectable, so it is not reported. The metal regularly closest to the exceedance level is copper with a mean value under 20% of the guideline.

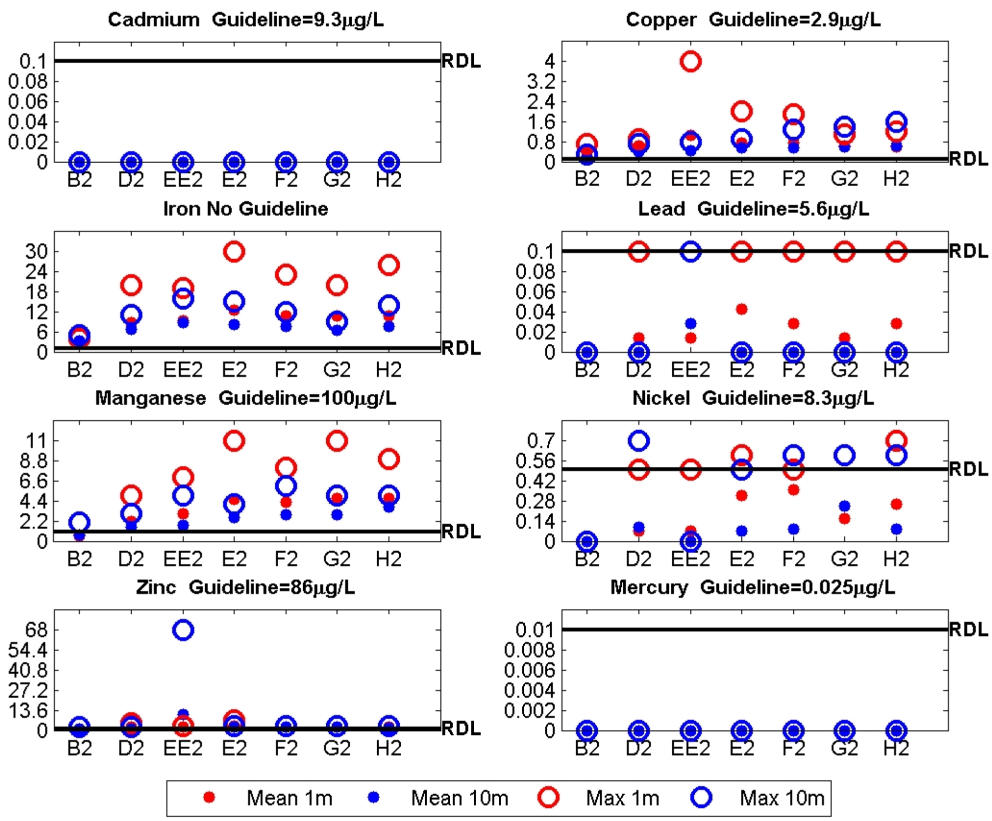


Figure 9. Mean and maximum values of metals (µg/L) over all twelfth quarter samples.

4.7 Profile Data

The CTD used in this program measures continuous profiles of temperature, salinity, fluorescence and dissolved oxygen with depth. In early quarterly reports (up to Quarterly Report 8) the profile data was compared to the BBPMP data from the centre of Bedford Basin. This provided a check on the ranges and quality of the data collected for this survey. BBPMP has discontinued the time series contour plots so this comparison is no longer feasible. However, the contour plots of profile time series are useful in visualizing the longer term variation in the state of the harbour. These plots will be continued in the annual summary section of every fourth quarterly report (12, 16 and 20). An annual summary for year 3 is included in this report as an appendix.

4.7.1 Salinity and Temperature

The temperature, salinity and density (derived from temperature and salinity) profile data provides valuable information on the physical state of the harbour that is very useful in interpreting the water quality data in the weekly surveys. The data is discussed in that context in the survey reports. As time series, the data is useful in characterizing changes in the state of the harbour on meteorological (storms etc) and seasonal timescales. The most interesting point is probably the centre of Bedford Basin as this reflects not only the near surface (upper 20 m) response to wind and rain, but also shows the effects of the periodic intrusion of dense shelf bottom water into the Basin (forced by local and shelf-wide meteorological events). This longer term variation is discussed in the annual summaries.

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. However, the un-calibrated 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 and space, 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.

The phytoplankton in Halifax Harbour generally exhibit more or less typical estuarine behaviour in the winter. That is, low productivity (<5 mg/m^3) during the winter followed by the strongest bloom of the year (40-80 mg/m^3) as sunlight returns in the spring (typically March). After the spring bloom, when light is plentiful, the behaviour seems to be affected by anthropogenic nutrient input. There are sporadic phytoplankton blooms throughout the summer and into the fall. These blooms can be close to the spring bloom in magnitude (30-40 mg/m^3) and occur until the drop in light levels in late fall and winter. There is a less distinct fall bloom that does not appear to be significantly different in intensity, based on fluorescence, than the blooms occurring throughout the summer. Phytoplankton blooms tend to start in the Basin and migrate outward to the rest of the harbour. The profile maximum values generally decrease in magnitude and occur lower in the water column further out of the harbour. The data in the Basin generally represents the maximum concentrations observed and is representative of the timing of phytoplankton activity in the remainder of the harbour. During this quarter there were three surveys, 126 (28 Mar 07), 130 (23 May 07) and 131 (5 Jun 07), with significant ($>$ 20 mg/m^3) fluorescence levels. Between these surveys the levels were moderate, but generally well above the winter “background’ levels ($<$ 3 mg/m^3).

4.7.3 Dissolved Oxygen

Comparison between dissolved oxygen determinations by different methods/instruments has proven uncertain. Part of this uncertainty is due to the vagaries of the instruments themselves. Additionally, small variations in processing procedures, particularly with “alignment” procedures, that assign depths to the DO measurements obtained with the CTD, can add uncertainty. The CTD sensors are quite stable, but tend to lose sensitivity with time. Due to the nature of the CTD itself, they cannot be user calibrated. The BBPMP routinely collects water samples for ground truthing their CTD DO measurements. The samples are analyzed with a well calibrated bench top DO meter. This data can be used to adjust the profile data. The BBPMP publishes the weekly profile data on their website. For purposes of comparison the DO values at 1 and 10 m are estimated from the plots, and are compared with corresponding values from the HHWQMP profiles in Table 8, below. Note that the BBPMP station is approximately 125 m east of the HHWQMP site G2 and that BBPMP samples are generally collected on the day following the HHWQMP samples, so direct correspondence is not to be expected.

Table 8. Comparison of HHWQMP and BBPMP dissolved oxygen data.

Survey	HHWQMP, site G2 (mg/L)		BBPMP (mg/L)		Ratio (BBPMP/HHWQMP)	
Number	1m	10m	1m	10m	1m	10m
126 (28 Mar 07)	9.2	8.3	11.4	10.1	1.24	1.22
127 (10 Apr 07)	8.2	8.1	10.1	10.0	1.24	1.23
128 (24 Apr 07)	7.8	7.5	10.0	9.3	1.28	1.24
129 (8 May 07)	8.3	7.6	10.0	9.4	1.20	1.24
130 (23 May 07)	8.0	7.4	10.6	9.6	1.32	1.29
131 (5 Jun 07)	7.5	7.5	9.1	9.1	1.22	1.22
132 (29 Jun 07)	6.2	6.0	8.4	7.7	1.36	1.29

The data generally covaries, with the BBPMP data being about 25% higher than the HHWQMP. This ratio is quite consistent given the uncertainties, including the differences in time and location. This difference is significant and should be considered in interpreting the HHWQMP data.

The Harbour Task Force Class SA, SB and SC water use classifications have guidelines for dissolved oxygen of 8.0, 7.0 and 6.0 mg/L respectively. Class SA pertains to the Outer Harbour and Class SC pertains to the Narrows and Inner Harbour. The remainder of the harbour is classified as SB. Based on the un-adjusted HHWQMP data, at the start of the quarter there is an apparent intrusion of oxygen rich water that raises the DO in the bottom of the Basin. The DO levels are relatively high everywhere and the applicable guidelines are met everywhere. By the following survey, levels drop slightly and there are exceedances of the class SB guideline in the bottom few metres of the Basin and the class SA guideline in the bottom 1m of the Outer Harbour. The class SA exceedance recovers in the next two surveys then re establishes throughout the water column by the end of the quarter. The DO at the bottom of the Basin drops monotonically throughout the quarter to just under 6.0 mg/L. If the HHWQMP data is scaled up by 25%, as indicated by the comparison above, there would be no exceedances throughout the quarter.

4.8 Supplemental Sample

Fairview Cove

A supplementary sample was taken in a very large and very distinct plume from the Fairview Cove Storm Overflow at 0939 ADT. This site (44° 39.91’ N, 63° 37.85’ W) was about 100m NNW from the outfall, about 15 m from the previous sample taken in survey 124 (28 Feb 07). The tide was low and the wind was light (approx. 10 km/hr) from the southwest, roughly along shore from the outfall toward the Narrows. The plume was first observed in the Narrows while steaming north into the Basin (Figure 10). The plume was visible along the shore as the boat approached the outfall from within the Basin. Entering the plume near the outfall, the water in the plume was very turbid with a distinct front defining the plume edge (Figure 11). Figure 12 shows the Fairview Cove outfall, a very large outfall with sewage entering the receiving water directly at the surface with little or no momentum. The view of the plume from the vicinity of the sample site looking toward the Narrows and a view of the plume edge leaving the plume are shown in Figures 13 and 14.

At the sample site the plume was very shallow, perhaps 5 cm. Clear water was visible in the boat wake as the boat drifted. The sample was taken as near the surface as possible but was below the surface plume.

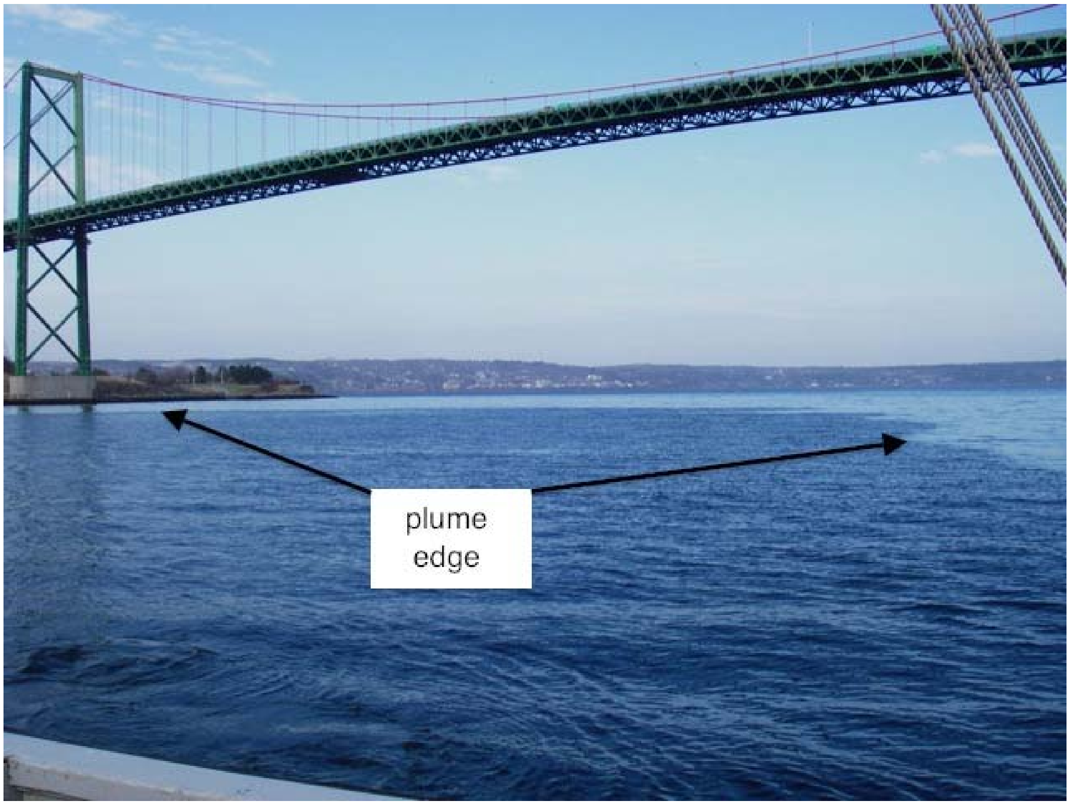


Figure 10. Plume seen from Narrows heading into Basin.

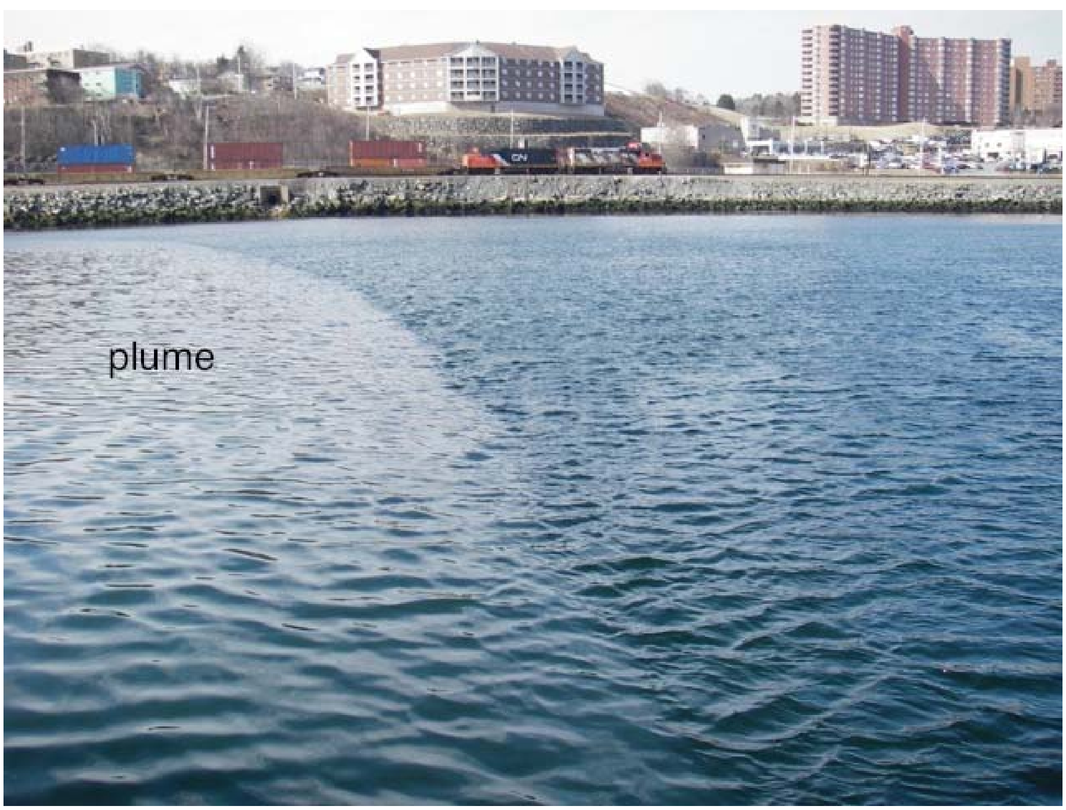


Figure 11. Plume edge, entering plume near outfall.

Figure 12. The Fairview Cove combined sewer overflow.

Figure 13. Plume from near sample site looking toward the Narrows.

Figure 14. Meander in plume edge.

The results of the lab analysis are presented in Table 9. The FC (6400 cfu/100 mL), ammonia (0.12 mg/L) and copper (0.8 ug/L) are relatively high, the highest in the survey but not particularly high compared with other values measured this quarter. The remaining results are within the ranges observed elsewhere in this survey.

Table 9. Supplemental sample lab results.

	UNITS	1m	RDL
BACTERIA			
Fecal Coliform	CFU/100mL	6400	1
INORGANICS			
Carbonaceous BOD	mg/L	NA	5
Nitrogen (Ammonia Nitrogen)	mg/L	0.12	0.05
Total Suspended Solids	mg/L	4.8	0.5
OIL & GREASE			
Total Oil & Grease	mg/L	NA	5
METALS WITH GUIDELINES			
Cadmium (Cd)	ug/L	0.0	0.1
Copper (Cu)	ug/L	0.8	0.1
Lead (Pb)	ug/L	0.0	0.1
Manganese (Mn)	ug/L	3.0	1
Mercury (Hg)	ug/L	0.0	0.01
Nickel (Ni)	ug/L	0.6	0.5
Zinc (Zn)	ug/L	2.0	1
METALS WITH NO GUIDELINES			
Cobalt (Co)	ug/L	0.0	0.1
Iron (Fe)	ug/L	8.0	1

Dartmouth Cove

A regular summer monthly sample was taken at the DC site (Figure 1) in survey 132 (29 June 2007). This was a single sample at 1m analyzed for all parameters except $CBOD_5$ and total oil and grease. The results of the analysis are presented in Table 10. In this sample FC, ammonia and TSS are relatively high, about the same as the maximum values in the regular survey sites. The metals concentrations are unusual. The mercury concentration of 0.4 ug/L is 16 times the applicable 0.025 ug/L guideline. Typically mercury levels are not detectable in the harbour at a 0.01 ug/L detection limit. The zinc concentration (68 ug/L) is also very high, more than 10 times higher than the next highest value for the rest of the survey. The concentration is still below the 86 ug/L guideline. The other detectable metals were relatively high, but not the highest observed in the rest of the survey.

Table 10. Dartmouth Cove sample lab results (29 Jun 07).

	UNITS	1m	RDL
BACTERIA			
Fecal Coliform	CFU/100mL	820	1
INORGANICS			
Carbonaceous BOD	mg/L	NA	5
Nitrogen (Ammonia Nitrogen)	mg/L	0.17	0.05
Total Suspended Solids	mg/L	3.4	0.5
OIL & GREASE			
Total Oil & Grease	mg/L	NA	5
METALS WITH GUIDELINES			
Cadmium (Cd)	ug/L	ND	0.1
Copper (Cu)	ug/L	0.8	0.1
Lead (Pb)	ug/L	ND	0.1
Manganese (Mn)	ug/L	5.0	1
Mercury (Hg)	ug/L	0.4	0.01
Nickel (Ni)	ug/L	ND	0.5
Zinc (Zn)	ug/L	68.0	1
METALS WITH NO GUIDELINES			
Cobalt (Co)	ug/L	0.0	0.1
Iron (Fe)	ug/L	12.0	1

5 Summary

For each item, a brief statement of summary is provided along with any changes that occurred during the quarter and any new or ongoing issues.

5.1 Reporting

Survey Reports

The 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
– None

Quarterly Reports

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. Each quarterly report contains a discussion of any supplementary samples taken in the quarter.

Changes
– None

5.2 Sampling Program

The sampling route selection continues as per the end of the ninth quarter. As of that time the routes were modified to always either start or end in the Northwest Arm, where the survey boat is based. This was done based on travel time considerations and does introduce an early morning/late afternoon bias into the NW Arm data. The morning sampling may coincide with the peak diurnal sewage flows and may result in a bias in water quality samples near the chain rock outfall (e.g. RNSYS, PC). This is also a function of the plume trajectory at the time of sampling. This should be considered in a detailed analysis of RNSYS and PC water quality data. The sampling sites remain as at the end of quarter 10. The last change has been the addition of the HP sites. The sample analysis remains the same as at the end of quarter nine. The last modification was the addition of the high resolution metals analysis.

Changes
- None

5.3 Water Quality Parameters

Fecal Coliform

In general, the geometric mean coliform values are well above primary contact guidelines in the Inner Harbour. Outside of the Inner Harbour high values are more sporadic. The occurrence of high values outside the Inner Harbour are primarily dependant on oceanographic conditions that may transport water from the Inner Harbour either up or down harbour, and secondarily dependant on loading events (e.g. storms) that may increase loads thereby raising levels everywhere. Both of these often act together. This quarter, the spatial distribution of fecal coliform seemed shifted down-harbour, in the 1m and up-harbour in the 10m samples. The maximum mean values are quite high, but their distribution is quite contained. There are only six sites (four at 1m and two at 10m) having geometric means greater than 200 cfu/100 mL and all of these are in the Inner Harbour.

With respect to compliance with Task Force guidelines the most numerous exceedances are in the class SB rated areas adjacent to the Inner Harbour. This quarter class SB exceedances are very limited and all but one are to the south, at BRB and section C. The class SA guideline in the Outer Harbour is generally not met at HC and the HP sites, likely due to the periodic influence of the Tribune Head outfall. The class SA guideline is met at B2 throughout the quarter.

Changes

- None

Outstanding item: The current Canadian Environmental Quality Guidelines (ceqg-rcqe.ccme.ca) 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 it would be advantageous to future endeavours if the monitoring program could bridge to the use of this tracer. Enterococci are considered to be more specific than fecal coliform in identifying contamination by human waste. In Halifax the overwhelming source of bacterial contamination is sewage. The concentration of fecal coliform in the Harbour would likely correlate very strongly with the more human specific enterococci. Limited sampling of both parameters could allow investigation of this correlation.

Ammonia Nitrogen

Ammonia nitrogen has consistently been present at levels that are around the detection limit of 0.05 mg/L. Overall, in this quarter, just over 60% of samples had detectable levels of ammonia. The values are generally relatively uniform throughout the harbour except they tend to be somewhat lower in the Outer Harbour at B2. There is definite temporal variability. There was one survey with no detectable values and one survey with the quarterly maximum values at every site. The reason for the temporal variability is not clear. There does not seem to be a simple correlation between ammonia concentrations and meteorological/oceanographic conditions, as is evident in the coliform data.

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 should continue to be considered for monitoring.

Changes

- None

$CBOD_5$

Based on recommendations in Quarterly Report 2, $CBOD_5$ was dropped from regular analysis in survey 49 (25 May 2005). Until that time there were 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. There was no $CBOD_5$ monitoring this quarter.

Changes

- None

Total Suspended Solids

The TSS values in the harbour are generally moderate with no obvious strong correlation in space or time with oceanographic or sewage loading conditions. This quarter the survey means ranged from 2.3 to 6.0 mg/L. There are at times higher values that seem to be associated with more extreme events (e.g. storms, plankton blooms etc). These events are generally identifiable visually and are usually documented in field notes. In this quarter the highest values were in the first survey and lowest in the last. These surveys corresponded to relatively high and low fluorescence levels respectively. Within the quarter the means were all similar and seemed independent of fluorescence levels. The only clear spatial pattern is that the TSS is generally lower in the outer Harbour at B2.

Changes:

- None

Total Oils and Grease

Based on recommendations in Quarterly Report 5, total oils and grease was dropped from regular analysis in survey 75 (23 Nov 05), due to lack of detection. It is retained in supplemental sample analysis. This quarter the TOG analysis for the supplemental samples in Fairview Cove and Dartmouth Cove was inadvertently omitted.

Changes
- None

Metals

In general the metals with guidelines are present at levels well below the guidelines. The metal that is consistently closest to exceeding the guideline is copper. In this quarter the mean copper values are less than 20% of the 2.9 µg/L guideline. However in this quarter there were two single guideline exceedances. In survey 130 (23 May 07) a copper concentration of 4.0 µg/L was measured. In survey 132 (19 Jun 07) the Dartmouth Cove (DC) sample had a very high value of mercury. The concentration of 0.4 µg/L is 16 times the 0.025 µg/L guideline. Mercury is very seldom detectable at the 0.01 µg/L RDL.

Changes:
- None

Fluorescence

Un-calibrated fluorescence provides a relative measure of chlorophyll and hence phytoplankton activity throughout the Harbour. The HHWQMP data allows for the gross identification of phytoplankton activity and is particularly useful in the interpretation of the DO data. The fluorescence data could also be useful to add a spatial interpretation to the detailed phytoplankton analysis at the BBPMP site.

During this quarter there was variable phytoplankton activity. In three surveys there appeared to be blooms in progress. Other than this, the fluorescence levels were variable and moderate.

Changes
- None

Dissolved Oxygen

To date, oxygen levels as measured in the program, are generally relatively 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. This quarter comparison with the ground truthed BBPMP DO data suggests that the HHWQMP data dissolved oxygen data is low by approximately 25%. This should be considered in the interpretation of the DO data. There appeared to be an intrusion of well oxygenated water into the Basin preceding the first survey of the quarter (126, 28 May 07). If the HHWQMP data are adjusted to correspond to the BBPMP data there were no exceedances of applicable guidelines this quarter, even in the Basin Bottom water. There are continuing issues of DO sensor calibration/ground truth (Section 4.7.3).

Changes

- None

References

CCME, 1999. Canadian water quality guidelines for the protection of aquatic life: In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

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.

Halifax Harbour Task Force. (1990). Halifax Harbour Task Force Final Report. Prepared for Nova Scotia Department of Environment, R. Fournier ed.

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.

Jordan, F. (1972), Oceanographic Data of Halifax Inlet", BIO data series, B1-D-72-8.

JWL and COA (2004 – 2005). Halifax Harbour Waster Quality Monitoring Program, Weekly and Quarterly Reports 2004 to 2008, report to the Halifax Regional Municipality, Harbour Solutions Project. http://www.halifax.ca/harboursol/waterqualitydata.html

USEPA (1985). Rates Constants, and Kinetics Formulations in Surface Water Quality Modeling (Second Edition). EPA 600385040.

Halifax Harbour
Water Quality Monitoring Program
Quarterly Report 12

APPENDIX

Annual Summary Year Three

21 June 2006 - 19 June 2007

March 2010

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1 Introduction

The following is a summary of data from year three, from 21 June 2006 through 19 June 2007. It includes information provided in Quarterly Reports 9 through 12. There is a very large amount of information in this data bearing on oceanographic and water quality processes in the Harbour. The detailed process-oriented analysis of this data is beyond the scope of a monitoring program, but some discussion of these processes is included. The focus of this summary is with the compliance/exceedance of existing water quality guidelines as developed by the Halifax Harbour Task Force (1990).

2 Hydrographic Data

The temperature and salinity data reflect the dynamic state of the harbour and therefore represent a base from which to interpret the water quality data. To some extent the temperature and salinity, and resultant density stratification, in Halifax Harbour vary predictably on seasonal timescales. The surface water generally warms in spring and summer, reaching a maximum in late August or early September, and cools in fall and winter (minimum late February early March). The surface salinity is low with spring freshet in the Sackville River and other tributaries. On top of the seasonal signal is a large amount of variability, mostly on a meteorological timescale (days to weeks). Large rainfall events cause freshening of the harbour similar in magnitude to the freshet anytime throughout the year. Wind forcing directly on the harbour can push surface water either up or down harbour for days at a time resulting in local upwelling or downwelling and enhanced vertical mixing. On a larger scale, the passage of weather systems/storms on the continental shelf can cause larger scale upwelling or downwelling along the coast. Upwelling pushes colder saltier bottom water into the harbour, forcing the warmer fresher harbour water out of the harbour in a surface layer. Downwelling is the reverse. These two layer events are very effective in exchanging harbour water and can result in rapid changes in water properties.

Perhaps the most oceanographically interesting feature of the Halifax Harbour is Bedford Basin. The Basin is a fiord. The near surface water (<20-30 m) exchanges freely with the remainder of the harbour and to a large extent reflects conditions there. The deep water (up to 70m) is relatively isolated by a sill (20-25 m) in the Narrows and is only renewed periodically by the upwelling of dense continental shelf bottom water over the sill. This water displaces and/or mixes with the existing bottom water. As a result of this mechanism, the bottom water in the Basin is normally denser than any water in the remainder of the harbour, reflecting its origins in deeper continental shelf water. These renewals can be seen in the salinity and temperature data, but often the most telling signature of this phenomenon is the dissolved oxygen of the deep bottom water. Under normal conditions, the dissolved oxygen in this water drops as oxygen is consumed by decomposing organic matter, present in the sediments and “raining” down from the surface water. With time, the dissolved oxygen can become very low. The water in an intrusion is generally well oxygenated and dramatically increases the DO. The DO therefore tends to reflect the time since the previous renewal. Between intrusions vertical diffusion slowly decreases the bottom water density by mixing with less dense overlying water. Historical information (i.e. The BBPMP) indicates that these events occur on average once or twice a year in Bedford Basin. Less intense upwelling can occur more often, resulting in intrusion at intermediate depth in the Basin. All intrusions can have surface signatures as the deeper, generally colder, more saline, water is displaced upward and flushed out in the surface layer.

The salinity and temperature data from station B2 in the centre of Bedford Basin, for the year including quarters 9, 10, 11 and 12 are shown in Figure 1. The temperature data shows the seasonal temperature trend in the surface water with a maximum temperature of about 18º C at the end of August and a minimum of less than 2º C in the beginning of March. There are six or seven upper water column "freshening" events, due to precipitation /snowmelt evident in the salinity data.

In both data sets the effects of intrusions, characterized by abrupt changes in water properties, is apparent. Particularly evident in the salinity data is the large intrusion of very saline water at the end of October.

3 Fluorescence

The fluorescence data collected by the CTD is a proxy for chlorophyll and can be used to get a relative sense of primary productivity (See Section 4.8 in the main report). The units of the values discussed here are mg/m^3 as generated by the CTD data processing software, but should not be interpreted strictly as biomass measurements.

Phytoplankton blooms tend to start in the Basin and migrate outward to the rest of the harbour. The profile maximum values generally decrease in magnitude and occur lower in the water column further out of the harbour. Figure 2 shows the time series of fluorescence profiles in the centre of the Basin (site G2). The data in the Basin generally represents the maximum fluorescence observed (though not always at G2) and is representative of the timing of phytoplankton activity in the remainder of the harbour. This shows relatively continuous moderate activity throughout the summer (quarter 9). There is a relatively intense bloom at the end of September followed by a decline and relatively low levels throughout the winter until the spring bloom in March.

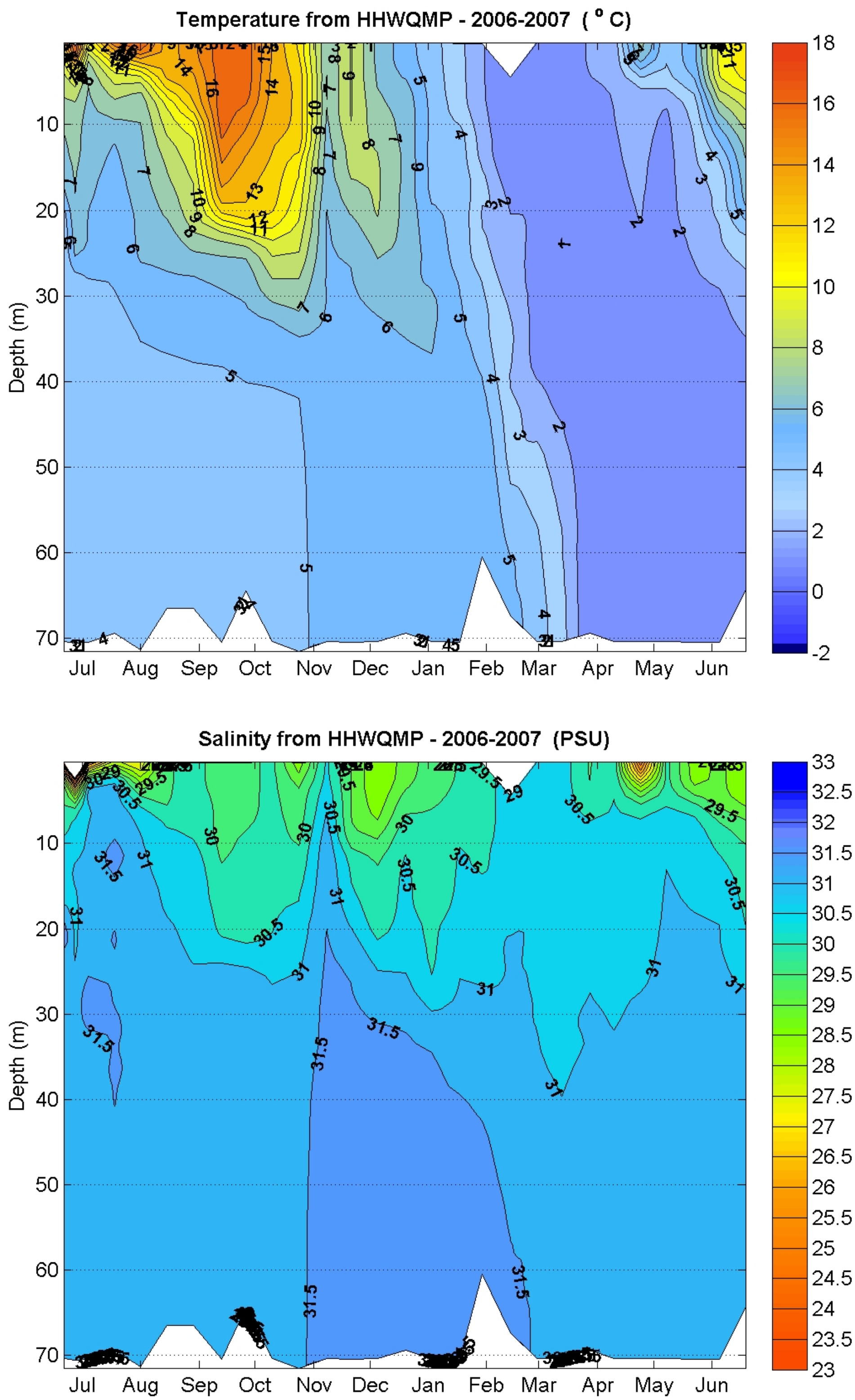


Figure 1. HHWQMP temperature and salinity data from Station G2 (21 June 2006 to 19 June 2007).

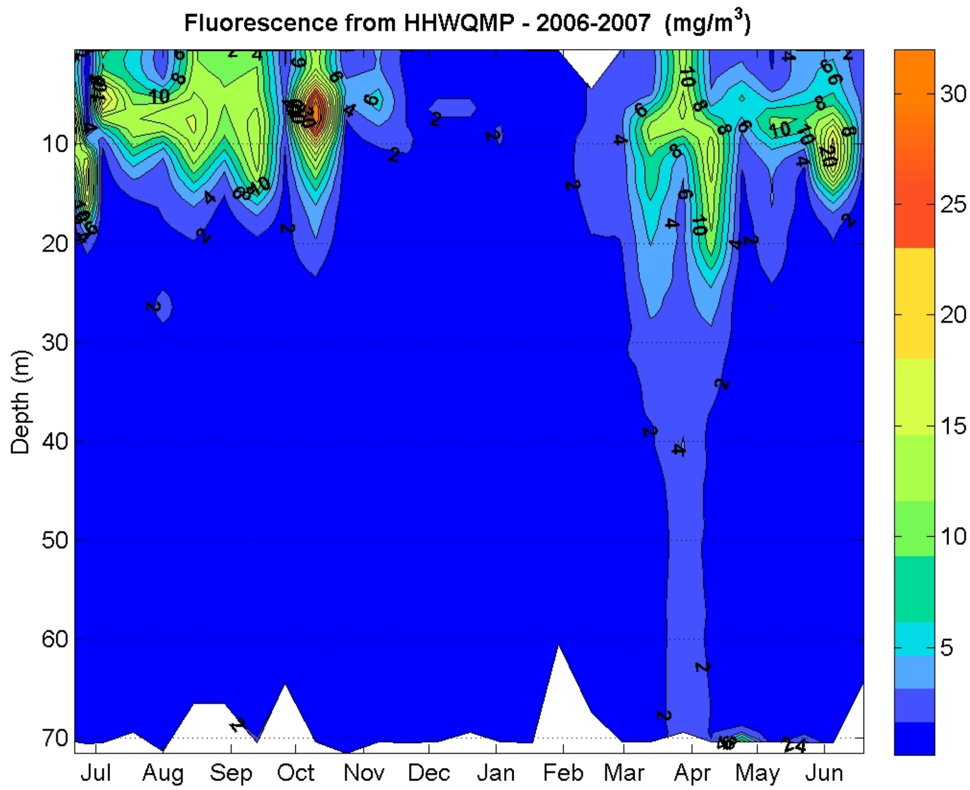


Figure 2. HHWQMP fluorescence data from Station G2 (21 June 2006 to 19 June 2007).

During blooms, particularly in summer, maximum concentrations generally occur in Bedford Basin. In the Inner Harbour, the typical profile maximum values are about half those in the Basin. In the Outer Harbour the profile maximum values are lower still, usually 3-4 mg/ m^3. Consistent with the previous year it appears that, while there is a definite spring bloom, phytoplankton activity continues sporadically throughout the spring, summer and fall, until activity ceases due to lack of light in the late fall and winter.

4 Dissolved Oxygen

During this period there was periodic additional data collected to verify the Dissolved Oxygen data acquired with the Seabird profiler. Throughout the program the DO data at station G2 is compared to that at the nearby BBPMP site (discussed in all quarterly reports). The results are mixed, but, with recent corrections to the BBPMP data, it appears that the Seabird values were always equal to or lower than the other methods. This difference could be as much as 20%. This uncertainty must be considered in the following discussion.

4.1 Harbour and Basin Surface Water

There are spatial variations in dissolved oxygen in any survey. These patterns vary from survey to survey depending on the dynamic state of the Harbour. Sometimes these patterns are significant, but most of the time the spatial variations are small compared to the large-scale temporal variations. The general trends can be seen in the upper portion (top 20-25 m) of the Basin time series contours in Figure 3. This plot shows that July through December the surface water oxygen levels were variable and the near surface gradients were relatively steep. If scaled to match the BBPMP data the surface levels would not be below 7.0 mg/L In December and January the surface DO increases and becomes more vertically uniform, mixing into the deeper water. The maximum values occur in March, corresponding to spring bloom.

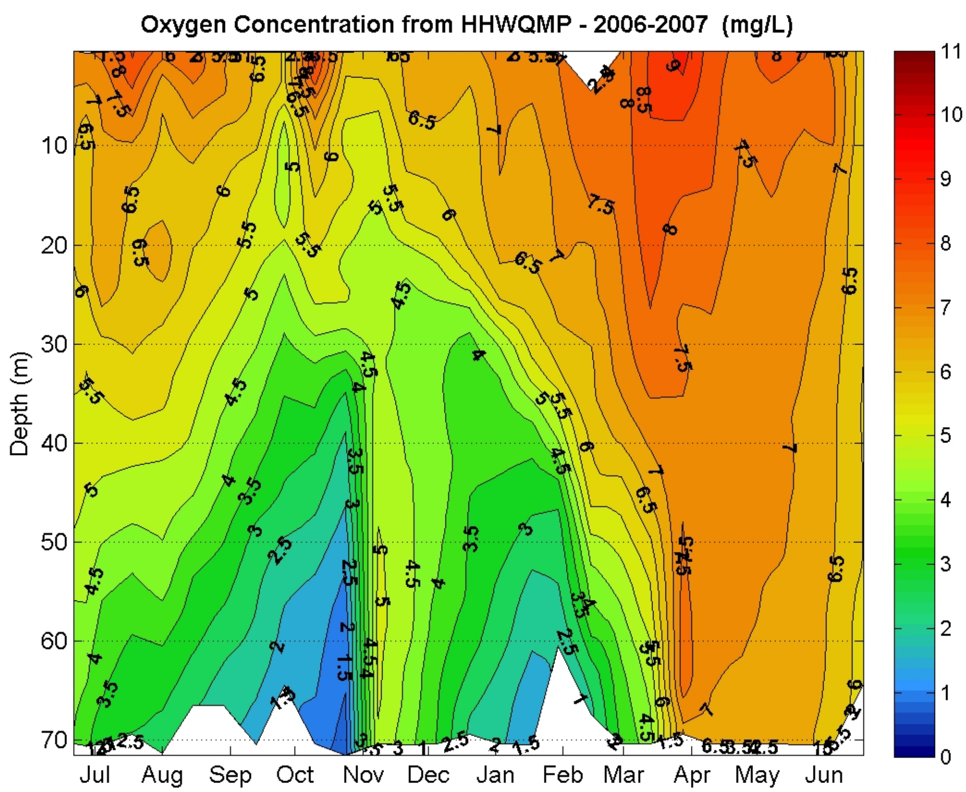


Figure 3. HHWQMP dissolved oxygen data from Station G2 (21 June 2006 to 19 June 2007).

4.2 Bedford Basin Bottom Water

The Dissolved Oxygen in the Bedford Basin bottom water (Figure 3) generally responds to different processes than the surface water (Section 2). Sometimes, but not always, the signature of a deep intrusion can be seen in the near-surface water as the oxygen depleted bottom water is displaced upward and flushed out of the harbour. The reason this is not always seen is likely a function of state of the upper water column and the magnitude of intrusion. The volume of bottom water is also considerably smaller than the near surface water. An event that has a large effect on bottom water will be "diluted" in its surface signature.

This bottom water only rarely has dissolved oxygen above the Class SB guideline (7.0 mg/L). In this period there is one large intrusion at the end of October, as documented in the hydrographic data. There is also an intrusion/mixing event in March. This is not particularly evident as an intrusion in the hydrographic data but results in well oxygenated water throughout the water column. This results in a period for which the DO in the bottom water, scaled to match the BBPMP data, meets the class SB guideline.

5 Fecal Coliform

Geometric Means

Maps showing the annual geometric mean fecal coliform concentrations at 1 and 10 m are presented in Figure 4. The key characteristics of the distribution are that the highest concentrations are in the Inner Harbour, specifically the EE section, in both the 1 and 10 m samples. This is consistent with the distribution of outfalls in the harbour. Additionally, south of the Narrows (E section) the concentrations are higher in the 1 m samples, while north of the Narrows the concentrations in the 10 m samples are higher than in the 1 m samples. In the Narrows the mean concentrations are similar in the 1 and 10 m samples.

Within the basic annual pattern there is quite a bit of variability in both the magnitude and distribution of the bacteria concentrations in the harbour. These variations are due to interactions of meteorological and oceanographic factors affecting source strength, effluent trajectory and mixing, and bacteria die-off on seasonal, weekly and daily timescales. Maps representing the geometric mean values over all samples for each of the four quarters are reproduced from the quarterly reports in Figures 5 through 8. In these figures, values in red exceed swimming guidelines (200 cfu/100 mL); values in blue exceed shellfishing guidelines (14 cfu/100 mL); and values in green indicate suitability for either activity. In each figure, separate maps are presented for the 1 and 10 m samples. There is significant seasonal variation. This is due to differences in bacteria decay and circulation. Cooler water and reduced sunlight both increase bacterial survival times, tending to result in higher concentrations in the cold water and short days of fall and winter. Increased harbour flushing, due to high freshwater input (e.g. spring freshet or storms) or upwelling/downwelling along the coast can also result in lower concentrations.

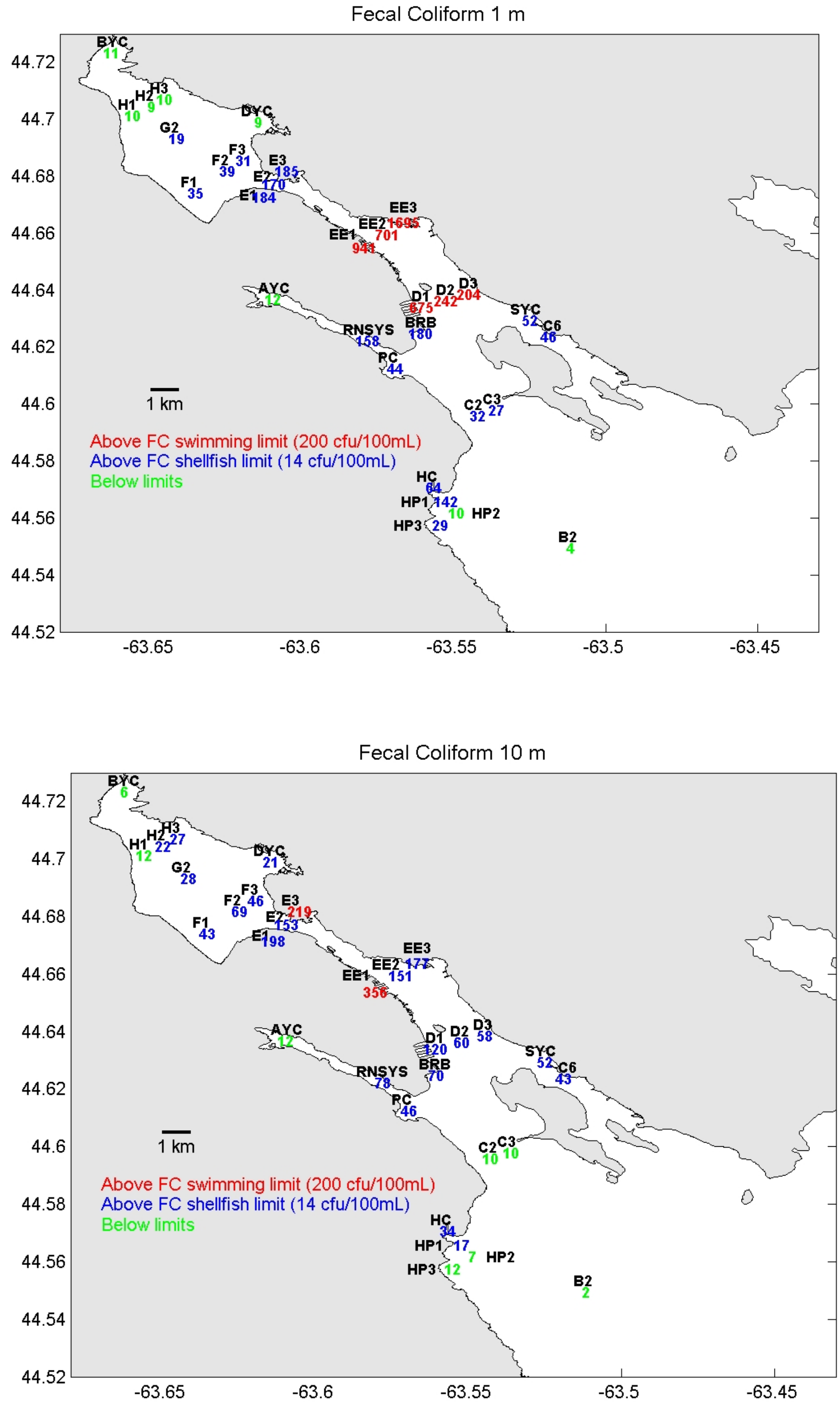


Figure 4. Fecal coliform annual geometric means (cfu/100mL), 21 June 2006 to 19 June 2007.

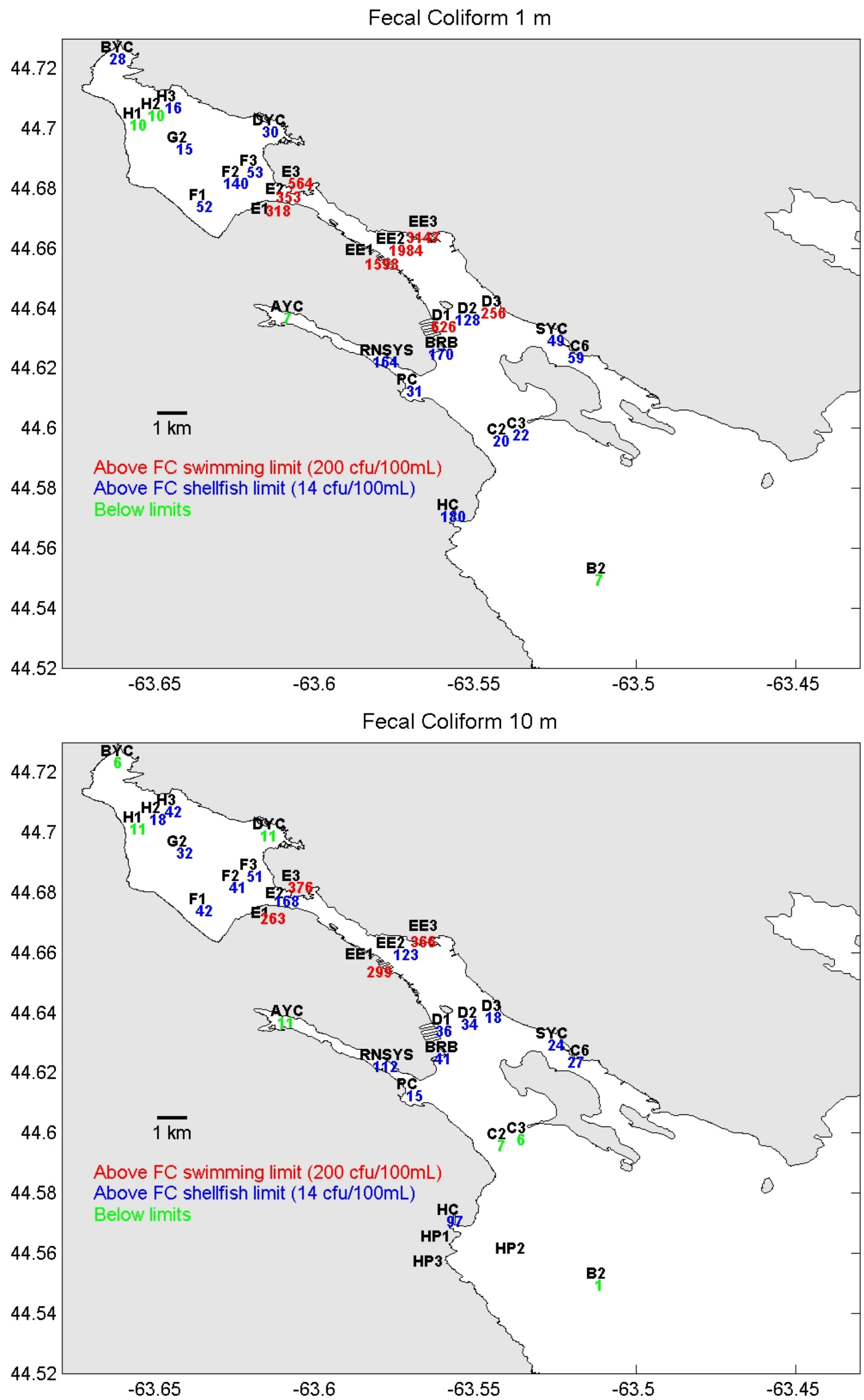


Figure 5. Fecal coliform geometric means (cfu/100mL), summer 2006 (21 June to 13 September 2006).

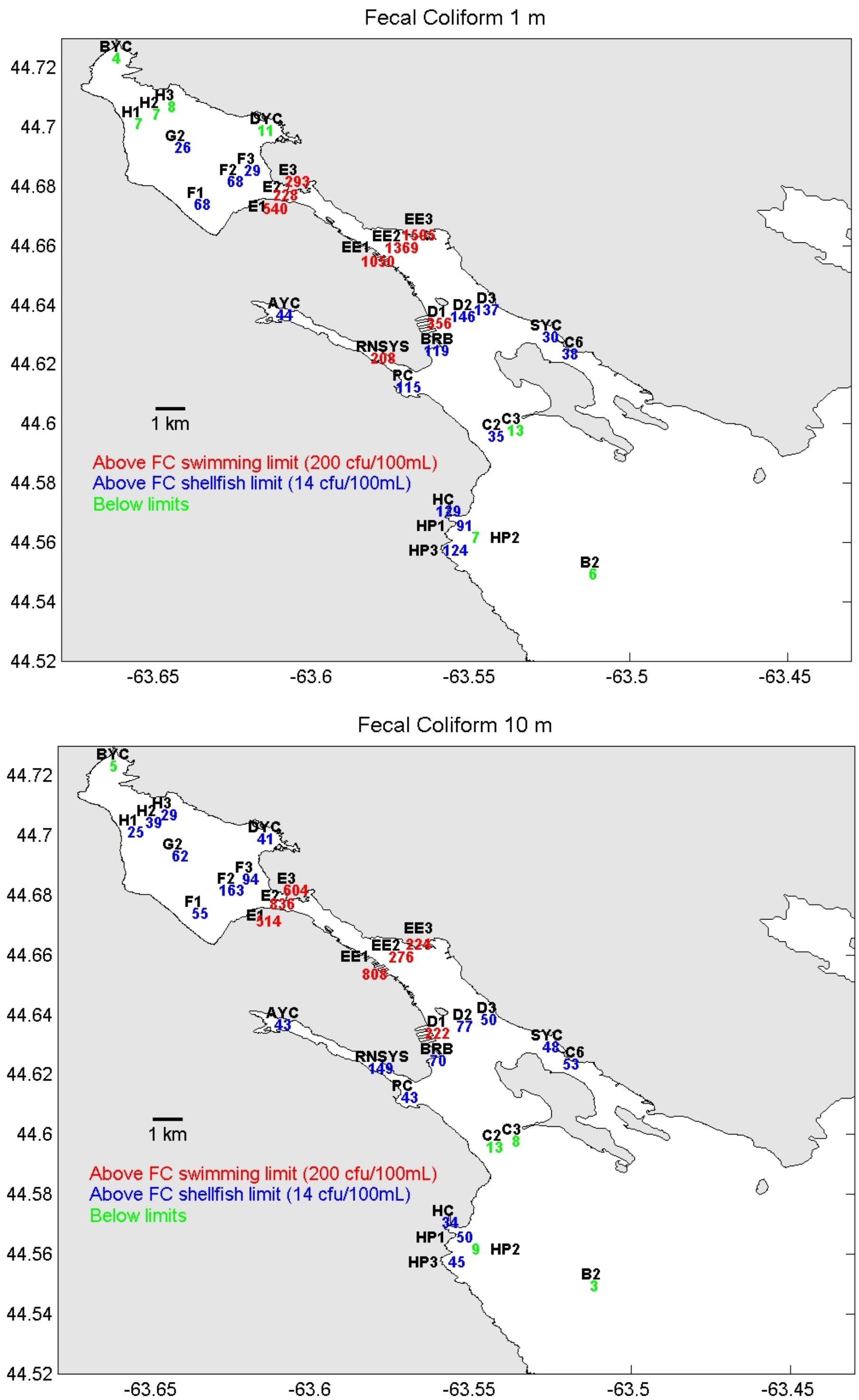


Figure 6. Fecal coliform geometric means (cfu/100mL), fall 2006 (26 September to 5 December 2006).

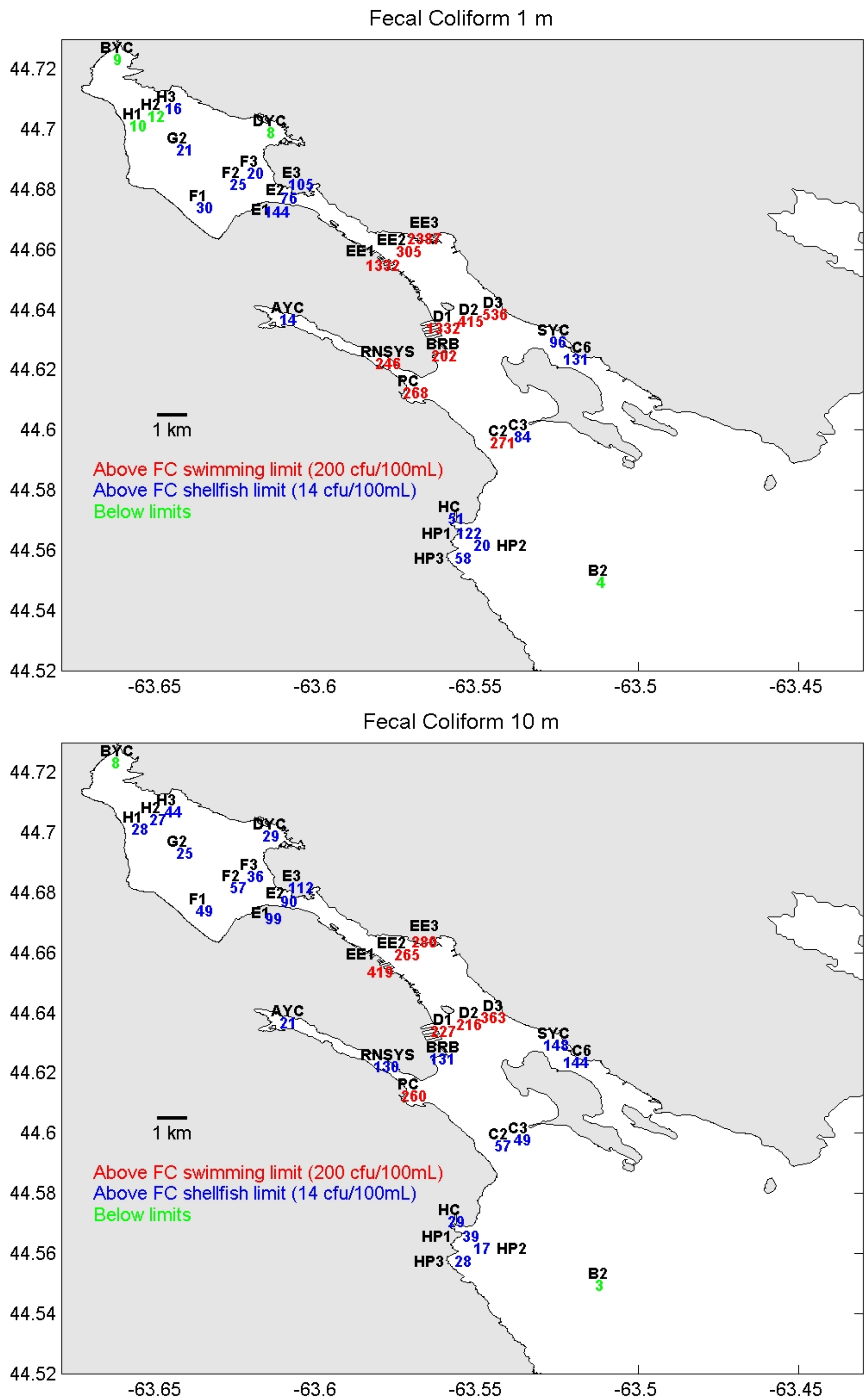


Figure 7. Fecal coliform geometric means (cfu/100mL), winter 2006/2007 (20 December 2006 to 13 March 2007).

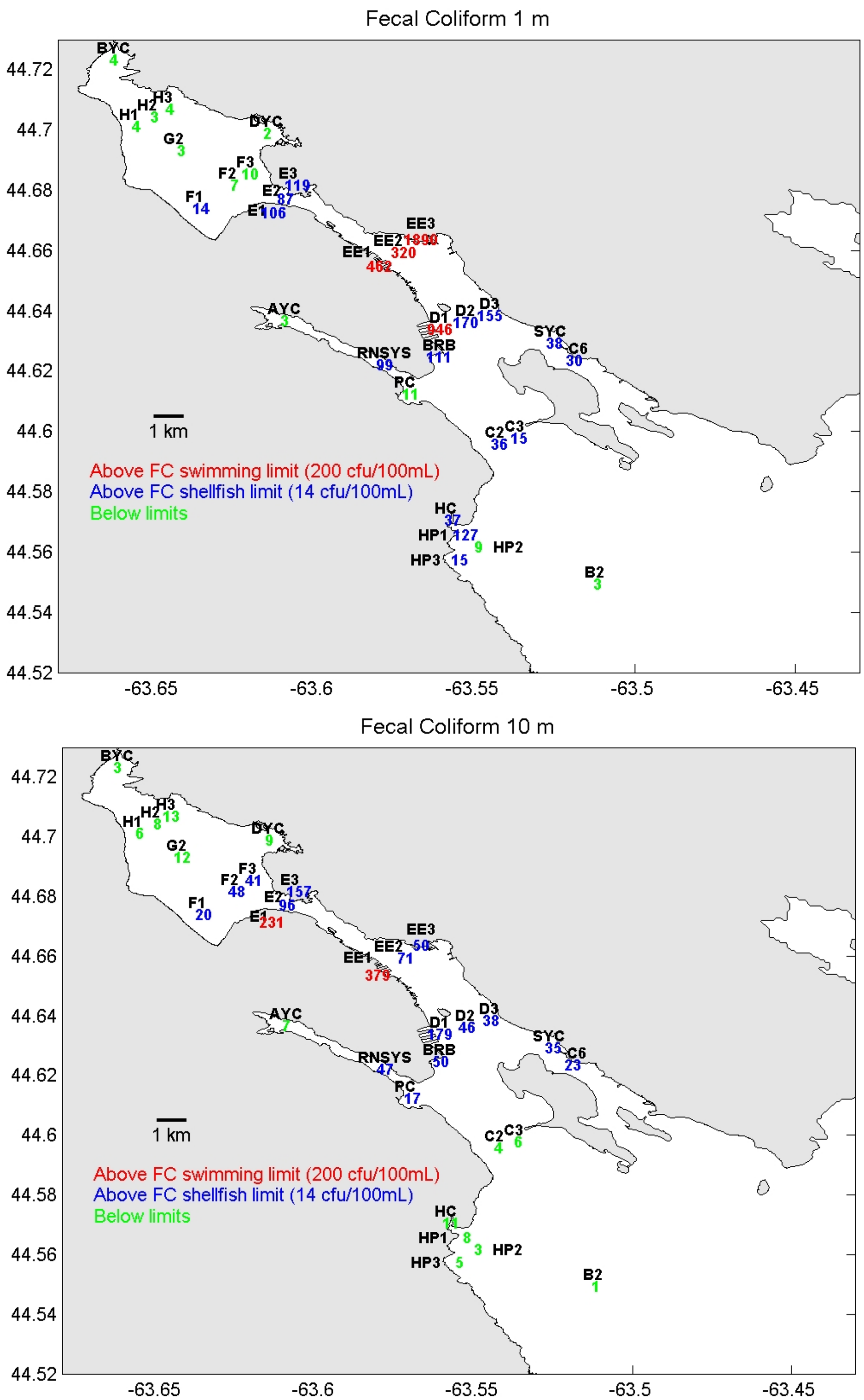


Figure 8. Fecal coliform geometric means (cfu/100mL), spring 2007 (28 March to 19 June 2007).

Thirty Day Floating Means

The seasonal trends are also evident in the floating thirty-day geometric mean, compiled for the entire year here in Tables 1 and 2. Overall there tends to be an increase in bacteria concentration in the fall and winter, but this is not universal. The concentrations at a given site are also affected by the harbour circulation. In the late summer early fall the concentrations are highest in the narrows. This may be attributable to a higher probability of up-harbour surface transport at that time. There is also significant survey to survey variability in the bacteria concentrations. This is likely mostly due to the higher frequency variability in harbour flushing on the meteorological timescale (3-5 days).

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

	Outer Harbour							Northwest Arm			Eastern Pass.		Inner Harbour		
	B2	HP1	HP2	HP3	HC	C2	C3	PC	RNSYS	AYC	C6	SYC	BRB	D1	D2
Survey105	15				295	173	249	138	36	9	93	201	387	1098	475
Survey107	6				343	45	167	165	392	7	19	54	931	2513	633
Survey108	6				448	31	54	45	436	4	24	22	335	846	305
Survey109	6				58	18	61	18	868	2	11	16	472	537	216
Survey110	1				27	5	4	6	414	3	340	36	115	498	170
Survey111	1				71	3	1	3	1165	15	418	26	51	56	41
Survey112	1				268	2	1	10	246	12	112	25	27	396	20
Survey113	5				339	12	10	43	47	11	28	23	25	106	36
Survey114	11	51	1	130	116	15	10	280	9	7	9	10	120	1189	207
Survey115	5	10	3	411	129	22	32	1030	99	12	15	13	243	478	928
Survey116	5	48	2	55	131	17	3	249	711	104	10	7	331	478	149
Survey117	3	123	7	65	106	113	15	172	1216	86	61	54	234	520	224
Survey118	8	396	12	56	83	257	31	64	524	228	115	102	172	492	189
Survey119	8	282	64	225	97	476	177	296	180	54	258	384	476	3409	763
Survey120	5	251	27	48	110	309	248	438	200	103	165	314	680	2239	550
Survey121	2	487	14	9	188	359	154	669	69	33	161	282	508	1419	308
Survey122	5	237	7	7	83	334	142	555	60	21	157	237	192	1083	329
Survey123	5	106	18	31	64	181	47	626	192	6	175	118	159	918	386
Survey124	5	39	27	67	20	105	24	383	399	4	202	44	72	1448	292
Survey125	2	27	18	124	17	124	23	117	1381	3	56	10	90	640	285
Survey126	9	17	16	22	15	453	87	35	154	3	58	25	74	889	390
Survey127	13	36	24	22	15	403	152	10	65	1	14	38	66	1269	276
Survey128	6	148	14	4	28	92	29	7	22	3	16	68	49	1061	338
Survey129	2	585	4	4	25	11	4	3	34	2	8	24	22	818	118
Survey130	1	470	2	4	27	6	3	6	105	2	4	10	111	722	205
Survey131	1	582	7	11	50	4	3	6	93	3	38	33	364	293	99
Survey132	1	212	10	42	131	10	11	14	185	3	59	94	856	1166	108

	Inner Harbour							Bedford Basin								
	D3	EE1	EE2	EE3	E1	E2	E3	F1	F2	F3	DYC	G2	H1	H2	H3	BYC
Survey105	1590	2475	1860	19672	18	63	71	11	32	27	57	15	72	20	25	62
Survey107	1251	3145	2064	3541	21	130	566	11	20	45	54	37	42	36	38	62
Survey108	1086	2699	5421	1938	107	464	1254	47	77	20	80	20	22	20	60	135
Survey109	800	1915	4624	2366	486	358	2049	215	86	7	40	7	5	7	32	54
Survey110	404	1361	4717	2470	4692	2686	2615	868	1348	77	15	16	7	7	17	217
Survey111	7	928	802	475	4692	1438	3291	178	626	653	11	17	2	3	2	30
Survey112	19	861	907	609	3767	1959	1887	61	990	400	14	31	3	7	5	7
Survey113	68	521	827	2042	686	158	364	94	108	68	34	7	2	3	4	2
Survey114	195	805	1991	1635	175	47	141	30	34	20	7	5	2	4	5	1
Survey115	925	1028	1911	1989	222	70	159	23	13	5	3	6	4	3	1	3
Survey116	122	1657	5026	2072	461	524	476	29	31	9	2	36	7	10	4	4
Survey117	274	1955	2299	2841	552	367	361	85	44	8	4	69	15	9	9	7
Survey118	89	1441	1272	2084	465	221	226	225	96	35	15	203	21	25	42	7
Survey119	1649	1441	423	612	196	77	136	134	89	63	24	78	22	21	59	15
Survey120	1115	678	426	715	141	100	141	147	67	104	13	77	40	68	75	23
Survey121	776	700	483	2718	71	50	115	42	78	55	7	38	17	34	29	23
Survey122	479	637	322	2281	87	40	46	29	47	21	4	31	12	24	12	9
Survey123	304	1090	293	7245	91	26	56	17	15	9	14	13	6	8	7	6
Survey124	250	1330	184	3527	101	53	73	23	5	7	1	9	6	7	5	3
Survey125	283	2573	208	9735	176	142	184	7	4	6	1	4	4	3	6	5
Survey126	386	1813	193	4518	53	62	73	5	3	4	1	3	4	3	7	4
Survey127	463	842	231	2700	20	13	30	4	2	2	1	2	2	2	5	3
Survey128	247	394	393	770	19	12	35	9	4	4	1	2	3	2	3	1
Survey129	171	447	308	2002	119	77	137	14	4	15	1	2	1	1	1	1
Survey130	65	207	409	551	525	154	120	18	9	31	2	3	4	1	3	4
Survey131	44	290	408	2131	1570	400	277	59	16	27	3	7	6	3	3	9
Survey132	56	122	722	469	186	139	170	36	26	15	6	5	12	6	8	14

Note: Red indicates exceedance of swimming criteria (mean >200), yellow denotes "questionable" water quality, (mean < 200, but one or more samples >400), and green indicates compliance with criteria.

Table 2. 30 day geometric mean (number of samples) of 10 m fecal coliform concentrations (CFU/100 mL).

	Outer Harbour							Northwest Arm			Eastern Pass.		Inner Harbour		
	B2	HP1	HP2	HP3	HC	C2	C3	PC	RNSYS	AYC	C6	SYC	BRB	D1	D2
Survey105	1				53	6	6	8	48	9	9	15	22	7	53
Survey107	1				110	3	16	57	111	7	7	26	161	14	57
Survey108	1				266	3	13	65	191	4	20	78	102	31	72
Survey109	1				394	21	160	50	141	3	20	71	106	38	27
Survey110	1				98	10	1	6	92	4	167	36	20	66	24
Survey111	1				105	10	1	9	277	25	184	37	16	137	27
Survey112	1				59	3	2	13	226	31	102	18	30	183	27
Survey113	17				63	4	4	18	180	33	32	17	31	285	44
Survey114	4	56	4	180	24	4	6	25	105	21	14	9	89	591	80
Survey115	3	20	3	38	31	7	6	32	118	14	16	24	71	485	63
Survey116	1	30	3	32	48	15	7	64	185	15	24	27	109	304	56
Survey117	2	46	6	20	31	16	9	55	113	32	80	75	46	86	52
Survey118	4	92	19	50	25	47	27	105	99	133	148	178	90	111	141
Survey119	5	66	57	59	22	99	67	176	82	169	271	447	79	144	261
Survey120	3	23	20	24	38	275	179	412	80	142	280	530	148	243	438
Survey121	1	23	10	10	79	197	133	760	61	42	541	319	111	213	361
Survey122	3	16	6	8	88	128	136	492	73	17	541	247	196	262	405
Survey123	3	31	24	24	97	54	49	667	195	4	256	139	209	441	431
Survey124	3	73	31	57	28	25	34	280	406	3	46	54	206	441	291
Survey125	2	56	14	45	12	15	13	205	366	3	20	30	143	312	96
Survey126	2	14	4	10	10	14	7	59	95	7	33	65	70	128	36
Survey127	2	3	3	2	6	5	6	22	37	5	33	60	38	312	45
Survey128	1	2	2	1	4	2	4	8	20	8	33	27	14	349	45
Survey129	1	3	2	1	2	1	4	3	26	3	10	7	14	610	41
Survey130	1	4	2	2	5	2	2	3	18	3	7	7	35	123	24
Survey131	1	6	2	4	25	2	2	5	19	4	11	17	70	56	32
Survey132	1	13	5	13	72	3	7	22	44	11	42	96	123	73	64

	Inner Harbour							Bedford Basin								
	D3	EE1	EE2	EE3	E1	E2	E3	F1	F2	F3	DYC	G2	H1	H2	H3	BYC
Survey105	22	107	37	725	92	23	40	20	34	21	5	32	4	21	27	4
Survey107	60	310	95	262	66	63	317	17	12	12	3	33	4	15	187	4
Survey108	71	455	126	148	138	143	404	36	16	15	5	45	9	12	106	5
Survey109	15	409	113	47	348	215	1138	35	6	12	6	23	5	5	39	13
Survey110	21	216	134	511	472	268	704	65	46	117	22	23	15	15	9	13
Survey111	6	263	261	648	512	340	2893	47	57	402	29	27	26	20	16	6
Survey112	15	607	452	731	575	959	1703	105	345	313	37	46	62	50	72	4
Survey113	10	896	172	257	243	1003	868	80	159	261	49	39	43	28	85	4
Survey114	31	1008	190	320	235	901	463	47	146	82	30	35	22	18	14	4
Survey115	46	941	91	104	684	1160	602	19	41	55	24	27	10	9	3	3
Survey116	80	1165	313	224	2200	1719	1143	39	125	54	31	46	6	21	4	4
Survey117	135	592	294	97	1045	918	779	40	102	41	29	35	8	35	14	5
Survey118	297	672	576	350	317	494	371	80	442	61	52	134	30	135	94	7
Survey119	901	104	267	297	147	139	117	61	231	46	25	118	57	68	100	11
Survey120	710	203	341	780	131	121	107	117	208	119	51	121	75	76	140	23
Survey121	429	157	389	471	65	73	109	110	113	61	28	45	38	40	63	20
Survey122	429	1017	608	352	60	61	78	76	43	37	52	29	39	60	67	16
Survey123	356	1261	374	242	69	60	83	42	15	13	28	13	23	26	24	9
Survey124	370	1316	231	287	94	56	77	29	10	17	12	8	13	13	14	5
Survey125	168	695	115	210	111	85	153	25	18	27	12	4	9	5	12	3
Survey126	67	519	58	115	62	45	143	19	31	33	12	6	7	4	13	2
Survey127	42	304	44	41	76	52	93	10	27	18	6	3	4	4	8	1
Survey128	11	241	31	20	48	27	60	10	15	14	7	6	2	6	4	1
Survey129	24	168	57	41	322	53	65	6	17	18	3	3	1	3	2	1
Survey130	8	104	39	33	308	27	76	12	26	31	7	12	4	6	6	3
Survey131	39	218	93	103	1098	166	221	29	130	117	11	35	7	13	22	5
Survey132	35	625	111	26	621	366	418	71	200	115	24	114	20	41	88	13

Note: Red indicates exceedance of swimming criteria (mean >200), yellow denotes "questionable" water quality, (mean < 200, but one or more samples >400), and green indicates compliance with criteria.

Time Series

Figures 9 through 12 show time series of the fecal coliform concentrations at representative sites in the Outer Harbour, NW Arm, Inner Harbour and Bedford Basin. The most obvious observation is the large survey to survey variation at all points. However, the mean patterns discussed above can be seen as trends in the time series data, namely:

- values are highest in the Inner Harbour
- values tend to be highest in the fall and winter
- in the Inner Harbour the highest values tend to be in the 1 m samples
- in the Basin the highest values tend to be in the 10 m samples

As discussed in quarterly and various weekly reports, the significant week to week variations in FC levels and distribution appear to correlate, at least qualitatively, with observed meteorological and oceanographic phenomena. Variations in circulation can displace high bacteria counts either up or down harbour as well as increase or decrease vertical differences and increase or decrease overall concentrations (periods of low or high flushing). The easiest place to see this is in the Outer Harbour at site B2 (Figure 12). The concentrations here are generally <10 cfu/100 mL, but wind/intrusion events that move the surface water out of the harbour are occasionally strong enough to result in quite high concentrations here. In addition to advection and dispersion, cloud cover can reduce bacteria decay rate causing increased concentrations. The seasonal variation is less obvious at sites close to outfalls where the concentration depends more on source strength than mixing/decay.

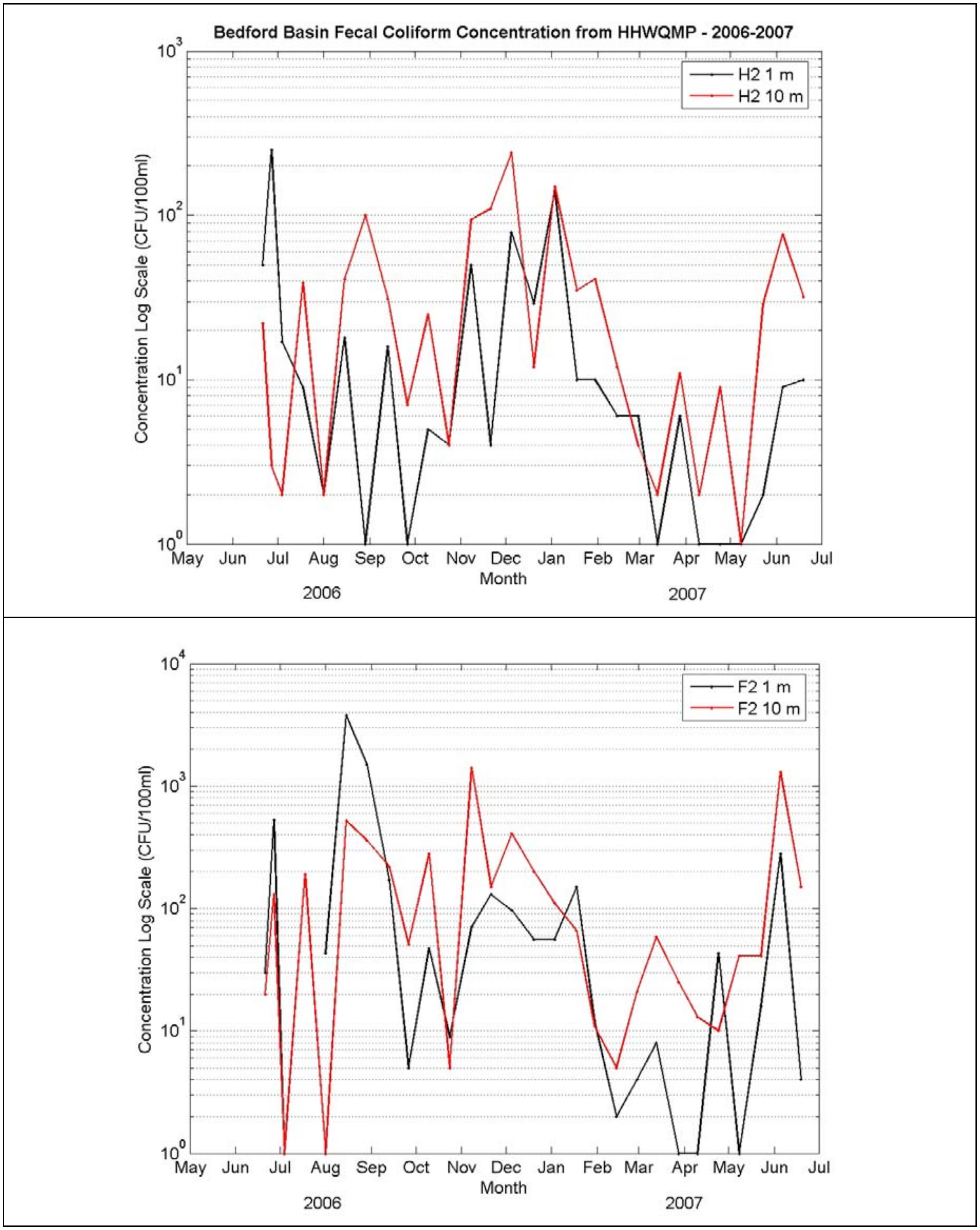
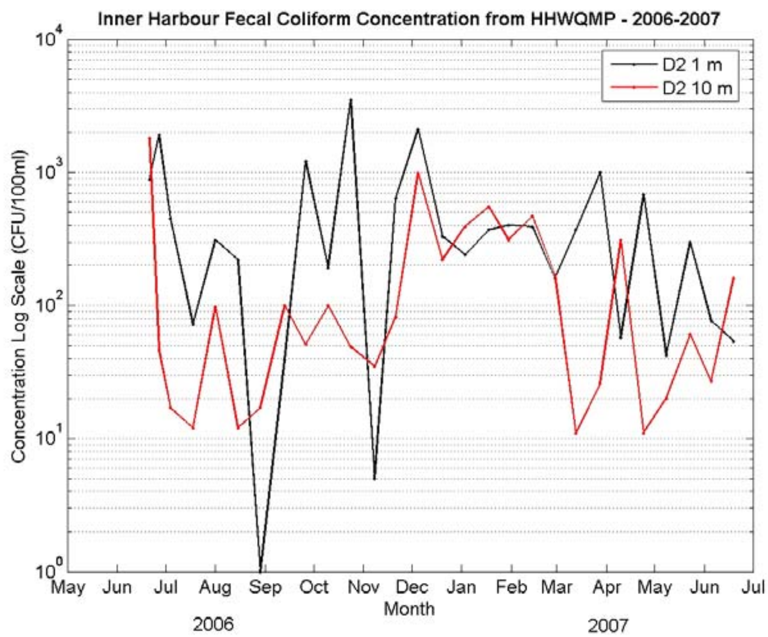


Figure 9. HHWQMP Bedford Basin Fecal Coliform Concentration (21 June 2006 to 19 June 2007).



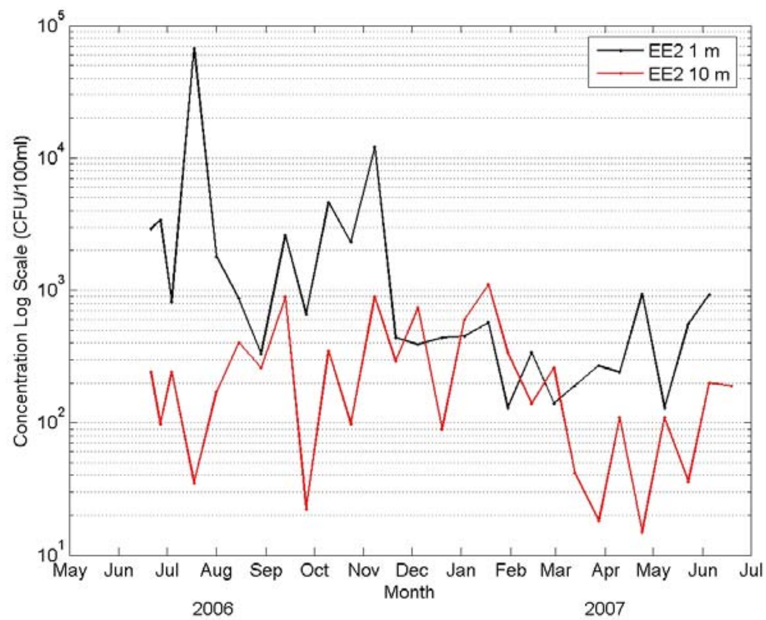


Figure 10. HHWQMP Inner Harbour Fecal Coliform Concentration (21 June 2006 to 19 June 2007).

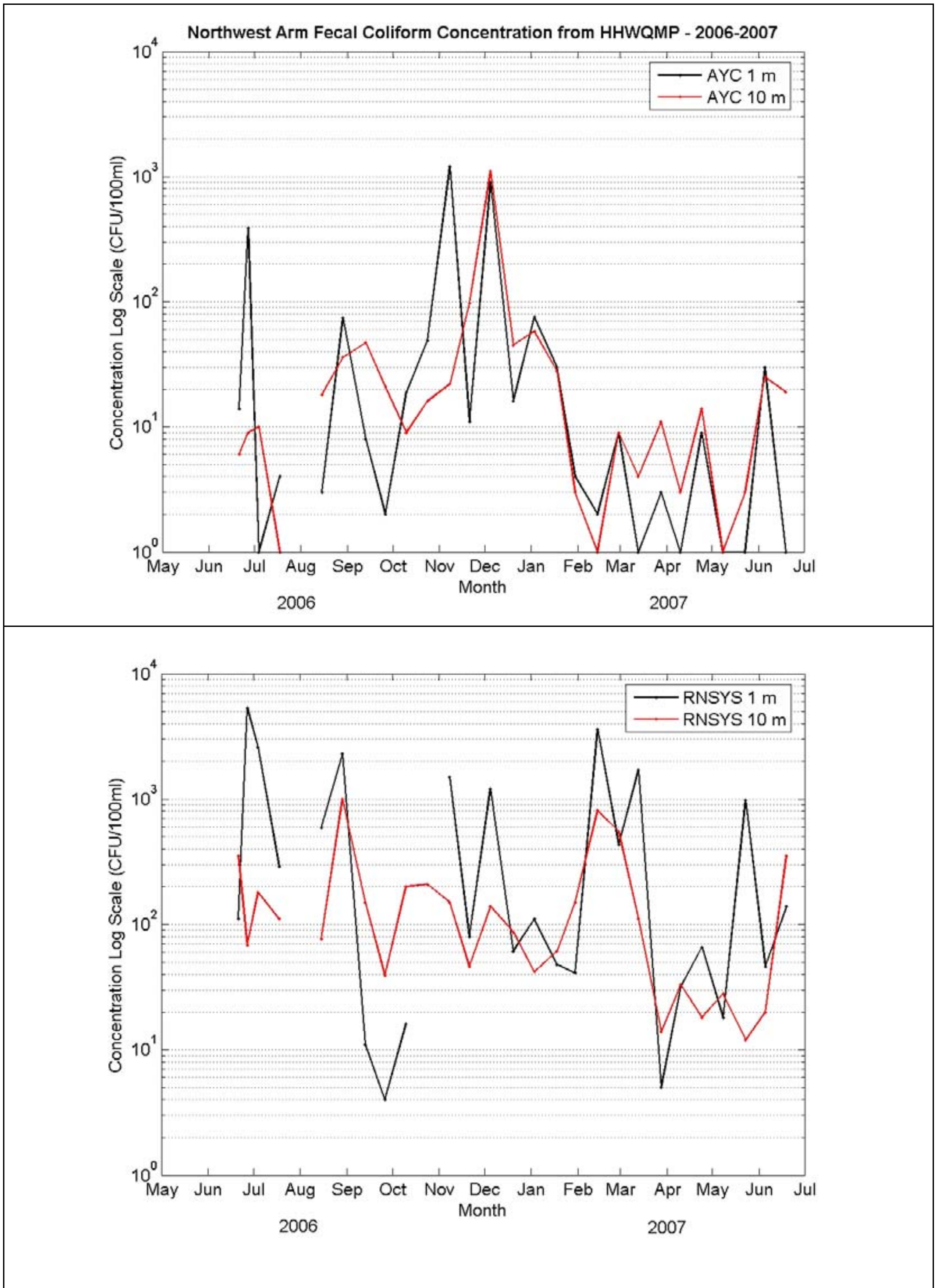
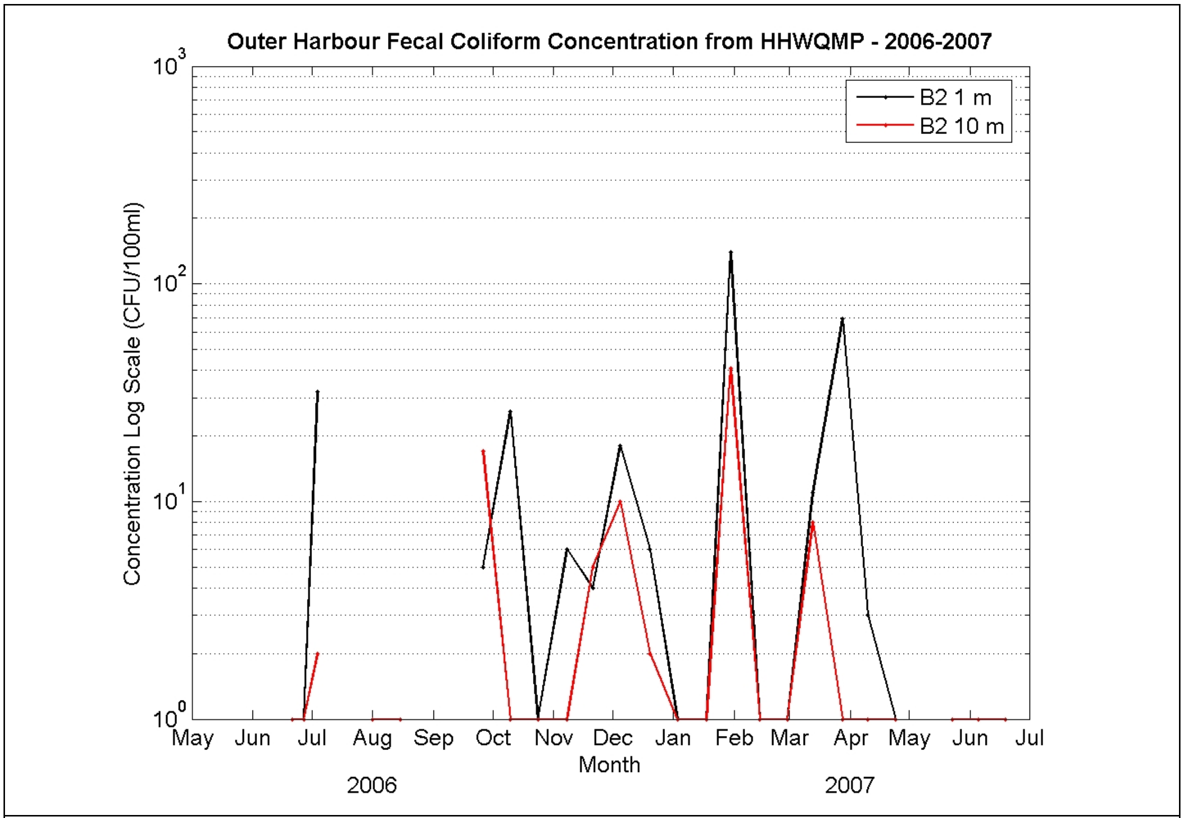


Figure 11. HHWQMP Northwest Arm Fecal Coliform Concentration (21 June 2006 to 19 June 2007).



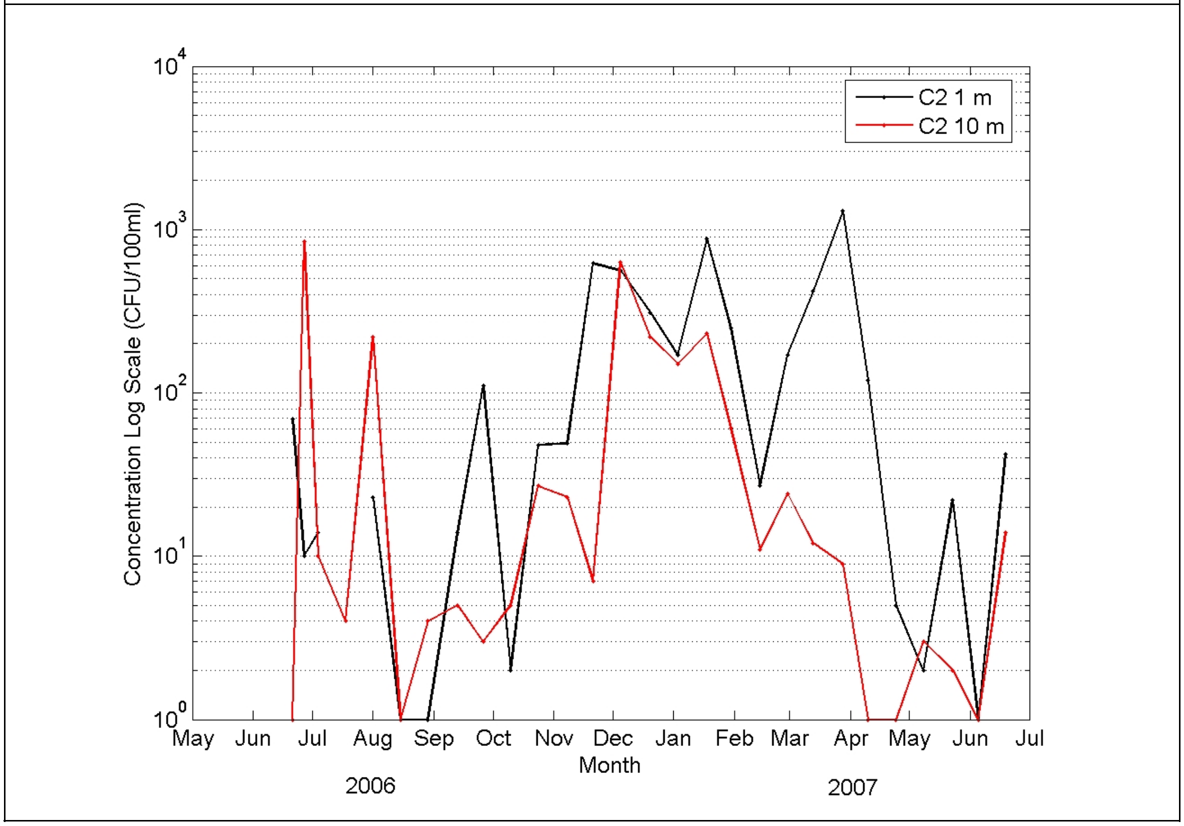


Figure 12. HHWQMP Outer Harbour Fecal Coliform Concentration (21 June 2006 to 19 June 2007).

6 Ammonia Nitrogen

The measured values of ammonia nitrogen at 1 and 10m over the entire third year are presented in Tables 3 and 4. Samples that were below the RDL of 0.05 mg/L have been assigned values of 0.025 (RDL/2) for statistical purposes, and are shaded green. Ammonia Nitrogen has consistently been present at levels that are around the detection limit of 0.05 mg/L. The overall mean concentration over the entire year was about 0.06 mg/L. While there are spatial (site to site) variations, there is not a readily discernable pattern, except that the concentrations at B2 (Outer Harbour) are lowest of any site.

There is temporal variability, the survey mean concentrations vary from <0.05 to 0.13 mg/L. Overall, there does not appear to be a simple correlation between ammonia concentrations and meteorological events/oceanographic conditions, as is seen in the coliform data. There does appear to be seasonal component with ammonia concentrations being somewhat higher in the fall and winter. This may be inversely related to phytoplankton activity (fluorescence).

Table 3. Annual Summary of 1 m Ammonia Nitrogen

1 m	B2	D2	EE2	E2	F2	G2	H2	mean	max
21-Jun-06	ND	ND	0.050	ND	ND	ND	ND	0.029	0.050
4-Jul-06	ND	0.100	0.050	ND	ND	ND	ND	0.039	0.100
18-Jul-06	ND	ND	ND	ND	ND	ND	ND	ND	ND
1-Aug-06	ND	0.060	ND	ND	ND	ND	ND	0.030	0.060
15-Aug-06	ND	ND	ND	ND	ND	ND	ND	ND	ND
29-Aug-06	ND	ND	ND	ND	ND	ND	ND	ND	ND
13-Sep-06	ND	ND	ND	ND	ND	ND	ND	ND	ND
26-Sep-06	0.050	0.060	0.060	0.080	0.060	0.070	0.070	0.064	0.080
10-Oct-06	ND	ND	0.090	ND	ND	ND	ND	0.034	0.090
24-Oct-06	ND	0.120	0.110	0.120	0.100	0.110	0.110	0.099	0.120
8-Nov-06	ND	ND	0.180	0.080	0.080	0.070	0.070	0.076	0.180
21-Nov-06	ND	0.070	0.100	0.110	0.100	0.090	0.080	0.082	0.110
5-Dec-06	ND	0.080	0.090	0.120	0.120	0.120	0.110	0.095	0.120
20-Dec-06	ND	0.060	0.070	0.080	0.080	0.090	0.090	0.071	0.090
3-Jan-07	ND	0.070	0.070	0.070	0.080	0.080	0.080	0.068	0.080
18-Jan-07	ND	0.070	0.070	0.080	0.080	0.080	0.080	0.069	0.080
30-Jan-07	ND	0.000	0.060	0.060	0.070	0.060	0.080	0.051	0.080
14-Feb-07	ND	0.090	0.070	0.070	0.060	0.060	0.080	0.065	0.090
28-Feb-07	0.060	0.100	0.110	0.150	0.090	0.100	0.160	0.110	0.160
13-Mar-07	ND	ND	0.080	0.100	0.050	0.070	0.070	0.060	0.100
28-Mar-07	0.070	0.060	0.070	0.060	ND	0.050	0.090	0.061	0.090
10-Apr-07	ND	ND	ND	ND	ND	ND	ND	ND	ND
24-Apr-07	ND	0.070	0.080	0.060	ND	0.070	ND	0.051	0.080
8-May-07	ND	0.060	0.070	0.070	ND	0.070	0.070	0.056	0.070
23-May-07	ND	ND	ND	ND	ND	0.090	ND	0.034	0.090
5-Jun-07	0.060	0.060	0.060	0.100	ND	0.050	0.140	0.071	0.140
19-Jun-07	0.090	0.100	0.130	0.160	0.140	0.140	0.160	0.131	0.160
mean	0.033	0.055	0.068	0.067	0.054	0.063	0.067	0.058	
max	0.090	0.120	0.180	0.160	0.140	0.140	0.160		0.180

Table 4. Annual Summary of 10 m Ammonia Nitrogen

10 m	B2	D2	EE2	E2	F2	G2	H2	mean	max
21-Jun-06	ND	ND	0.060	0.060	0.050	0.050	0.050	0.046	0.060
4-Jul-06	ND	0.070	ND	0.070	ND	ND	0.060	0.043	0.070
18-Jul-06	ND	ND	ND	0.140	ND	ND	ND	0.041	0.140
1-Aug-06	ND	ND	ND	ND	ND	0.050	0.070	0.035	0.070
15-Aug-06	ND	ND	ND	ND	ND	ND	ND	ND	ND
29-Aug-06	ND	ND	ND	ND	ND	ND	ND	ND	ND
13-Sep-06	ND	ND	ND	ND	ND	ND	ND	ND	ND
26-Sep-06	ND	ND	ND	0.070	0.080	0.060	0.120	0.058	0.120
10-Oct-06	ND	ND	ND	ND	0.060	0.070	0.090	0.046	0.090
24-Oct-06	ND	ND	ND	0.090	0.120	0.120	0.120	0.075	0.120
8-Nov-06	ND	ND	0.080	0.060	0.070	0.050	0.060	0.053	0.080
21-Nov-06	ND	ND	0.060	0.090	0.090	0.070	0.070	0.061	0.090
5-Dec-06	ND	0.080	0.080	0.100	0.100	0.090	0.090	0.081	0.100
20-Dec-06	ND	ND	ND	0.100	0.060	ND	ND	0.041	0.100
3-Jan-07	ND	0.060	0.050	0.070	0.070	0.070	0.060	0.058	0.070
18-Jan-07	0.050	0.070	0.090	0.070	0.060	0.060	0.070	0.067	0.090
30-Jan-07	ND	0.050	0.050	0.060	0.060	0.060	0.050	0.051	0.060
14-Feb-07	0.060	0.060	0.050	0.060	0.060	0.060	0.060	0.059	0.060
28-Feb-07	0.080	0.080	0.080	0.110	0.090	0.100	0.090	0.090	0.110
13-Mar-07	ND	ND	ND	ND	0.050	ND	0.090	0.038	0.090
28-Mar-07	0.060	ND	0.050	0.080	0.060	0.090	0.090	0.065	0.090
10-Apr-07	ND	ND	ND	ND	ND	ND	ND	ND	ND
24-Apr-07	ND	ND	ND	0.080	0.090	0.080	0.090	0.059	0.090
8-May-07	ND	0.060	0.050	0.090	0.080	0.100	0.130	0.076	0.130
23-May-07	ND	ND	0.060	0.090	0.080	ND	0.050	0.051	0.090
5-Jun-07	0.060	ND	ND	0.080	0.060	ND	0.070	0.049	0.080
19-Jun-07	0.100	0.110	0.100	0.140	0.140	0.150	0.170	0.130	0.170
mean	0.035	0.040	0.045	0.070	0.063	0.059	0.070	0.055	
max	0.100	0.110	0.100	0.140	0.140	0.150	0.170		0.170

7 Total Suspended Solids

The measured values of TSS at 1 and 10 m over the entire year are presented in Tables 5 and 6. The RDL for the analysis is 0.5 mg/L. There was a single value below detection. For statistical purposes this value has been replaced with the RDL/2 (0.025 mg/L). On average the TSS levels are quite low. The annual mean level is about 3.2 mg/L. There is no appreciable difference in the 1 and 10 m samples. There is survey to survey variability with survey means ranging from a low of 1.2 to a high of about 5.6 mg/L. Overall, as with ammonia, there does not appear to be a simple correlation between TSS concentrations and meteorological events/oceanographic conditions. There are occasional higher values that seem to be associated with more extreme events (e.g. storms, plankton blooms etc). These events are generally identifiable visually and are usually documented in field notes. The only easily identified spatial variation is that TSS tends on average to be lower at B2 in the Outer Harbour.

Table 5. Annual summary of 1 m TSS values

1 m	**B2**	**D2**	**EE2**	**E2**	**F2**	**G2**	**H2**	**mean**	**max**
21-Jun-06	3.0	4.0	3.0	4.0	4.0	4.0	2.0	3.4	4.0
4-Jul-06	7.0	5.0	8.0	5.0	7.0	4.0	5.0	5.9	8.0
18-Jul-06	missing	2.0	3.0	5.0	3.0	4.0	6.0	3.8	6.0
1-Aug-06	2.0	3.0	3.0	6.0	2.0	2.0	3.0	3.0	6.0
15-Aug-06	5.0	5.0	7.0	7.0	6.0	7.0	4.0	5.9	7.0
29-Aug-06	missing	2.3	2.9	4.1	4.2	5.1	4.1	3.8	5.1
13-Sep-06	missing	1.3	2.1	2.1	1.9	2.6	2.4	2.1	2.6
26-Sep-06	1.0	1.0	1.0	1.2	1.8	1.0	2.5	1.4	2.5
10-Oct-06	0.8	2.2	7.0	5.0	6.2	4.6	8.0	4.8	8.0
24-Oct-06	0.6	1.0	missing	1.0	1.0	1.8	1.6	1.2	1.8
8-Nov-06	0.9	1.0	1.0	1.0	2.5	2.0	4.0	1.8	4.0
21-Nov-06	1.8	1.2	2.2	1.9	2.2	1.1	1.8	1.7	2.2
5-Dec-06	1.0	2.0	3.0	2.0	1.0	2.0	1.0	1.7	3.0
20-Dec-06	1.8	2.8	2.4	4.6	2	3.7	6.4	3.4	6.4
3-Jan-07	2.1	1.4	1.8	1.3	3.3	3.5	2.2	2.2	3.5
18-Jan-07	0.7	1.5	2.7	3.2	1.4	1.6	1.5	1.8	3.2
30-Jan-07	1.3	2.4	0.8	1.1	ND	0.7	2.3	1.2	2.4
14-Feb-07	0.6	3.5	2.2	1.8	2.1	5.1	1.9	2.5	5.1
28-Feb-07	3.0	2.8	2.0	1.7	3.0	4.0	4.1	2.9	4.1
13-Mar-07	2.6	2.3	6.8	5.1	3.9	4.5	5.2	4.3	6.8
28-Mar-07	4.3	7.1	3.6	2.8	4.0	10.0	10.0	6.0	10.0
10-Apr-07	2.5	4.7	4.0	2.2	5.2	4.5	4.9	4.0	5.2
24-Apr-07	3.9	1.7	2.9	5.6	6.7	3.4	5.2	4.2	6.7
8-May-07	missing	6.2	3.3	3.0	3.1	3.0	1.8	3.4	6.2
23-May-07	1.0	2.0	2.7	8.0	5.7	2.0	7.0	4.1	8.0
5-Jun-07	1.5	3.0	2.6	3.2	2.3	4.4	7.9	3.6	7.9
19-Jun-07	1.5	3.3	1.3	1.5	2.2	3.8	2.4	2.3	3.8
mean	2.2	2.8	3.2	3.3	3.2	3.5	4.0	3.2	
max	7.0	7.1	8.0	8.0	7.0	10.0	10.0		10.0

Table 6. Annual summary of 10 m TSS values

10 m	B2	D2	EE2	E2	F2	G2	H2	mean	max
21-Jun-06	3.0	2.0	4.0	3.0	3.0	4.0	6.0	3.6	6.0
4-Jul-06	7.0	5.0	7.0	3.0	12.0	15.0	6.0	7.9	15.0
18-Jul-06	missing	2.0	3.0	3.0	5.0	3.0	2.0	3.0	5.0
1-Aug-06	7.0	3.0	4.0	3.0	3.0	4.0	3.0	3.9	7.0
15-Aug-06	4.0	5.0	5.0	3.0	8.0	5.0	6.0	5.1	8.0
29-Aug-06	missing	3.5	4.0	5.5	7.7	5.0	3.6	4.9	7.7
13-Sep-06	missing	1.9	3.0	3.1	missing	2.9	2.4	2.7	3.1
26-Sep-06	0.8	1.9	1.0	3.1	0.8	3.8	1.3	1.8	3.8
10-Oct-06	1.0	4.0	4.0	2.9	5.0	4.0	2.0	3.3	5.0
24-Oct-06	missing	missing	1.0	3.0	0.7	missing	2.0	1.7	3.0
8-Nov-06	0.8	1.0	1.2	1.4	1.0	2.1	4.0	1.6	4.0
21-Nov-06	1.8	1.2	2.6	3.1	1.1	1.5	1.2	1.8	3.1
5-Dec-06	1.2	1.4	1.0	1.0	2.1	1.1	2.0	1.4	2.1
20-Dec-06	1.0	2.9	2.1	1.9	1.5	2.5	1.6	1.9	2.9
3-Jan-07	ND	0.9	3.0	1.4	3.6	1.0	1.0	1.6	3.6
18-Jan-07	0.9	2.1	1.3	2.6	1.7	2.7	1.1	1.8	2.7
30-Jan-07	2.3	2.4	1.4	1.9	1.5	1.3	1.6	1.8	2.4
14-Feb-07	3.7	5.8	2.2	2.0	5.4	2.4	2.6	3.4	5.8
28-Feb-07	1.3	1.4	2.0	4.5	3.0	1.6	5.9	2.8	5.9
13-Mar-07	3.4	6.3	3.7	5.7	6.9	5.8	4.0	5.1	6.9
28-Mar-07	4.1	5.3	2.8	2.8	4.3	3.8	2.7	3.7	5.3
10-Apr-07	1.5	3.0	4.8	2.7	3.5	3.9	2.0	3.1	4.8
24-Apr-07	6.0	3.7	3.0	3.8	6.1	1.9	1.9	3.8	6.1
8-May-07	missing	1.6	2.6	2.2	2.7	9.3	7.3	4.3	9.3
23-May-07	2.0	1.0	4.0	0.9	2.0	5.3	6.0	3.0	6.0
5-Jun-07	2.0	6.5	6.9	5.0	4.2	7.9	5.7	5.5	7.9
19-Jun-07	1.6	1.7	3.2	2.6	2.6	1.9	2.2	2.3	3.2
mean	2.6	2.9	3.1	2.9	3.8	4.0	3.2	3.2	
max	7.0	6.5	7.0	5.7	12.0	15.0	7.3		15.0

8 Metals

A summary of all measured metals concentrations over year three are presented in Figure 13. There are some individual guideline exceedances, notably in copper and mercury, however the mean values for all metals are well below the guideline levels. The metal regularly closest to the exceedance level is copper with a mean value under 20% of the guideline. This may be somewhat misleading as mercury also has levels approaching the guideline occasionally but the detection limit is 40% of the guideline. If mercury were regularly at 20% of the guideline it would be mostly non-detectable.

This plot shows that of the metals for which guidelines exist copper, manganese and zinc regularly have detectable levels. Lead, nickel and mercury are occasionally detectable, while cadmium was not detected. Iron is regularly detected, but has no guideline. Note that cobalt is also measured but has no guideline and is not regularly detectable, so it is not reported.

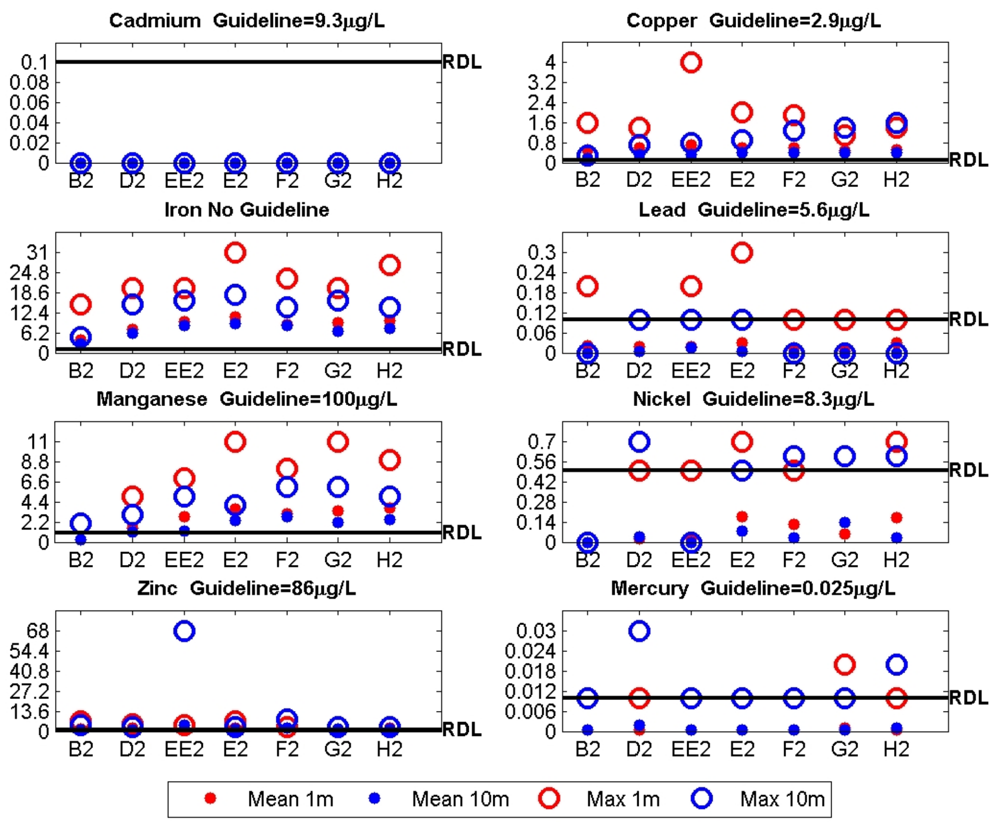


Figure 13. Mean and maximum values of metals (µg/L) over all year three samples.

9 References

Halifax Harbour Task Force. (1990). Halifax Harbour Task Force Final Report. Prepared for Nova Scotia Department of Environment, R. Fournier ed.