Halifax Harbour
Water Quality Monitoring Program
Quarterly Report #2

September - December 2004

HALIFAX
REGIONAL MUNICIPALITY

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Water Quality Monitoring Program
Quarterly Report #2

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

The weekly data sets are reviewed on a quarterly basis (13 weeks). The main objective of the quarterly reports is to summarize and evaluate the weekly data sets in terms of water quality objectives and concerns. The quarterly report also provides an opportunity to review the effectiveness of various aspects of the program and recommend changes that will improve the program.

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 will be documented in the quarterly reports.

Table of Contents

List of Figures

List of Tables

1 Introduction

This quarterly report represents a summary of Halifax Harbour Water Quality Monitoring Project (HHWQMP) data collected from 22 September 2004 to 14 December 2004. The analysis presented here represents an evolving presentation of the data. The data for the period are discussed in terms of compliance/exceedance of applicable water quality guidelines, and also as they affect recommendations for modification of the program. The emphasis in this report is the start of an assessment of the efficacy of the sampling program and the potential for introduction of systematic sampling bias in the data. This is a necessary step in the more detailed statistical analysis of the data which can occur as the project proceeds. In addition, the graphical presentation/analysis of the data has been enhanced. Particularly, the fecal coliform analysis has been modified to be in accordance with procedures presented the Guidelines for Canadian Recreational Water Quality (GCRWQ) (Health and Welfare Canada, 1992).

2 Weekly Reporting

The basic weekly report format is discussed in detail in the introduction of the project report binder and in Quarterly Report #1 (QR#1) (JWL and COA, 2004). There are continued slight modifications and enhancements to the format as experience dictates. These include, addition of sampling time markers in the water level plots (Week 17, 13 Oct), standardization of contour intervals for cross section plots and correction of contouring problems on longitudinal section plots (Week 26, 14 Dec), and adjustment of the wind scale (Week 19, 26 Oct).

The internal structure of the MATLAB scripts continues to be revised to streamline the processing. Ultimately these scripts, which track the complete sequence of the data processing/display can be provided as part of the data documentation.

3 Sampling Program

Survey sampling was conducted from one of two vessels based at the Armdale Yacht Club (AYC). The details of the sampling program are discussed in the introduction section of the project report binder and QR#1. The locations of the 34 sampling sites are included for reference in Figure 1. Sampling involves the collection of continuous profile data and discrete water samples at 1 and 10m water depth. A summary of the sampling and analysis schedules and relevant established criteria are reiterated in Table 1.

Issues and changes in the sampling procedure occurring during the second quarter are summarized in the following sub-sections.

3.1 Sampling Order

Sampling order is varied to minimize biasing the collected data with respect to known diurnal variations in sewage load and sunlight (i.e. we do not repeatedly sample at a particular site at the same time of day, in order to avoid the morning and late-day 'flush'). A variable circuit was designed that results in 'quasi' random sampling, subject to certain operational constraints. This procedure is discussed in QR#1. The efficacy of the sampling procedure, with respect to sample timing, is discussed in subsections below. The sampling order for this quarter is presented in Table 2.

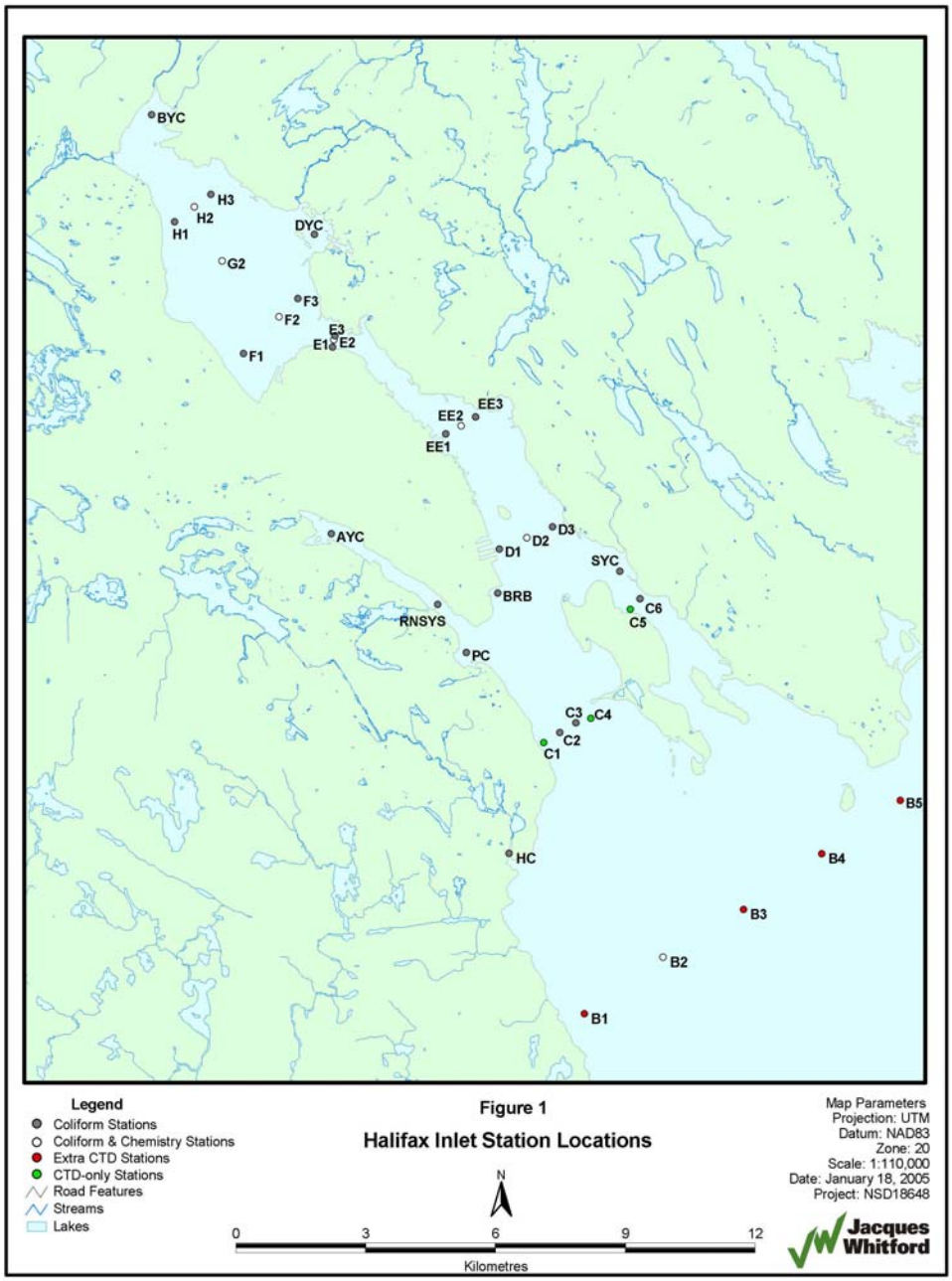

Figure 1. Location of the water quality monitoring sampling sites

Table 1. Summary of measured parameters

	EQL		Harbour Task Force Guideline	Water Use Category	Sampling Stations (refer to Fig. 1)	Sampling frequency
	value	units				
Profile Data					All	weekly
Salinity	n/a	PSU	n/a	n/a		
Temperature	n/a	C°	n/a	n/a		
Chlorophyll *a*	n/a	ug/L	n/a	n/a		
			8	SA		
Dissolved Oxygen	n/a	mg/L	7	SB		
			6	SC		
Secchi depth	n/a	m	n/a	n/a		
Bacteria Samples					Bacteria + Chemical	weekly
		cfu/	14	SA		
Fecal Coliform	0	100m l				
			200	SB		
Chemical Samples					Chemical sites	bi-weekly
CBOD	5	mg/L	none			
Ammonia Nitrogen	0.05	mg/L	none			
			<10%			
TSS	0.5	mg/L	background	all		
Total Oil and Grease	5	mg/L	10	all		
Metal scan					Chemical sites	bi-weekly
Cadmium	3	ug/L	9.3	all		
Chromium	20	ug/L	50.0	all		
Copper	20	ug/L	2.9	all		
Lead	5	ug/L	5.6	all		
Manganese	20	ug/L	100.0	all		
Nickel	20	ug/L	8.3	all		
Zinc	50	ug/L	86.0	all		
Aluminum	100	ug/L	none			
Antimony	20	ug/L	none			
Arsenic	20	ug/L	none			
Barium	50	ug/L	none			
Beryllium	20	ug/L	none			
Bismuth	20	ug/L	none			
Boron	500	ug/L	none			
Cobalt	10	ug/L	none			
Lithium	20	ug/L	none			
Iron	500	ug/L	none			
Molybdenum	20	ug/L	none			
Selenium	50	ug/L	none			
Strontium	50	ug/L	none			
Thallium	1	ug/L	none			
Tin	20	ug/L	none			
Titanium	20	ug/L	none			
Uranium	1	ug/L	none			
Vanadium	20	ug/L	none			

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

Date	22-Sep-04	28-Sep-04	5-Oct-04	13-Oct-04	19-Oct-04	26-Oct-04	3-Nov-04	9-Nov-04	17-Nov-04	24-Nov-04	1-Dec-04	9-Dec-04	14-Dec-04
Survey #	14	15	16	17	18	19	20	21	21	23	24	25	26
code	a7	b13	a8	b11	b8	b7	b11	b12	b12	a11	a9	b14	a10
1	D3	HC	EE2	PC	SYC	D3	PC	AYC	AYC	PC	EE1	C1	D1
2	D2	B2	EE3	C2	C6	EE3	C2	RNSYS	RNSYS	C2	D1	C2	EE1
3	EE3	C3	D2	C1	C5	E3	C1	BRB	BRB	C1	BRB	PC	E1
4	EE2	C4	D3	HC	C4	F3	HC	D1	D1	HC	AYC	RNSYS	F1
5	E3	C5	SYC	B2	C3	DYC	B2	D2	D2	B2	RNSYS	AYC	G2
6	E2	C6	C6	C3	B2	H3	C3	EE2	EE2	C3	PC	BRB	H1
7	F2	SYC	C5	C4	HC	BYC	C4	EE1	EE1	C4	C2	D1	BYC
8	F3	D3	C4	C5	C1	H2	C5	E2	E2	C5	C1	D2	H2
9	DYC	EE3	C3	C6	C2	H1	C6	E1	E1	C6	HC	EE2	H3
10	H3	E3	B2	SYC	PC	G2	SYC	F2	F2	SYC	B2	EE1	DYC
11	H2	F3	HC	D3	RNSYS	F1	D3	F1	F1	D3	C3	E2	F3
12	BYC	DYC	C1	EE3	AYC	F2	EE3	G2	G2	D2	C4	E1	F2
13	H1	H3	C2	E3	BRB	E1	E3	H1	H1	EE3	C5	F2	E2
14	G2	BYC	PC	F3	D1	E2	F3	H2	H2	EE2	C6	F1	E3
15	F1	H2	RNSYS	DYC	D2	EE1	DYC	BYC	BYC	E3	SYC	G2	EE2
16	E1	H1	AYC	H3	EE2	EE2	H3	H3	H3	E2	D3	H1	EE3
17	EE1	G2	BRB	BYC	EE1	D2	BYC	DYC	DYC	F2	D2	H2	D2
18	D1	F1	D1	H2	E2	D1	H2	F3	F3	F3	EE3	BYC	D3
19	BRB	F2	EE1	H1	E1	BRB	H1	E3	E3	DYC	EE2	H3	SYC
20	AYC	E1	E1	G2	F2	AYC	G2	EE3	EE3	H3	E3	DYC	C6
21	RNSYS	E2	F1	F1	F1	RNSYS	F1	D3	D3	H2	E2	F3	C5
22	PC	EE1	G2	F2	G2	PC	F2	SYC	SYC	BYC	F2	E3	C4
23	C2	EE2	H1	E1	H1	C2	E1	C6	C6	H1	F3	EE3	C3
24	C1	D2	BYC	E2	H2	C1	E2	C5	C5	G2	DYC	D3	B2
25	HC	D1	H2	EE1	BYC	HC	EE1	C4	C4	F1	H3	SYC	HC
26	B2	BRB	H3	EE2	H3	B2	EE2	C3	C3	E1	H2	C6	C1
27	C3	AYC	DYC	D2	DYC	C3	D2	B2	B2	EE1	BYC	C5	C2
28	C4	RNSYS	F3	D1	F3	C4	D1	HC	HC	D1	H1	C4	BRB
29	C5	PC	F2	BRB	E3	C5	BRB	C1	C1	BRB	G2	C3	PC
30	C6	C2	E2	RNSYS	EE3	C6	RNSYS	C2	C2	RNSYS	F1	B2	RNSYS
31	SYC	C1	E3	AYC	D3	SYC	AYC	PC	PC	AYC	E1	HC	AYC

3.2 Sampling Bias

The purpose of varying sample collection order is to randomize the time of day at which samples are collected, so as to eliminate bias due to diurnal fluctuation in the system. Additionally, the sampling conditions will be evaluated to document any introduced bias in other known environmental factors, which may affect water column concentrations. The following is a first look at potential bias with respect to time of day, water level, and rainfall.

3.2.1 Time of Day

Sewage flows have significant regular diurnal variations, which can affect the water quality in the harbour, particularly in the vicinity of outfalls in the Inner Harbour. 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 *a* and dissolved oxygen. The variation in sewage load is primarily an issue in the Inner Harbour, relatively close to the outfalls, while the sunlight affects the entire harbour. There are two issues regarding potential bias in sampling time. The first is the relative bias between sites—that is, can the statistics from one site be compared with those from another site? The second is the absolute bias to the environmental forcing, or, how well does the dataset represent typical conditions in the harbour? Our sampling has operational constraints which introduce a morning/early afternoon bias to the entire dataset. It is unlikely that this can be addressed except to document it.

Figure 2 represents the sampling time at each site since the start of the program in June 2004. The sites are generally sorted from north to south. There are a few patterns which emerge. The stations at the north end of Bedford Basin have less of a 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. This is a function of travel time from the Northwest Arm. Even if a site is sampled first, time is still taken to travel there. Given that sampling begins at the same time every week (07:00), and the boat originates in the Northwest Arm, it would be expected that Armdale Yacht Club (AYC) would have the earliest and latest sample times. This is the case except for outliers at Herring Cove, B2 and C3, the result of a single survey which was delayed due to contingencies. Given the necessary operational constraints the sampling scheme has resulted in a reasonably uniform distribution in the inner harbour (Section D through Section E) where diurnal fluctuations would likely be greatest. The diagram indicates that Station E1 was never sampled as early as E2 and E3. There appears to be no systemic reason for this, but occurred due to sampling delays when E1 was sampled early. A similar situation affects Site F1.

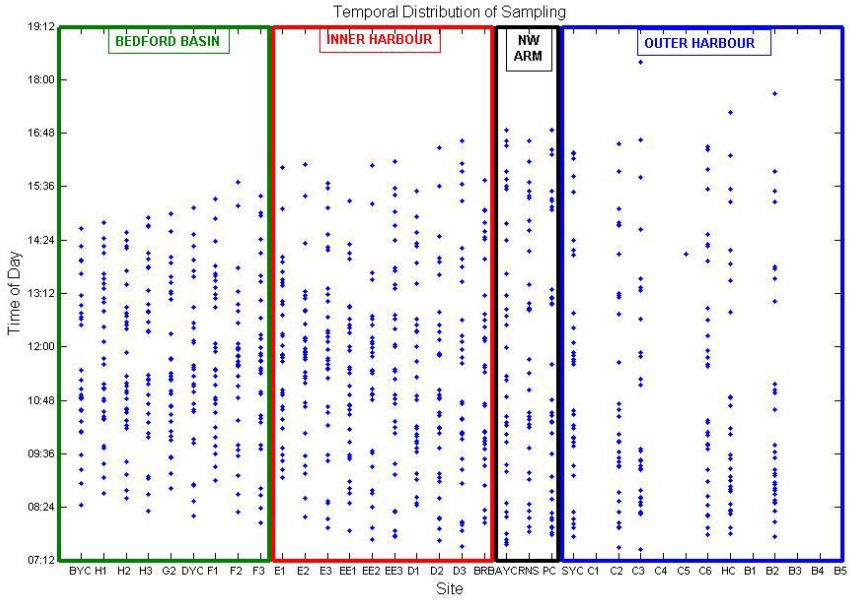

Figure 2. Temporal sampling distribution by site

3.2.2 Water Levels

The water level at the time of sampling can affect the results. The two most obvious effects would be expected to be whether a particular sample was taken upstream or downstream (based on tide direction) from the nearest outfall, and the variation in initial dilution from shallow outfalls. These are both issues primarily in the Inner Harbour. In the many shallow outfalls that currently exist in the harbour, the change in water depth can be a significant part of the water depth at the outfall. This can have a major effect on initial dilution and can affect whether a discrete plume or "pool" of effluent can exist at a sample site.

It also has been raised that there is a potential bias for when sampling on a weekly basis. Sampling which occurs on the same day every second week (the chemical sampling) could occur at the same point in the fortnightly tidal cycle (i.e. the same tidal range). An initial assessment of the tidal signal in Halifax Harbour indicates that the fortnightly cycle is sufficiently irregular (i.e. the tides are sufficiently "mixed") that this problem is unlikely, particularly given the variation in sampling day (Tuesday or Wednesday, sometimes Thursday). This issue may be revisited more rigorously at a later time.

A preliminary assessment of water level during sampling follows. 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 June 2004 to December 2004 is shown in Figure 3**.** The red line is the baseline against which water levels during sampling will be compared. The overall water level distribution is slightly bi-modal, expected given the primarily sinusoidal nature of the tides. The minimum roughly corresponds to the mean tide level. However the distribution is actually relatively flat,

between 0.6 m and 1.8 m. In an ideal situation each site would be sampled in a distribution similar to the overall distribution.

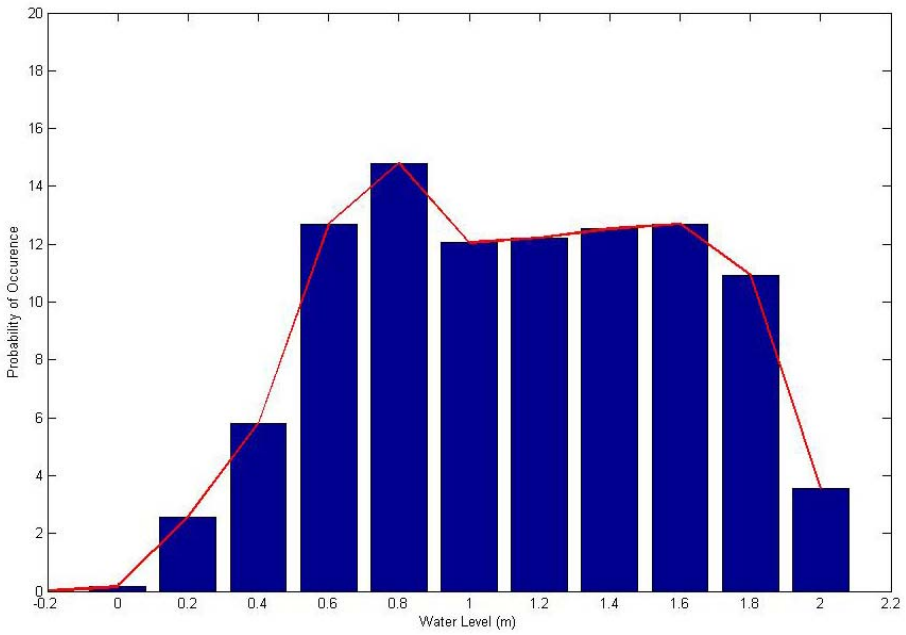

Figure 3. Probability distribution of water levels at Halifax, June to December 2004

Figure 4 show the distribution of water levels at the time of sampling compared to the overall water level distribution. The sampling distributions show that a relatively full range of water levels has been sampled at each site. There are no great variations from the baseline distribution except perhaps a slight bias toward higher water levels in the Northwest Arm.

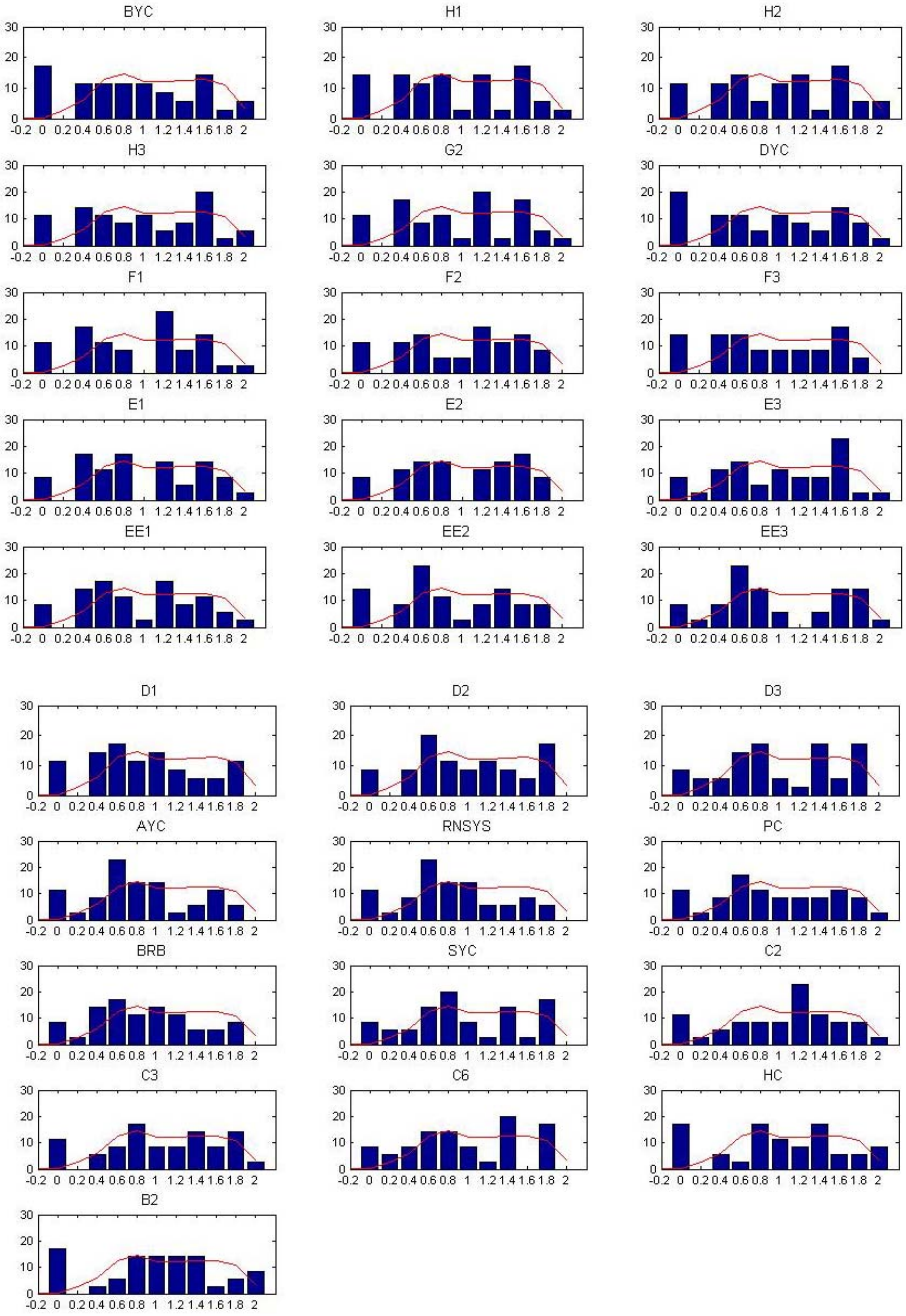

Figure 4. Water level distribution at each site during sampling

3.2.3 Precipitation

Rainfall affects both the sewage loads and the dynamics of the harbour. Following a rain event, effluent flows increase in a combined sewage system; collected material in the sewage pipes can be flushed; and the harbour, in response to the increased fresh water input, can become more stratified, enhancing estuarine circulation. The combination of increased flow and stratification can have a great effect on the near field behaviour of the plumes from the outfalls. These effects lag the rainfall by some time and persist for some period after the rain stops. The duration of the impact, of course, depends on the magnitude of the rain event. For purposes of discussion we will, somewhat arbitrarily, select a three day 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 the entire analysis period (23 June to 14 December). The blue bars on this plot represent a similar analysis performed for sampling days. The plot indicates that our sampling is relatively unbiased with respect to precipitation. Over the entire six month period about 44 % of days had precipitation less than 5 mm in the 72 hour window. The sampling day distribution includes 46% of these "dry days". On the other end, we generally have a good match given the limited number of samples. We did not sample the extreme wet end of the distribution (>50 mm), though, given the relatively small number of samples (26), even one sample in this region would have over-represented the distribution.

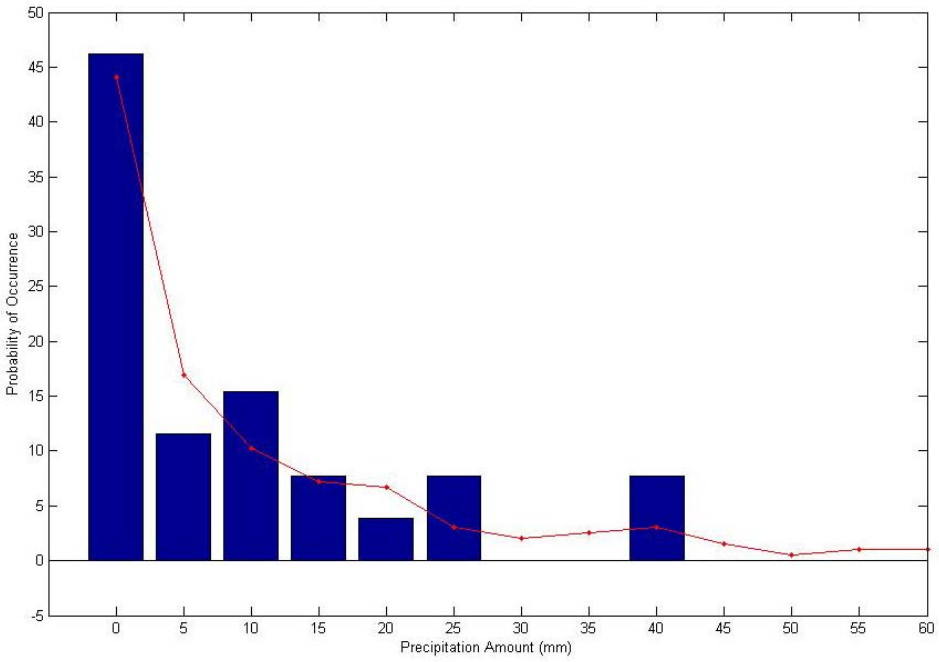

Figure 5. Probability distribution of cumulative 72 hour rainfall

3.3 Samples of Opportunity

On recommendations from discussions on the first quarterly report, a "sample of opportunity" procedure has been instituted to sample visible phenomenon (front's slicks, clouds, boils, etc.) when and if they are observed. The samples are accompanied by photographs and field notes to document the sampled conditions. Up to the date covered in this report (December 14, 2004), there have been none of these samples taken. These samples, in which reduced water quality is expected, should be processed for the full suite of analyses currently performed.

3.4 Sampling Protocol

Sampling protocol has been directed by experience and lab directions. CTD casts are performed according to the manufacturer's recommendation. These protocols will be documented and added to the project binder with weekly and quarterly reports.

4 Water Quality Results and Discussion

Preliminary results are discussed in the following sections with emphasis on any need for modifications to the initial program.

4.1 Fecal Coliform

As discussed in QR#1, fecal coliform (FC) data exhibit a great deal of variability. The appropriate measure for central tendency is generally either the median of samples, or the geometric mean. The Guidelines for Canadian Recreational Water Quality (GCRWQ) (Health and Welfare Canada 1992) evaluate criteria exceedance based on geometric mean. This will be used subsequently. Because zeros are not valid in the geometric mean calculation, ones (1s) are substituted for zero values. The result of this is that there will be no zeros in the geometric mean plots. The values of one are likely artificial and actually represent measurements of ones or zeros. Out of range values are generally reported by the lab as >10,000 in the resolution the analysis is being performed (see Lab Resolution section below and in QR#1). For analysis purposes, these values are relatively arbitrarily replaced by 14,999, simply a number >10,000 which is easily identified.

A map displaying median values was included in the first quarterly report and is included again here for reference as Figure 6 (values in red exceed guidelines). Figure 7 is a re-plot of those data using the geometric mean method (values in red exceed swimming guidelines; values in blue exceed shellfishing guidelines). Although the numbers change, the general pattern does not. The number of sites with values greater than swimming guidelines is reduced, while the number of sites exceeding shellfishing guidelines is increased. Figure 8 contains the same graphic for the second quarter. There is a

significant increase in values between the quarters. This is likely attributable to the cooler water and reduced sunlight, both of which increase bacterial survival times. The area affected by very high values of FC in the second quarter includes the northern end of the Inner Harbour and extends further to the south to include the Black Rock Beach, Purcell's Cove and Eastern Passage sites. As in the first quarter, the values at 1 m are, in general, higher than those at 10 m. The exception to this is in Bedford Basin, where the 10 m samples are almost always higher than the 1m samples. This also occurs in the second quarter (Figure 8) at two of the three stations in the Narrows. Water density data indicates that in the Basin, the coliform are associated with a deeper layer representative of the water in the Inner Harbour, while the 1 m sample generally occurs in a slightly less dense layer likely resulting from freshwater runoff into the Basin. The Inner Harbour is likely to be the source of bacteria over much of the Basin, rather than either a local source, or the Mill Cove sewage treatment plant (STP). It is also possible that the effluent from the Mill Cove STP generally stays submerged below the pycnocline which tends to exist in the northern Basin.

Significant variations in FC levels from week to week appear to correlate with meteorological and oceanographic phenomena. For example, Survey #24 (1 Dec) occurred at a time of relatively warm weather and moderate rainfall. The resulting snowmelt from the end of November storm caused the harbour to be highly stratified, probably the most stratified since the beginning of the project. The fecal coliform levels during this event were the highest observed to date with values greater than 200 cfu/100mL in all surface samples. A FC value of 560 cfu/100mL was recorded in the surface sample at B2, our reference site. The highest value recorded at this site aside from this survey was 72 cfu/100ml on 13 Oct. These correlations will be investigated further in future reports.

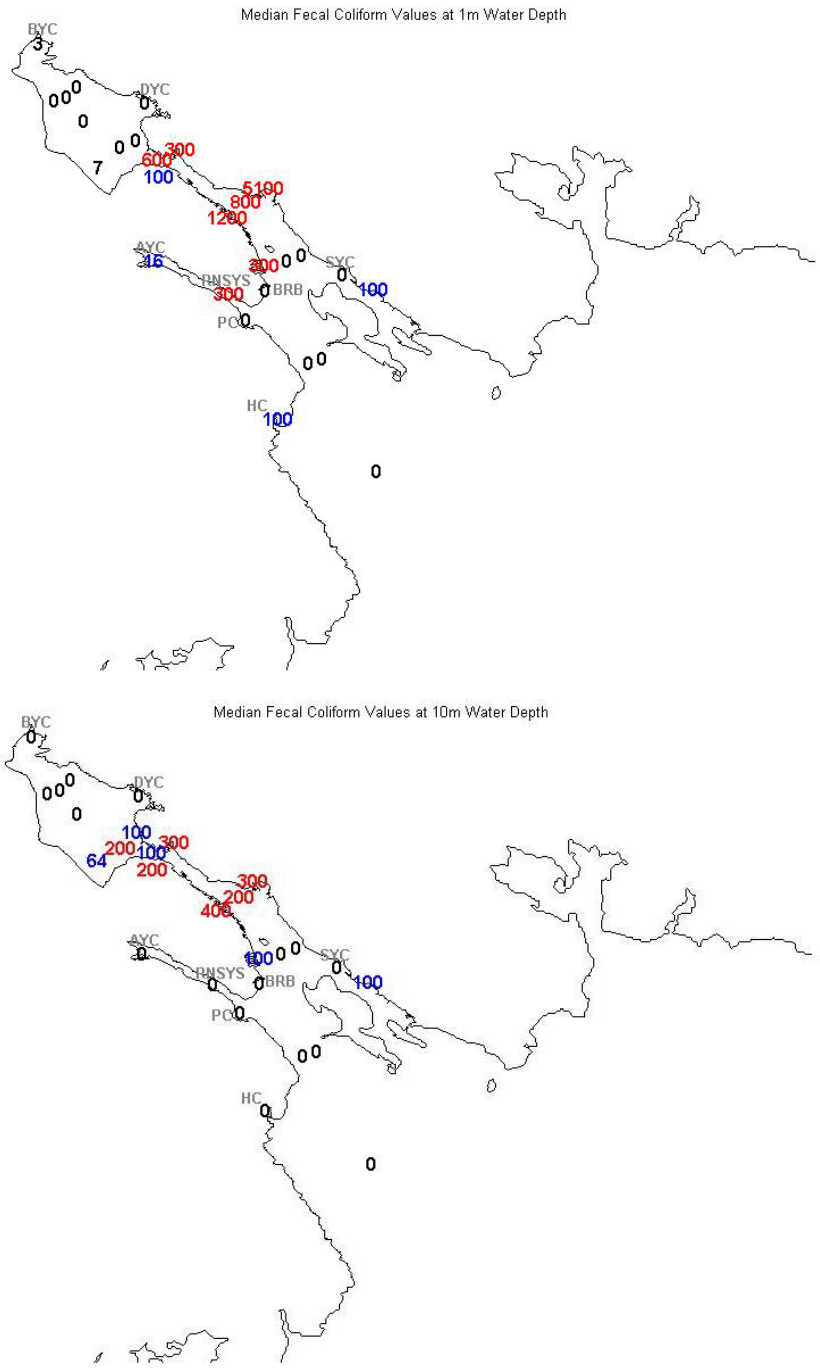

Figure 6. Fecal coliform median levels, 23 June thru 14 Sept. 2004

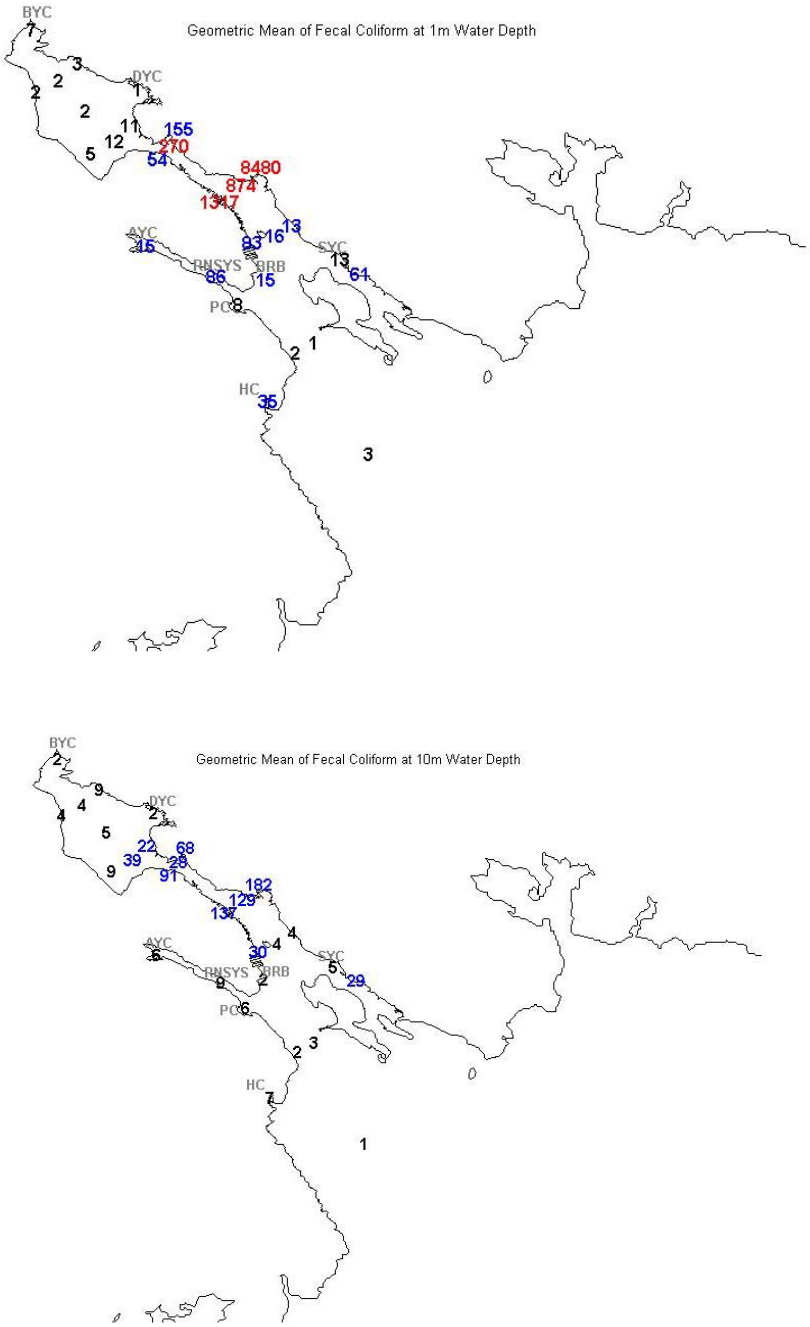

Figure 7. Fecal coliform geometric means (cfu/100mL), 23 June thru 14 Sept. 2004

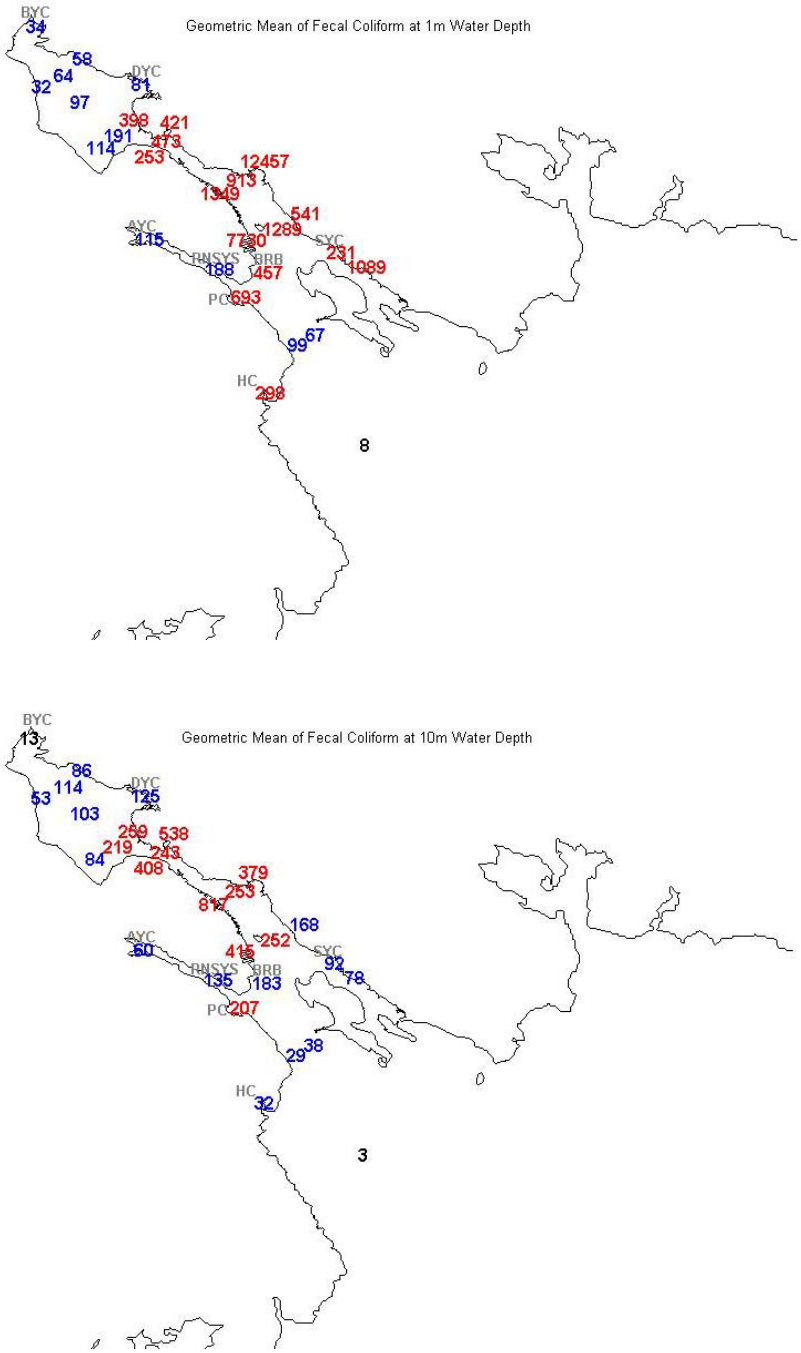

Figure 8. Fecal Coliform Geometric Means (cfu/100mL) 22 Sept. thru 14 Dec. 2004

4.1.1 Guideline Exceedance

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

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

1. ACCEPTABLE, defined as a geometric mean < 200 cfu/100mL
2. QUESTIONABLE, geometric mean less than 200 cfu/100mL but one or more samples >400 cfu/100mL
3. NOT ACCEPTABLE, geometric mean >200 cfu/100mL.

If there are missed samples within the 30 day period, the analysis uses a reduced number of samples, rather than extending the time beyond thirty days. Tables 3 and 4 show the results of the analysis for the 1m and 10m samples respectively. These tables indicate a general increase in bacteria concentrations over the quarter. At the start of the quarter the areas exceeding the criteria in the 1m samples are limited to the Inner Harbour, except Site C6 in Eastern Passage. Overall, for the near surface samples, the 22 Sep analysis has 7 unacceptable sites, 10 questionable and 11 acceptable. By the end of the period (14 Dec), the areas exceeding the criteria include the Inner Harbour, the Outer Harbour, save Site B2 (the reference site), regions of the southern Basin, Eastern Passage sites, and the Northwest Arm sites except Armdale Yacht Club. Overall the count at this time is 19 unacceptable sites, 9 questionable and no acceptable sites. Similar patterns are seen in the 10m samples, (Table 4), although the values tend to be lower, with 4/15/19 (U/Q/A) in September going to 10/9/9 in December.

Interestingly, at many sites, seemingly those relatively removed from potential direct influence from outfalls and variations in freshwater input (primarily the Basin), the values of the smoothed 30 day average tend to increase relatively monotonically over the period (e.g. see Table 3, Sites B2, C2, C3, SYC, and D3). This may support the theory that the increase is due to decreasing sunlight and water temperatures.

Table 3. Five sample geometric mean of 1m fecal coliform concentrations (#/100 ml)

	Outer Harbour				Eastern Passage		Inner Harbour									
	B2	**HC**	**C2**	**C3**	**C6**	**SYC**	**BRB**	**D1**	**D2**	**D3**	**EE1**	**EE2**	**EE3**	**E1**	**E2**	**E3**
22-Sep-04	3	188	8	1	278	7	119	707	239	34	1505	1759	7652	63	499	36
28-Sep-04	3	216	3	1	1396	3	77	1020	162	11	1052	377	13115	98	599	45
05-Oct-04	1	182	4	2	3505	4	101	1518	223	31	1214	333	18155	188	981	52
13-Oct-04	2	227	7	5	1999	10	107	8166	187	51	1498	439	14574	201	657	185
19-Oct-04	5	733	12	21	1312	37	117	9594	806	165	1261	531	18460	272	769	615
26-Oct-04	7	531	41	43	2285	71	147	7797	1102	209	1886	755	27099	602	1109	1070
03-Nov-04	11	383	146	71	1845	268	330	7797	1151	545	2531	5168	19857	811	1299	1018
09-Nov-04	11	235	327	162	1331	274	760	9005	931	767	1435	3917	13512	254	378	925
17-Nov-04	6	131	330	101	965	350	1205	9722	1026	523	1273	2946	11569	313	618	1184
24-Nov-04	4	68	264	88	658	334	944	6134	1117	729	1268	1897	11569	244	535	410
01-Dec-04	15	84	371	166	673	991	1168	6870	1218	1011	1014	1399	9173	447	389	309
09-Dec-04	14	167	230	191	726	1371	813	6870	1595	1502	900	503	11623	185	186	186
14-Dec-04	32	227	334	230	563	1374	915	5027	2387	1848	1375	675	8347	269	281	138

	Bedford Basin									Northwest Arm		
	F1	**F2**	**F3**	**DYC**	**G2**	**H1**	**H2**	**H3**	**BYC**	**PC**	**RNSYS**	**AYC**
22-Sep-04	31	27	44	2	9	6	6	2	19	31	25	49
28-Sep-04	46	79	34	1	17	3	7	3	17	21	10	99
05-Oct-04	62	105	47	5	17	11	26	10	19	129	14	113
13-Oct-04	144	279	129	13	45	10	74	34	49	427	42	232
19-Oct-04	194	343	424	37	98	24	67	83	53	379	48	190
26-Oct-04	141	266	591	80	218	44	133	154	70	715	148	112
03-Nov-04	144	305	845	168	105	68	81	114	68	2294	798	91
09-Nov-04	84	153	285	97	55	25	30	41	18	1083	393	45
17-Nov-04	57	136	334	106	48	31	35	34	16	871	499	53
24-Nov-04	39	108	422	95	51	17	29	22	11	1177	761	34
01-Dec-04	83	135	321	171	79	37	58	41	32	1446	821	77
09-Dec-04	91	103	207	152	100	40	80	44	44	942	439	107
14-Dec-04	149	121	445	213	208	96	196	105	109	932	453	160

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

Table 4. Five sample geometric mean of 10m fecal coliform concentrations (#/100 ml)

	Outer Harbour				Eastern Passage		Inner Harbour									
	B2	**HC**	**C2**	**C3**	**C6**	**SYC**	**BRB**	**D1**	**D2**	**D3**	**EE1**	**EE2**	**EE3**	**E1**	**E2**	**E3**
22-Sep-04	1	17	2	7	10	7	4	254	6	34	595	186	282	205	28	34
28-Sep-04	1	14	2	9	10	4	7	252	6	31	587	128	239	164	82	127
05-Oct-04	1	9	3	5	6	12	16	206	17	22	995	119	229	286	120	571
13-Oct-04	2	10	3	10	22	34	25	303	27	36	1480	158	323	341	390	613
19-Oct-04	3	17	9	27	43	54	69	272	83	85	1275	121	397	551	411	571
26-Oct-04	4	47	25	57	50	50	321	430	372	110	1013	529	471	446	363	539
03-Nov-04	4	55	26	58	102	60	229	451	406	202	1452	518	632	767	491	644
09-Nov-04	4	38	46	68	115	74	262	565	394	243	1101	478	458	501	277	504
17-Nov-04	2	36	63	50	74	60	377	639	396	169	1101	503	402	573	333	629
24-Nov-04	3	37	58	37	79	69	299	636	396	193	1153	423	418	315	101	582
01-Dec-04	2	46	44	41	56	64	218	478	255	192	569	303	293	351	110	507
09-Dec-04	3	48	47	49	116	211	296	574	381	217	344	247	303	188	91	415
14-Dec-04	7	54	56	54	114	185	352	526	544	242	332	369	342	310	172	454

	Bedford Basin									Northwest Arm		
	F1	**F2**	**F3**	**DYC**	**G2**	**H1**	**H2**	**H3**	**BYC**	**PC**	**RNSYS**	**AYC**
22-Sep-04	13	45	45	25	30	31	31	32	2	35	4	10
28-Sep-04	14	112	54	34	47	33	40	36	2	28	4	14
05-Oct-04	34	82	200	83	66	39	53	52	2	51	15	42
13-Oct-04	68	115	276	183	172	53	104	103	3	116	21	70
19-Oct-04	59	152	257	208	146	35	105	106	6	110	56	45
26-Oct-04	177	592	448	216	374	75	235	208	6	175	225	141
03-Nov-04	143	650	592	159	190	71	201	177	8	377	345	136
09-Nov-04	131	460	332	105	127	34	86	87	13	580	232	93
17-Nov-04	80	271	352	57	66	38	77	57	17	605	274	123
24-Nov-04	67	205	237	41	41	34	63	35	11	497	266	73
01-Dec-04	71	179	150	51	50	51	88	53	36	303	213	58
09-Dec-04	87	184	82	53	62	52	52	49	44	192	140	52
14-Dec-04	140	377	179	174	124	166	166	136	57	183	189	63

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.

4.1.2 Lab Resolution

As discussed in detail in QR#1, the lab can measure FC values in various ranges. The report also included a proposed scheme which varies resolution for certain sites based on expected values. The purpose of the scheme is to minimize out-of-range and/or under-resolved values. The scheme was instituted for the survey of Dec 9 (Week 25). As it has only been in place for two surveys in this report, insufficient data exists to evaluate its effect. The procedure will be continued and re-evaluated regularly.

4.2 Ammonia Nitrogen

The laboratory estimated quantification level (EQL) for ammonia nitrogen is 0.05 mg/L. The values obtained for this period are shown in Table 5. Overall, 68% of all samples had detectible values of ammonia. This compares with 42% for the first quarter. For the purpose of computing statistics, the EQL value was used for values below detection. The values for this quarter, though more numerous, are similar in magnitude to those observed in the first quarter and vary over a relatively small range. However, as opposed to the first quarter values, there appears to be little systematic variation with depth. The average and maximum values over all surveys are plotted over a centerline section of the harbour in Figure 9. The highest values tend to be in the surface sample near the head of the Basin at H2. The next highest values tend to be in the 10 m sample at the southern end of the Basin at F2. This latter observation is consistent with the first quarter results.

Table 5. Ammonia Nitrogen summary (mg/L)

1 M	B2	D2	EE2	E2	F2	G2	H2	mean	max
Sep-28	0.05	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.06
Oct-13	0.05	0.12	0.12	0.13	0.11	0.1	0.15	0.11	0.15
Oct-26		0.08	0.06	0.08	0.06	0.08	0.23	0.10	0.23
Nov-09	0.05	0.06	0.05	0.06	0.08	0.08	0.08	0.07	0.08
Nov-24	0.05	0.06	0.08	0.05	0.06	0.05	0.08	0.06	0.08
Dec-09	0.05	0.05	0.05	0.11				0.07	0.11

10 M	B2	D2	EE2	E2	F2	G2	H2	mean	max
Sep-28	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Oct-13	0.07	0.09	0.09	0.11	0.12	0.10	0.13	0.10	0.13
Oct-26		0.05	0.05	0.07	0.18	0.07	0.08	0.08	0.18
Nov-09	0.06	0.08	0.05	0.09	0.09	0.08	0.07	0.07	0.09
Nov-24	0.05	0.08	0.05	0.05	0.05	0.05	0.07	0.06	0.08
Dec-09	0.05	0.05	0.05	0.05				0.05	0.05

Note: green highlights indicate values below detection limits (0.05 mg/L)

There appears to be some systematic temporal variability in the data. For example, on 28 Sept only two samples had values above detection limits and a maximum value of 0.06 mg/L was reported. On 13 Oct no samples were below detection and the average over all samples was 0.11 mg/L.

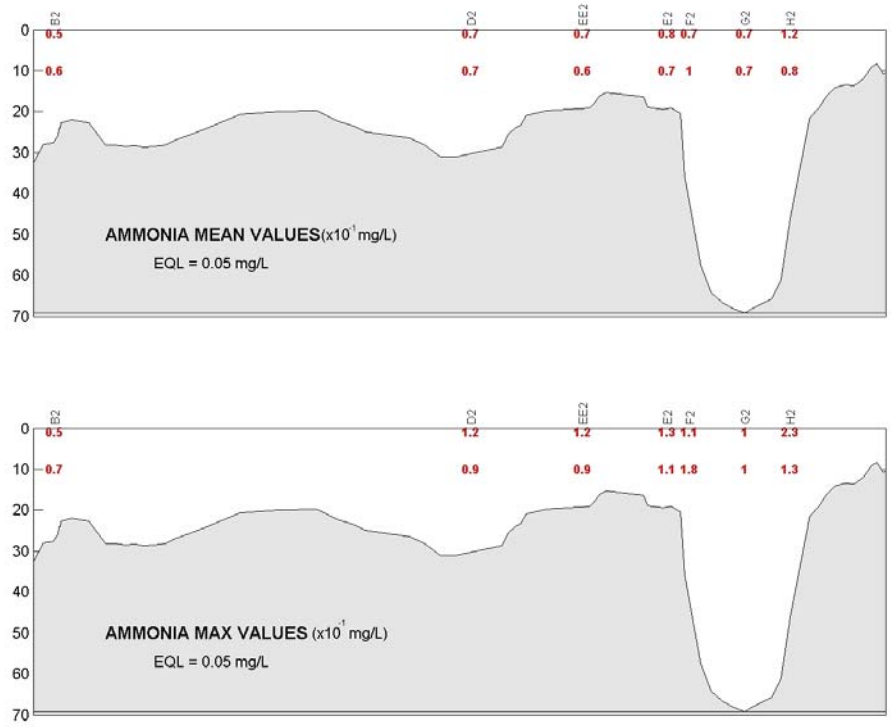

Figure 9. Mean and maximum value of ammonia nitrogen

4.3 Carbonaceous Biochemical Oxygen Demand

Since the start of the program, there have been two samples with detectible values of CBOD (EQL=5.0 mg/L). These occurred in the second quarter at station B2 (6 mg/L) on 13 Oct, and D2 – 1m (5 mg/L) on 26 Oct. A discussion of the probable reason for the undetectable values is contained in the first quarterly report. It is recommended that this parameter be dropped for regular bi-weekly sampling and retained for samples of opportunity.

4.4 Total Suspended Solids

A summary of the TSS values for this quarter is shown in Table 6. Overall, the TSS values in the second quarter were somewhat higher than in the first quarter. The mean value over all stations is greater than 4 mg/L for three of six surveys, whereas in the first quarter there were no survey mean values over 4 mg/L. The mean over all surveys for the first quarter is about 2.6 mg/L and in the second quarter it is approximately 4.5 mg/L. There is definite temporal variability with uniformly high values occurring on 9 Dec and

26 Oct. On these dates there were elevated values throughout the Harbour with survey means (over all samples) of 7.1 and 6.1 mg/L respectively. There does not appear to be a simple correlation with environmental parameters (rainfall, wind speed) for this variability, indicating that there are probably multiple factors involved.

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

1 M	B2	D2	EE2	E2	F2	G2	H2	mean	max
04-Sep-28	2.00	1.00	1.20	2.20	2.40	1.60	4.20	2.09	4.20
04-Oct-13	3.00	3.80	1.60	2.80	3.00	2.60	4.40	3.03	4.40
04-Oct-26		11.10	5.10	6.90	4.40	3.60	4.00	5.85	11.10
04-Nov-09	3.60	4.40	2.20	2.20	2.80	4.20	2.00	3.06	4.40
04-Nov-24	2.00	4.90	4.90	4.40	9.50	4.20	6.70	5.23	9.50
04-Dec-09	3.10	5.10	4.00	10.50				5.68	10.50
mean	2.74	5.05	3.17	4.83	4.42	3.24	4.26	4.15	
max	3.60	11.10	5.10	10.50	9.50	4.20	6.70		11.10

10 M	B2	D2	EE2	E2	F2	G2	H2	mean	max
04-Sep-28	2.20	1.40	1.60	3.20	3.20	3.80	4.20	2.80	4.20
04-Oct-13	2.00	1.80	1.80	2.80	9.80	2.00	2.00	3.17	9.80
04-Oct-26		5.60	9.30	10.20	4.90	5.30	3.10	6.40	10.20
04-Nov-09	4.70	3.20	3.80	6.40	2.90	4.00	2.00	3.86	6.40
04-Nov-24	2.00	2.70	2.20	3.60	6.00	5.30	9.50	4.47	9.50
04-Dec-09	4.40	14.20	7.10	8.50				8.55	14.20
mean	3.06	4.82	4.30	5.78	5.36	4.08	4.16	4.88	
max	4.70	14.20	9.30	10.20	9.80	5.30	9.50		14.20

Note: Green highlights indicate values below detection limit. (EQL= 1 mg/L except = 2mg/L for samples with lab duplicates).

Figure 10 shows the quarterly mean and maximum values plotted over a north south centerline section of the Harbour. There appears to be some systematic spatial variation, the most obvious being that on average the values at B2 are lowest. This is consistent between the first and second quarters. The highest values for this quarter tend to be in the vicinity of the Narrows (E2 and F2) rather than in the Basin, as was the case in the first quarter. There is not a large difference in values between the surface and 10m values, though the 10m values are slightly higher. This is the reverse of the first quarter and perhaps reflects reduced water column stratification and planktonic input during this period.

Although the values are higher than in the first quarter, there continues to be values <EQL. It is recommended that the sample size be increased to 1 L to reduce the EQL by half.

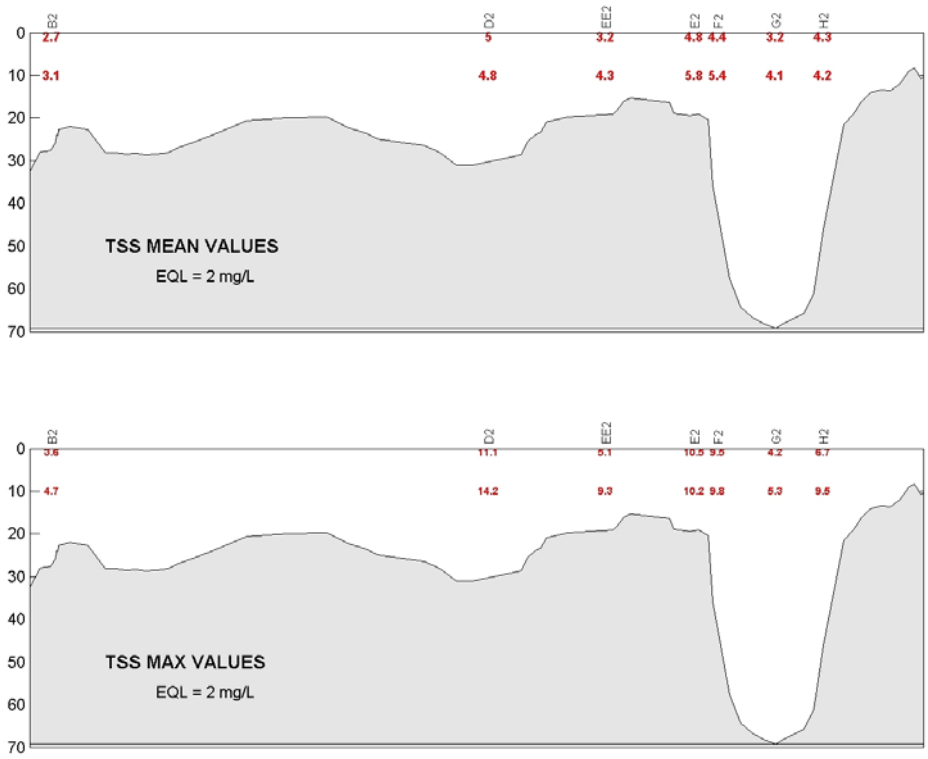

Figure 10. Mean and maximum values of TSS

4.5 Total Oils and Grease

There have been no samples with a value above detection limits in the first two quarters. It is recommended that lacking the availability of a more sensitive test that this parameter be dropped from regular sampling and should be retained for samples of opportunity.

4.6 Metals

In the second quarter there have been of twelve measurements of metals of interest in excess of EQL's, out of a possible total of 630 measurements (seven sites, two depths, plus one QA/QC, six surveys, seven metals – not counting missed samples) or less than 2%, or conversely 98% non-detectible values. The second quarter values are summarized in Table 7. Values in red indicate exceedance of guidelines.

Table 7. Summary of metal values >EQL for 22 Sep thru 14 Dec 2004

Lead EQL= 5 µg/L Guideline = 5.6 µg/L

Survey Date	Value (µg/L)	Site	Depth (m)	Notes
28-Sep-04	5.2	D2	10	
13-Oct-04	8.2	H2	1	QAQC <5
	5.5	H2	10	
9-Nov-04	8.0	F2	1	
	5.1	G2 (QAQC)	1	primary <5

Manganese EQL= 20 µg/L Guideline=100 µg/L

Survey Date	Value (µg/L)	Site	Depth (m)
28-Sep-04	70	B2	10
	33	F2	10
26-Oct-04	24	F2	1

Zinc EQL = 50 µg/L Guideline = 86 µg/L

Survey Date	Value(µg/L)	Site	Depth (m)
28-Sep-04	56	B2	10
	60	F2	10
13-Oct-04	83	H2	1
26-Oct-04	71	D2	1

The only guideline exceedances are two values of lead, one of which was in a QA/QC sample. Of the detected metals, only manganese really has sufficient resolution to evaluate the state of the Harbour with respect to the applicable guidelines. For example the mean concentration of lead could be 4 µg/L, close to the 5.6 µg/L guideline, and it would not be detected. It may be sufficient just to document that guidelines are currently met, but this may limit the utility of the data in assessing the "assimilative capacity" of the Harbour in then context of future waste treatment decisions. This secondary use of the data should be considered when it does not add to the cost of the project.

The first quarter measurements were nearly identical to those of the second quarter, with fourteen detectible values out of a possible 735 (seven surveys instead of six for second quarter), each resulting in 98% of non-detectible values. The main difference is that 12 of the detectible values in the first quarter were manganese, with one each of copper and zinc. There were also two exceedances of the guideline, in this case in the copper and zinc samples.

The metal scan determines concentrations of many metals for which no guidelines exist. Of these, boron lithium strontium, titanium, and uranium have detectible and quite consistent concentrations across all samples and all surveys. Typical concentrations are: boron (4000 µg/L), lithium (180 µg/L), strontium (6300 µg/L), titanium (70 µg/L), and

uranium (3.2 µg/L). Other metals show up sporadically. Aluminum, which occurred three times at levels of 110—140 µg/L, is the most common followed by vanadium, which appeared twice at levels of 10-13 µg/L. Molybdenum (39 µg/L) and iron (550 µg/L) each occurred once.

Copper has been identified as a key metal tracer in previous studies. This is because sewage monitoring has indicated that it has the highest source concentration compared to the water quality guideline, indicating that it is the most likely of the water quality guideline to be exceeded. Copper is under-resolved at the current EQL. In addition to the issues related to the resolution of metals such as copper, mercury, which has a specified guideline, is not included in the current analysis suite.

The metals concentrations measured indicate that the concentrations are generally well below guidelines, however the techniques being used result in mostly non-detectible values. The continuation of monitoring using the current methodology would likely provide little new information at considerable expense. Metals are, however, important, as they are parameters for which guidelines exist. In addition, metals concentrations in harbour sediments, which are linked to water column concentrations, were a primary issue in the environmental assessment of the previously proposed Halifax Harbour Cleanup project. This will continue to be an issue in the future. Eliminating monitoring for metals would not seem to be a justifiable option and other strategies are explored below.

The following are options to increase data resolution:

1. Use new, more sensitive scanning instruments/techniques which could potentially reduce EQL values (P. Yeats (BIO), R. Kean (RPC), pers. comm.), with a comparable per sample cost. This option should be investigated further for future implementation.

2. Reduce sampling schedule in favour of increased lab resolution. Lacking scanning technology of sufficient resolution and similar cost, the sampling program should be reduced and higher resolution lab analysis for specific metals performed. A mixed approach is recommended. The final configuration will depend on cost but the following strategy is recommended:

    A. A one time (perhaps annual) survey of the current sites with high resolution lab analysis.
    B. Periodic high resolution analysis at site B2 and an inner harbour site probably E2, but perhaps F2 or EE2, based on existing data. The frequency of sampling to be determined by budgetary considerations.

4.7 Chlorophyll *a*

In the first seven weeks of the quarter, the mean chlorophyll *a* observations (2.2 – 3.2 mg/m^3) over the entire harbour is increased over an apparent minimum background mean levels since the start of the program (approximately 1.0-1.4 mg/m^3). These mean values were accompanied by maximum values on the order of 20 to 35 mg/m^3. This compares with the three week period in the first quarter where survey mean values were elevated to approximately 8 mg/m^3. The values seem to vary systematically with time over the surveys; however, it cannot be ruled out, from the data alone, that these differences are caused by higher frequency fluctuations. In the second half of the quarter, the survey mean values dropped back to 1.0 to 1.9 mg/m^3, with maximum values from 3 to 19 mg/m^3. There appeared to be little systematic spatial variability from week to week, however the maximum observed value occurred north of the Narrows in 9 of the 13 weeks.

4.8 Dissolved Oxygen

As presented in QR#1, problems with DO data started in Week 5. These problems persisted into this quarter until Week 20. The data in this period, particularly in the near surface are questionable. The most reliable DO data are the data from the deep Basin. Dissolved oxygen levels in the deepest Basin waters (site G2 – approximately 70 m) continued to drop over the quarter from about 3.5 mg/L to 1.6 mg/L. This trend is expected to continue until the bottom waters are renewed by upwelling of coastal bottom water over the sill in the narrows.

With the instrument problems resolved, the dissolved oxygen values from Week 20 through Week 26 (Dec 14) were relatively high (8-10 mg/L) and uniform throughout most of the harbour. No exceedances of the relevant guidelines were observed anywhere except in the lower waters of Bedford Basin. In the Basin, the class SB criterion of 7 mg/L was always exceeded in water deeper than 25-35 m, depending on the week.

The quality control of the dissolved oxygen data would be improved if one or two water samples could be analyzed independently. This would clarify “questionable” data and expedite troubleshooting of potential instrument problems. It is recommended that this procedure be implemented.

5 Summary and Action Items

A brief statement of summary is provided along with any changes that occurred during the quarter, and action items that remain to be discussed with the Harbour Solution Project Team. These items reflect issues arising in this quarter as well as issues brought forward from previous quarterly reports.

5.1 Reporting

Weekly Reports

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

Changes – Minor changes in data presentation to make reports more legible and useable.

Action – Continued review of report for required adjustment due to program adaptations.

Quarterly Reports

Summary Statement – Quarterly report format and content continues to evolve.

Changes – Inclusion of sections evaluating sampling bias, upgrading graphics/analysis for water quality parameters.

Action – Continued development of format, particularly water quality data analysis/display. Documentation of sampling and analysis methods along with QA/QC procedures for inclusion in the project binder.

5.2 Sampling Program

Summary Statement – Sampling continues as per end of first quarter.

Changes – Implementation of "Sample of Opportunity" protocol

Action – Continued analysis of sampling scheme with respect to sample bias/adjustment of scheduling to improve efficiency as dictated. Consider modification of analysis suite to include/improve/remove some parameters (see below).

5.3 Water Quality Parameters

Fecal Coliform

Summary Statement – FC observations are high especially in the Inner Harbour. Levels are high at some recreational areas. Overall, the second quarter levels are higher than reported in the first quarter.

Changes – revised analytical resolution was initiated.

Action – Consider substitution of alternate and or additional tracers. Evaluate effects of revised analytical resolution.

Ammonia Nitrogen

Summary Statement – Ammonia nitrogen has detectable values in more than half the samples.

Changes – None.

Action – Consider monitoring more nitrogen species (QR#1).

CBOD

Summary Statement – Two samples had detectible CBOD levels at the EQL of 5 mg/L.

Changes – None.

Action – Consider recommendation for deleting from regular bi-weekly analysis suite. Should be retained for "Samples of Opportunity".

Total Suspended Solids

Summary Statement – Measured values are higher than for first quarter, but still have samples below EQL.

Changes – None.

Action – Consider recommendation to use of larger samples to reduce EQL to 0.5 mg/L.

Total Oils and Grease

Summary Statement – None detected.

Changes – None.

Action – Consider recommendation for deleting from regular bi-weekly analysis suite. Should be retained for "Samples of Opportunity.

Metals

Summary Statement – There were only two exceedances of metals guideline over the period (two samples with elevated lead levels). The metals concentrations in the harbour are under-resolved by our present technique (98% zeros).

Changes – None.

Action – Consider recommended modification to metals analysis (Section 4.6 above)

Chlorophyll *a*

Summary Statement – Chlorophyll *a* levels vary spatially and temporally throughout the harbour.

Changes – None.

Action – Establish dialogue with BIO basin monitoring program to establish ground truthing.

Dissolved Oxygen

Summary Statement – For this period oxygen levels are high in surface waters, but low in the deep water of Bedford Basin.

Changes – Additional quality control procedure implemented.

Action – Establish dialogue with BIO basin monitoring program. Consider recommendation for collecting samples for Winkler titration.

References

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