

Figure 3.5-15

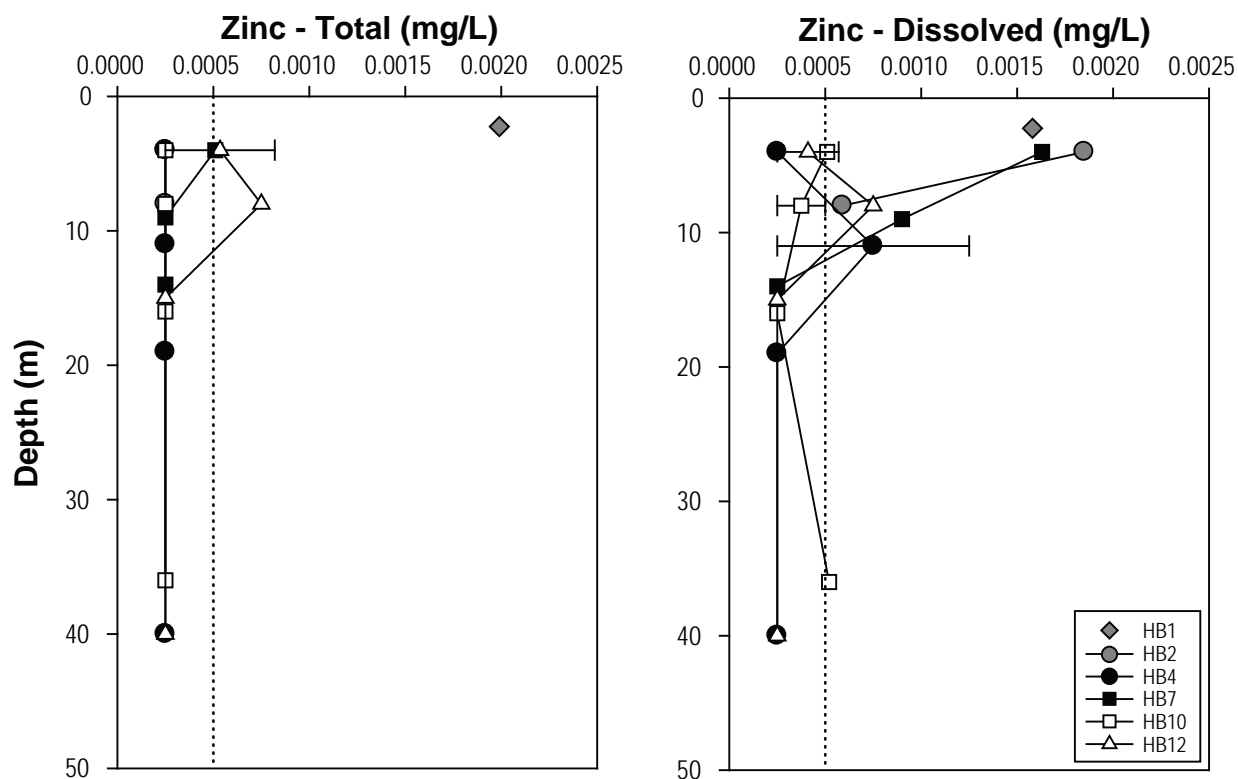


Figure 3.5-16

3.5.2 Summer

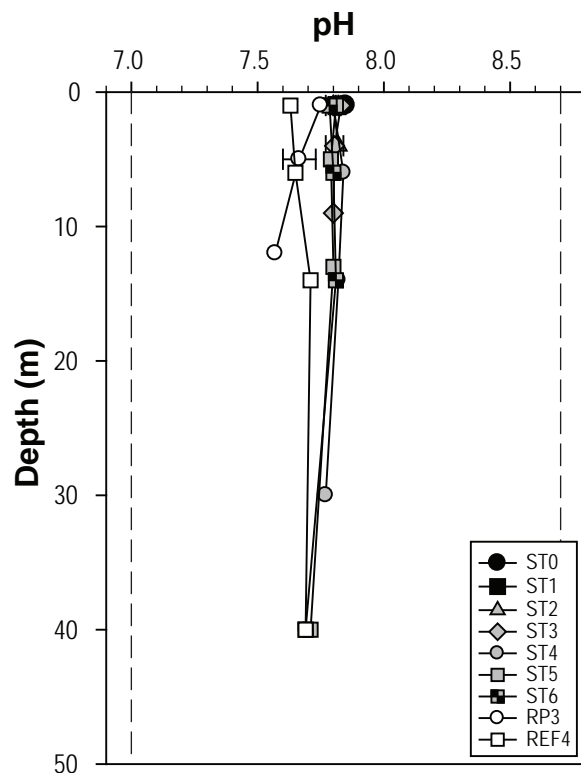
3.5.2.1 Roberts Bay and Reference Bay

Summer water quality samples were collected from seven sites in Roberts Bay (ST0 to ST6) on August 15, 2009, and two sites in Reference Bay (RP3 and REF4) on August 18, 2009. Samples were collected from both above and below the pycnocline (depth permitting) to characterize the vertical distribution of water quality parameters. Profiles of water quality parameters are shown in Figures 3.5-17 to 3.5-24, and all water quality data and realized detection limits are presented in Appendix 3.5-2.

Late summer pH levels were slightly lower at Reference Bay sites (average of 7.67) than at Roberts Bay sites (average of 7.80). pH did not vary consistently with depth, and was relatively constant among the sites in each bay (Figure 3.5-17). TSS concentrations ranged from 3.8 mg/L at several sites to 10.4 mg/L at site ST6 at 40-m depth (Figure 3.5-17). TSS tended to increase with depth, suggesting that suspended particles were settling out of the surface layer. Turbidity ranged from 0.19 NTU at ST4 at 30-m depth to 0.74 NTU at the surface of ST1 (Figure 3.5-17). Unlike TSS, turbidity was highest in surface waters and tended to decrease below the pycnocline. This discrepancy between TSS and turbidity trends may be due to the presence of dissolved light-scattering particles in the surface that would affect turbidity but not TSS concentrations.

Deep water nutrient concentrations measured in summer samples tended to be similar to winter levels (with the notable exception of deep water nitrate concentrations at ST4 and REF4 during summer, which were below detection limits). The main seasonal difference in nutrient profiles was that surface concentrations of nitrate, silicate (Figure 3.5-18), orthophosphate, and total phosphorus (Figure 3.5-19) were all markedly lower in summer than in winter. The trend was most evident for surface nitrate which dropped from 0.054 mg/L in winter (average of all sites) to below the detection limit (<0.006 mg/L) in late summer. This depletion of nitrate (as well as the extremely low phytoplankton biomass; see Section 3.7) suggests that phytoplankton growth during the late summer was likely limited by the availability of nitrate. Similar to the seasonal nitrate trend, surface orthophosphate dropped from 0.038 to 0.015 mg/L and surface silicate dropped from 1.4 to 0.64 mg/L from winter to summer. Total phosphorus concentrations and trends were very similar to orthophosphate, suggesting that orthophosphate made up the majority of the total phosphorus pool. Summer nitrite concentrations were always below the detection limit (<0.002 mg/L; Appendix 3.5-2). Ammonia concentrations tended to be near or below the analytical detection limit (<0.005 mg/L), and a maximum ammonia concentration of 0.017 mg/L was measured at site ST3 in Roberts Bay (Figure 3.5-18). TOC concentrations remained relatively consistent in deep waters from winter to summer, but average surface TOC levels increased from 0.89 mg/L in winter to 1.1 mg/L in summer, and reached a maximum summer concentration of 1.7 mg/L at REF4 in Reference Bay (Figure 3.5-19). These pronounced vertical trends in nutrients and TOC suggest that algal growth was occurring in surface waters of Roberts and Reference bays.

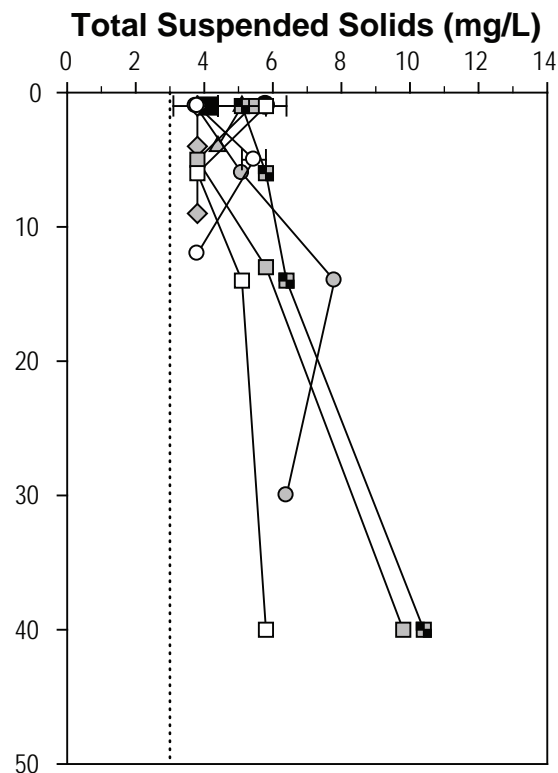
While overall nutrient trends were generally similar in Roberts and Reference Bays, sites in Reference Bay tended to have slightly lower surface concentrations of silicate and orthophosphate and slightly higher surface concentrations of TOC than Roberts Bay sites. Because nitrate is likely the limiting nutrient in these marine systems, the higher winter nitrate concentration in the surface waters of Reference Bay was likely able to support higher levels of phytoplankton growth during the summer in this embayment. This would explain the slightly greater drawdown of surface silicate and orthophosphate and higher TOC observed at Reference Bay sites in late summer.



Notes: Error bars are standard error of the mean.

Analytical detection limit = 0.1 pH units.

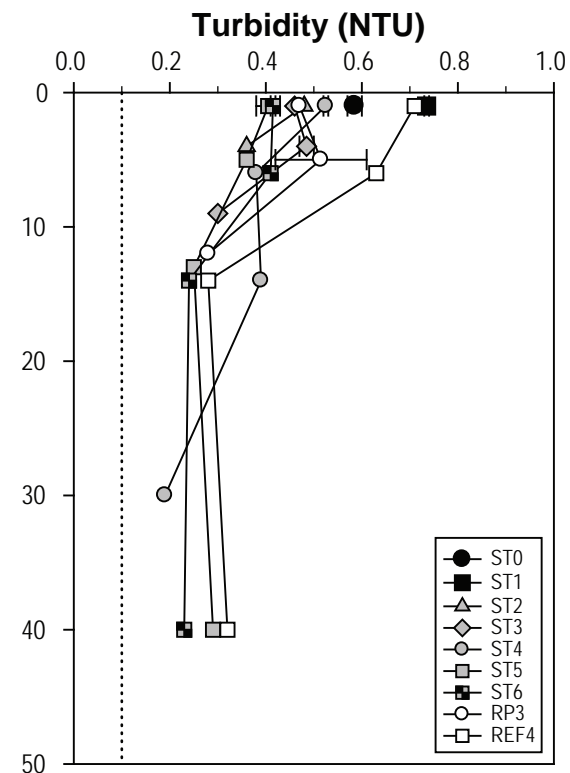
Dashed lines represent CCME water quality guideline (pH 7.0-8.7).



Notes: Error bars are standard error of the mean.

Dotted line represents analytical detection limit (3 mg/L).

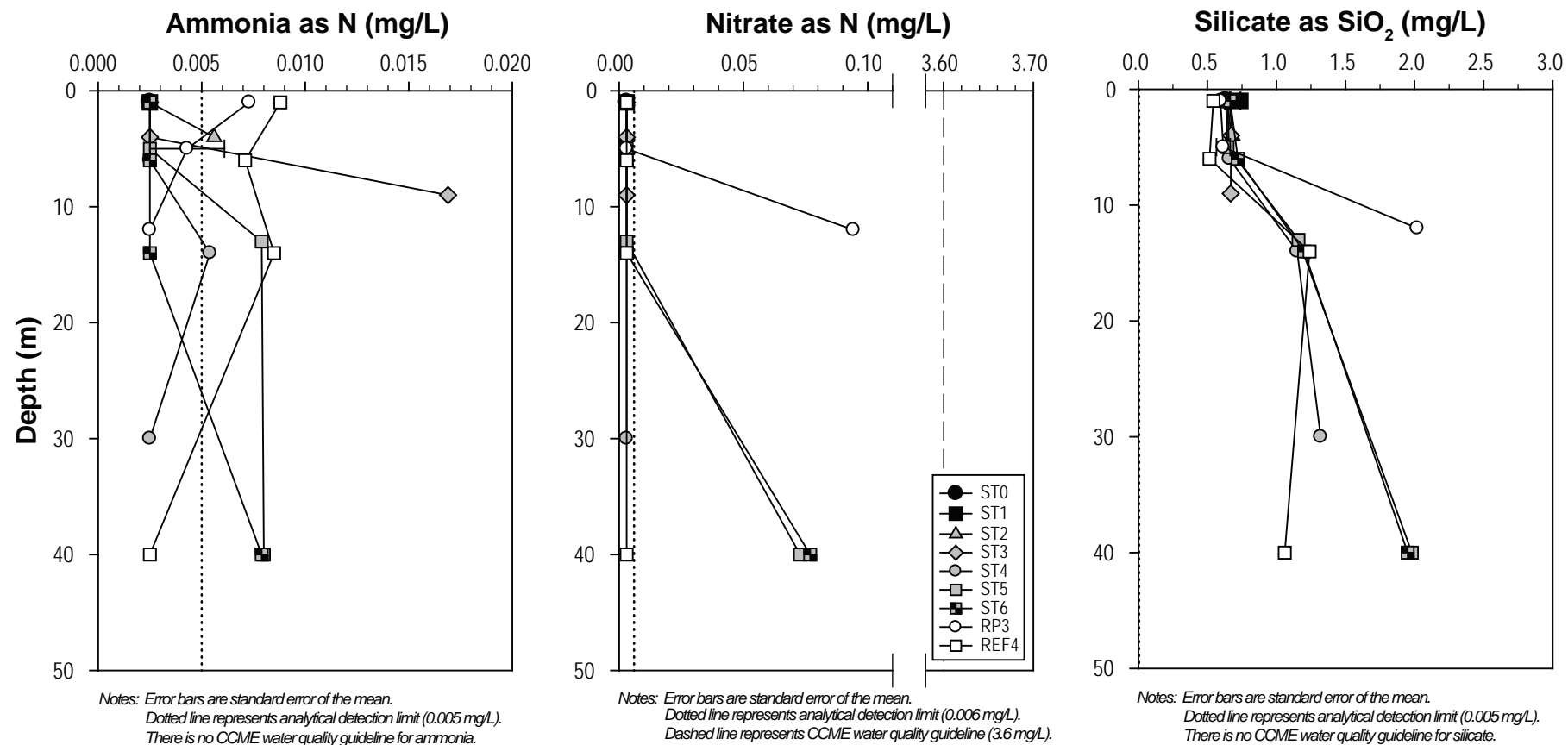
CCME guideline: maximum increase of 25 mg/L from background levels for short-term exposure, and maximum average increase of 5 mg/L from background levels for longer-term exposure.

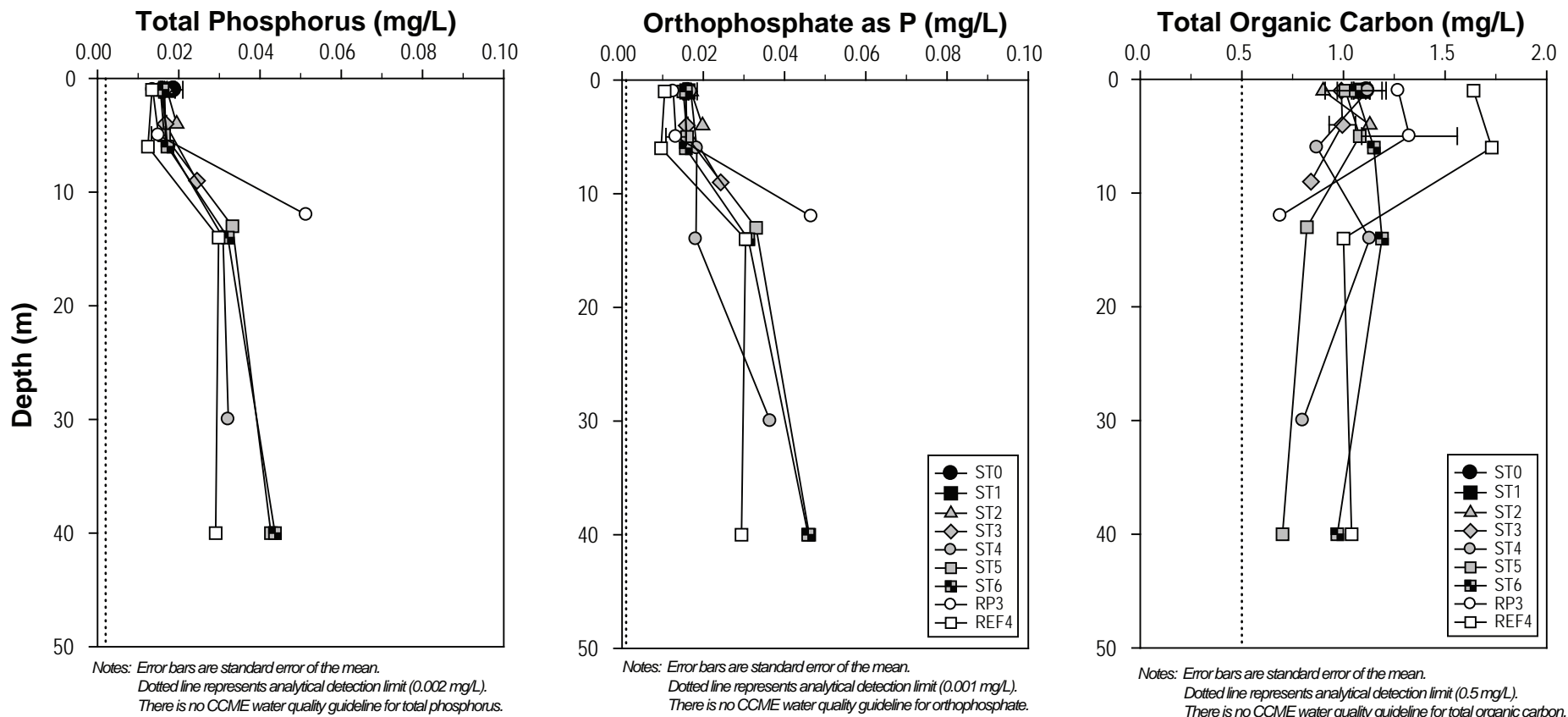


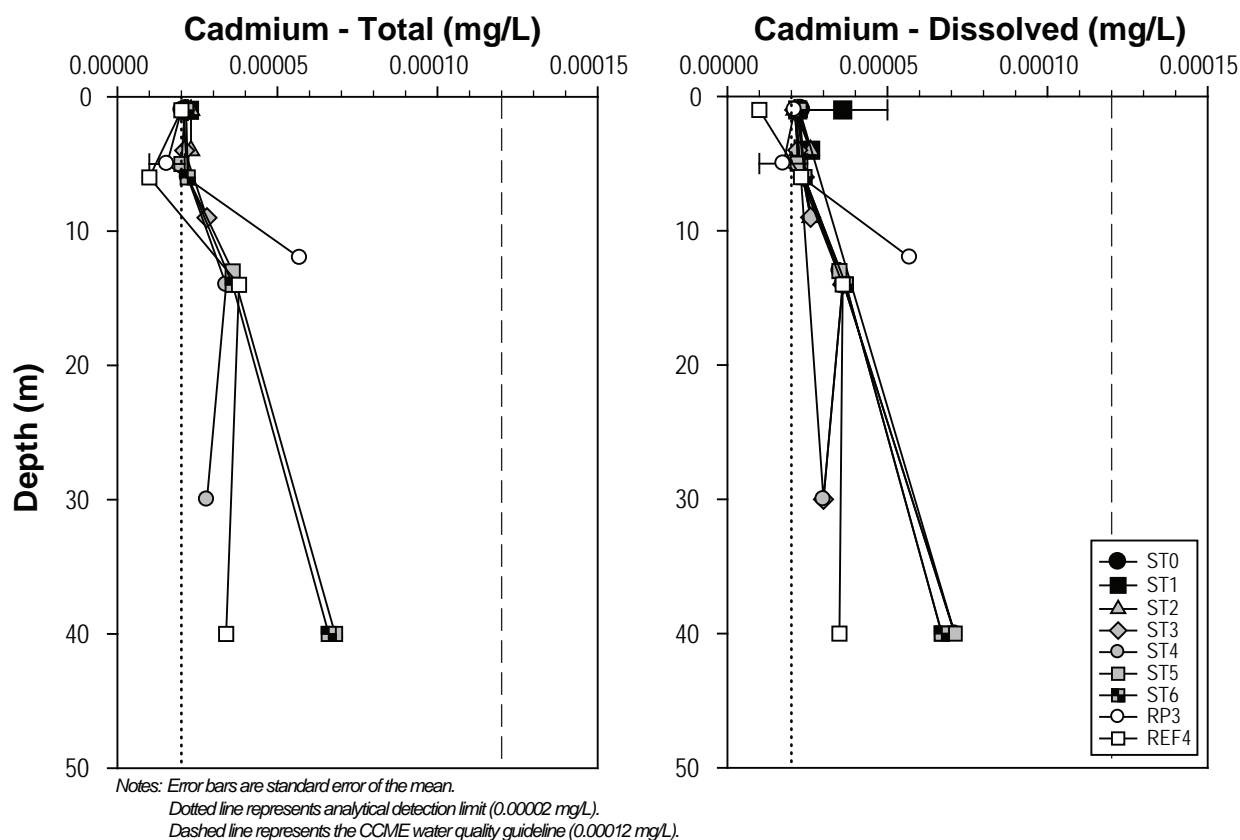
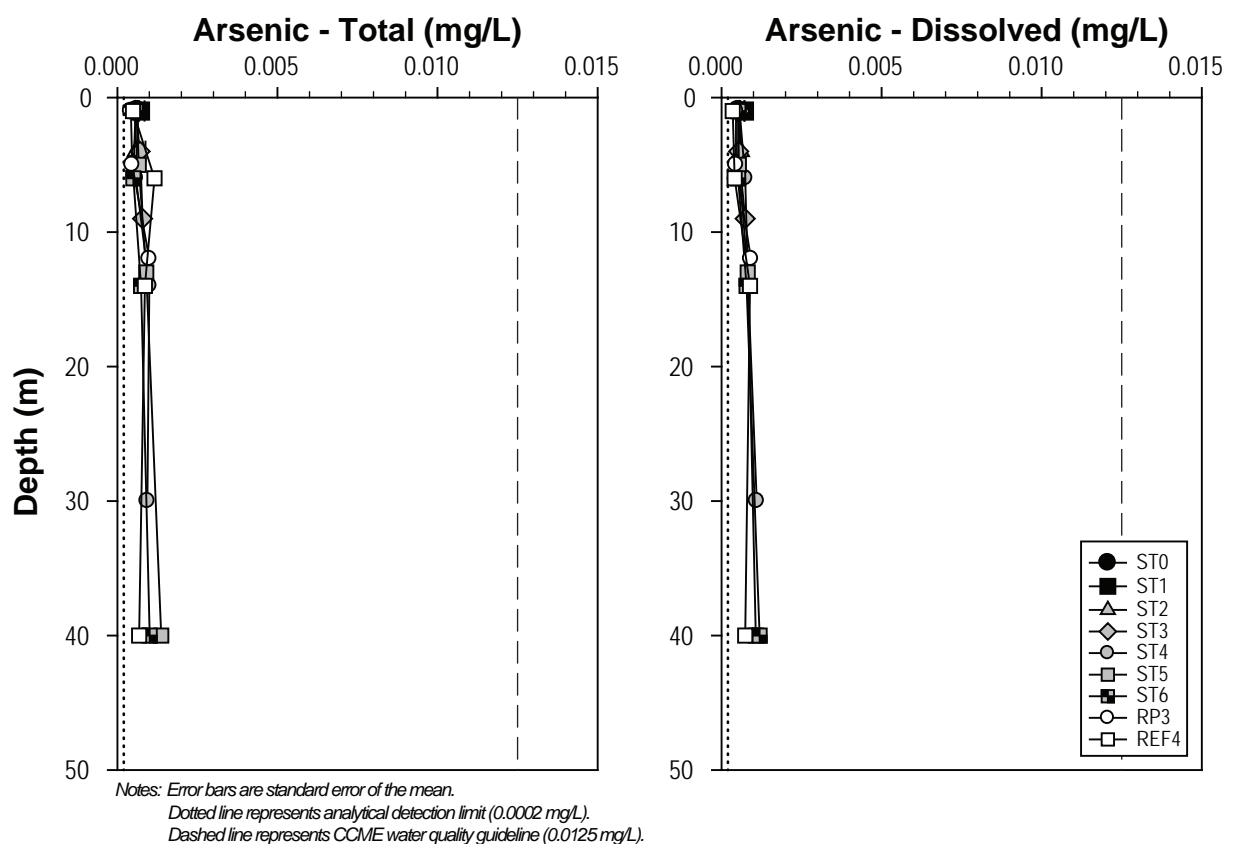
Notes: Error bars are standard error of the mean.

Dotted line represents analytical detection limit (0.1 NTU).

CCME guideline: maximum increase of 8 NTU from background levels for short-term exposure, and maximum average increase of 2 NTU from background levels for longer-term exposure.

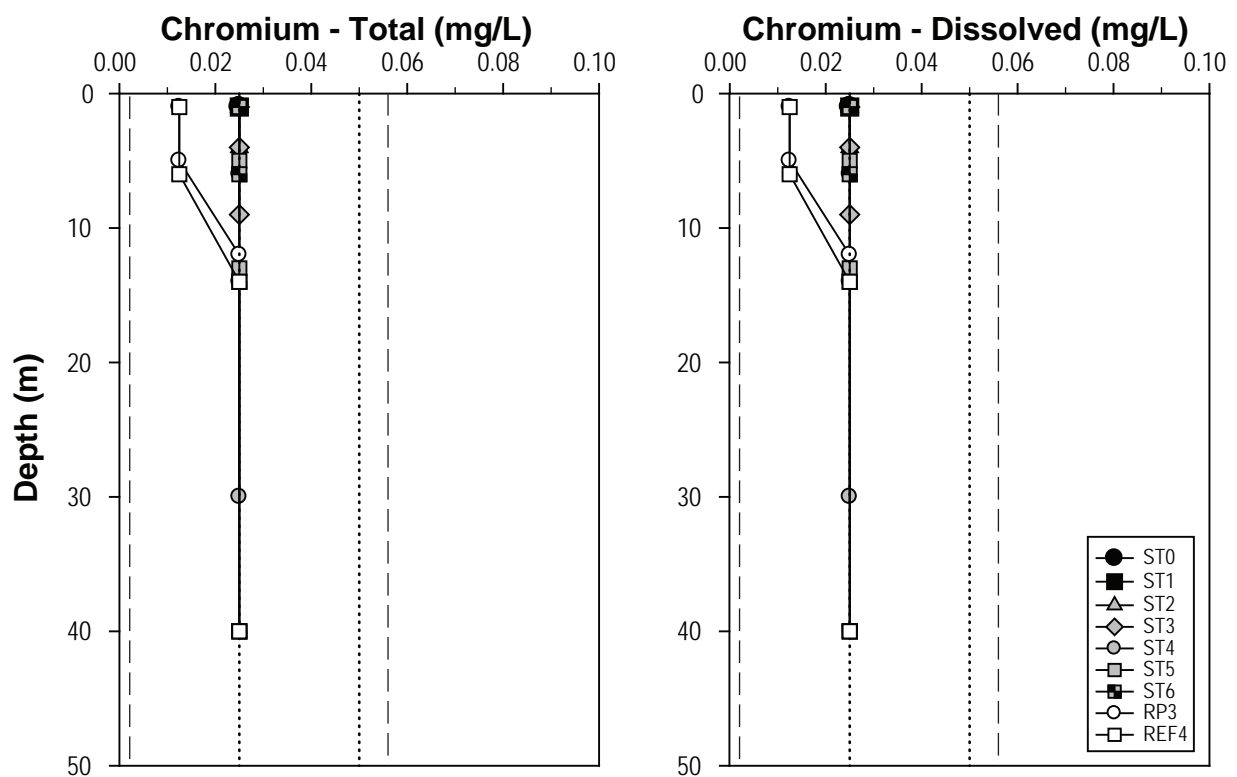




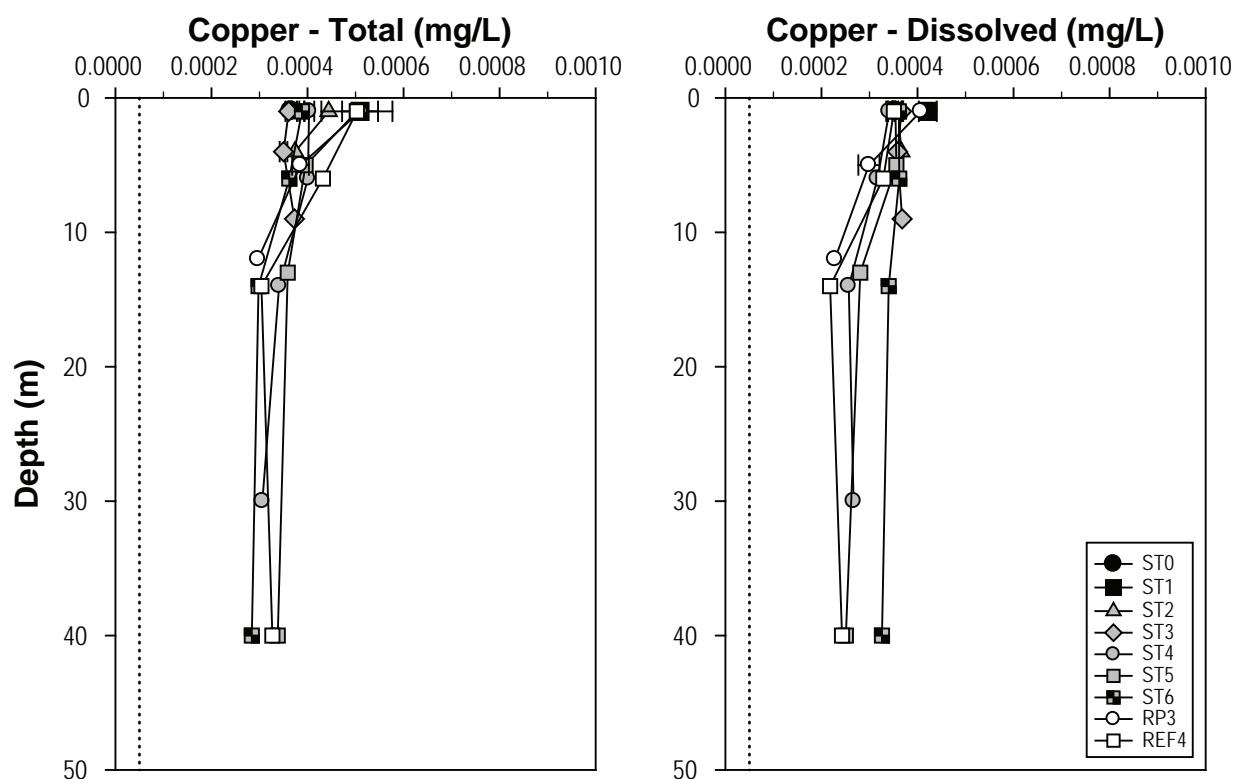


**Arsenic and Cadmium Concentrations in
Roberts and Reference Bays,
Hope Bay Belt Project, August 2009**

Figure 3.5-20



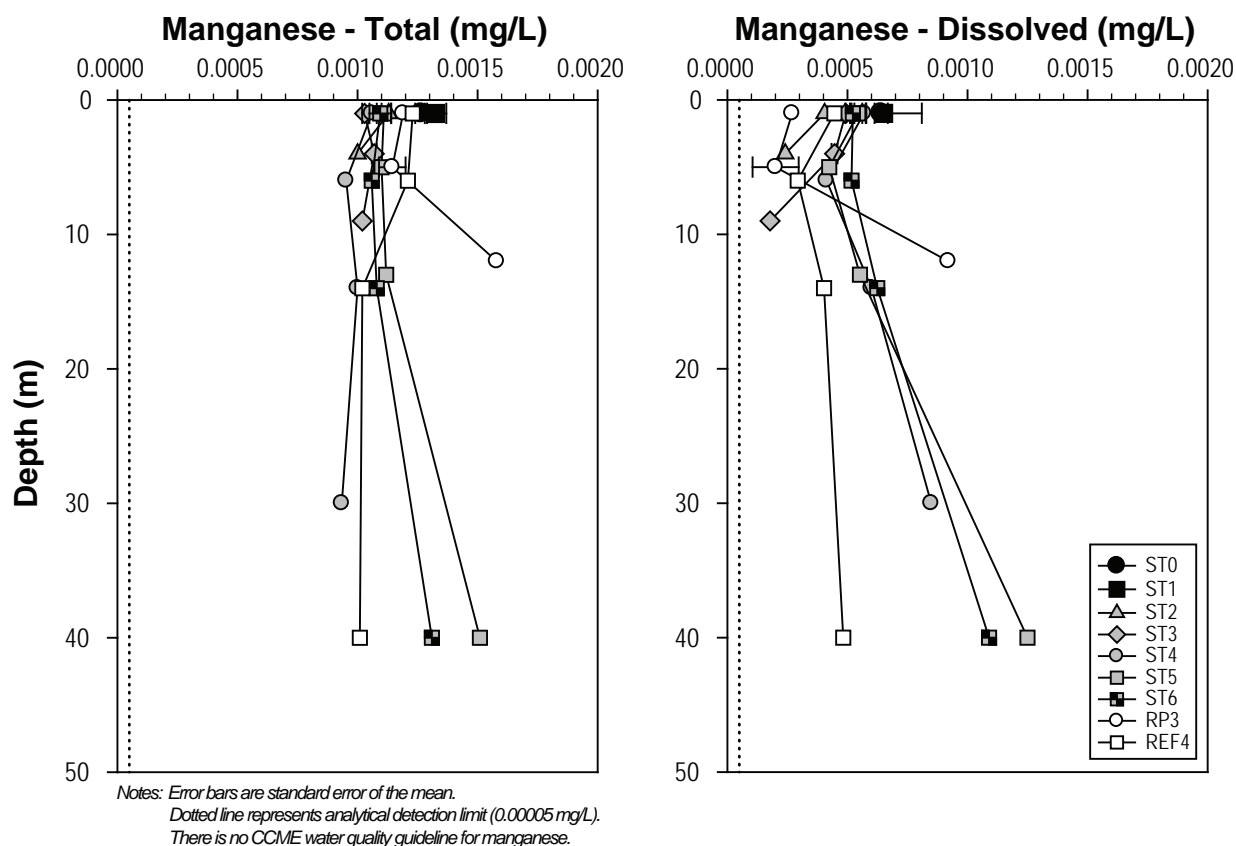
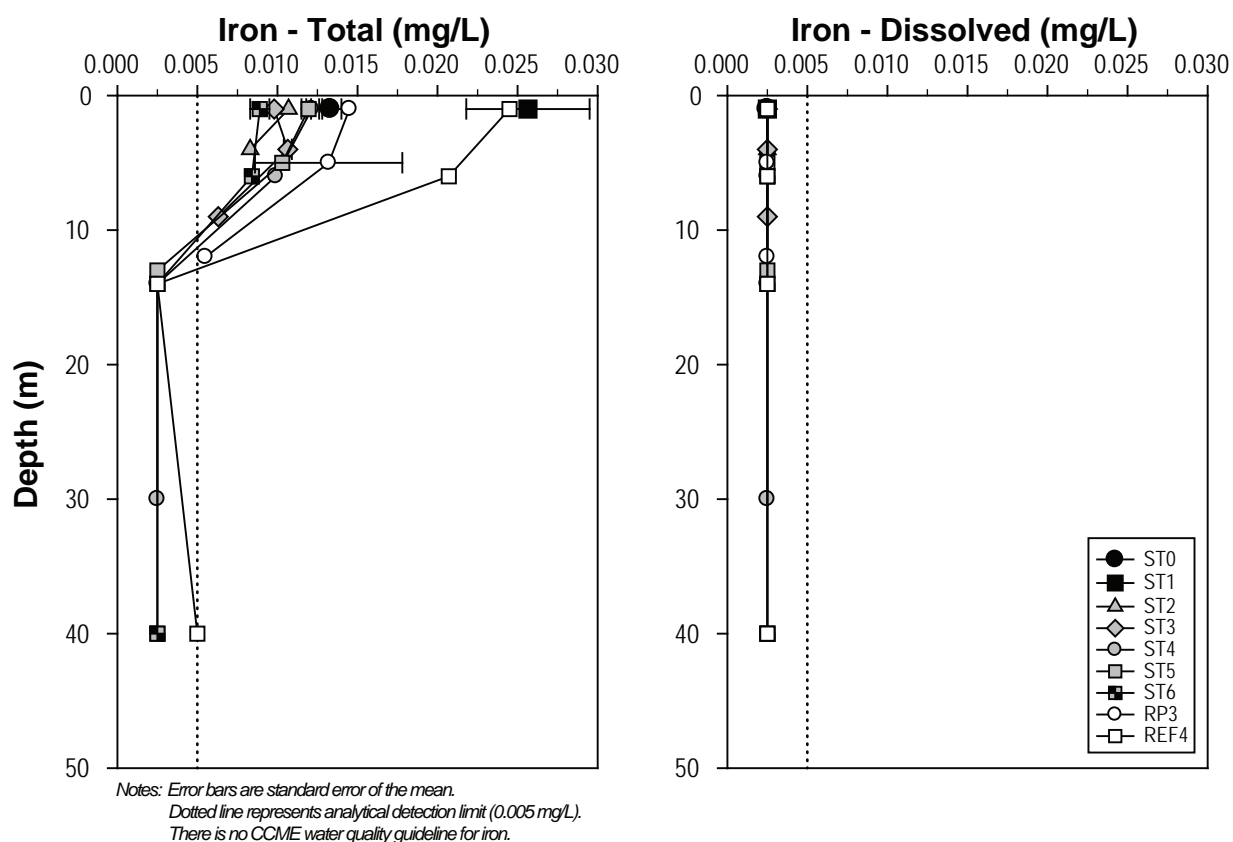
Notes: Error bars are standard error of the mean.
Dotted line represents analytical detection limit (0.05 mg/L).
Dashed lines represents CCME water quality guideline of 0.056 mg/L for Cr(III) and 0.0015 mg/L for Cr(VI).



Notes: Error bars are standard error of the mean.
Dotted line represents analytical detection limit (0.00005 mg/L).
There is no CCME water quality guideline for copper.

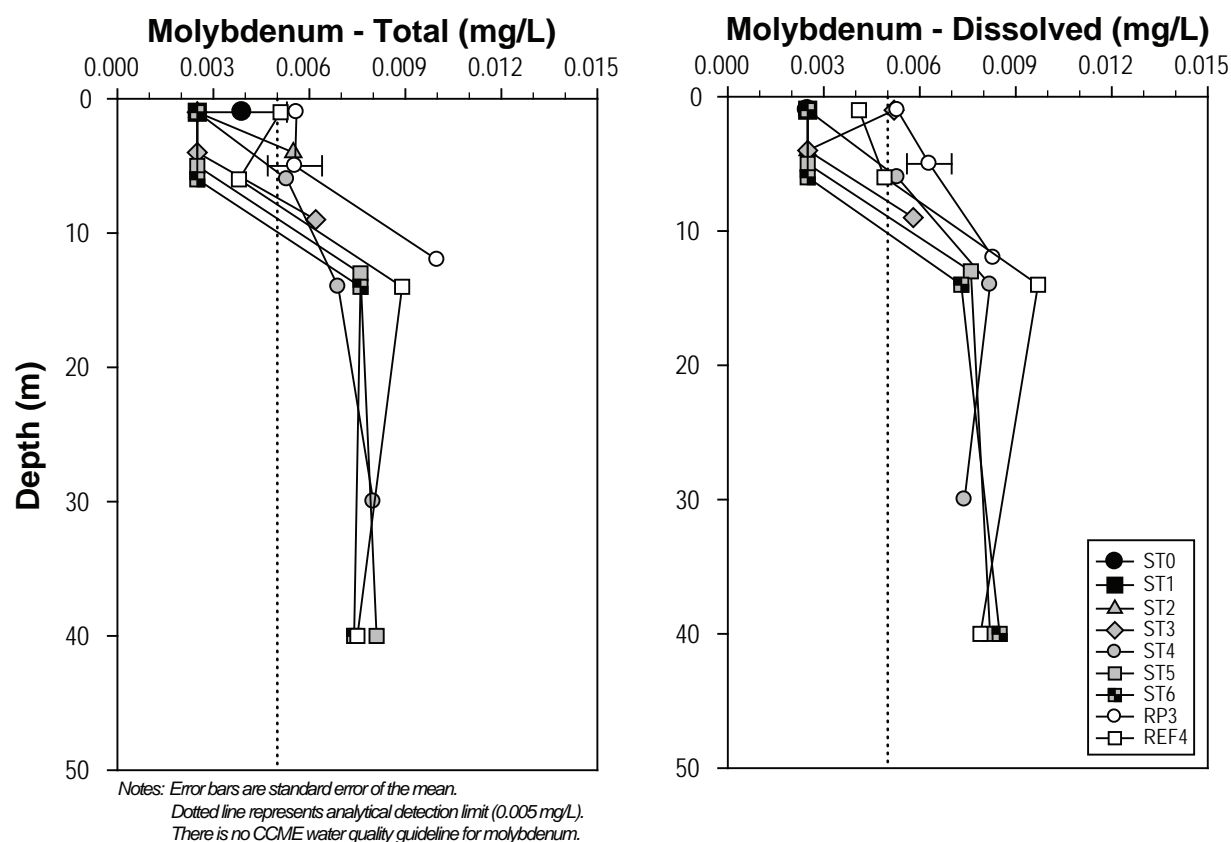
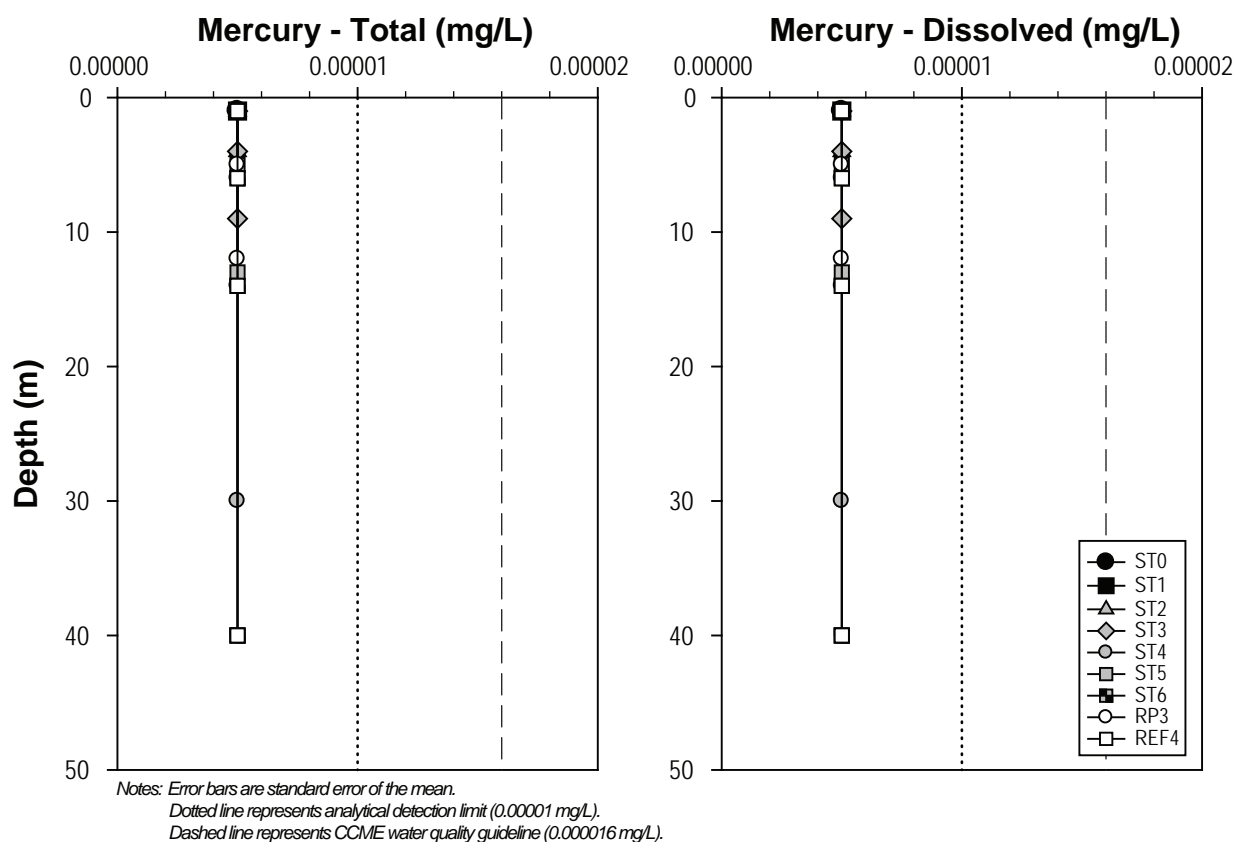
**Chromium and Copper Concentrations in
Roberts and Reference Bays,
Hope Bay Belt Project, August 2009**

Figure 3.5-21



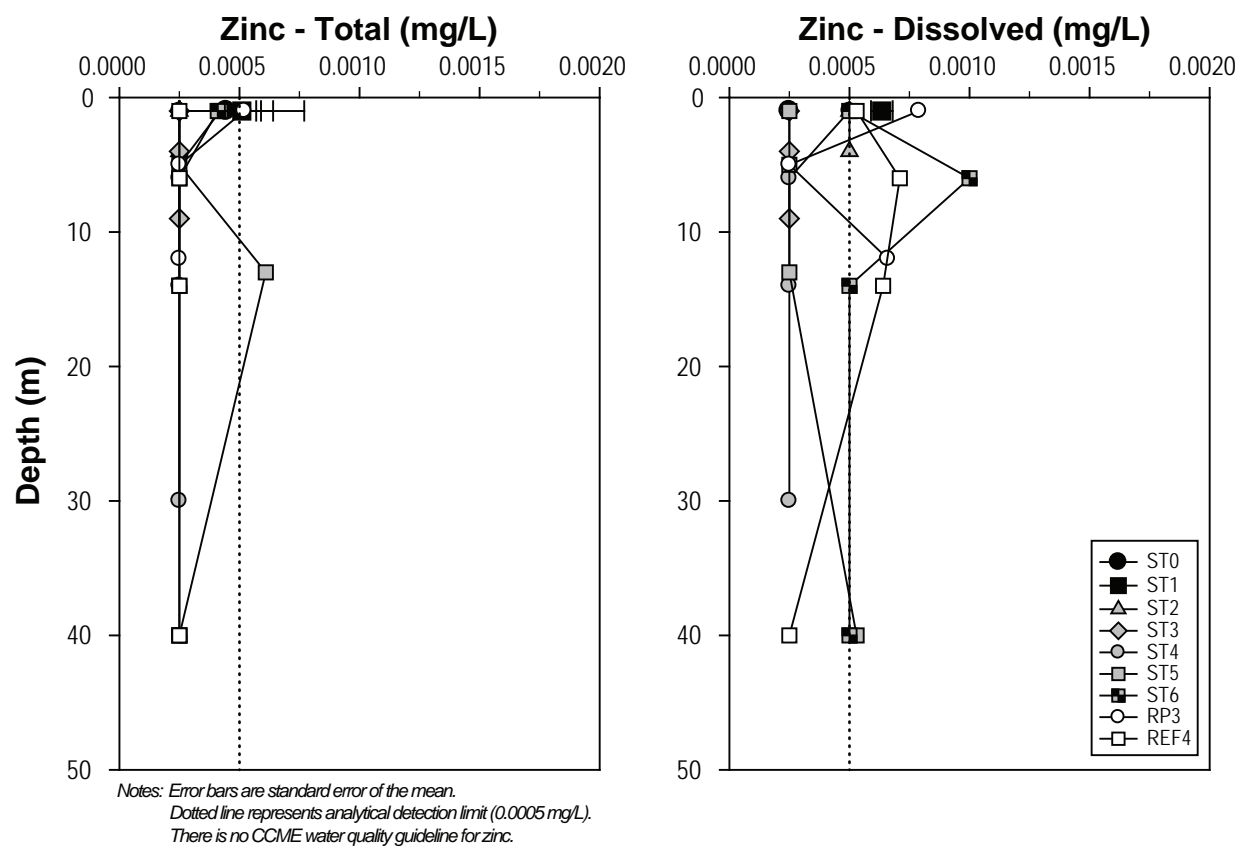
**Iron and Manganese Concentrations in
Roberts and Reference Bays,
Hope Bay Belt Project, August 2009**

Figure 3.5-22



**Mercury and Molybdenum Concentrations in
Roberts and Reference Bays,
Hope Bay Belt Project, August 2009**

Figure 3.5-23



Concentrations of several metals varied markedly between the winter and summer sampling periods. As seen with the macronutrients (nitrate, phosphate, and silicate), surface concentrations of micronutrients including cadmium (Figure 3.5-20) and molybdenum (Figure 3.5-23) were slightly drawn down in the summer, while deep water concentrations were relatively constant from winter to summer. The opposite trend was observed for total iron, as surface concentrations increased to between 0.0084 and 0.026 mg/L in summer, while bottom water concentrations were near or below detection limits (<0.005 mg/L; Figure 3.5-22). This depth gradient suggests that iron may be entering Roberts and Reference bays through riverine or atmospheric sources. Summer chromium (Figure 3.5-21) and mercury (Figure 3.5-23) concentrations were always below their respective detection limits (<0.05 and <0.00001 mg/L). Arsenic concentrations were slightly lower than winter levels (Figure 3.5-20), averaging 0.00074 mg/L. Overall, metal concentrations in Roberts and Reference bays were generally comparable.

3.5.3 Comparison with CCME Water Quality Guidelines

All water quality data collected in Roberts, Hope, and Reference bays were compared to the CCME's water quality guidelines for the protection of marine aquatic life (CCME 2007). Water quality parameters were generally below recommended guidelines, with the exception of chromium in Hope Bay and mercury in Roberts Bay during winter. All metal concentrations were below guidelines in samples collected during summer.

Table 3.5-1 shows the percentage of water quality samples in which parameter concentrations were higher than water quality guidelines, and Table 3.5-2 shows the factor by which concentrations were higher than guidelines. The CCME guideline for chromium is dependent on its oxidation state: the guideline for hexavalent chromium (Cr(VI)) is 0.0015 mg/L and the interim guideline for trivalent chromium (Cr(III)) is 0.056 mg/L (CCME 1999). Routine analytical laboratories cannot analyze for the individual species, and as a result, total chromium results are used to compare with CCME guidelines to be conservative. Chromium most commonly occurs in surface waters as hexavalent chromium (Cr(VI)) (CCME 1999), although the Cr(VI) oxidation state may only be marginally higher than Cr(III) (Ahern et al. 1985). The values presented in Tables 3.5-1 and 3.5-2 should be considered as maximum possible values, assuming that chromium exists entirely as Cr(VI) or Cr(III). Concentrations of total chromium were higher than CCME chromium guidelines in a maximum of 50% to 100% of winter samples collected from the following Hope Bay sites: HB2, HB4, HB7, HB10, and HB12.

In Roberts Bay, total mercury concentrations were higher than the CCME guideline of 0.000016 mg/L for inorganic mercury in 20% of samples collected from site WT6 and 40% of samples from WT4. Since the analysis of total mercury includes both organic and inorganic forms, the values presented in Tables 3.5-1 and 3.5-2 should be considered as maximum possible values, assuming that total mercury consists entirely of inorganic mercury. Previous studies have shown that inorganic mercury is typically more abundant than organic mercury in seawater (e.g., Mason et al. 1995; Mason et al. 1998).

3.5.4 Quality Assurance/Quality Control (QA/QC) – Water Quality

For QA/QC purposes, replicate samples were collected at 20% of the sample depths. Analytical results for travel, field, and equipment blanks collected as part of the 2009 marine water quality sampling program are presented in Appendices 3.5-1 and 3.5-2. Two travel blanks, one field blank, and one equipment blank were collected in 2009, making up approximately 5% of total samples collected. All analytical results for blank samples were below detection limits; therefore, no corrections were applied to the water quality data.

Table 3.5-1. Marine Water Quality, Percent of Samples in which Concentrations are Higher than CCME Guidelines, Hope Bay Belt Project, 2009

Site	Sampling Season	Total Number of Samples Collected	CCME Guideline Value ^a :	pH	Nitrate (as N)	Arsenic (As) Total	Cadmium (Cd) Total	Chromium (Cr) Total		Mercury (Hg) Total
				7.0–8.7	3.6 mg/L	0.0125 mg/L	0.00012 mg/L	0.0015 mg/L ^b	0.056 mg/L ^c	0.000016 mg/L ^d
Roberts Bay										
WT0	Winter	1		0	0	0	0	-	0	0
WT1	Winter	2		0	0	0	0	-	0	0
WT2	Winter	2		0	0	0	0	-	0	0
WT4	Winter	5		0	0	0	0	-	0	40
WT6	Winter	5		0	0	0	0	-	0	20
ST0	Summer	2		0	0	0	0	-	0	0
ST1	Summer	2		0	0	0	0	-	0	0
ST2	Summer	2		0	0	0	0	-	0	0
ST3	Summer	4		0	0	0	0	-	0	0
ST4	Summer	5		0	0	0	0	-	0	0
ST5	Summer	5		0	0	0	0	-	0	0
ST6	Summer	5		0	0	0	0	-	0	0
Hope Bay										
HB1	Winter	1		0	0	0	0	-	0	0
HB2	Winter	2		0	0	0	0	100	100	0
HB4	Winter	5		0	0	0	0	80	80	0
HB7	Winter	4		0	0	0	0	50	50	0
HB10	Winter	5		0	0	0	0	100	100	0
HB12	Winter	5		0	0	0	0	100	100	0
Reference Bay										
REFW	Winter	5		0	0	0	0	-	0	0
RP3	Summer	3		0	0	0	0	-	0	0
REF4	Summer	5		0	0	0	0	-	0	0

Values represent percentages of 2009 samples that are higher than CCME guidelines.

a) Canadian water quality guidelines for the protection of marine aquatic life (CCME 2007).

b) Refers to the guideline for hexavalent chromium (Cr(VI)). The guideline for Cr(VI) of 0.0015 mg/L is below the analytical detection limit for chromium in seawater (<0.05 mg/L). Sample concentrations that were below the detection limit for chromium were not assessed against this guideline because it was not possible to determine whether actual concentrations were higher or lower than the guideline of 0.0015 mg/L. Reported percentage represents the maximum possible assuming that all chromium in samples was in the form of Cr(VI).

c) Refers to the interim guideline for trivalent chromium (Cr(III)). Reported percentage represents the maximum possible assuming that all chromium in samples was in the form of Cr(III).

d) Guideline refers to inorganic mercury. Reported percentage represents the maximum possible assuming that all mercury in samples was inorganic.

'-' indicates that total chromium concentrations were below the analytical detection limit (<0.05 mg/L) in all samples collected from this site.

Table 3.5-2. Marine Water Quality, Factor by which Average Concentrations are Higher than CCME Guidelines, Hope Bay Belt Project, 2009

Site	Sampling Season	Total Number of Samples Collected	CCME Guideline Value ^a :	pH	Nitrate (as N)	Arsenic (As) Total	Cadmium (Cd) Total	Chromium (Cr) Total	Mercury (Hg) Total	
				7.0–8.7	3.6 mg/L	0.0125 mg/L	0.00012 mg/L	0.0015 mg/L ^b	0.056 mg/L ^c	0.000016 mg/L ^d
Roberts Bay										
WT0	Winter	1		-	-	-	-	-	-	-
WT1	Winter	2		-	-	-	-	-	-	-
WT2	Winter	2		-	-	-	-	-	-	-
WT4	Winter	5		-	-	-	-	-	-	1.78
WT6	Winter	5		-	-	-	-	-	-	1.44
ST0	Summer	2		-	-	-	-	-	-	-
ST1	Summer	2		-	-	-	-	-	-	-
ST2	Summer	2		-	-	-	-	-	-	-
ST3	Summer	4		-	-	-	-	-	-	-
ST4	Summer	5		-	-	-	-	-	-	-
ST5	Summer	5		-	-	-	-	-	-	-
ST6	Summer	5		-	-	-	-	-	-	-
Hope Bay										
HB1	Winter	1		-	-	-	-	-	-	-
HB2	Winter	2		-	-	-	-	41.7	1.12	-
HB4	Winter	5		-	-	-	-	42.4	1.14	-
HB7	Winter	4		-	-	-	-	34.2	-	-
HB10	Winter	5		-	-	-	-	39.2	1.05	-
HB12	Winter	5		-	-	-	-	53.1	1.42	-
Reference Bay										
REFW	Winter	5		-	-	-	-	-	-	-
RP3	Summer	3		-	-	-	-	-	-	-
REF4	Summer	5		-	-	-	-	-	-	-

Values represent the factor by which site averages are higher than CCME guidelines.

Even though a percentage of samples may be higher than a guideline amount, the calculated site average may be below the guideline.

a) Canadian water quality guidelines for the protection of marine aquatic life (CCME 2007).

b) Refers to the guideline for hexavalent chromium (Cr(VI)). The guideline for Cr(VI) of 0.0015 mg/L is below the analytical detection limit for chromium in seawater (<0.05 mg/L). Sample concentrations that were below the detection limit for chromium were not assessed against this guideline because it was not possible to determine whether actual concentrations were higher or lower than the guideline of 0.0015 mg/L. Reported factor represents the maximum possible assuming that all chromium in samples was in the form of Cr(VI).

c) Refers to the interim guideline for trivalent chromium (Cr(III)). Reported factor represents the maximum possible assuming that all chromium in samples was in the form of Cr(III).

d) Guideline refers to inorganic mercury. Reported factor represents the maximum possible assuming that all mercury in samples was inorganic.

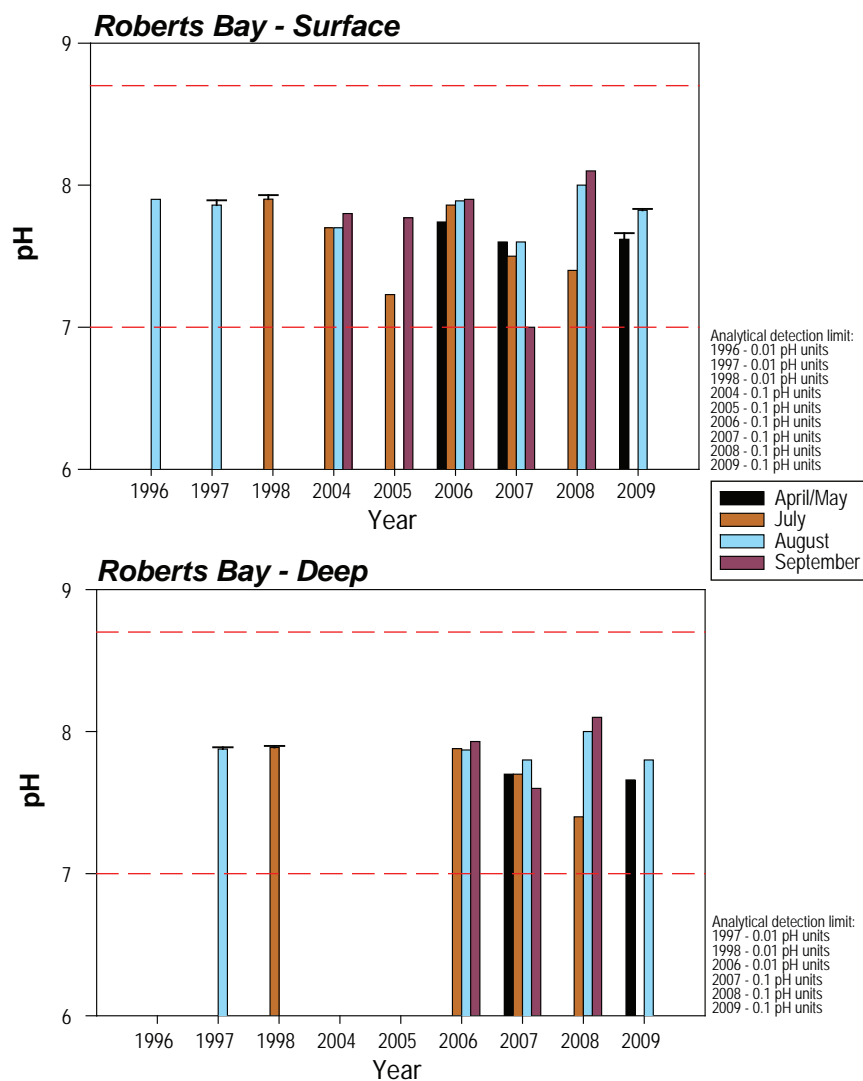
3.5.5 Historical Trends in Water Quality

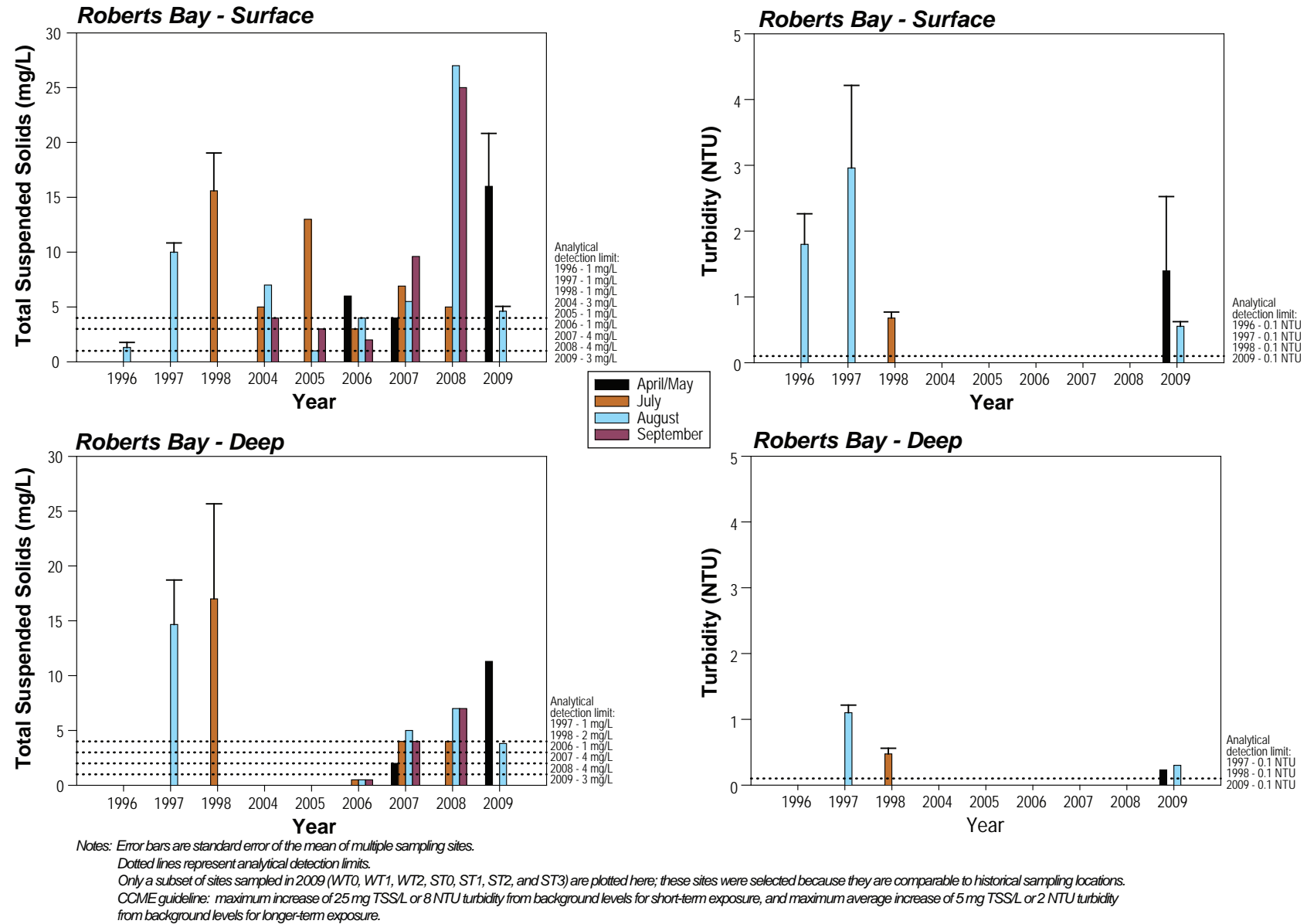
Marine water quality data for Roberts Bay and/or Hope Bay were collected in: 1997, 1998, 2004, 2005, 2006, 2007, 2008, and 2009. Historical water quality trends for Roberts Bay are shown in Figures 3.5-25 to 3.5-38, and trends for Hope Bay are shown in Figures 3.5-39 to 3.5-52. Water quality samples from Reference Bay have not been collected prior to 2009.

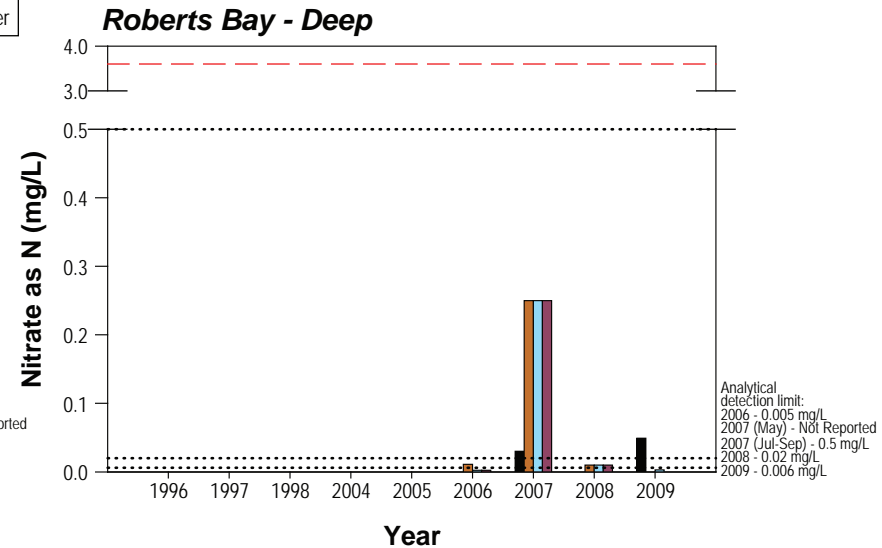
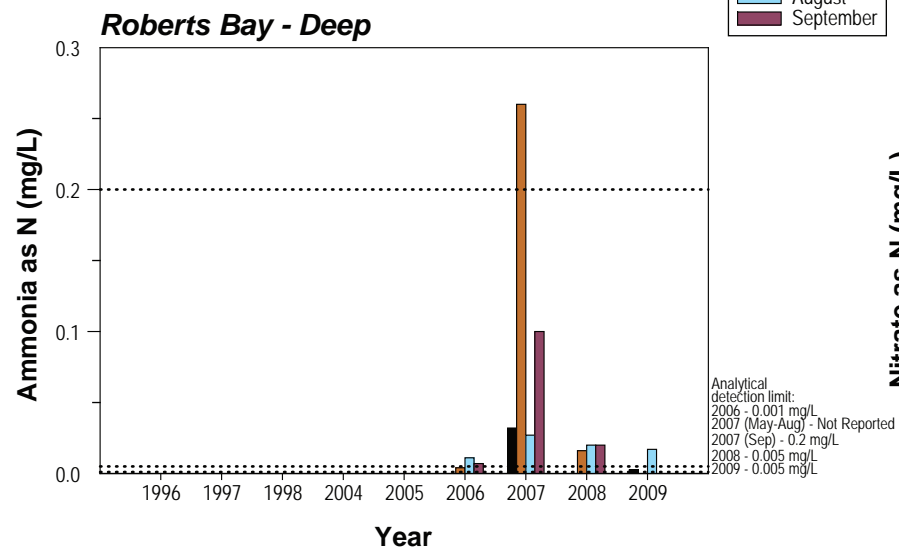
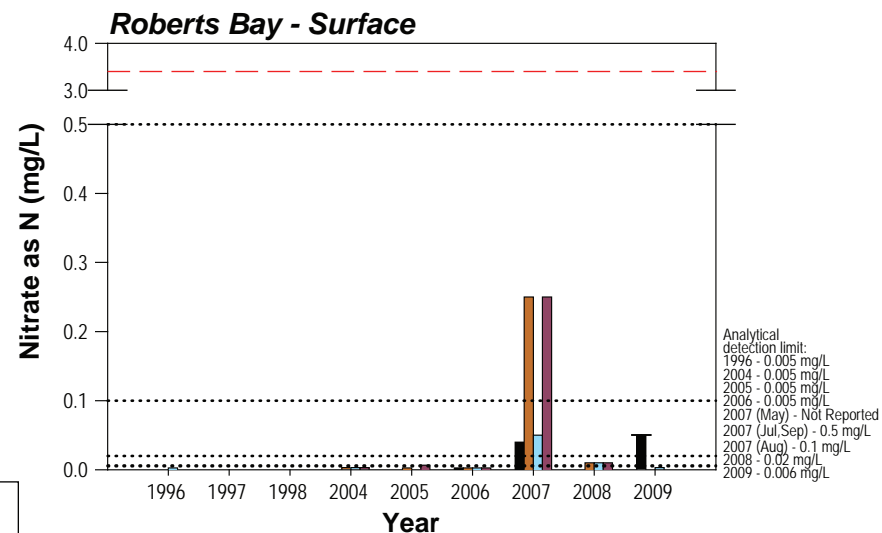
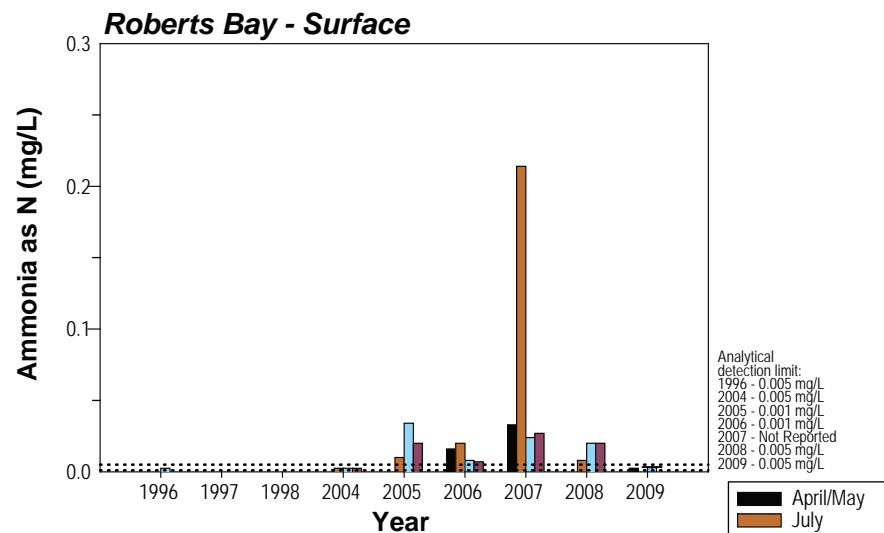
The differences among annual data sets in terms of when (sampling dates) and where (sampling depth/location) samples were collected can have a significant effect on monthly averages of parameters. Comparisons between years are further complicated by differences in analytical methodology and detection limits. Figure 2.3-1 shows the historical water quality sampling locations, and Table 2.3-1 presents the methodological details of historical water quality sampling.

Historically, water quality parameters have generally remained below CCME guidelines in Roberts Bay and Hope Bay, with the following exceptions: arsenic in Roberts Bay from 2004 to 2006, cadmium in Roberts Bay in 1996 and in Hope Bay in 2008, chromium in Hope Bay in 2009, and mercury in Roberts Bay in 2009¹. Concentrations of nutrients and metals generally had similar yearly ranges. In both Roberts Bay and Hope Bay, historical summer nitrate concentrations tended to be below analytical detection limits (Figures 3.5-27 and 3.5-41). In Roberts Bay, concentrations of arsenic were unusually high between 2004 and 2006 (Figure 3.5-30). The cause of these elevated arsenic levels is unclear as much lower concentrations of arsenic were measured in Roberts Bay samples collected between 2007 and 2009.

¹ Mercury concentrations were higher than CCME guidelines in 2009 samples from sites WT4 and WT6 in Roberts Bay. These sites were included in Figure 3.5-7, but were not included in the historical dataset plotted in Figure 3.5-36 because sites WT4 and WT6 were not comparable to historical sampling locations.







Notes: Error bars are standard error of the mean of multiple sampling sites.

Dotted lines represent analytical detection limits.

Red dashed line represents CCME water quality guideline for nitrate as N (3.6 mg/L); there is no CCME water quality guideline for ammonia.

Only a subset of sites sampled in 2009 (WT0, WT1, WT2, ST0, ST1, ST2, and ST3) are plotted here; these sites were selected because they are comparable to historical sampling locations.