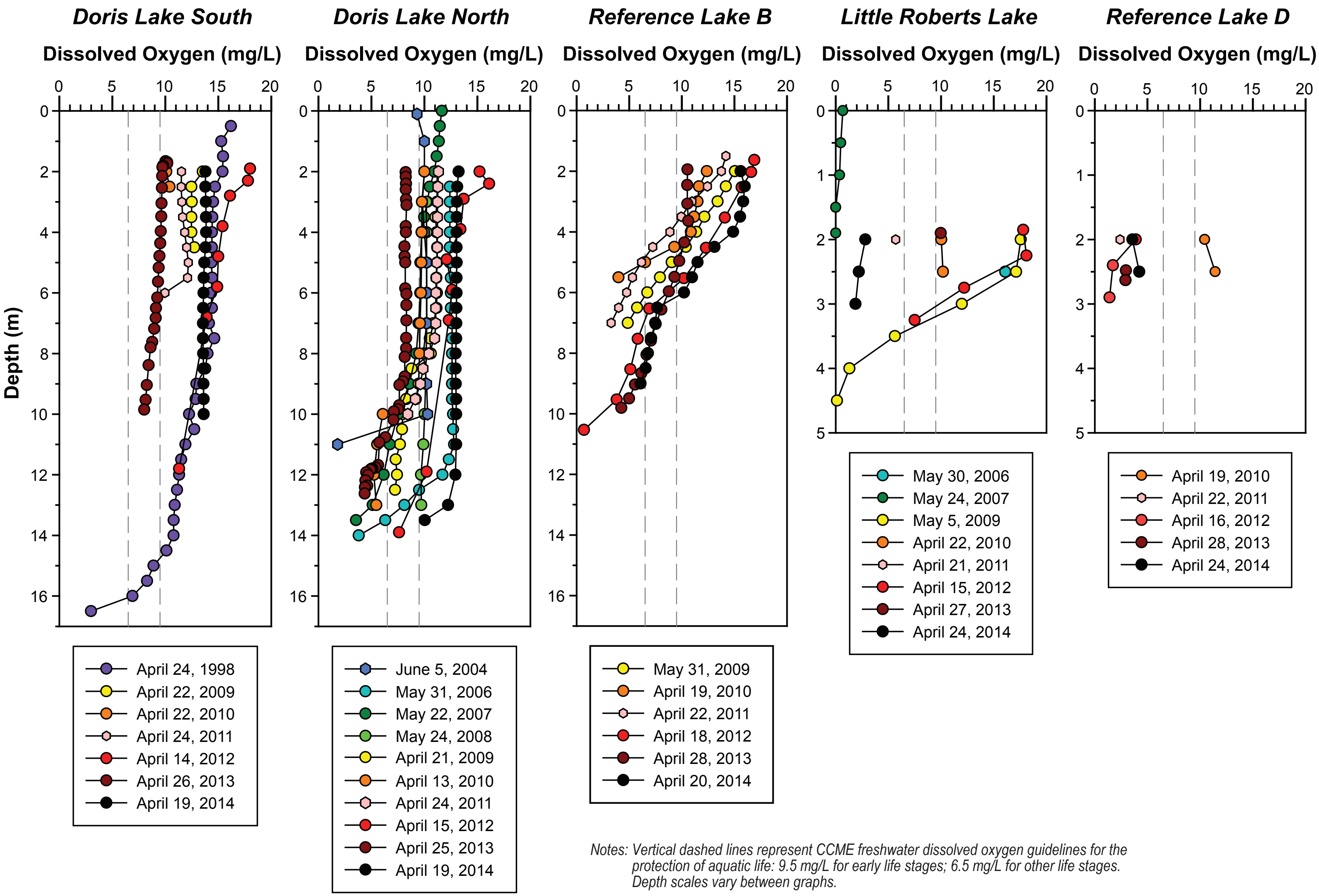
Figure 3.1-1

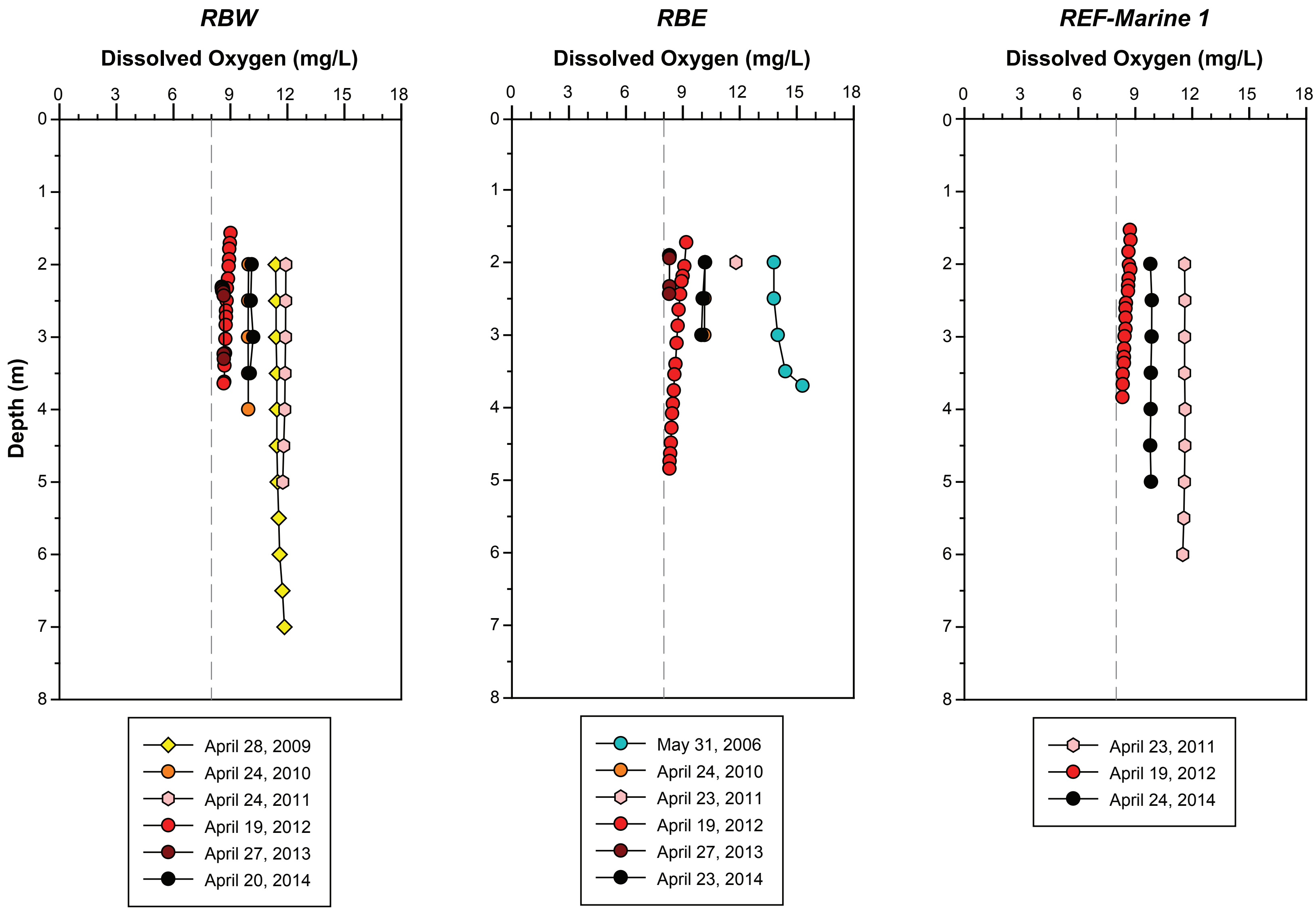
Winter Dissolved Oxygen Concentrations, Lake Sites, Doris North Project, 1998 to 2014



Notes: Vertical dashed lines represent CCME freshwater dissolved oxygen guidelines for the protection of aquatic life: 9.5 mg/L for early life stages; 6.5 mg/L for other life stages. Depth scales vary between graphs.

Figure 3.1-2

Winter Dissolved Oxygen Concentrations, Marine Sites, Doris North Project, 2006 to 2014



Notes: Vertical dashed lines represent the CCME interim guideline for the minimum concentration of dissolved oxygen in marine and estuarine waters (8.0 mg/L). Data not available for April 2013 at REF-Marine 1 due to CTD malfunction.

3.1.2 Marine

The 2014 under-ice dissolved oxygen concentrations were similar at both of the marine exposure sites RBW and RBE, averaging 10.10 and 10.06 mg/L throughout the water column, respectively (Figure 3.1-2). These concentrations are above the CCME interim guideline for the minimum dissolved oxygen concentrations for the protection of aquatic life in marine and estuarine waters (8.0 mg/L). Baseline under-ice dissolved oxygen concentrations at the marine exposure sites in 2010 were nearly identical to 2014 concentrations. Under-ice dissolved oxygen concentrations at the reference site (REF-Marine 1) in April 2014 were similar to those observed at the exposure sites (average of 9.83 mg/L) and within the range of concentrations observed historically. Thus, there was no evidence of adverse effects on marine dissolved oxygen levels as a result of Project activities.

3.2 SECCHI DEPTH

Secchi depth, a measure of water transparency, was evaluated for lake sites to determine whether there was any evidence that 2014 Project activities negatively affected lake water clarity. The results of statistical methods and analyses for the effects analysis for Secchi depth in lakes are provided in Appendix B.

3.2.1 Lakes

Figure 3.2-1 shows the mean annual Secchi depth at lakes sites from 1995 to 2014. Mean annual Secchi depth was similar among years and among exposure lakes, generally ranging between 1.0 and 2.1 m at Doris Lake South, Doris Lake North, and Little Roberts Lake. The Secchi depth recorded at Doris Lake South in August 2000 (4.2 m) was greater than in other years. Mean annual Secchi depths were generally greater at the reference lakes, ranging from 5.4 to 7.5 m in Reference Lake B, and from 2.1 to 3.7 m in Reference Lake D.

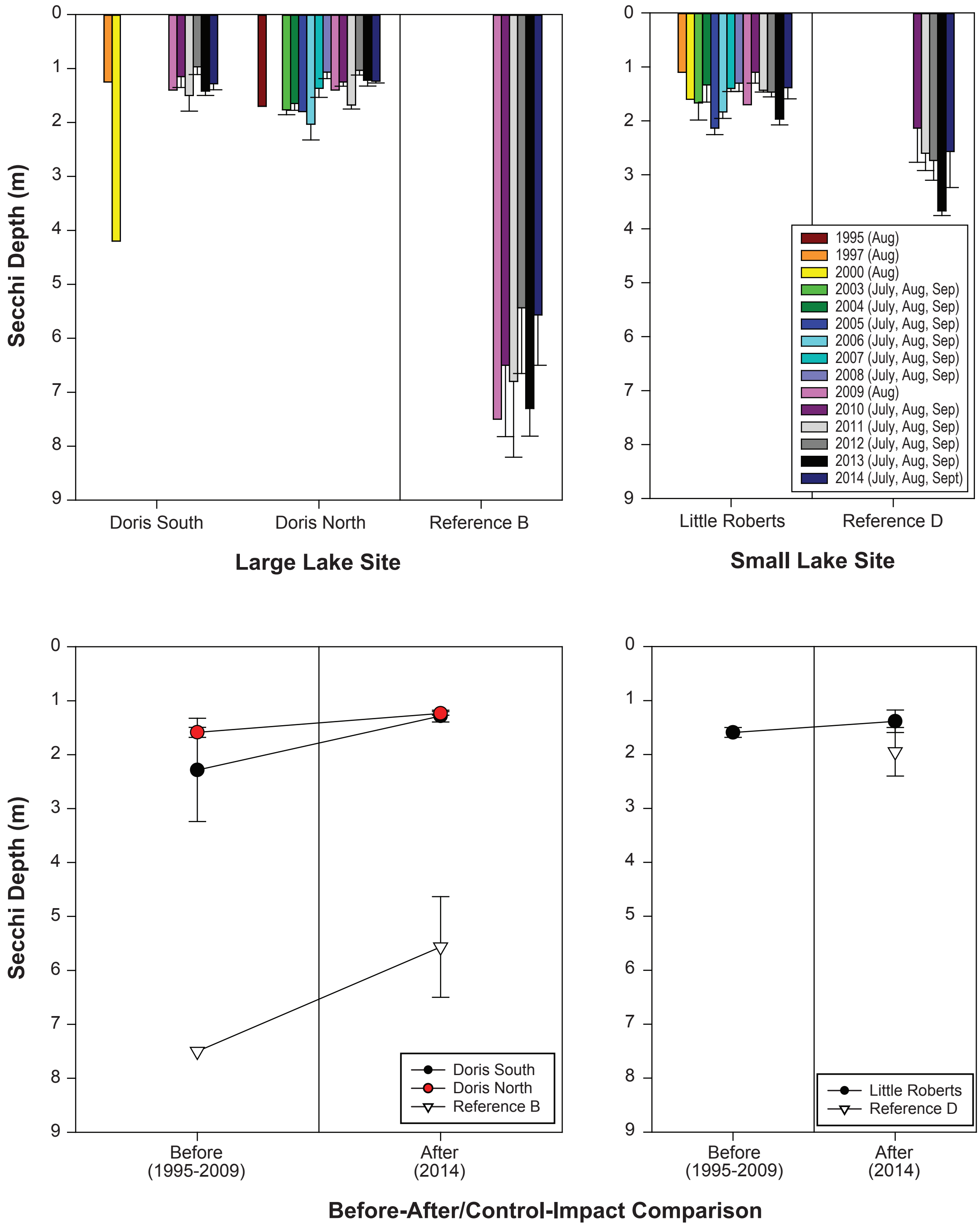
Mean 2014 Secchi depths in the exposure lakes were within the range of baseline measurements. The before-after comparison confirmed that the baseline mean Secchi depth was not distinguishable from the 2014 mean Secchi depth for any exposure lake ($p = 0.57$ for Doris Lake South, $p = 0.30$ for Doris Lake North, and $p = 0.57$ for Little Roberts Lake). Therefore, there was no apparent effect of 2014 Project activities on lake Secchi depth.

3.2.2 Marine

The Secchi depth at the shallow marine sites RBE and RBW typically reached the bottom in 2014. At site RBE, all Secchi depths measured in 2014 reached the bottom sediments, while at site RBW, all but one Secchi depth reached the bottom (Appendix A), indicating that water clarity was high and that the euphotic zone typically extended throughout the entire water column. As water clarity at marine sites was high in 2014, Secchi depth was not evaluated for RBE and RBW.

Figure 3.2-1

Secchi Depth, Lake Sites, Doris North Project, 1995 to 2014



Notes: Error bars represent the standard error of the mean.
Bottom depth was used as an estimate of Secchi depth when Secch depth reached the lake bottom.

3.3 WATER QUALITY

A specific set of water quality variables (see Table 2.3-1) was evaluated to determine whether 2014 Project activities resulted in adverse changes to water quality. Historical data collected from 1995 to 2009 were included in the effects analysis.

Graphical analyses, before-after comparisons, and BACI analyses (where possible) were all used to determine if there were changes in water quality variables in the Project area. For all graphical and statistical analyses, replicate samples collected on the same date and from the same depth were averaged prior to analysis. In addition, half the detection limit was substituted for water quality variables that were below analytical detection limits. The complete results of statistical methods and analyses are provided in Appendix B.

Water quality variables were compared to CCME water quality guidelines for the protection of aquatic life (CCME 2014a) to determine whether concentrations posed a concern for freshwater and marine aquatic life. Site-specific baseline conditions were considered in addition to CCME guidelines to help determine whether any detected changes could result in a potential adverse effect to freshwater and marine life.

3.3.1 Streams

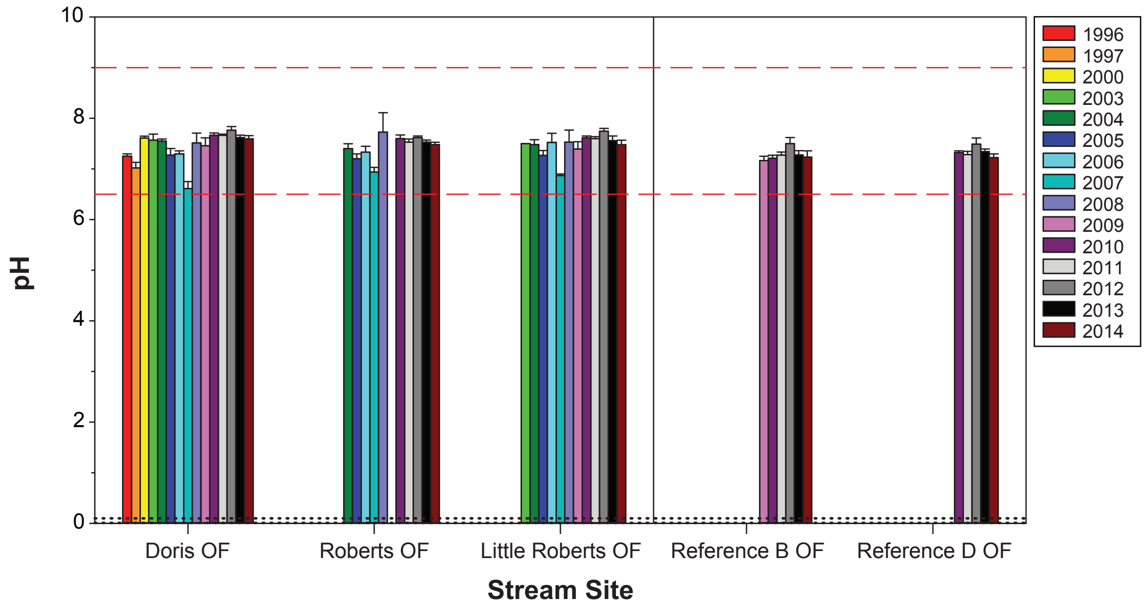
Water quality samples were collected from three exposure streams (Doris Outflow, Roberts Outflow, and Little Roberts Outflow) and two reference streams (Reference B Outflow and Reference D Outflow) in 2014. For the exposure streams, relevant baseline data were available from 1996, 1997, 2000, and 2003 to 2009 (though not all streams were sampled each year). For Reference B Outflow, the only available baseline data were from 2009, and no baseline data were available for Reference D Outflow. Graphs showing water quality trends in streams over time are shown in Figures 3.3-1 to 3.3-18. Statistical results are presented in Appendix B.

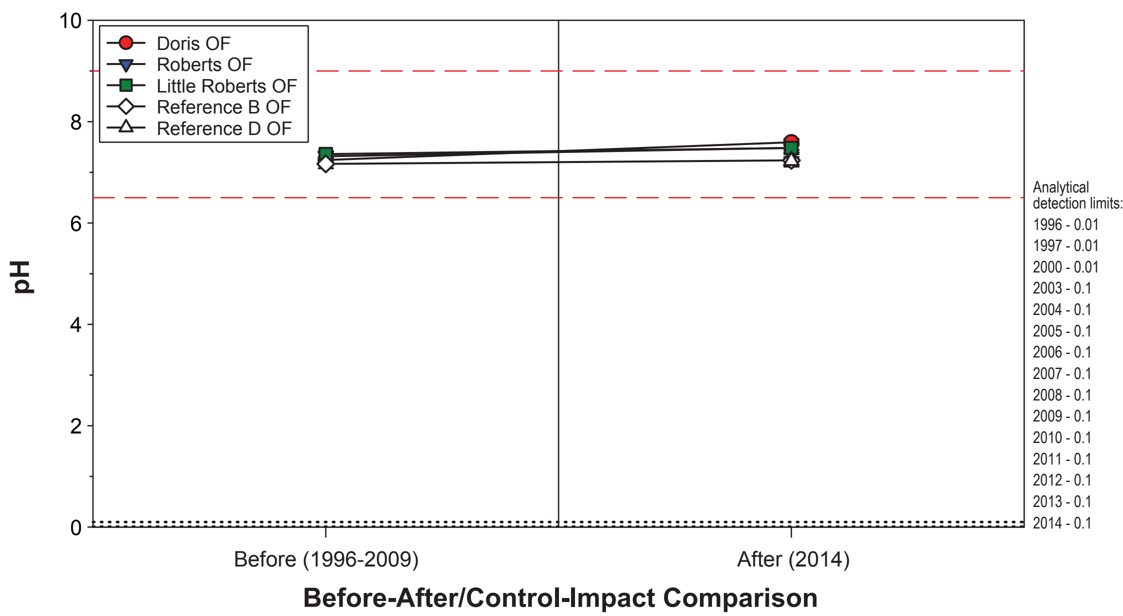
3.3.1.1 pH

pH is a required variable for water quality monitoring as per Schedule 5, s. 7(1)(c) of the MMER. 2014 pH levels in exposure and reference streams were within the recommended CCME guideline range of 6.5 to 9.0 (Figure 3.3-1). Exposure stream pH levels measured in 2014 ranged from 7.2 to 7.7, while reference stream pH ranged from 6.95 to 7.5. Mean 2014 pH levels in the exposure streams were within the range of baseline levels (Figure 3.3-1). The before-after comparison confirmed that the baseline (1996 to 2009) mean pH was not statistically distinguishable from the 2014 mean pH in any exposure stream ($p = 0.34$ for Doris Outflow, $p = 0.40$ for Roberts Outflow, and $p = 0.36$ for Little Roberts Outflow). Therefore, no effects of 2014 Project activities on the pH of exposure streams were detected.

Figure 3.3-1

pH, Stream Sites, Doris North Project, 1996 to 2014





Notes: Error bars represent the standard error of the mean.
Black dotted lines represent the analytical detection limit.
Red dashed lines represent the CCME freshwater guideline pH range (6.5–9.0).
pH is a required parameter for water quality monitoring as per Schedule 5, s. 7(1)(c) of the MMER.

3.3.1.2 Total Alkalinity

Total alkalinity is a required variable for effluent characterization and water quality monitoring as per Schedule 5, s. 4(1) and s. 7(1)(c) of the MMER. Total alkalinity (as $CaCO_3$) varied among streams with consistently higher levels in the exposure streams than the reference streams (Figure 3.3-2). The before-after comparisons determined that there were not significant differences between the before and after periods at any of the exposure streams ($p = 0.67$ for Doris Outflow, $p = 0.19$ for Roberts Outflow, and $p = 0.65$ for Little Roberts Outflow). Thus, there was no apparent effect of 2014 Project activities on exposure stream alkalinity.

3.3.1.3 Hardness

Hardness is a required variable for effluent characterization and water quality monitoring as per Schedule 5, s. 4(1) and s. 7(1)(c) of the MMER. Mean annual hardness (as $CaCO_3$) varied among streams with consistently higher levels in the exposure streams than the reference streams (Figure 3.3-3). However, the before-after comparisons determined that there were not significant differences between the before and after periods at any of the exposure streams ($p= 0.28$ for Doris Outflow, $p = 0.09$ for Roberts Outflow, and $p = 0.31$ for Little Roberts Outflow); therefore, there was no apparent effect of 2014 Project activities on stream hardness.

3.3.1.4 Total Suspended Solids

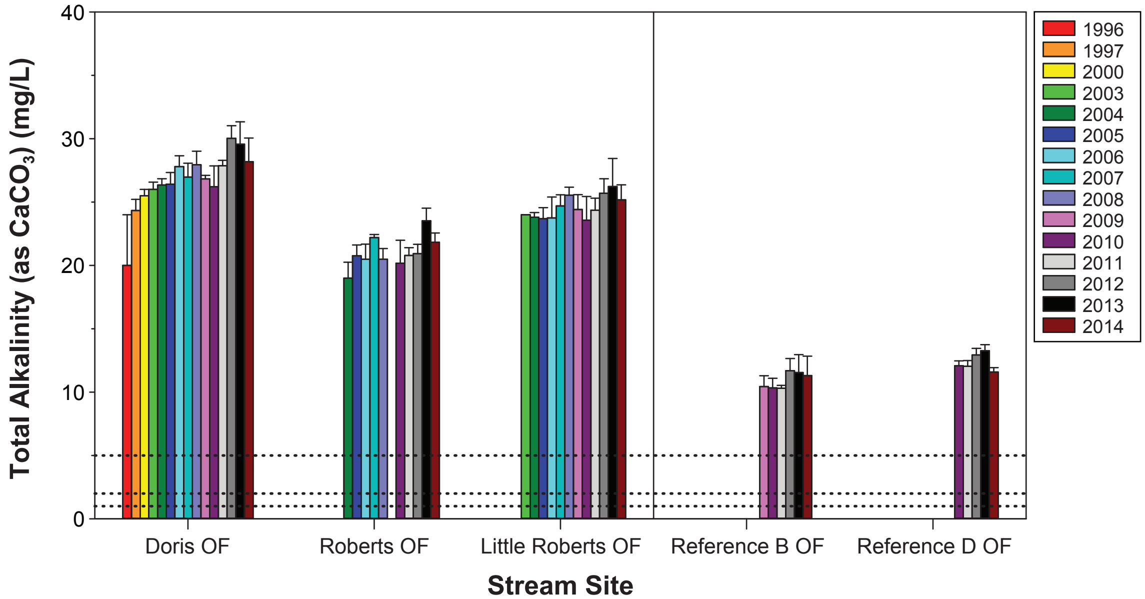
Total suspended solids (TSS) are regulated as deleterious substances in effluents as per Schedule 4 of the MMER. Mean TSS concentrations were variable among streams. Within each stream, there was also a large amount of inter-annual and within-year variability (Figure 3.3-4). It is therefore difficult to distinguish natural variability from potential effects resulting from Project activities.

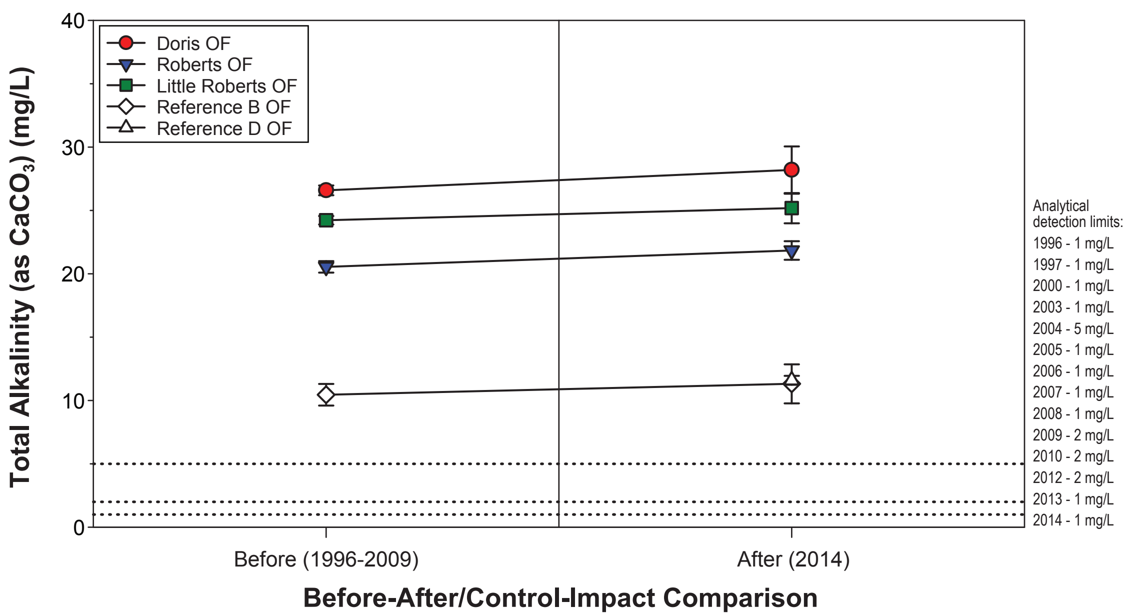
The mean 2014 TSS concentrations in all three exposure streams were within the range of the baseline means (Figure 3.3-4); before-after analysis confirmed that there was no evidence of a difference between 2014 and baseline concentrations in any of the exposure streams ($p = 0.61$ for Doris Outflow, $p = 0.74$ for Roberts Outflow and $p = 0.97$ for Little Roberts Outflow). Therefore, there was no evidence of an effect of 2014 Project activities on TSS concentrations in the exposure streams.

The CCME guideline for TSS is dependent upon background levels (for clear-flow waters with background TSS levels below 25 mg/L, a maximum increase of 25 mg/L is allowable for any short-term exposure or 5 mg/L for longer term exposure; CCME 2014a). Because there was no significant increase in TSS concentrations from baseline levels in Doris, Roberts or Little Roberts outflows, 2014 TSS concentrations in these streams were below the CCME guideline.

Figure 3.3-2

Total Alkalinity, Stream Sites, Doris North Project, 1996 to 2014



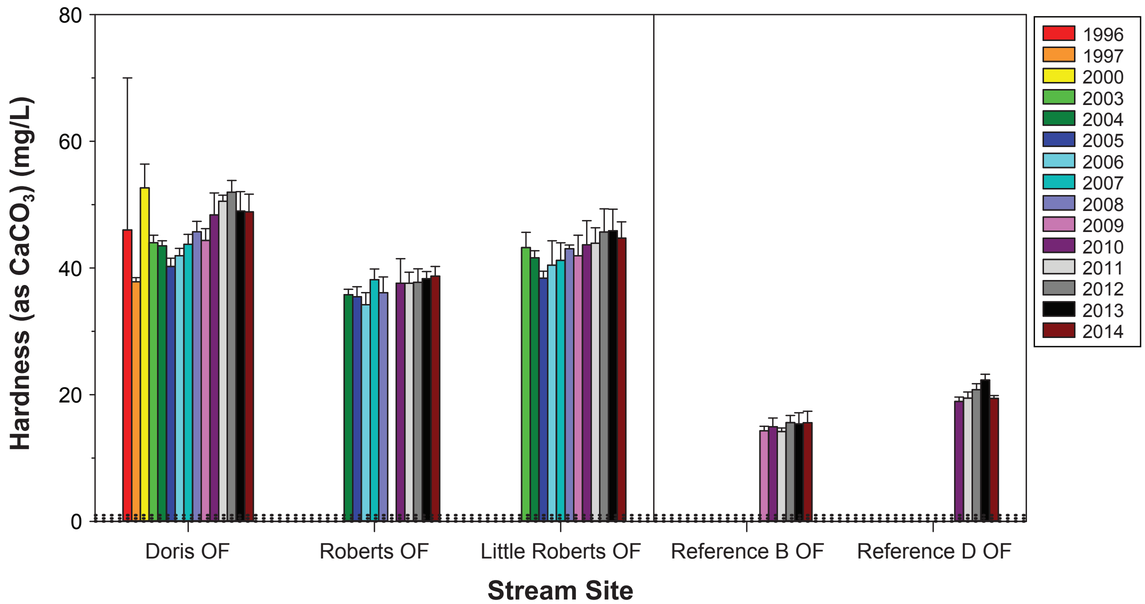


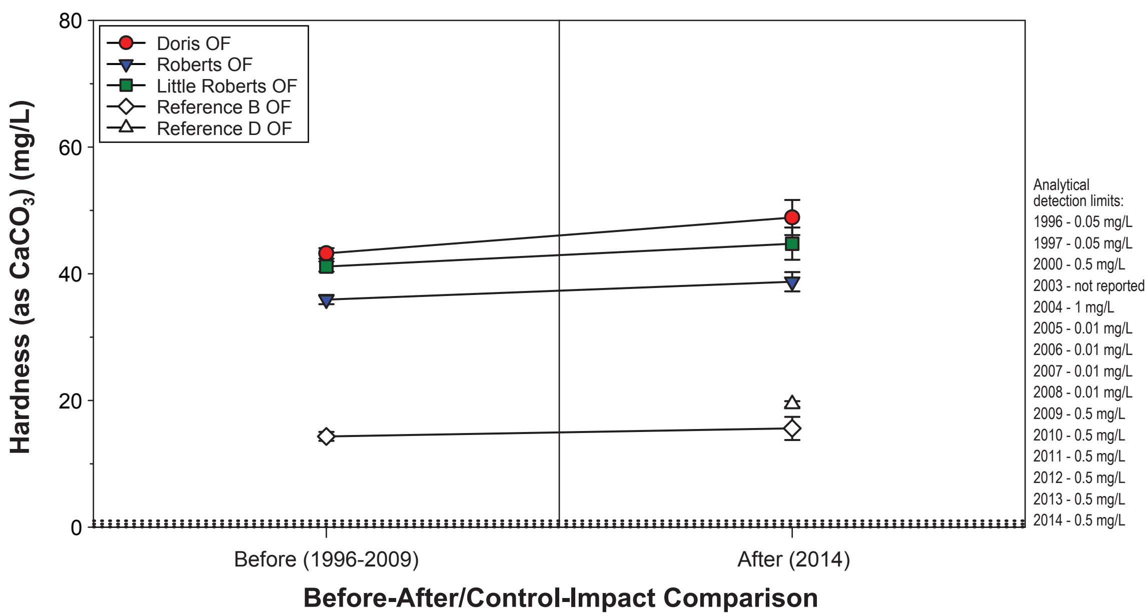
Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Total alkalinity is a required parameter for effluent characterization and water quality monitoring as per Schedule 5, s. 4(1) and s. 7(1)(c) of the MMER.

Figure 3.3-3

Hardness, Stream Sites, Doris North Project, 1996 to 2014

ERM

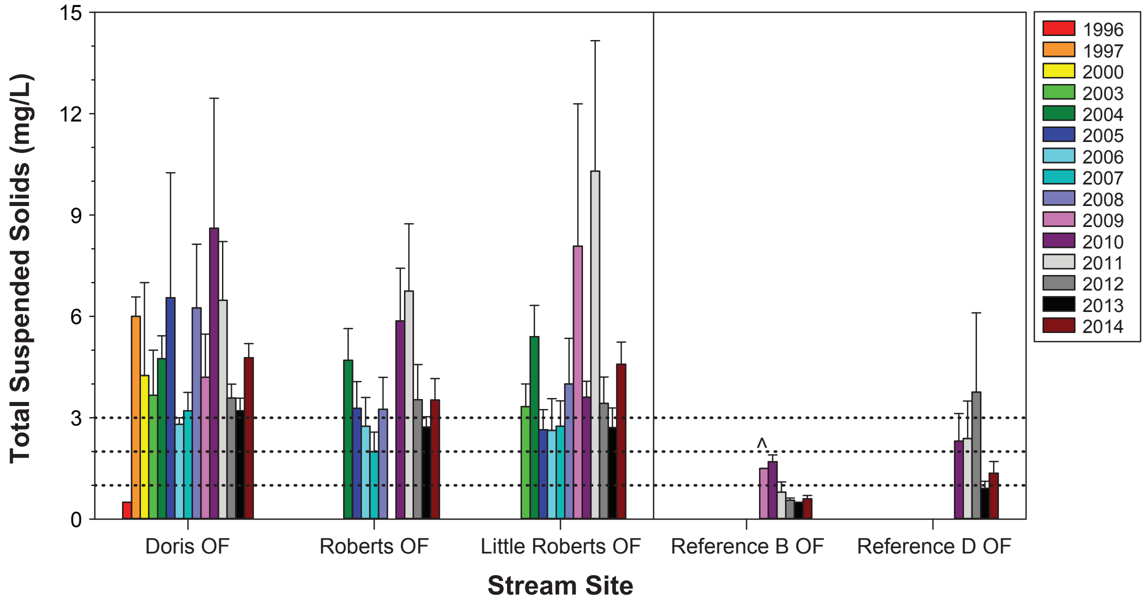


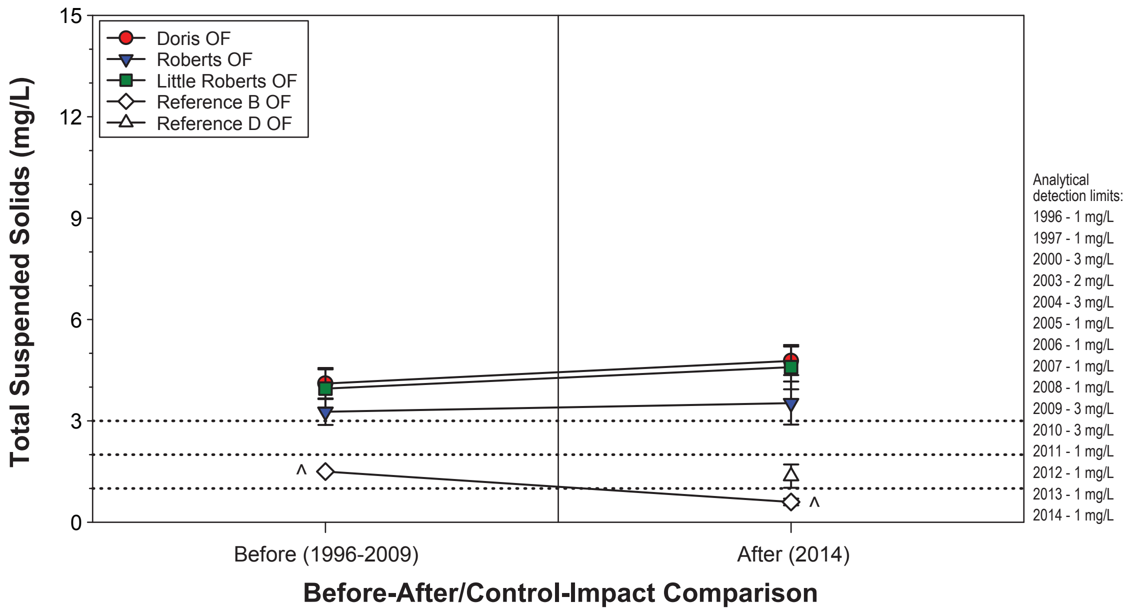


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits.
Hardness is a required parameter for effluent characterization and water quality monitoring as per Schedule 5, s. 4(1) and s. 7(1)(c) of the MMER.

Figure 3.3-4

Total Suspended Solids Concentration, Stream Sites, Doris North Project, 1996 to 2014





Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
The CCME freshwater guideline for total suspended solids is dependent upon background levels.
Total suspended solids are regulated as deleterious substances in effluents as per Schedule 4 of the MMER.

3.3.1.5 *Total Ammonia*

Total ammonia is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. All 2014 concentrations of total ammonia in exposure and reference streams were well below the pH- and temperature-dependent CCME guideline (Figure 3.3-5). Mean 2014 total ammonia concentrations were also within the range of baseline concentrations at each exposure stream, suggesting that there was no effect of Project activities on ammonia concentrations (Figure 3.3-5). The before-after analysis confirmed that there was no significant difference between 2014 and baseline means in any exposure stream ($p = 0.53$ for Doris Outflow, $p = 0.37$ for Roberts Outflow, and $p = 0.46$ for Little Roberts Outflow).

3.3.1.6 *Nitrate*

Nitrate is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. All 2014 nitrate concentrations in exposure and reference streams were well below the CCME guideline of 3.0 mg nitrate-N/L (Figure 3.3-6).

All 2014 nitrate concentrations measured at Roberts and Little Roberts outflows and the majority of 2014 concentrations measured at Doris Outflow were below the analytical detection limit of 0.005 mg nitrate-N/L. At Doris Outflow, the mean 2014 concentration was also within the range of baseline means (Figure 3.3-6). Statistical results for the before-after analysis are not presented because > 70% of nitrate concentrations in the baseline and 2014 datasets for each exposure stream were below analytical detection limits. Thus, through graphical analysis it was concluded that there was no effect of Project activities on nitrate in the exposure streams.

3.3.1.7 *Total Cyanide*

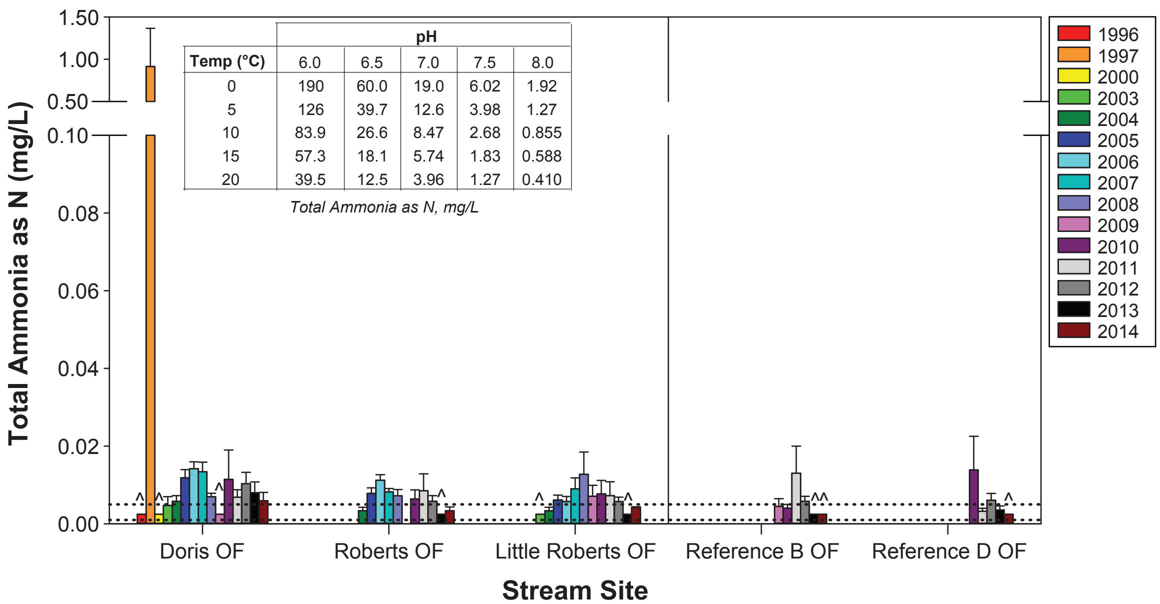
Total cyanide is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. All 2014 cyanide concentrations in exposure and reference streams were below the analytical detection limit of 0.001 mg/L (Figure 3.3-7). Therefore, there was no evidence of an effect of Project activities on total cyanide concentrations in the exposure streams.

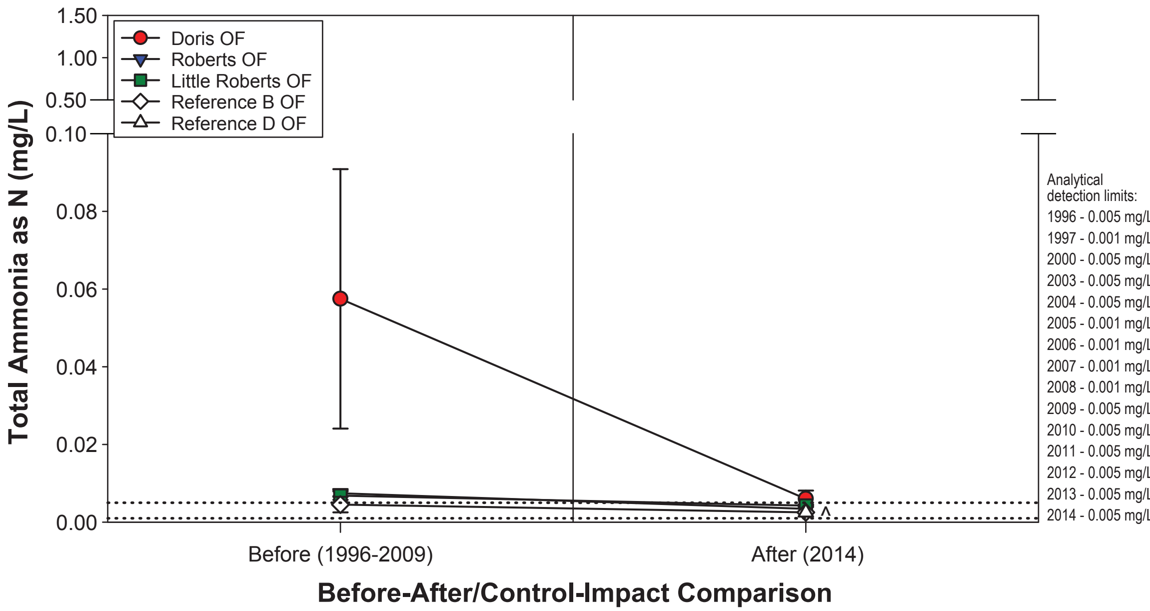
Free cyanide concentrations (cyanide existing in the form of HCN and CN-) in stream samples were also measured in 2014 to allow for direct comparisons with the CCME guideline (0.005 mg/L as free cyanide). The 2014 free cyanide concentrations in stream samples were always below the detection limit of 0.001 mg/L and the CCME guideline for free cyanide (Appendix A). There was no effect of Project activities on free cyanide concentrations in the exposure streams.

3.3.1.8 *Radium-226*

Radium-226 is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. All 2014 radium-226 concentrations in exposure streams were below the analytical detection limit of 0.01 Bq/L (Figure 3.3-8). Therefore, there was no evidence of an effect of Project activities on radium-226 concentrations in the exposure streams.

Total Ammonia Concentration, Stream Sites, Doris North Project, 1996 to 2014



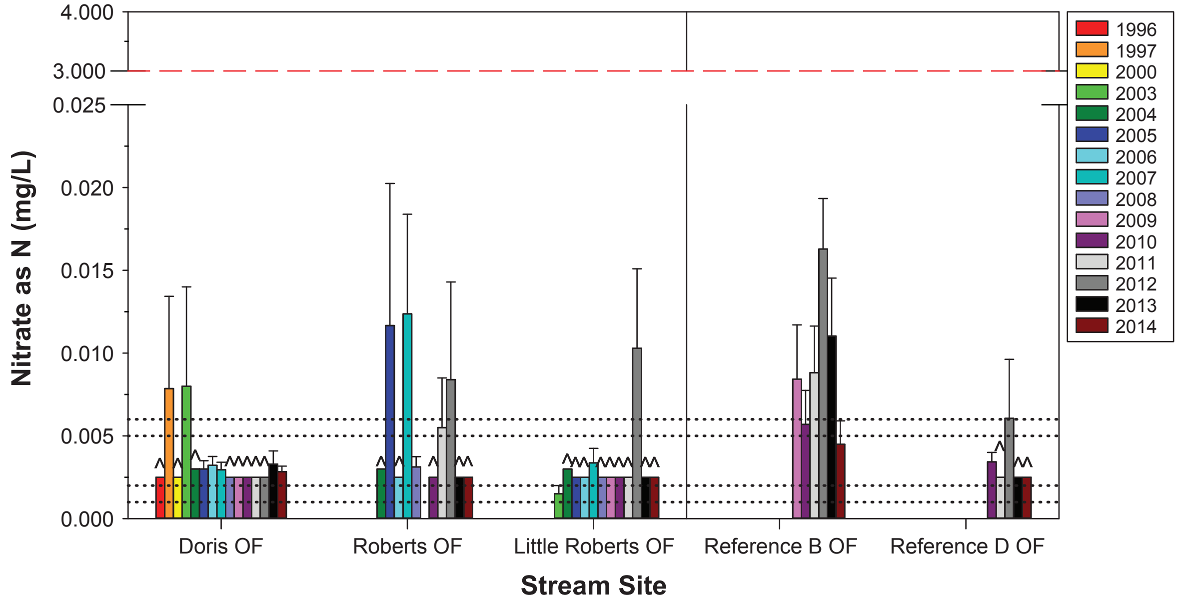


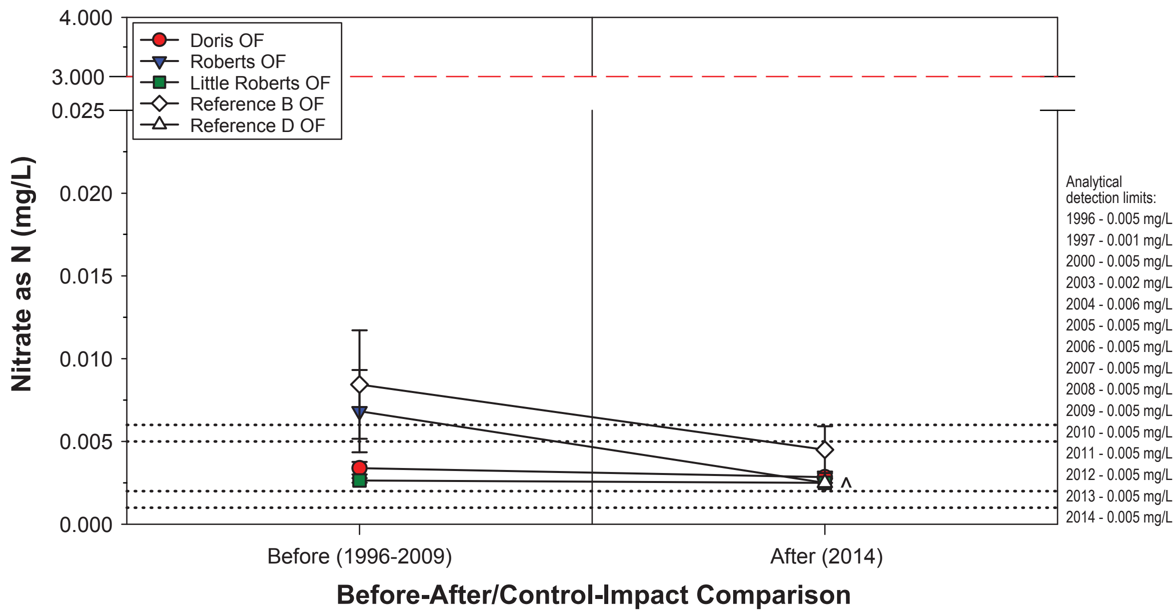
Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Inset table shows the pH- and temperature-dependent CCME freshwater guideline for total ammonia.
Total ammonia is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of the MMER.

Figure 3.3-6

Nitrate Concentration, Stream Sites, Doris North Project, 1996 to 2014

ERM

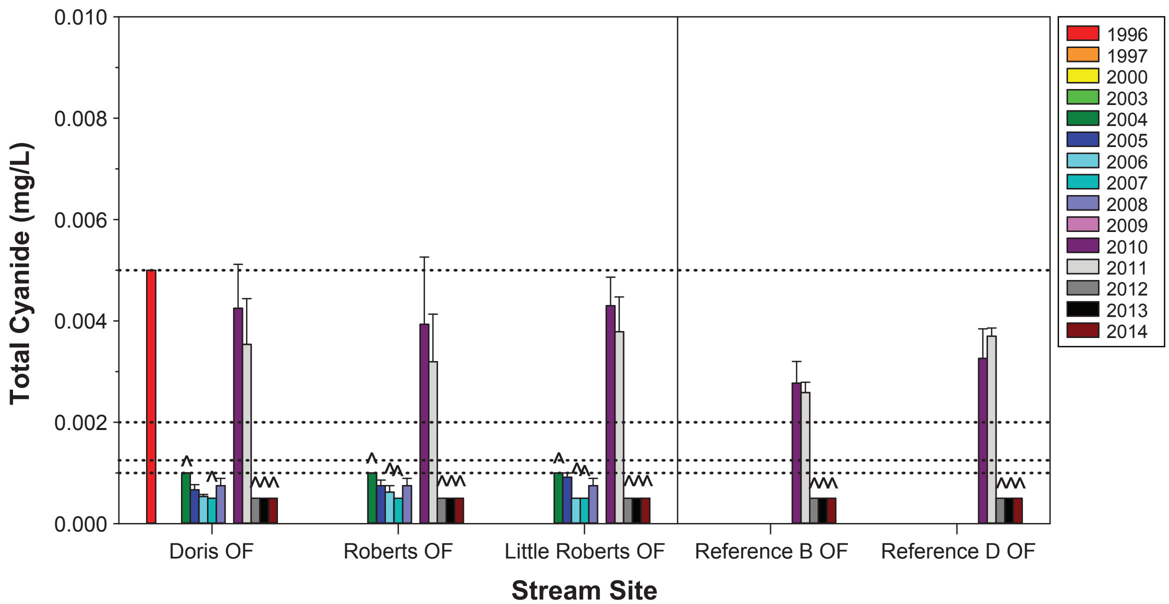


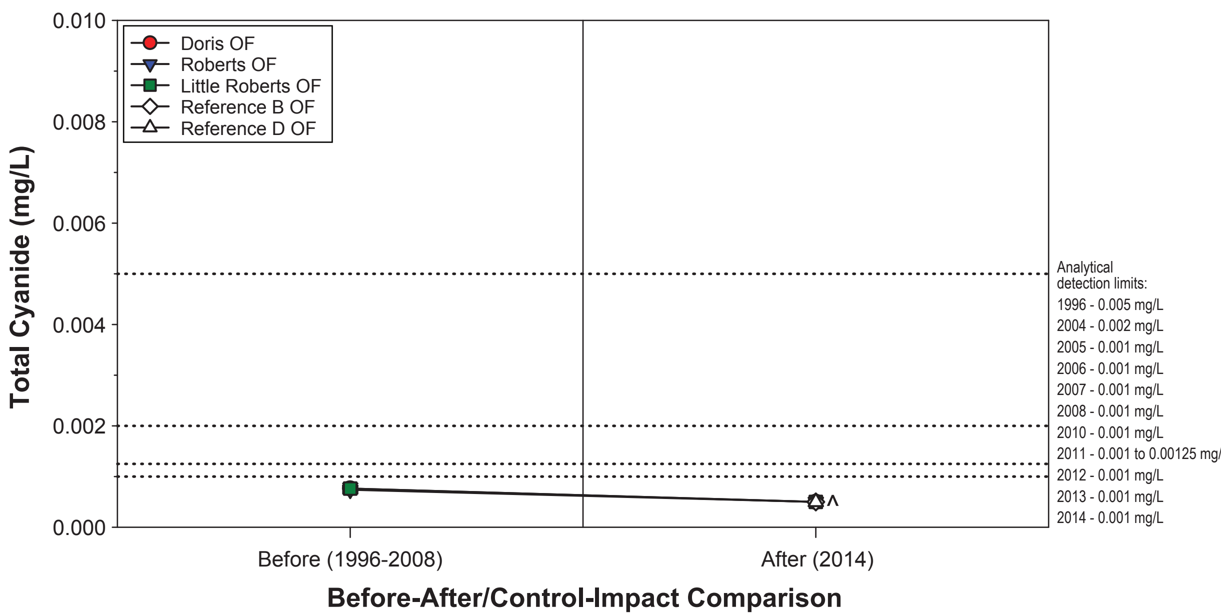


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed line represents the CCME freshwater guideline for nitrate as N (3.0 mg/L; long-term concentration).
Nitrate is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of the MMER.

Figure 3.3-7

Total Cyanide Concentration, Stream Sites, Doris North Project, 1996 to 2014



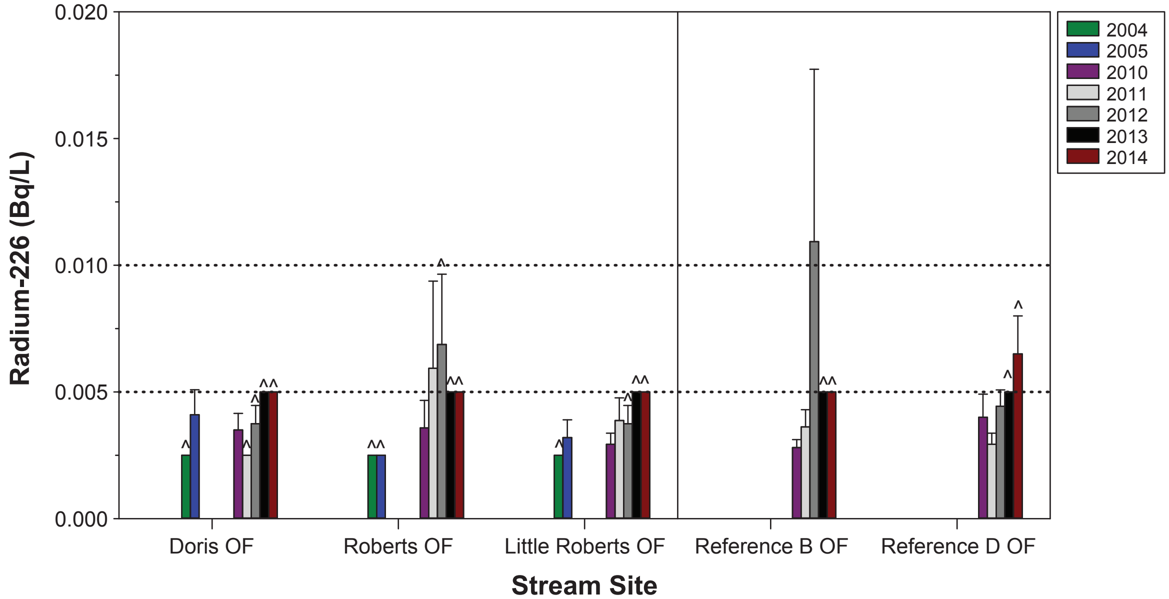


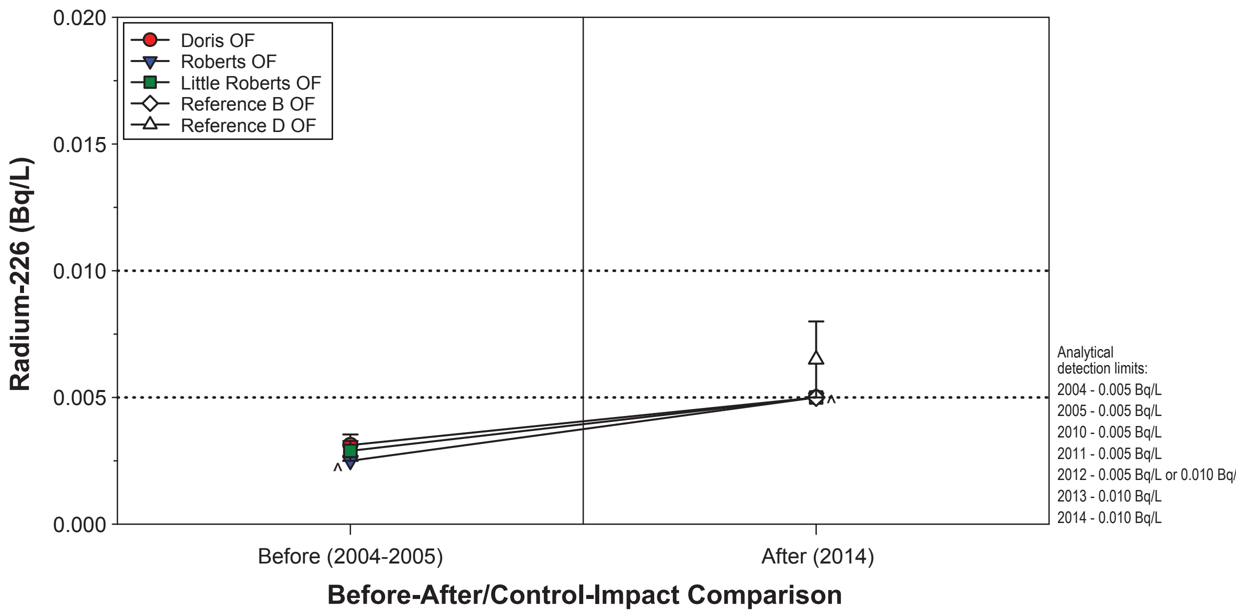
Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Total cyanide is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.

Figure 3.3-8

Radium-226 Concentration, Stream Sites, Doris North Project, 2004 to 2014

ERM





Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Radium-226 is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.

3.3.1.9 Total Aluminum

Total aluminum is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. Total aluminum concentrations were variable among streams. Within each stream, there was also a large amount of inter-annual and seasonal variability. In all exposure and reference streams, mean 2014 total aluminum concentrations were within or lower than the baseline range for each stream. Mean 2014 total aluminum concentrations in exposure streams were above the pH-dependent CCME guideline of 0.1 mg/L. However, this guideline was frequently exceeded in all exposure streams during baseline years, particularly in Roberts and Little Roberts outflows where nearly all mean baseline concentrations exceeded this guideline (Figure 3.3-9).

The before-after analysis revealed that the mean 2014 total aluminum concentration were not significantly different from baseline means for exposure streams ($p = 0.20$ for Doris Outflow; $p = 0.06$ for Roberts Outflow; and $p = 0.09$ for Little Roberts Outflow). Therefore, the results of graphical and statistical analyses suggest that Project activities in 2014 did not negatively affect total aluminum concentrations in any exposure stream.

3.3.1.10 Total Arsenic

Total arsenic is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. Mean 2014 total arsenic concentrations in the exposure streams were lower than the CCME guideline of 0.005 mg/L (Figure 3.3-10). Baseline total arsenic concentrations in exposure streams were generally similar to or slightly higher than 2014 concentrations (Figure 3.3-10).

The before-after comparison indicated that 2014 mean total arsenic concentrations were not significantly different from baseline mean total arsenic concentrations for any exposure stream ($p = 0.43$ for Doris Outflow; $p = 0.04$ for Roberts Outflow; $p = 0.36$ for Little Roberts Outflow). The result for Doris Outflow was marginally non-significant ($p = 0.04$); however, the BACI analyses did not indicate a significantly different trend between the before and after periods for Doris Outflow and the reference streams ($p = 0.82$). Therefore, there were no apparent adverse effects of Project activities on total arsenic concentrations in exposure streams in 2014.

3.3.1.11 Total Cadmium

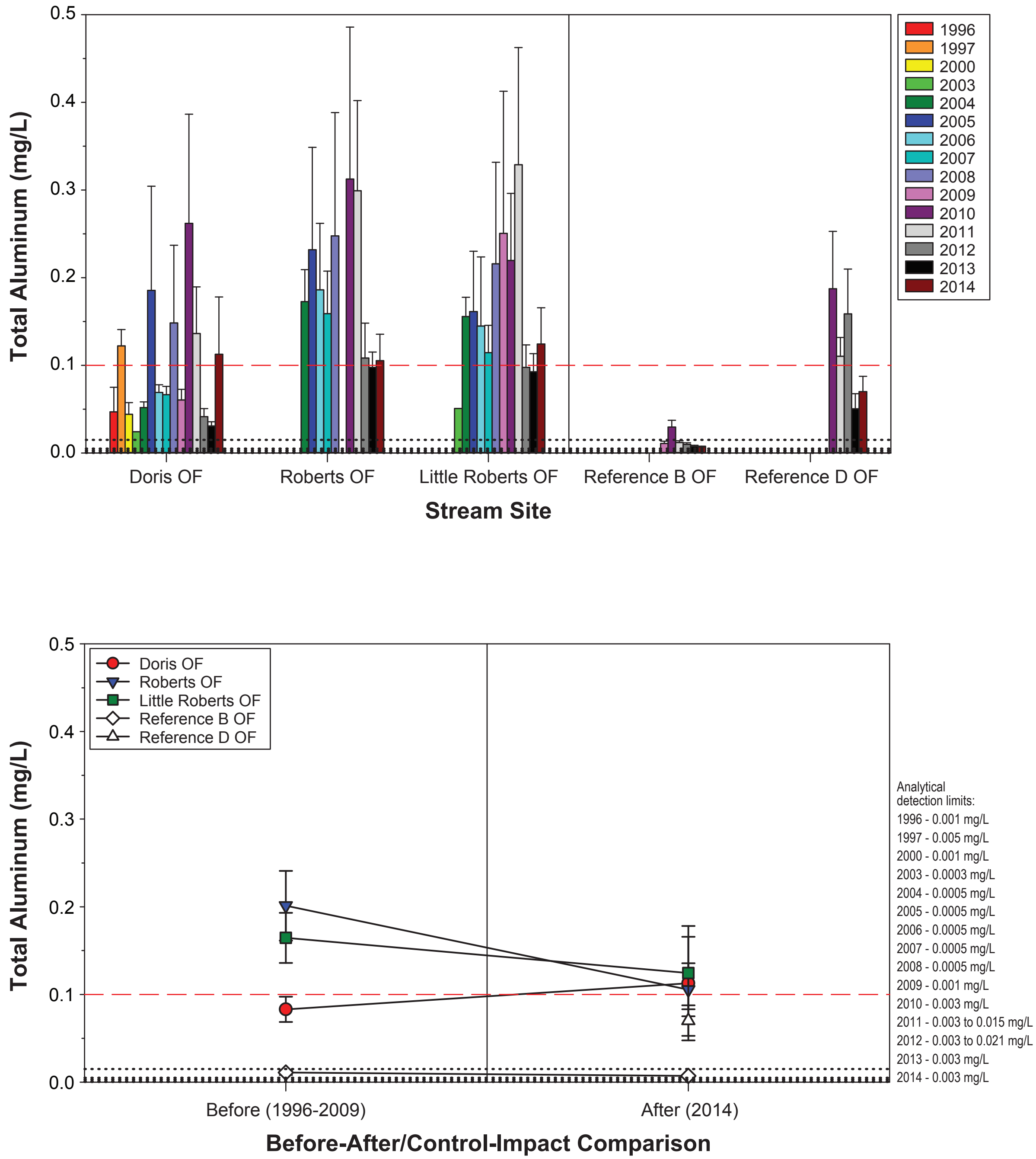
Total cadmium is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. Total cadmium concentrations measured at all exposure and reference streams in 2014 were below the analytical detection limit of 0.000005 mg/L (Figure 3.3-11; Appendix A). Therefore, there was no evidence of an effect of 2014 Project activities on cadmium levels in these exposure streams.

3.3.1.12 Total Copper

Total copper is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. In all exposure streams, mean 2014 copper concentrations were low compared to most baseline years and below the hardness-dependent CCME guideline (Figure 3.3-12). The before-after analysis indicated that there was no significant difference in the mean copper concentration between baseline years and 2014 for any exposure stream ($p = 0.75$ for Doris Outflow, $p = 0.34$ for Roberts Outflow, and $p = 0.18$ for Little Roberts Outflow). Therefore, there was no evidence of an effect of 2014 Project activities on total copper concentrations.

Figure 3.3-9

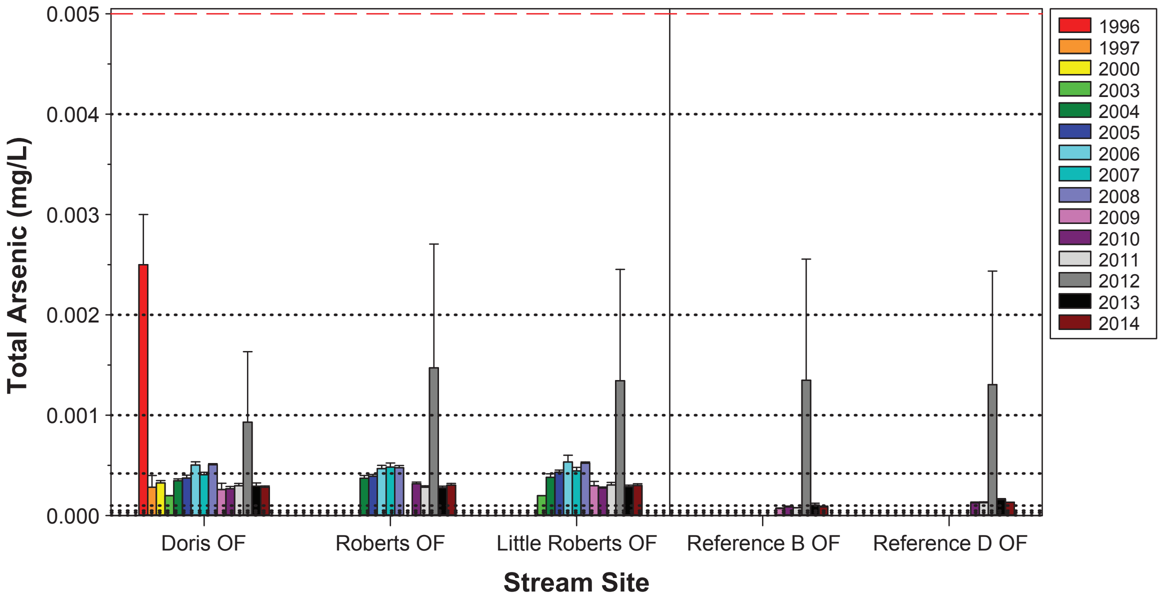
Total Aluminum Concentration, Stream Sites, Doris North Project, 1996 to 2014

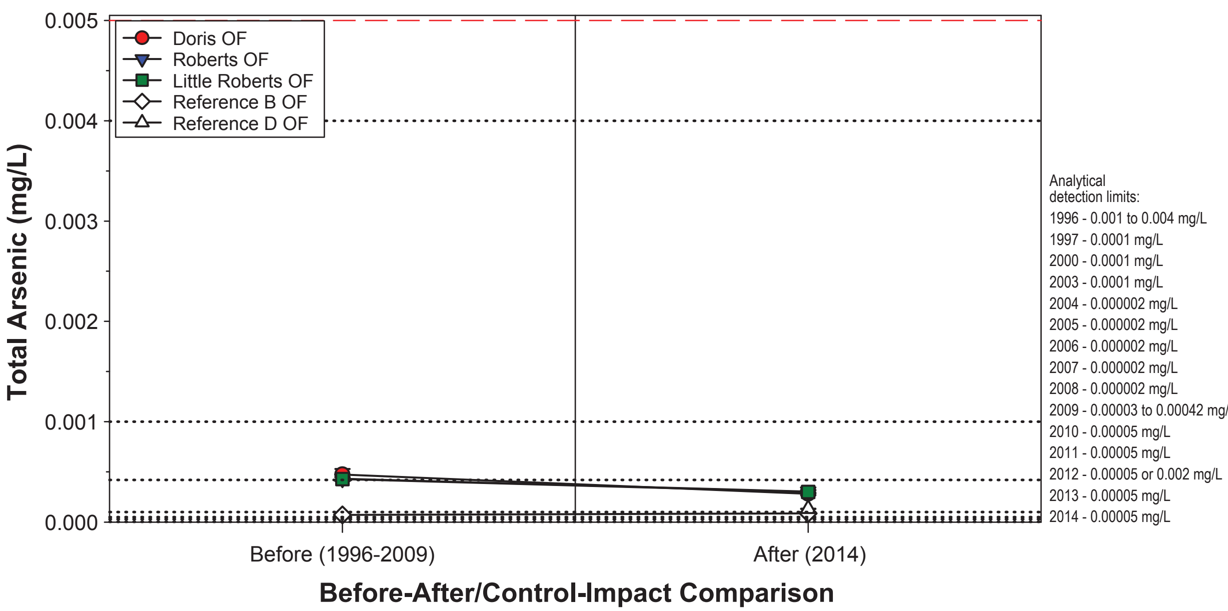


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Red dashed lines represent the pH-dependent CCME freshwater guideline for aluminum (0.005 mg/L at pH < 6.5; 0.1 mg/L at pH ≥ 6.5).
Mean annual pH levels were greater than 6.5 in all exposure and reference streams.
Total aluminum is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of the MMER.

Figure 3.3-10

Total Arsenic Concentration, Stream Sites, Doris North Project, 1996 to 2014

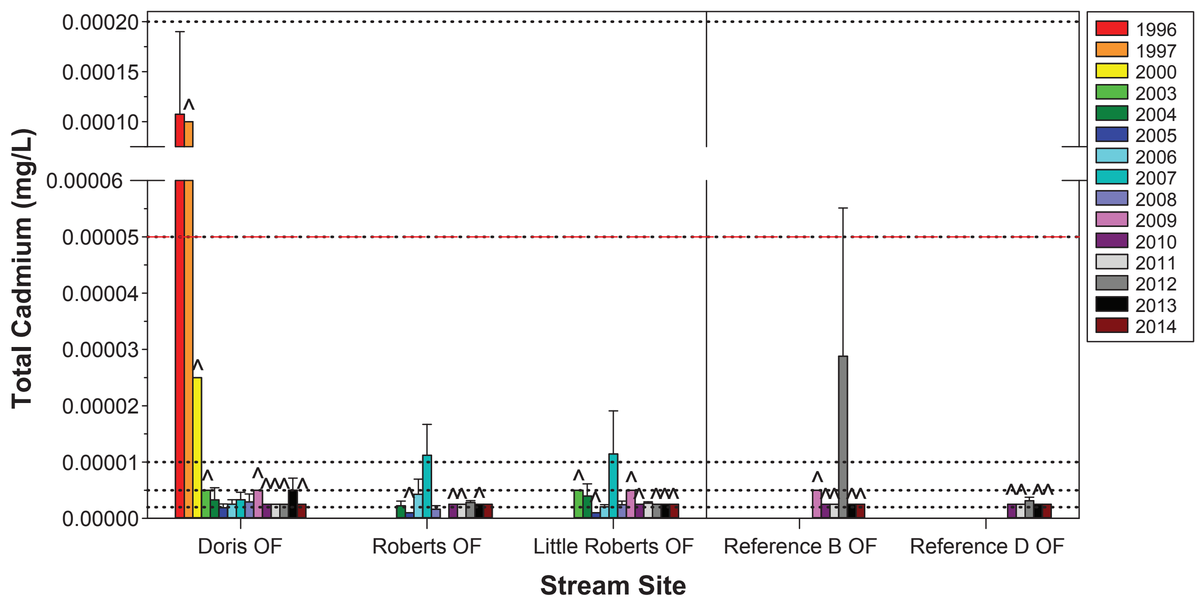


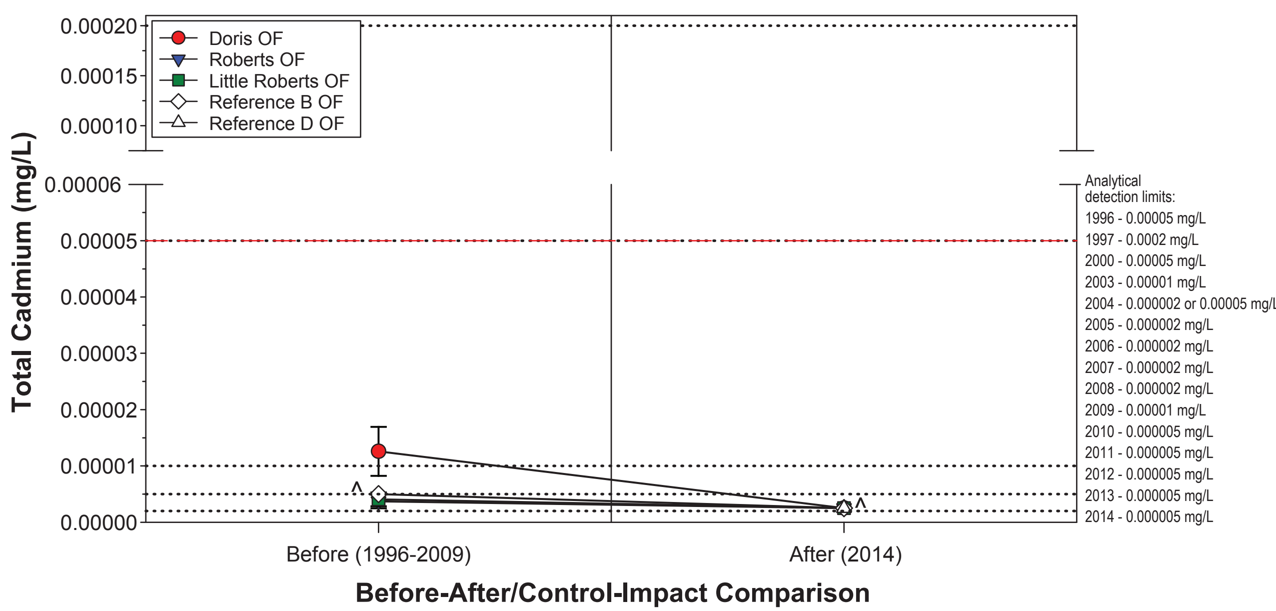


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Red dashed lines represent the CCME freshwater guideline for arsenic (0.005 mg/L).
Total arsenic is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.

Figure 3.3-11

Total Cadmium Concentration, Stream Sites, Doris North Project, 1996 to 2014

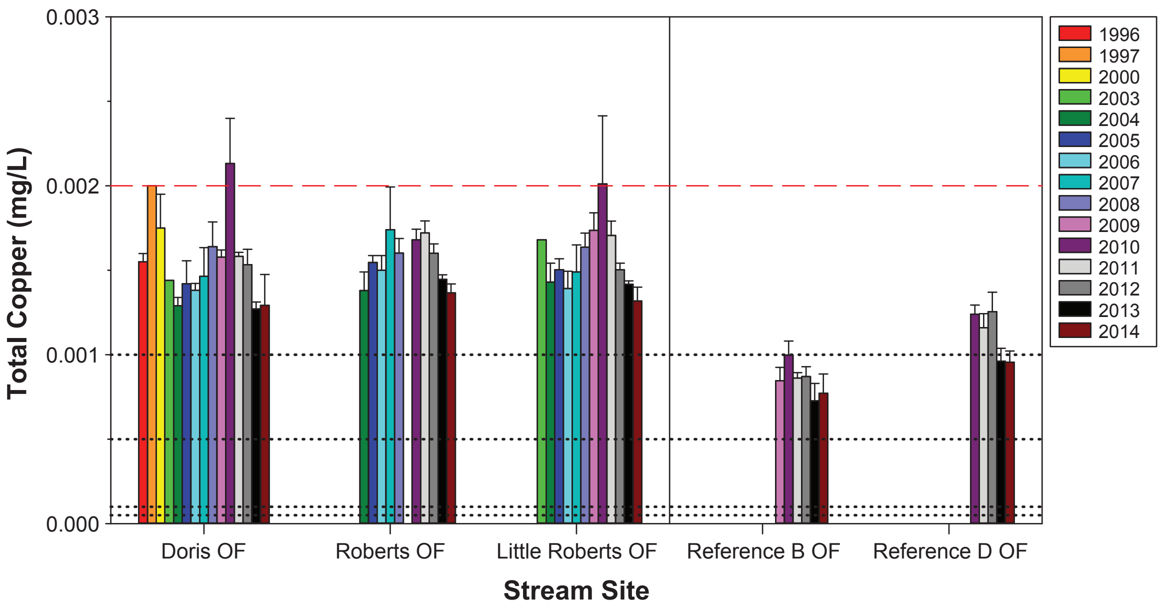


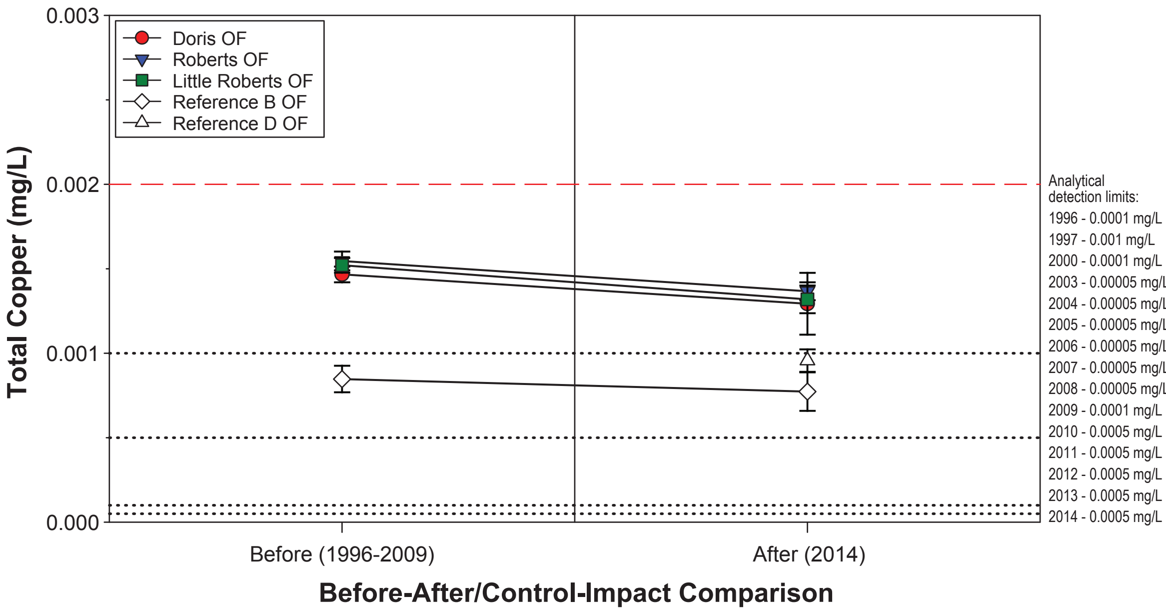


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
The CCME freshwater guideline for cadmium is hardness dependent.
Red dashed lines represent the minimum CCME freshwater guideline for cadmium based on the minimum hardness measured in exposure streams between 1996 and 2014 (hardness: 22 mg/L; CCME guideline: 0.00005 mg/L).
Total cadmium is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of the MMER.

Figure 3.3-12

Total Copper Concentration, Stream Sites, Doris North Project, 1996 to 2014





Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
The CCME freshwater guideline for copper is hardness dependent.
Red dashed lines represent the minimum CCME freshwater guideline for copper regardless of water hardness (0.002 mg/L).
Total copper is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.

3.3.1.13 Total Iron

Total iron is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. Mean total iron concentrations in exposure streams were within the range of baseline means. Within each stream, there was also a large amount of inter-annual variability (Figure 3.3-13). The mean 2014 total iron concentrations in exposure streams were below the CCME guideline concentration of 0.3 mg/L (Figure 3.3-13); however, total iron concentrations measured in June 2014 at exposure streams were greater than the CCME guideline level (Appendix A). Total iron concentrations in baseline samples were also occasionally above this guideline (Figure 3.3-13).

The before-after analysis confirmed that there was no significant difference between baseline and 2014 means for any exposure stream ($p = 0.10$ for Doris Outflow, $p = 0.40$ for Roberts Outflow, and $p = 0.50$ for Little Roberts Outflow), suggesting that 2014 Project activities did not affect total iron concentrations in the exposure streams.

3.3.1.14 Total Lead

Total lead is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. Total lead concentrations in all streams were well below the hardness-dependent CCME guideline (Figure 3.3-14). Mean 2014 lead concentrations in the exposure streams were lower than mean baseline levels. The before-after comparison confirmed that 2014 mean concentrations were not significantly different from baseline means for the exposure streams ($p = 0.94$ for Doris Outflow, $p = 0.12$ for Roberts Outflow, and $p = 0.25$ for Little Roberts Outflow). Thus, there was no evidence of Project-related effects on total lead in the exposure streams in 2014.

3.3.1.15 Total Mercury

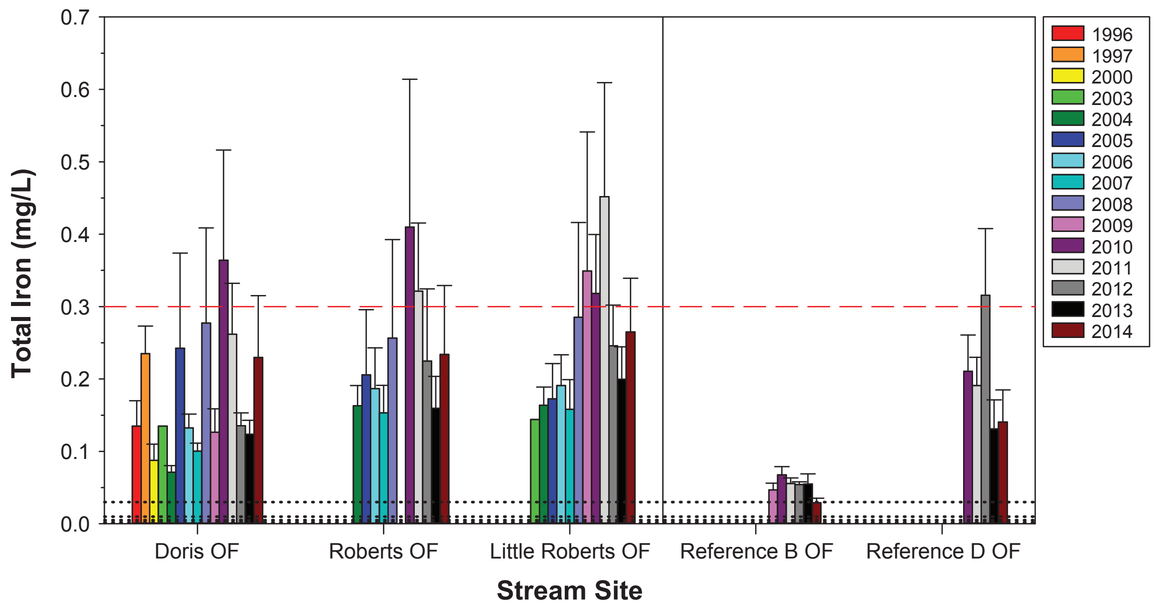
Total mercury is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. Mean 2014 total mercury concentrations at Roberts and Little Roberts outflows were similar to baseline means, suggesting that there was no effect of Project activities on mercury concentrations in these streams (Figure 3.3-15).

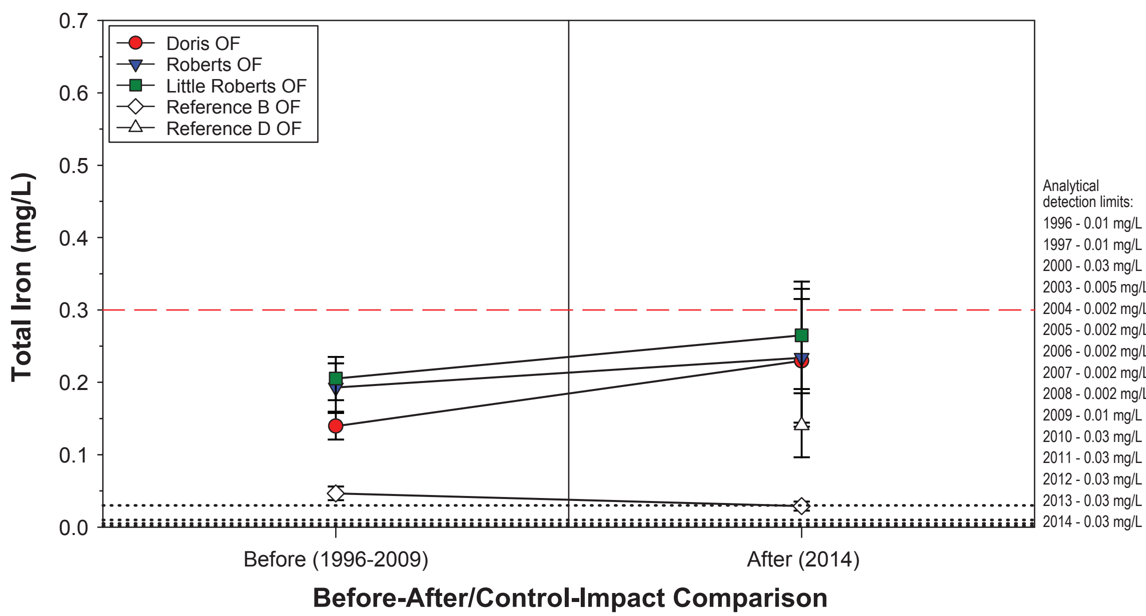
The before-after analysis confirmed that the baseline and 2014 means for total mercury in Roberts and Little Roberts outflows were not significantly different ($p = 0.0135$ for Roberts Outflow and $p = 0.85$ for Little Roberts Outflow); however, the difference was marginally non-significant for Roberts Outflow. The BACI analysis indicated evidence of a significantly different trend between before and after periods for Roberts Outflow and the reference streams ($p = 0.0004$). However, graphical analysis indicated that this difference was likely due to the high variability observed in mercury concentrations in 2013 in Roberts Outflow. In 2014 mercury concentrations in Roberts Outflow and the reference streams were similar, and any small differences are not likely due to Project-related effects.

At Doris Outflow comparisons to baseline data were problematic because of the high proportion of baseline data that are below detection limits (75%) and the widely variable historical detection limits; therefore the results of the before-after comparison were considered unreliable and were not discussed (Figure 3.3-15). However, total mercury concentrations measured in 2014 in Doris Outflow were similar to some historical concentrations and also similar to concentrations measured in Reference D Outflow. Thus, there was no evidence of an increase in total mercury concentrations in exposure streams due to 2014 Project activities.

Figure 3.3-13

Total Iron Concentration, Stream Sites, Doris North Project, 1996 to 2014

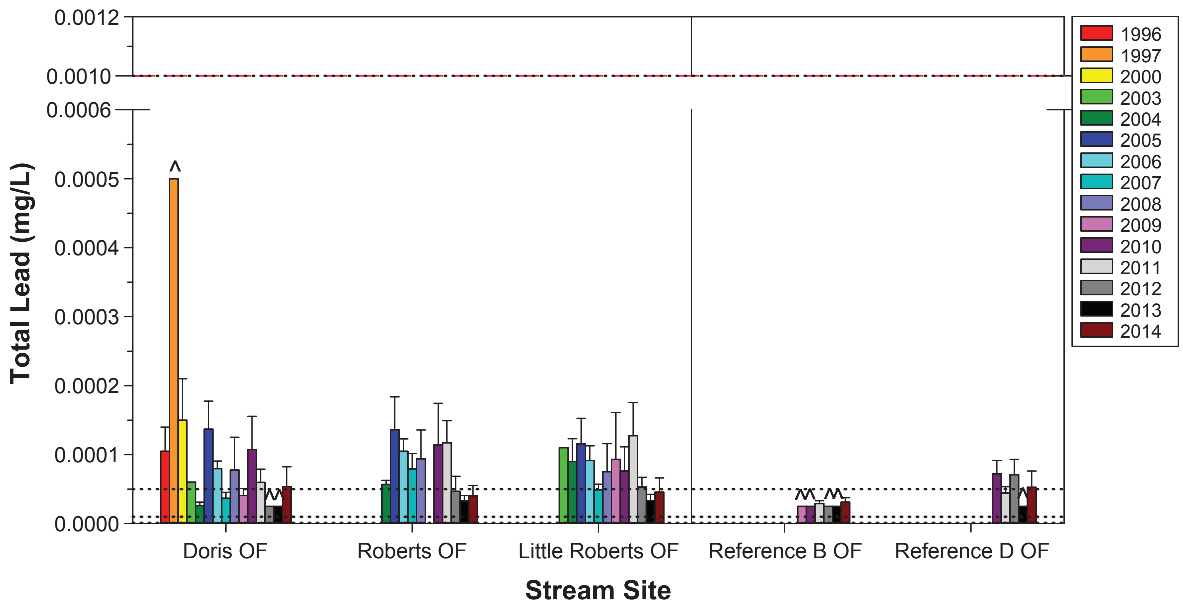


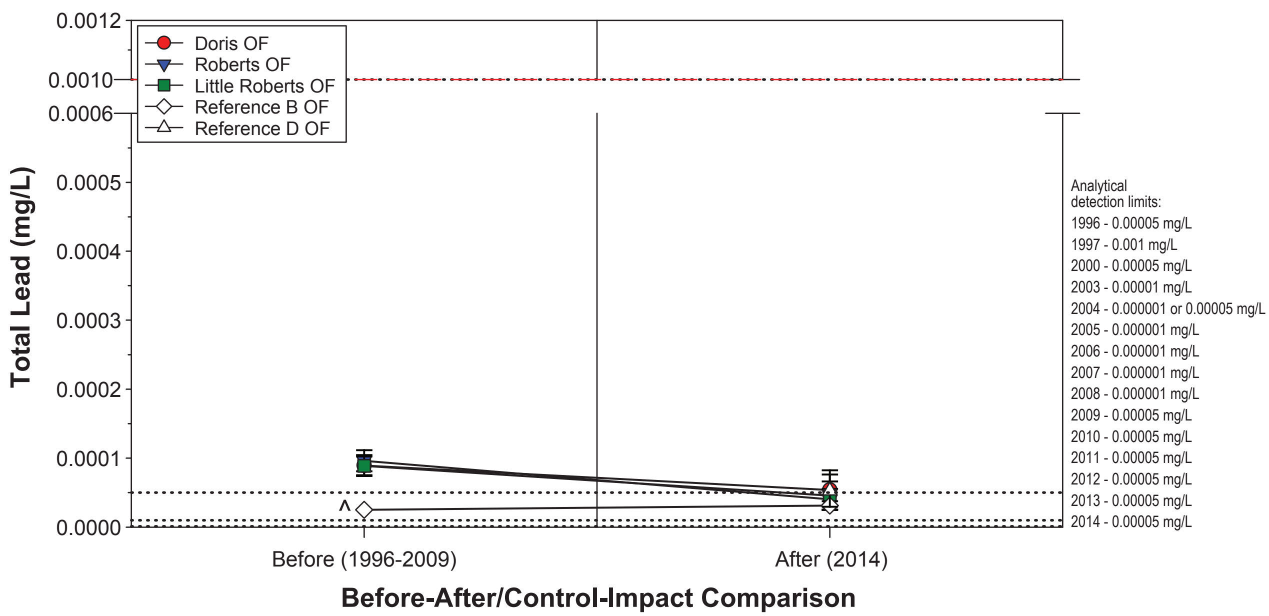


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Red dashed lines represent the CCME freshwater guideline for iron (0.3 mg/L).
Total iron is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of the MMER.

Figure 3.3-14

Total Lead Concentration, Stream Sites, Doris North Project, 1996 to 2014

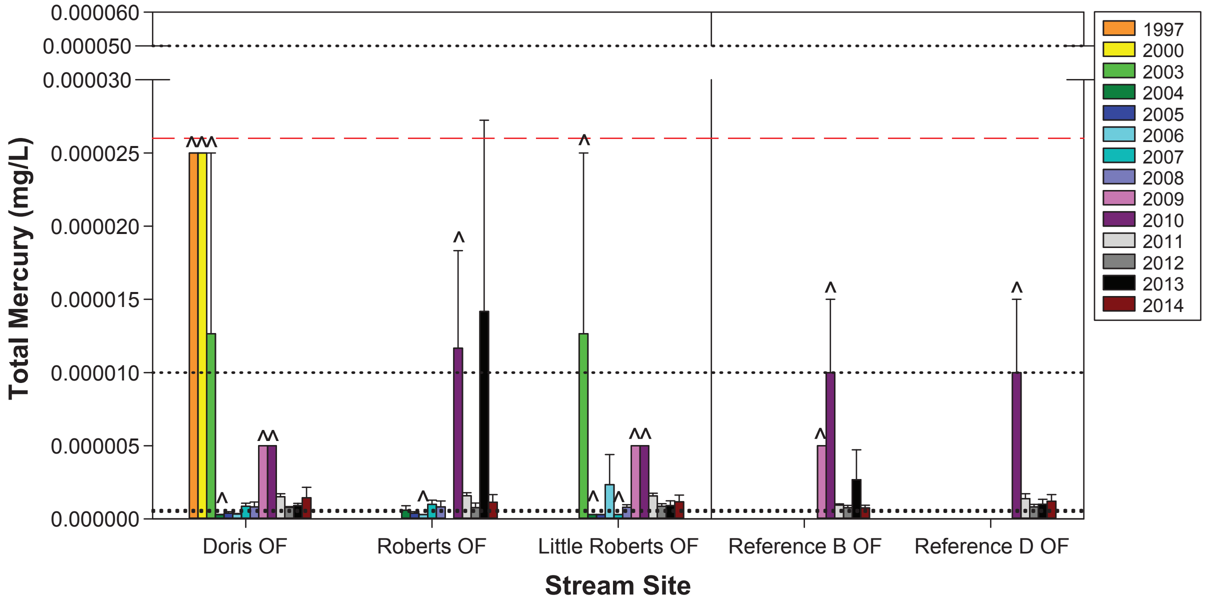


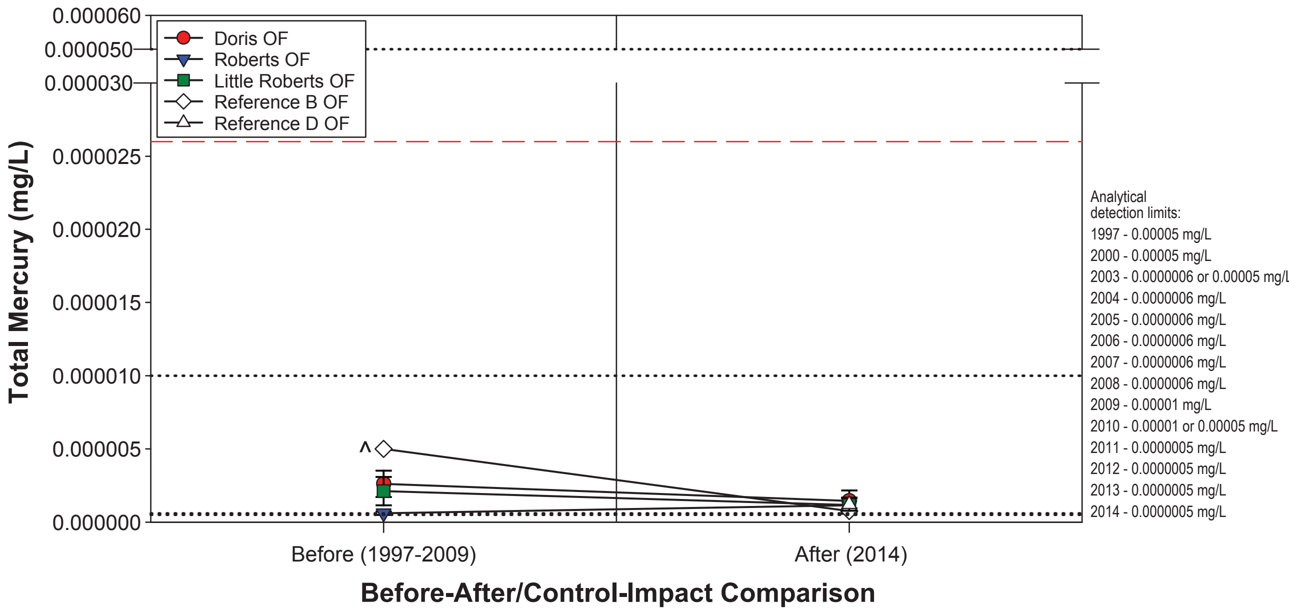


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
The CCME freshwater guideline for lead is hardness dependent.
Red dashed lines represent the minimum CCME freshwater guideline for lead regardless of water hardness (0.001 mg/L).
Total lead is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.

Figure 3.3-15

Total Mercury Concentration, Stream Sites, Doris North Project, 1997 to 2014





Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed lines represent the CCME freshwater guideline for inorganic mercury (0.000026 mg/L).
Total mercury is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of the MMER.

3.3.1.16 Total Molybdenum

Total molybdenum is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. Mean total molybdenum concentrations within each exposure stream were remarkably consistent over time (Figure 3.3-16). The before-after comparison revealed no significant difference between before and after periods for total molybdenum concentrations in exposure streams ($p = 0.04$ for Doris Outflow, $p = 0.47$ for Roberts Outflow, and $p = 0.84$ for Little Roberts Outflow). The difference was marginally non-significant for Doris Outflow; however, the BACI analyses did not indicate a significantly different trend between the before and after periods when comparing Doris Outflow to the reference streams ($p = 0.73$). Total molybdenum concentrations in all 2014 samples were well below the interim CCME guideline of 0.073 mg/L (Figure 3.3-16). Thus, there was no evidence of an increase in total molybdenum concentrations in streams due to 2014 Project activities.

3.3.1.17 Total Nickel

Total nickel is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. Mean 2014 nickel concentrations in all streams were well below the hardness-dependent CCME guideline (Figure 3.3-17). In all three exposure streams, concentrations in 2014 were similar to baseline concentrations (Figure 3.3-17), and the before-after analysis confirmed that there was no significant difference between mean baseline and mean 2014 nickel concentrations ($p = 0.24$ for Doris Outflow, $p = 0.35$ for Roberts Outflow, and $p = 0.64$ for Little Roberts Outflow). Therefore, there was no evidence of an effect of 2014 Project activities on total nickel concentrations in exposure streams.

3.3.1.18 Total Zinc

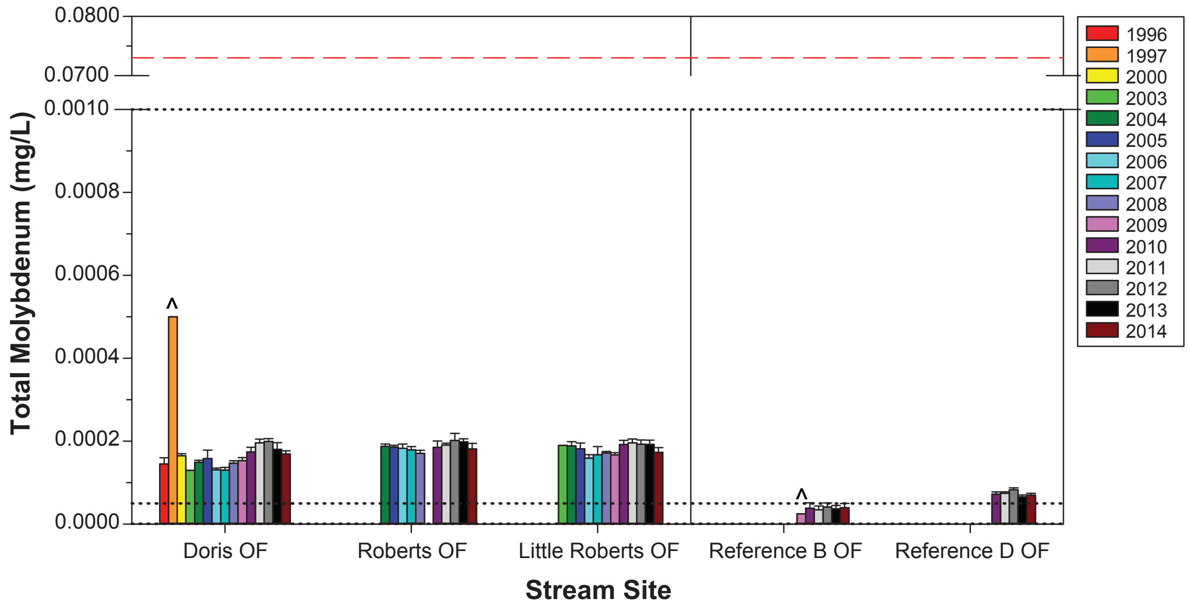
Total zinc is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. In Roberts and Little Roberts outflows, all 2014 zinc concentrations were below the detection limit of 0.003 mg/L. In Doris Outflow, 2014 concentrations were within range of baseline concentrations (Figure 3.3-18). The before-after analysis confirmed that there was no significant difference in zinc concentrations between 2014 and baseline years for Doris Outflow ($p = 0.95$). All 2014 total zinc concentrations in exposure streams were well below the CCME guideline of 0.03 mg/L (Figure 3.3-18). There was no apparent effect of Project activities on total zinc concentrations in the exposure streams.

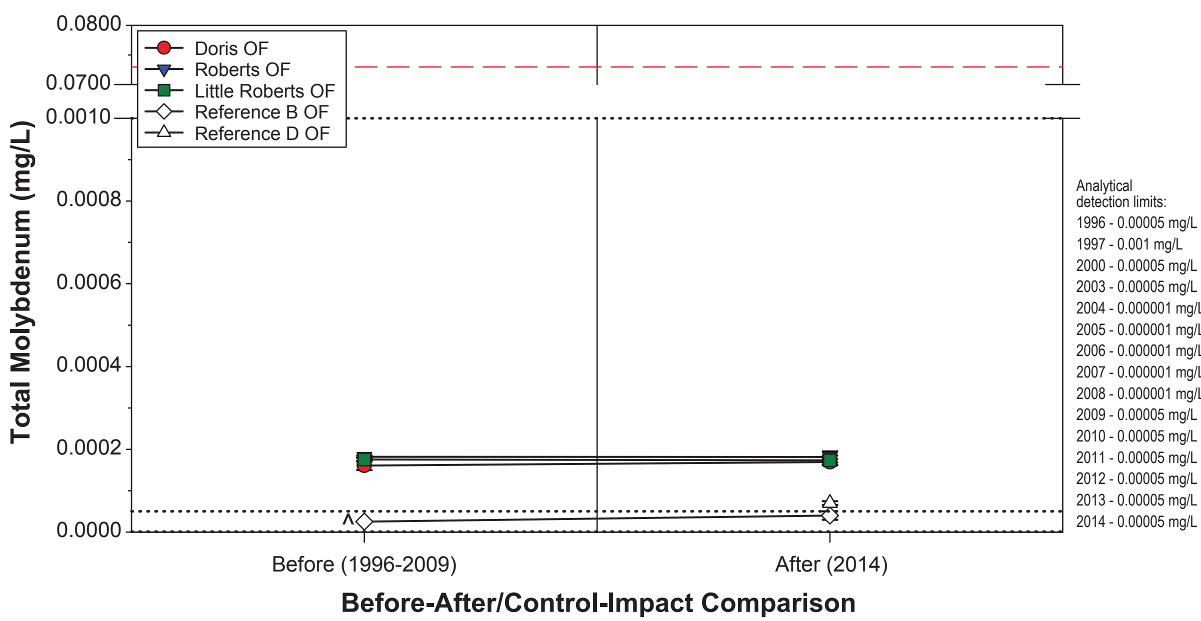
3.3.2 Lakes

Water quality samples from lakes were collected from three exposure lake sites (Doris Lake South, Doris Lake North, and Little Roberts Lake) and two reference lakes (Reference Lake B and Reference Lake D) in 2014. For the exposure lakes, relevant baseline data were available from 1995 to 1998, 2000, and 2003 to 2009 (though all lake sites were not sampled each year). The only available baseline data for Reference Lake B were from 2009, and no baseline data were available for Reference Lake D.

Figure 3.3-16

Total Molybdenum Concentration, Stream Sites, Doris North Project, 1996 to 2014

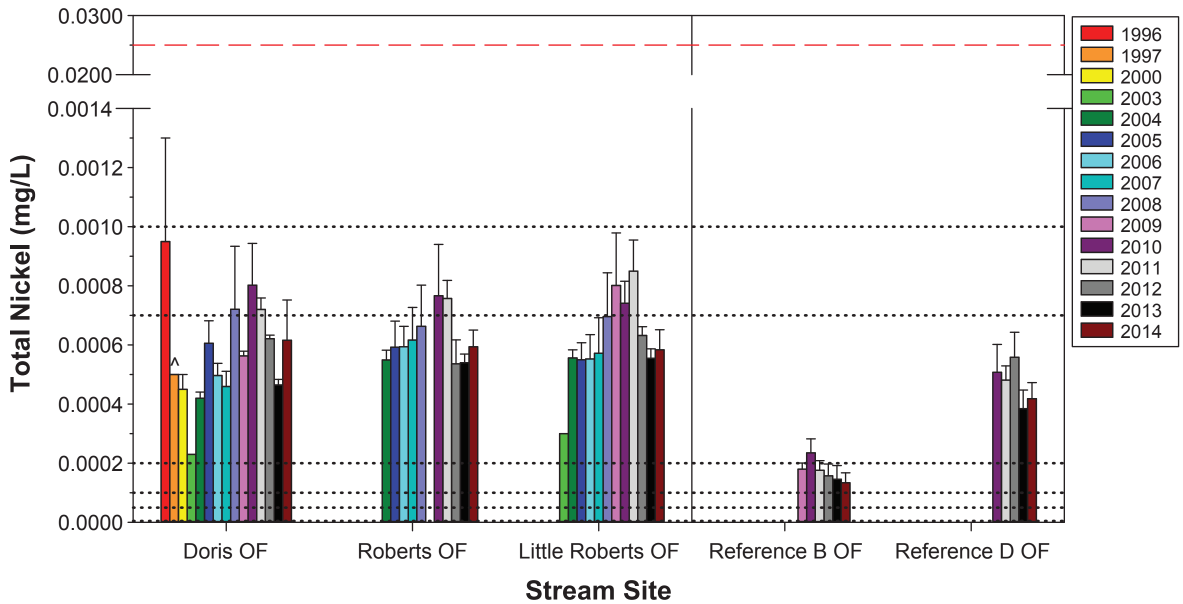


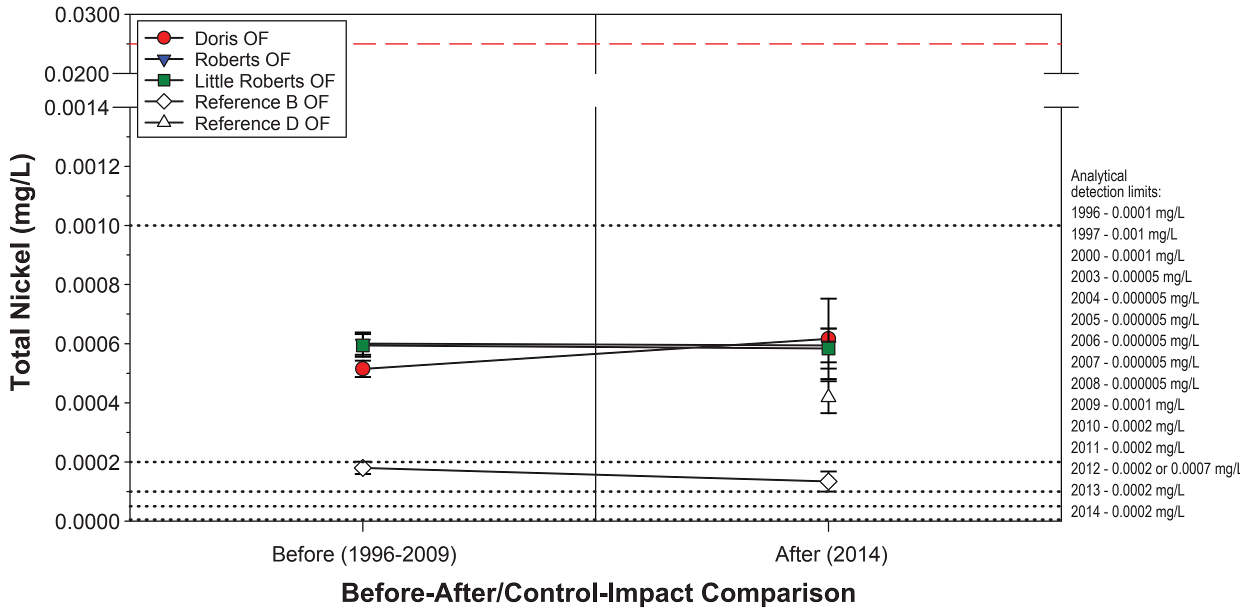


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed lines represent the interim CCME freshwater guideline for molybdenum (0.073 mg/L).
Total molybdenum is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of the MMER.

Figure 3.3-17

Total Nickel Concentration, Stream Sites, Doris North Project, 1996 to 2014

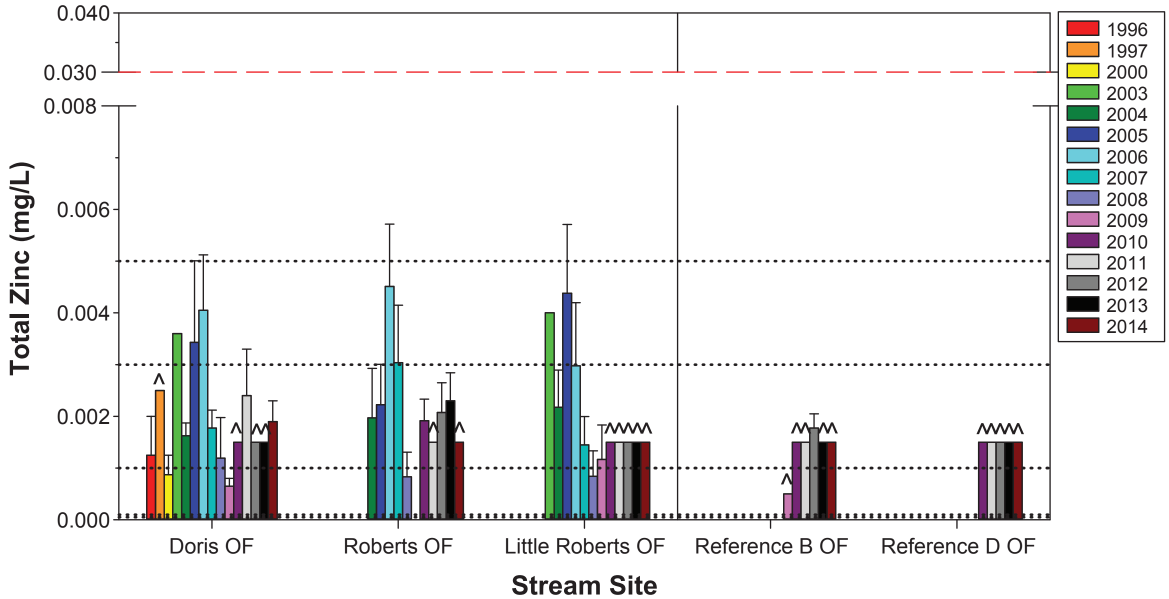


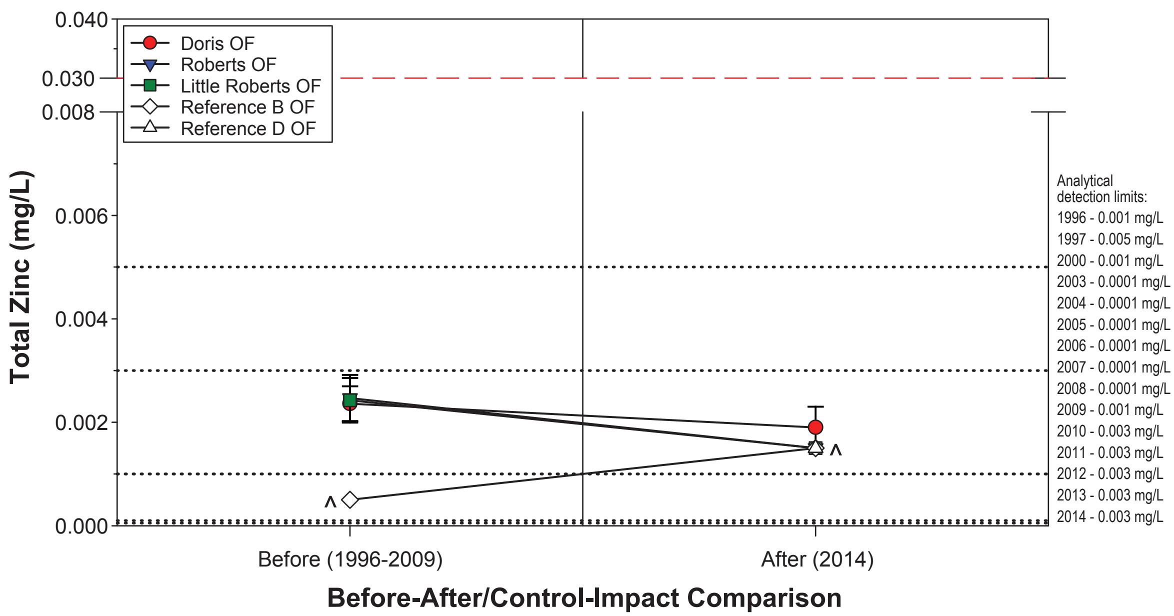


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
The CCME freshwater guideline for nickel is hardness dependent.
Red dashed lines represent the minimum CCME freshwater guideline for nickel regardless of water hardness (0.025 mg/L).
Total nickel is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.

Figure 3.3-18

Total Zinc Concentration, Stream Sites, Doris North Project, 1996 to 2014





Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed lines represent the CCME freshwater guideline for zinc (0.03 mg/L).
Total zinc is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.

Because of comparability in lake sizes, Reference Lake B was used as a reference site for the Doris Lake sites (these larger lakes are both > 3 km^2 in surface area) and Reference Lake D was used as a reference site for Little Roberts Lake (these smaller lakes are both < 1 km^2 in surface area). There was little evidence of vertical physico-chemical stratification in any lake, so all samples were included in graphical and statistical analyses regardless of depth of sampling, and no depth effect was introduced into statistical models. Because no baseline data were available for Reference Lake D, no statistical analyses were possible for this lake, and no BACI analysis was possible for Little Roberts Lake. Graphs showing water quality trends in lakes over time are shown in Figures 3.3-19 to 3.3-36. All statistical results are presented in Appendix B.

3.3.2.1 pH

pH is a required variable for water quality monitoring as per Schedule 5, s. 7(1)(c) of the MMER. pH levels measured in 2014 in exposure lakes were always within the recommended CCME guideline range of 6.5 to 9.0, and were similar to baseline pH levels (Figure 3.3-19). The before-after analysis confirmed that the mean baseline pH was not distinguishable from the mean 2014 pH in any exposure lake site ($p = 0.26$ for Doris Lake South, $p = 0.28$ for Doris Lake North, and $p = 0.0504$ for Little Roberts Lake). Thus, there was no apparent effect of 2014 Project activities on pH in exposure lakes.

3.3.2.2 Total Alkalinity

Total alkalinity is a required variable for effluent characterization and water quality monitoring as per Schedule 5, s. 4(1) and s. 7(1)(c) of the MMER. Total alkalinity (as $CaCO_3$) levels measured in 2014 were similar to baseline alkalinity levels (Figure 3.3-20). The before-after analysis confirmed that there was no significant difference between baseline years and 2014 for alkalinity in any exposure lake site ($p = 0.17$ for Doris Lake South, $p = 0.18$ for Doris Lake North, and $p = 0.0505$ for Little Roberts Lake). Thus, there was no evidence that 2014 Project activities affected total alkalinity in exposure lakes.

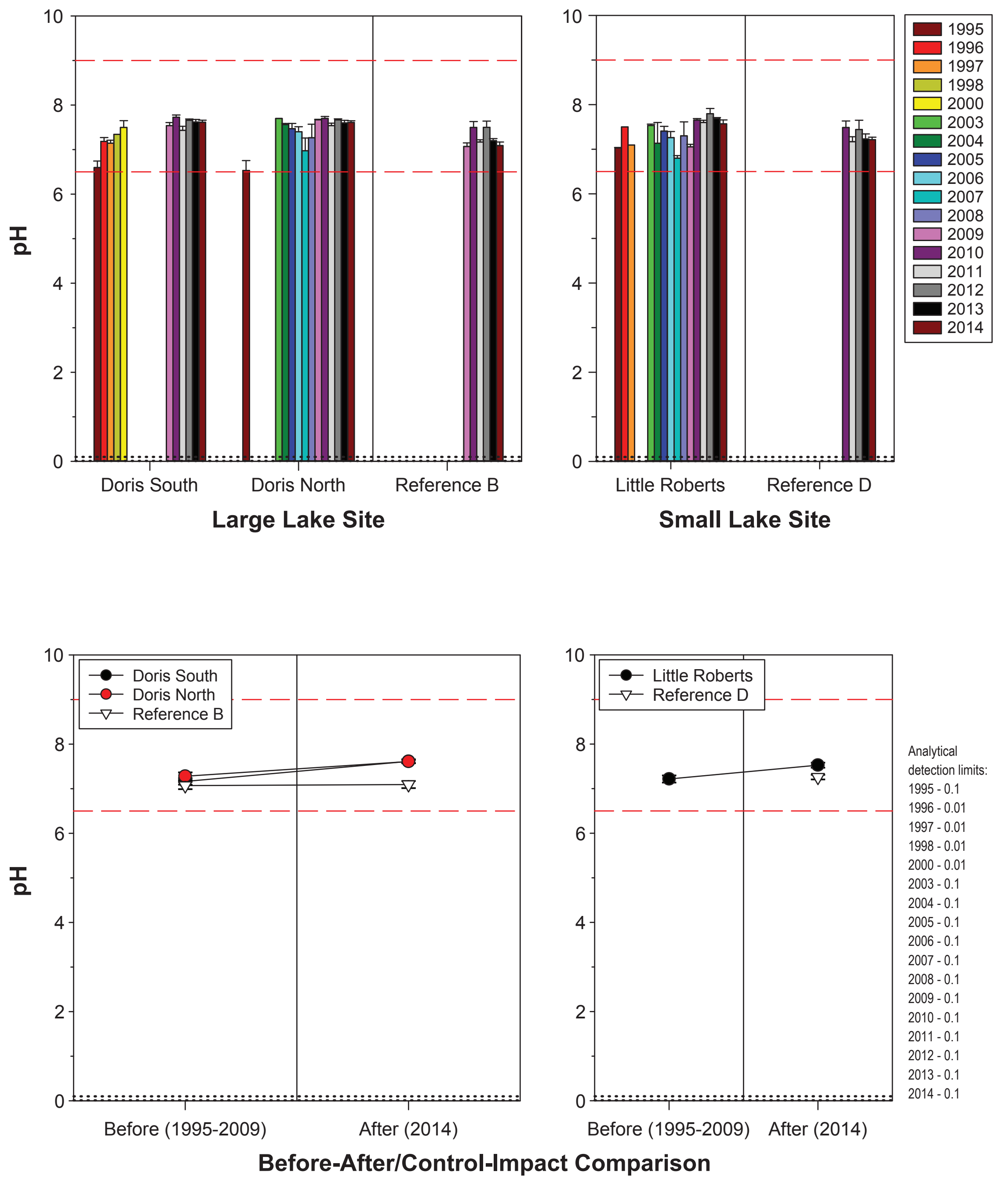
3.3.2.3 Hardness

Hardness is a required variable for effluent characterization and water quality monitoring as per Schedule 5, s. 4(1) and s. 7(1)(c) of the MMER. At the exposure sites, 2014 mean hardness levels were slightly higher than baseline means (Figure 3.3-21).

The before-after analysis indicated that this difference was statistically significant for Doris Lake South ($p = 0.0054$) and Little Roberts Lake ($p = 0.0053$), and marginally non-significant for Doris Lake North ($p = 0.04$). The BACI analysis showed that the change in hardness at Doris Lake South ($p = 0.29$) and Doris Lake North ($p = 0.10$) was paralleled at Reference Lake B; therefore, the difference in hardness levels in Doris Lake between baseline years and 2014 was likely attributable to a natural phenomenon. BACI analysis could not be performed for Little Roberts Lake because there are no baseline data for Reference Lake D. Although hardness was elevated in Little Roberts Lake under-ice, open-water season concentrations were within the range of baseline means. Combined, the evidence does not suggest a Project-related effect in Little Roberts Lake. The elevated hardness in Little Roberts Lake under-ice were more likely due to sample contamination or analytical error. Therefore, despite the results of the statistical analysis and elevated under-ice concentration in Little Roberts Lake the evidence suggests that Project activities did not affect hardness in exposure lakes in 2014.

Figure 3.3-19

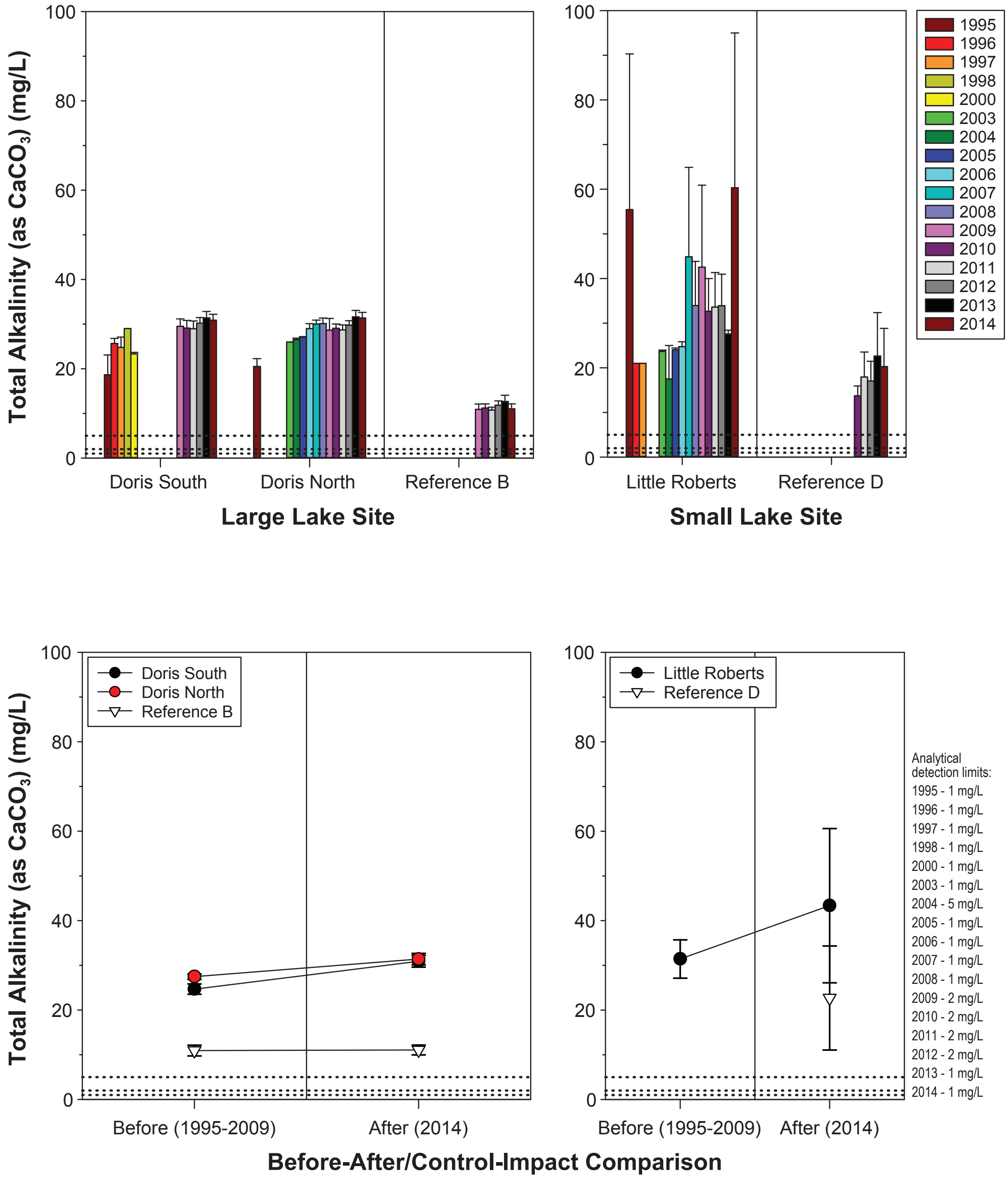
pH, Lake Sites,
Doris North Project, 1995 to 2014



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Red dashed lines represent the CCME freshwater guideline pH range (6.5–9.0).
pH is a required parameter for water quality monitoring as per Schedule 5, s. 7(1)(c) of the MMER.

Figure 3.3-20

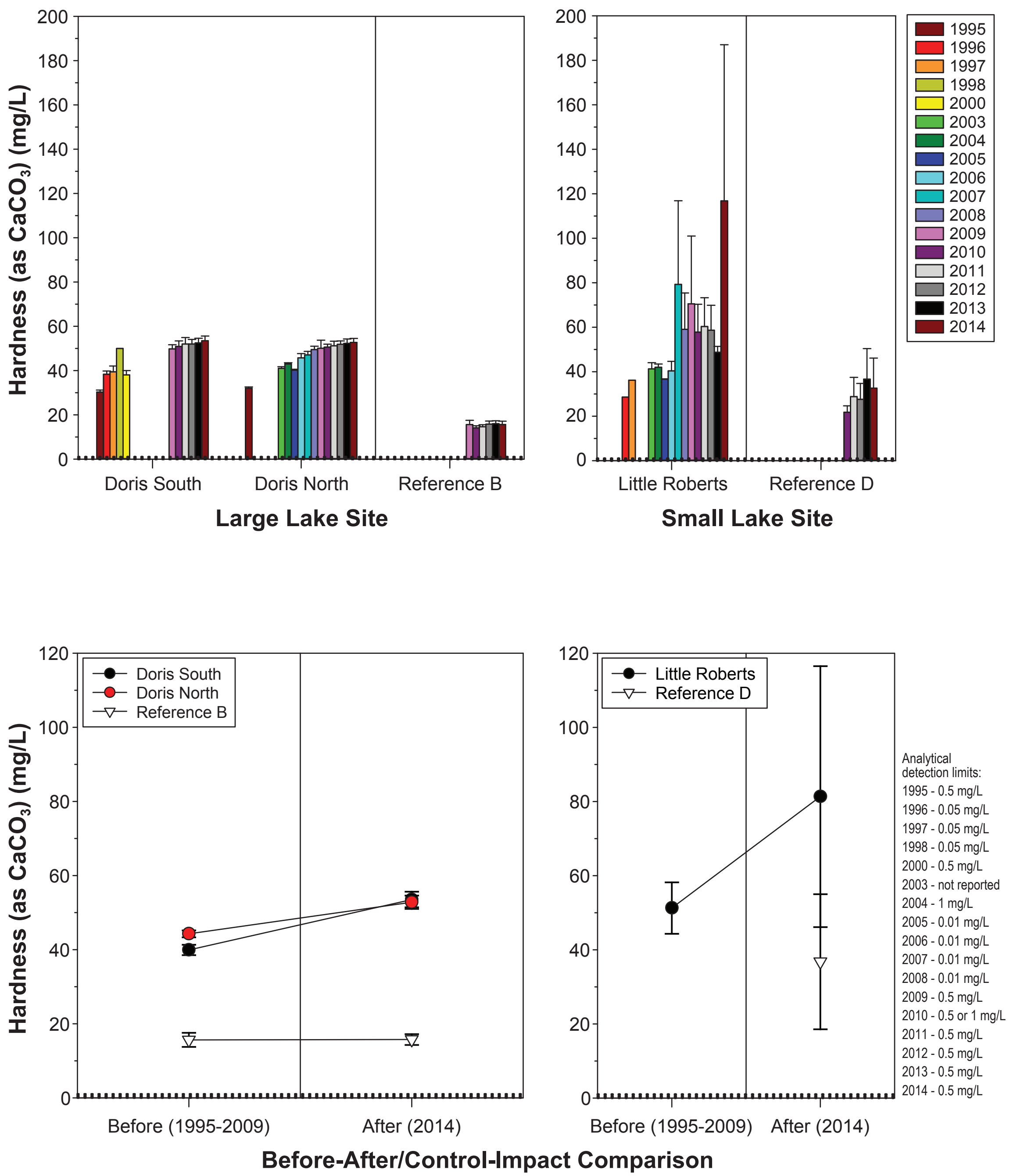
Total Alkalinity, Lake Sites, Doris North Project, 1995 to 2014



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Total alkalinity is a required parameter for effluent characterization and water quality monitoring as per Schedule 5, s. 4(1) and s. 7(1)(c) of the MMER.

Figure 3.3-21

Hardness, Lake Sites, Doris North Project, 1995 to 2014



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Hardness is a required parameter for effluent characterization and water quality monitoring as per Schedule 5, s. 4(1) and s. 7(1)(c) of the MMER.

3.3.2.4 Total Suspended Solids

TSS are regulated as deleterious substances in effluents as per Schedule 4 of the MMER. Mean TSS concentrations were inter-annually variable, particularly in Little Roberts Lake (Figure 3.3-22). Mean 2014 TSS concentrations measured in the exposure lakes were within the range of baseline concentrations, and the before-after analysis showed that 2014 means were not statistically different from baseline means in any of the exposure lake sites ($p = 0.75$ for Doris Lake South, $p = 0.73$ for Doris Lake North, and $p = 0.27$ for Little Roberts Lake). Therefore, there was no apparent effect of 2014 activities on TSS levels in these lakes.

The CCME guideline for TSS is dependent upon background levels (for clear-flow waters with background TSS levels below 25 mg/L, a maximum increase of 25 mg/L is allowable for any short-term exposure or 5 mg/L for longer term exposure; CCME 2014a). Because there was no increase in TSS concentrations from background levels, 2014 TSS concentrations in exposure lakes were below the CCME guideline.

3.3.2.5 Total Ammonia

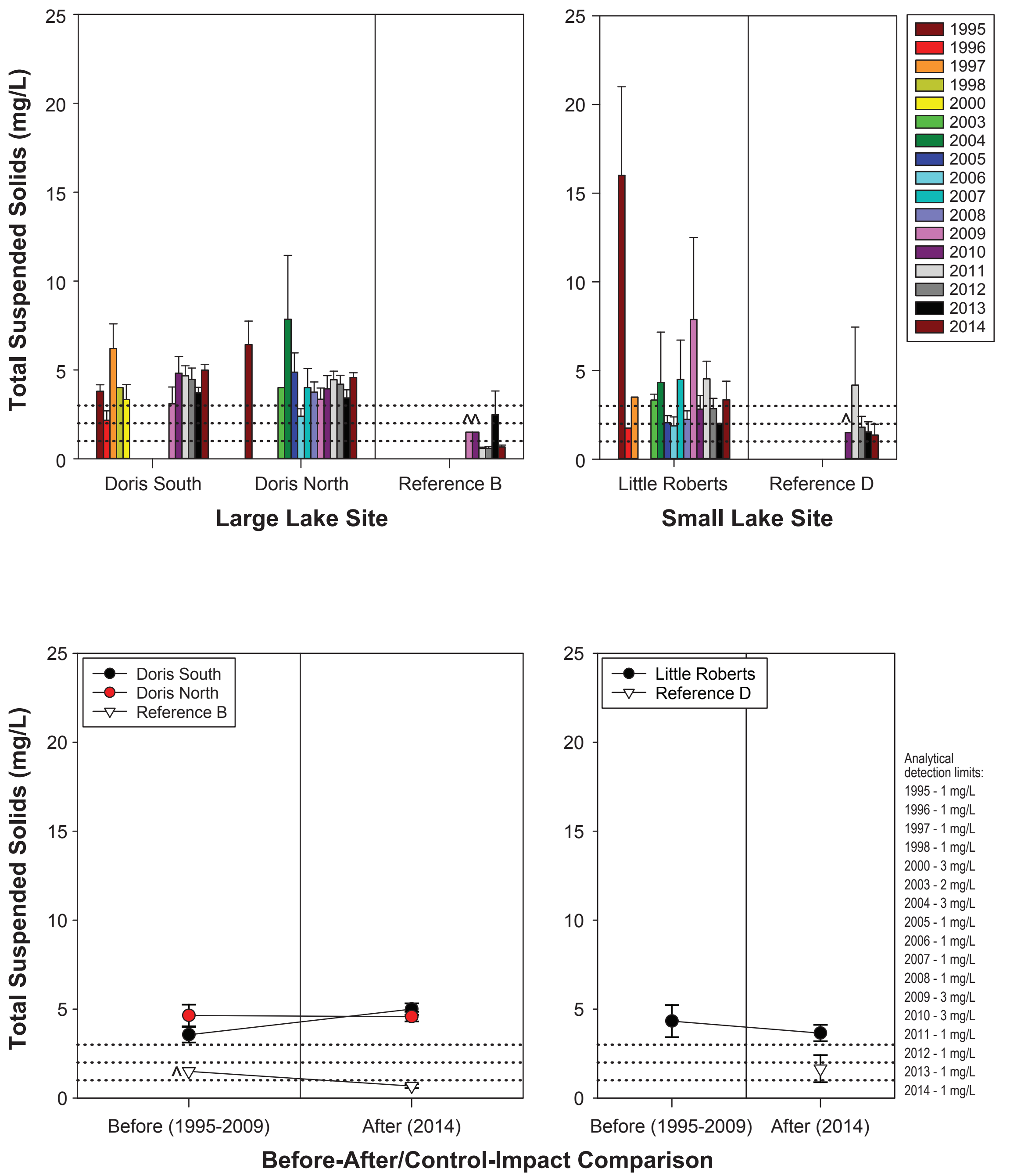
Total ammonia is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. Baseline and 2014 concentrations of total ammonia in exposure and reference lakes were always well below the pH- and temperature-dependent CCME guideline (Figure 3.3-23). Mean 2014 total ammonia concentrations at the exposure sites were within the range of baseline means at Doris Lake South and Little Roberts Lake suggesting that 2014 Project activities did not cause changes in ammonia concentrations at these sites (Figure 3.3-23). This was confirmed by the before-after analysis, which determined that there was no significant difference between baseline and 2014 means for either Doris Lake South ($p = 0.13$) or Little Roberts Lake ($p = 0.48$); therefore, there was no evidence of an effect of Project activities on ammonia concentrations at these sites. At Doris Lake North, all 2014 total ammonia concentrations were below the detection limit of 0.005 mg ammonia-N/L, and there was; therefore, no evidence of an effect of Project activities on total ammonia concentrations at this site.

3.3.2.6 Nitrate

Nitrate is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. Both within-year and inter-annual variability in nitrate concentrations were relatively high in the exposure and reference lakes (Figure 3.3-24). Nitrate concentrations measured in exposure lakes in 2014 were well below the long-term CCME guideline of 3.0 mg nitrate-N/L (Figure 3.3-24). The mean 2014 nitrate concentration at Doris Lake South and Little Roberts Lake were within the range of baseline means (Figure 3.3-24). The before-after analysis confirmed that the mean 2014 nitrate concentrations were not distinguishable from the baseline mean nitrate concentration at Doris Lake South ($p = 0.49$) or Little Roberts Lake ($p = 0.88$). At Doris Lake North concentrations in all 2014 samples were below the analytical detection limit of 0.005 mg/L. These results indicate that there were no effects of Project activities on nitrate concentrations in exposure lakes in 2014.

Figure 3.3-22

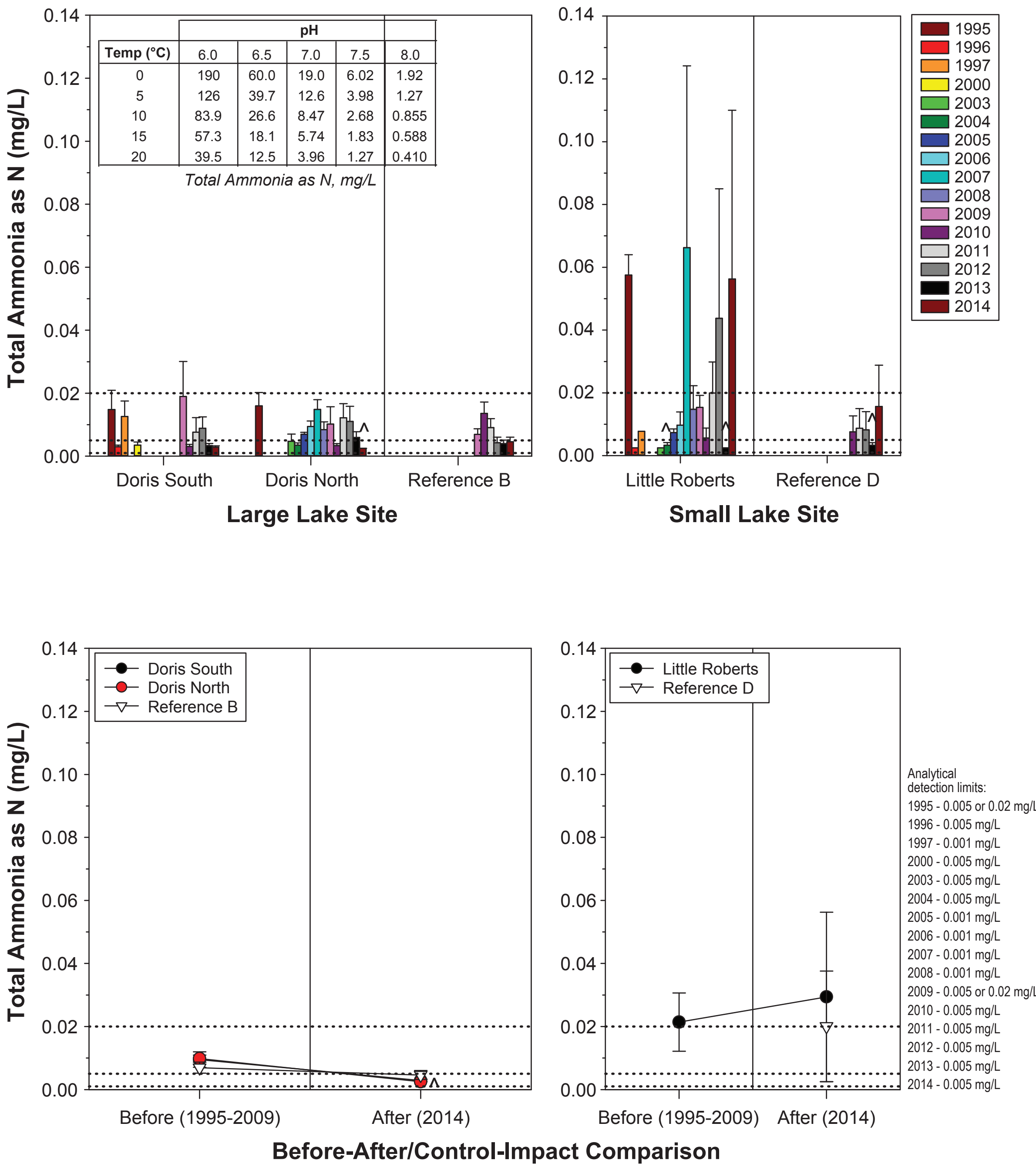
Total Suspended Solids Concentration, Lake Sites, Doris North Project, 1995 to 2014



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
The CCME freshwater guideline for total suspended solids is dependent upon background levels.
Total suspended solids are regulated as deleterious substances in effluents as per Schedule 4 of the MMER.

Figure 3.3-23

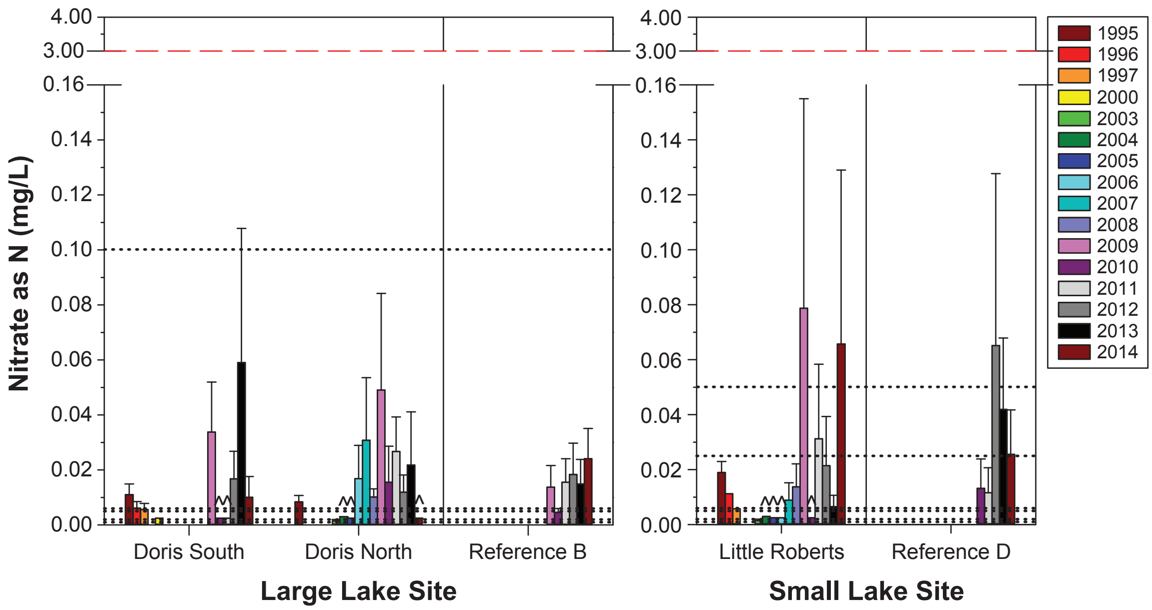
**Total Ammonia Concentration,
Lake Sites, Doris North Project, 1995 to 2014**

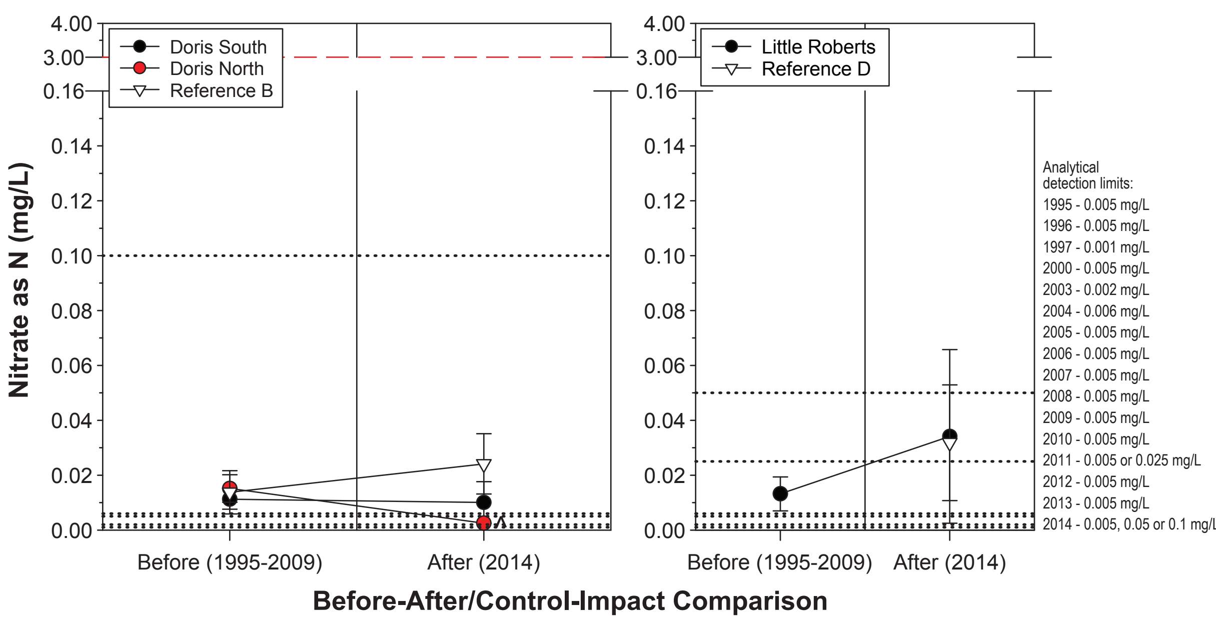


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Inset table shows the pH- and temperature-dependent CCME freshwater guideline for total ammonia.
Total ammonia is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of the MMER.

Figure 3.3-24

Nitrate Concentration, Lake Sites, Doris North Project, 1995 to 2014





Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed line represents the CCME freshwater guideline for nitrate as N (3.0 mg/L; long-term concentration).
The anomalously high nitrate concentrations of 4.51 mg/L reported for Doris South in August 1996 and 5.3 mg/L reported for Little Roberts Lake in September 2004 were considered outliers and was excluded from plots.
Nitrate is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of the MMER.

3.3.2.7 Total Cyanide

Total cyanide is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. All total cyanide concentrations measured in exposure and reference lakes in 2014 were below the analytical detection limit of 0.001 mg/L (Figure 3.3-25). Therefore, there was no evidence of an increase in total cyanide concentrations due to 2014 Project activities.

Free cyanide concentrations (cyanide existing in the form of HCN and CN-) in lake samples were measured in 2014 to allow for direct comparisons with the CCME guideline for cyanide (0.005 mg/L as free cyanide). Concentrations of free cyanide in lakes samples were always below the detection limit of 0.001 mg/L and the CCME guideline (Appendix A). Therefore, the cyanide levels in exposure lakes in 2014 would not be expected to pose a threat to freshwater aquatic life.

3.3.2.8 Radium-226

Radium-226 is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. All concentrations of radium-226 measured in 2014 at the exposure and reference lakes were below the analytical detection limit of 0.01 Bq/L (Figure 3.3-26 and Appendix A). Therefore, there was no evidence of an increase in Radium-226 concentrations due to 2014 Project activities.

3.3.2.9 Total Aluminum

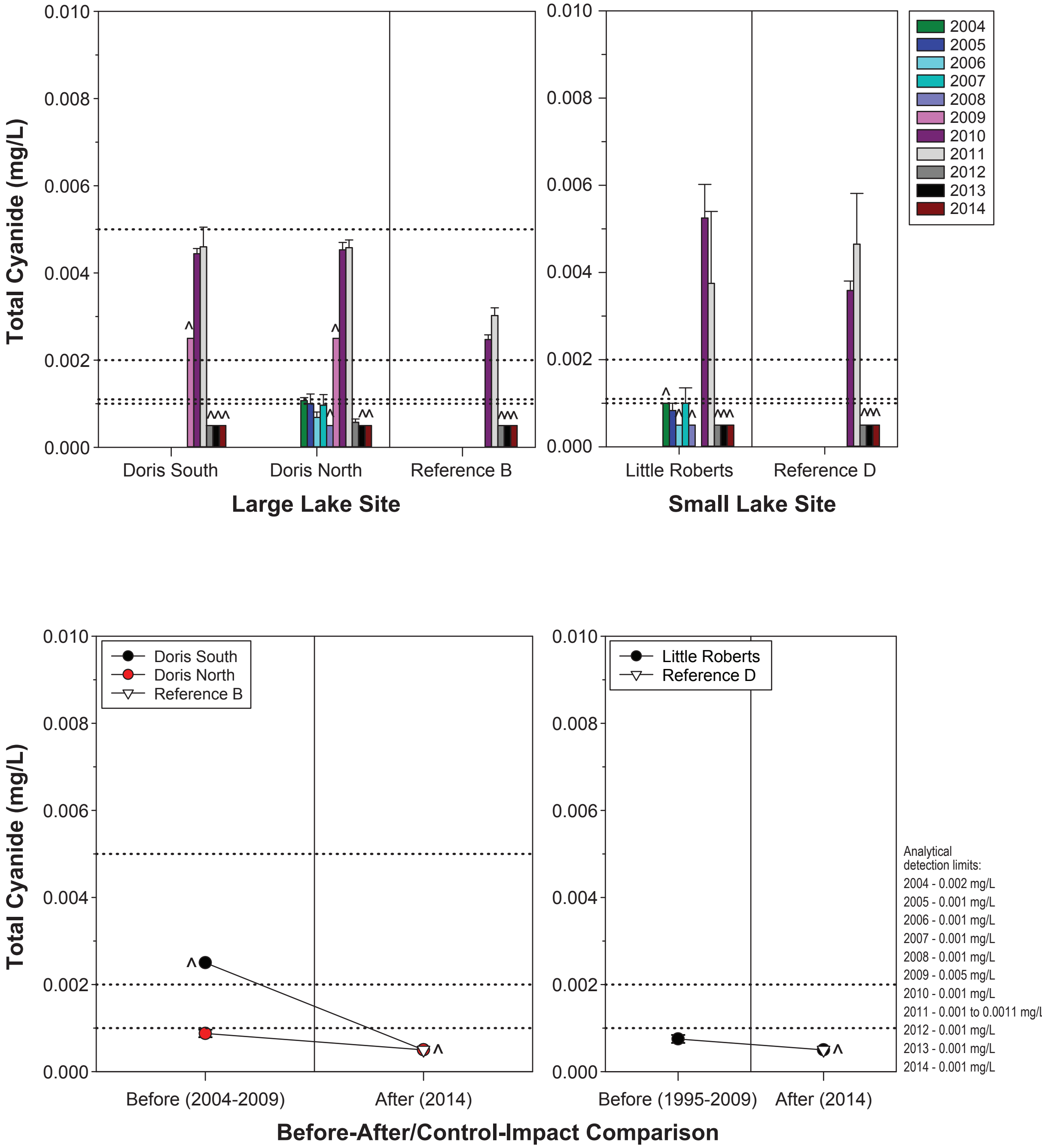
Total aluminum is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. In the exposure lake sites, mean 2014 total aluminum concentrations were within the range of baseline means, and below the pH-dependent CCME guideline of 0.1 mg/L (Figure 3.3-27). The before-after analysis confirmed that the mean 2014 total aluminum concentration was not distinguishable from the baseline mean for any exposure lake site ($p = 0.68$ for Doris Lake South, $p = 0.58$ for Doris Lake North, and $p = 0.48$ for Little Roberts Lake). Therefore, there was no apparent effect of 2014 Project activities on total aluminum concentrations in the exposure lakes.

3.3.2.10 Total Arsenic

Total arsenic is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. Mean 2014 total arsenic concentrations in exposure lakes were well below the CCME guideline of 0.005 mg/L, and were similar to or less than baseline means (Figure 3.3-28). Thus, 2014 activities did not appear to cause an increase in arsenic concentrations in lakes. The before-after comparison indicated that there was no difference between the 2014 mean arsenic concentration and the baseline mean at Doris Lake South ($p = 0.44$) and Little Roberts Lake ($p = 0.51$). The mean 2014 arsenic concentration at Doris Lake North was significantly lower than the baseline mean ($p = 0.001$); however, this was an artefact of the substitution of values that were below detection with half the analytical detection limit instead of the full detection limit, which would have resulted in the means being indistinguishable from each other ($p = 0.11$). Regardless, since the change was a decrease, there was no adverse effect of 2014 Project activities on arsenic concentrations in the exposure lakes.

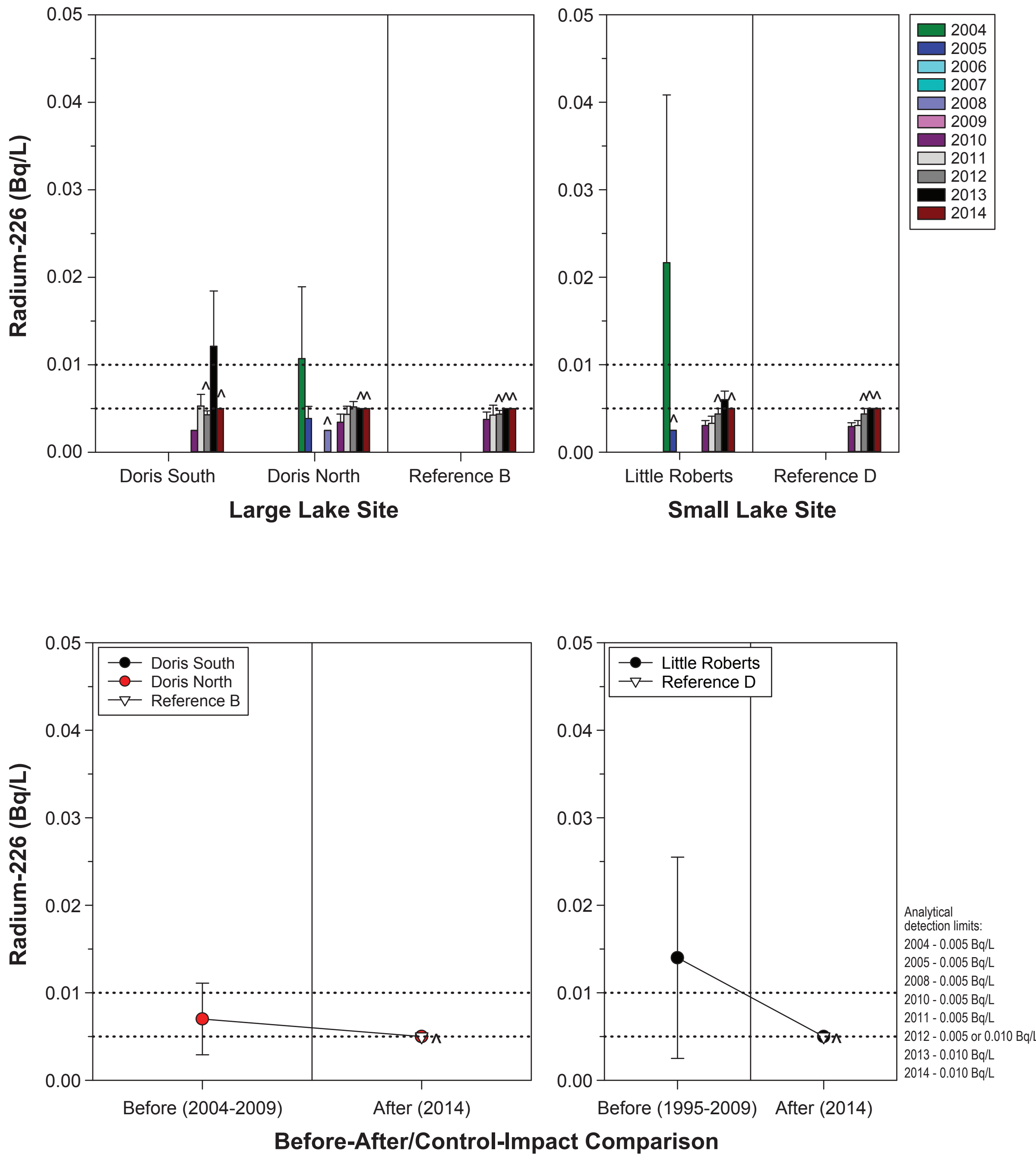
Figure 3.3-25

Total Cyanide Concentration, Lake Sites, Doris North Project, 2004 to 2014



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Total cyanide is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.

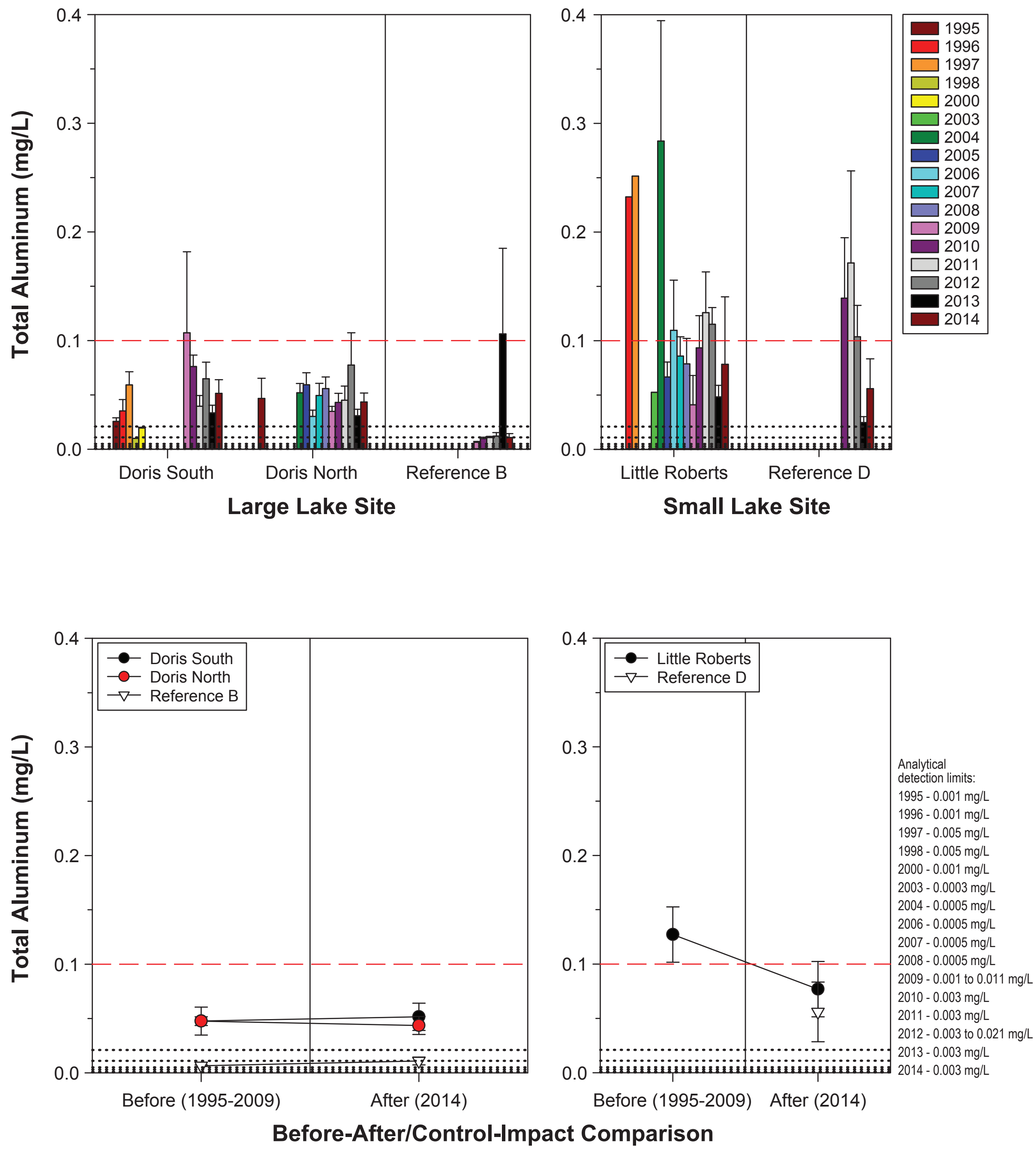
Figure 3.3-26
Radium-226 Concentration, Lake Sites, Doris North Project, 2004 to 2014



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Radium-226 is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.

Figure 3.3-27

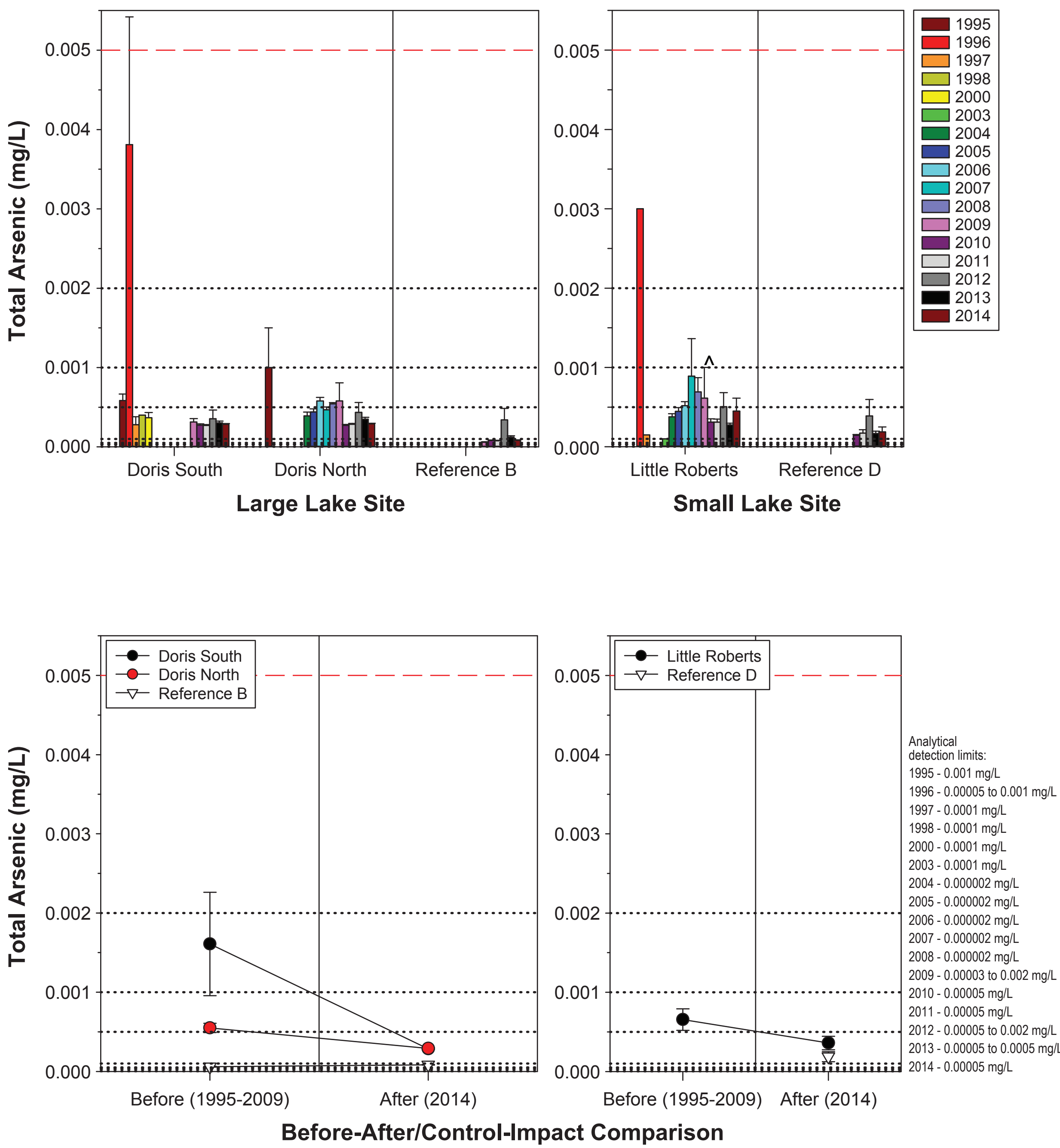
Total Aluminum Concentration, Lake Sites, Doris North Project, 1995 to 2014



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Red dashed lines represent the pH-dependent CCME freshwater guideline for aluminum (0.005 mg/L at pH < 6.5; 0.1 mg/L at pH ≥ 6.5).
Mean annual pH levels were greater than 6.5 in all exposure and reference lakes.
Total aluminum is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of the MMER.

Figure 3.3-28

Total Arsenic Concentration, Lake Sites, Doris North Project, 1995 to 2014



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed lines represent the CCME freshwater guideline for arsenic (0.005 mg/L).
Total arsenic is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.

3.3.2.11 *Total Cadmium*

Total cadmium is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. In 2014 the majority of exposure and reference lake total cadmium concentrations were below the analytical detection limit of 0.000005 mg/L, the exception was for some under-ice samples (Figure 3.3-29; Appendix A). Comparison to baseline data was problematic because of the high proportion of baseline and 2014 data that were below detection limits (96%, 72%, and 78% at Doris South, Doris North, and Little Roberts lakes, respectively), and the widely variable historical detection limits; therefore, the results of the before-after comparison were considered unreliable and not discussed. However, since the results for most samples were below the analytical detection limit in 2014 and some baseline and reference data were above the analytical detection limit, there was no apparent effect of Project activities on total cadmium at the exposure sites in 2014.

3.3.2.12 *Total Copper*

Total copper is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. In all three exposure lake sites, mean 2014 copper concentrations were within or below the range of baseline means (Figure 3.3-30). The mean 2014 total copper concentrations at all sites were below the minimum CCME guideline of 0.002 mg/L (Figure 3.3-30; Appendix A).

The before-after analysis found that 2014 mean copper concentrations were not distinguishable from baseline means at the exposure lake sites ($p = 0.14$ for Doris Lake South, $p = 0.16$ for Doris Lake North, and $p = 0.46$ for Little Roberts Lake). Therefore, there was no apparent effect of 2014 Project activities on total copper concentrations in any exposure lake.

3.3.2.13 *Total Iron*

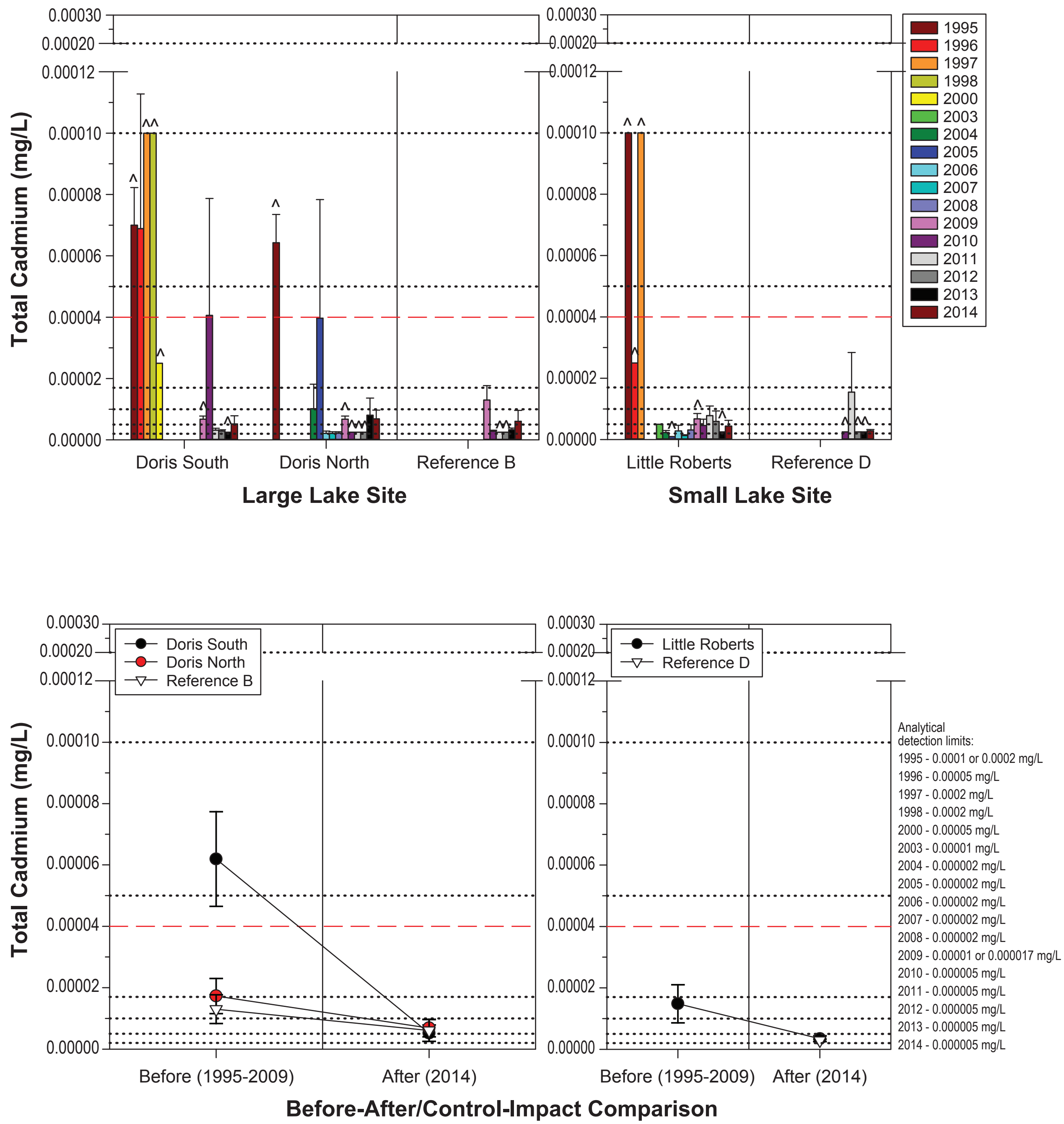
Total iron is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. Mean total iron concentrations measured at the exposure lake sites in 2014 were within the range of mean baseline concentrations except at Little Roberts Lake (Figure 3.3-31). At the exposure lake sites, except for Little Roberts Lake, mean total iron concentrations measured in 2014 were below the CCME guideline of 0.3 mg/L. At Little Roberts Lake, the observed under-ice total iron concentration was elevated above the CCME guideline, most likely due to sample contamination (Appendix A). For all exposure sites, the before-after analysis showed that mean 2014 total iron concentrations were not distinguishable from mean baseline concentrations ($p = 0.69$ for Doris Lake South, $p = 0.97$ for Doris Lake North, and $p = 0.61$ for Little Roberts Lake), suggesting that 2014 Project activities did not have an effect on total iron concentrations in exposure lakes (Figure 3.3-31).

3.3.2.14 *Total Lead*

Total lead is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. Total lead concentrations measured in exposure lakes in 2014 tended to be near or below the detection limit of 0.00005 mg/L and were always below the hardness-dependent CCME guideline (Appendix A). Mean 2014 total lead concentrations for all the exposure lakes were within the range of baseline means (Figure 3.3-32), suggesting that there was no adverse effect of Project activities on total lead concentrations in lakes. The before-after analysis confirmed that there was no significant difference between 2014 and baseline mean concentrations for any exposure lake ($p = 0.31$ for Doris Lake South, $p = 0.30$ for Doris Lake North, and $p = 0.51$ for Little Roberts Lake).

Figure 3.3-29

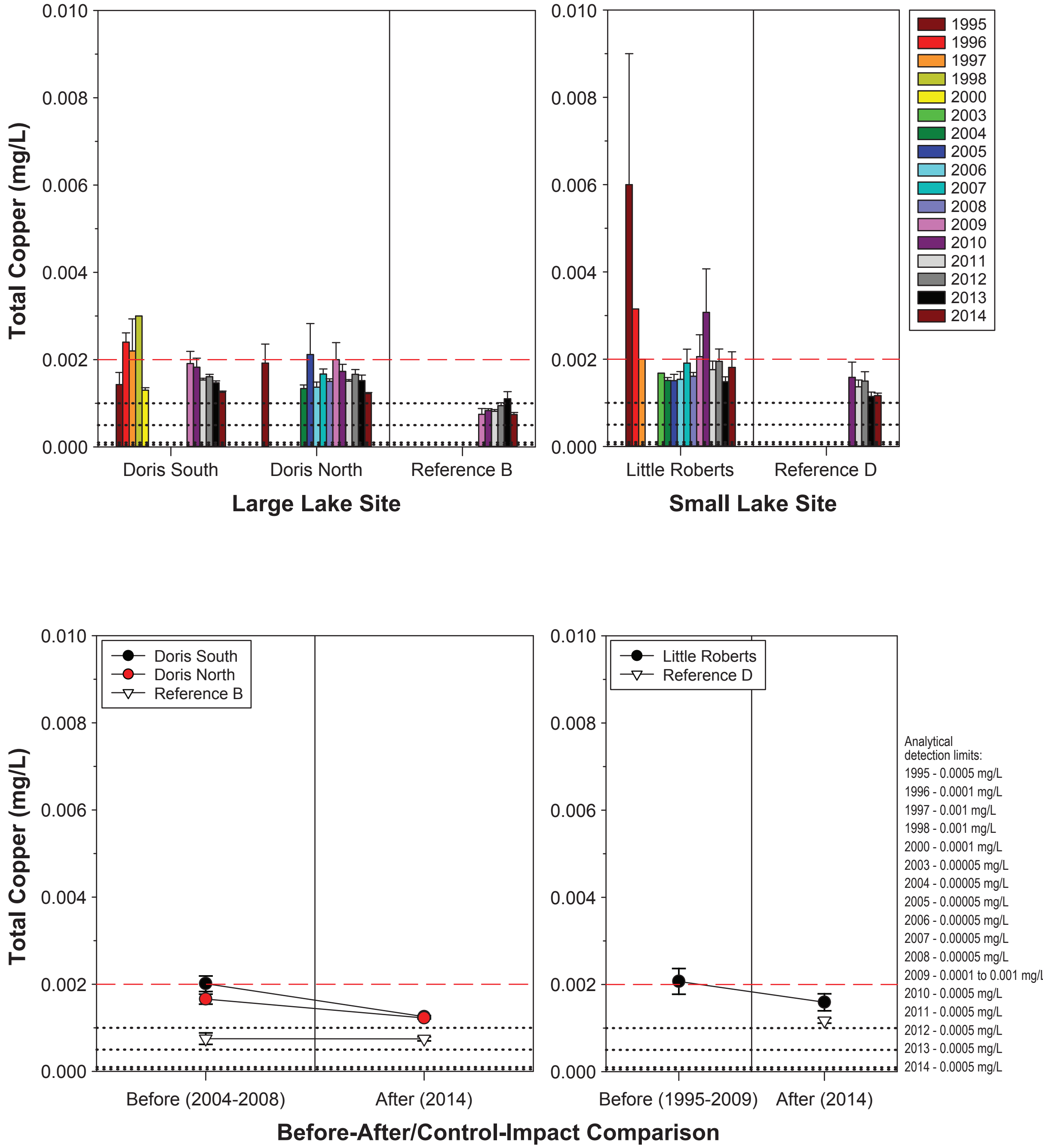
Total Cadmium Concentration, Lake Sites, Doris North Project, 1995 to 2014



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
The CCME freshwater guideline for cadmium is hardness dependent.
Red dashed lines represent the minimum CCME freshwater guideline for cadmium based on the minimum hardness measured in exposure lakes between 1996 and 2014 (hardness: 14.3 mg/L; CCME guideline: 0.00004 mg/L).
Total cadmium is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of the MMER.

Figure 3.3-30

Total Copper Concentration, Lake Sites, Doris North Project, 1995 to 2014

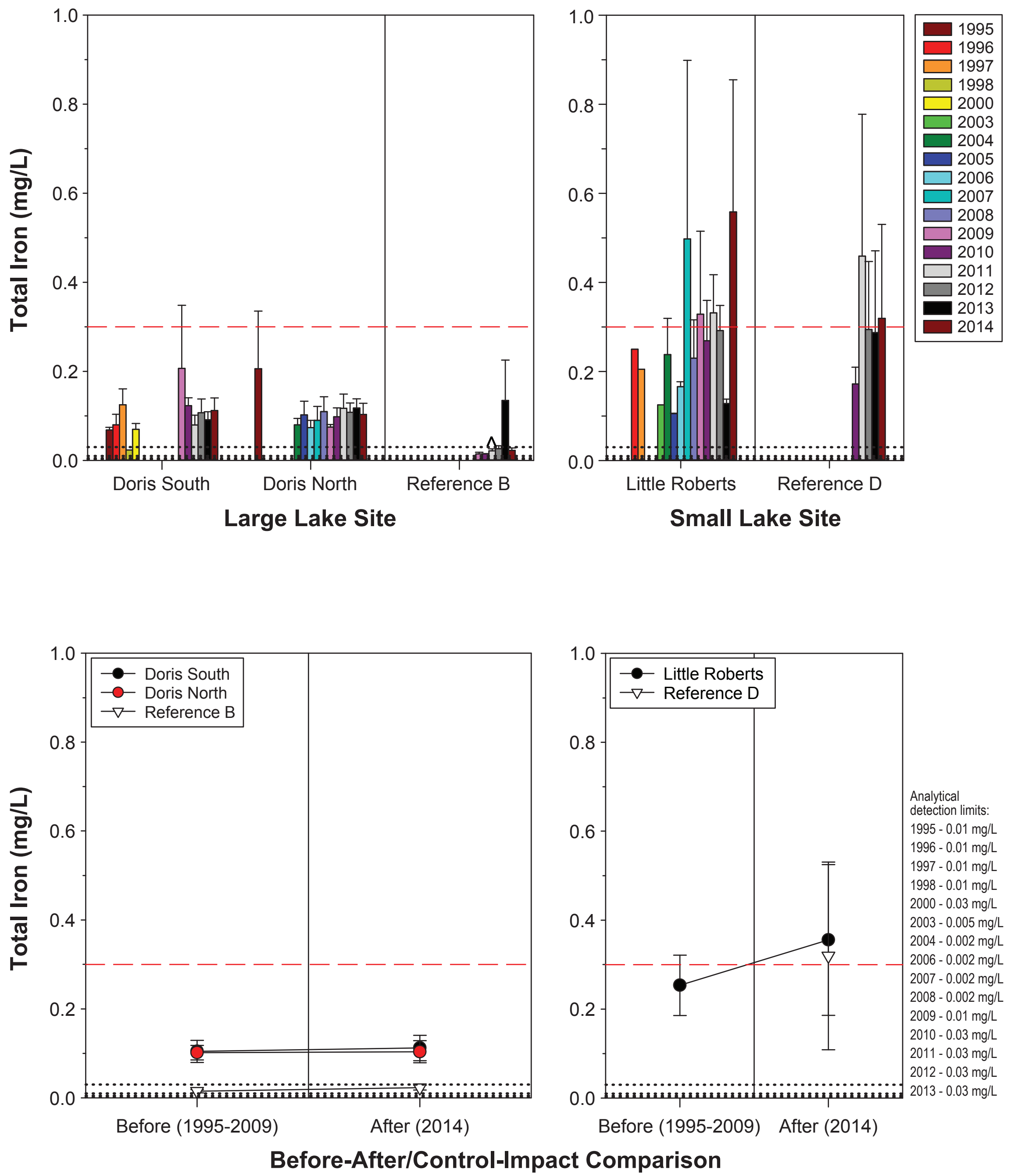


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
The CCME freshwater guideline for copper is hardness dependent.
Red dashed lines represent the minimum CCME freshwater guideline for copper regardless of water hardness (0.002 mg/L).
Total copper is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.

Figure 3.3-31

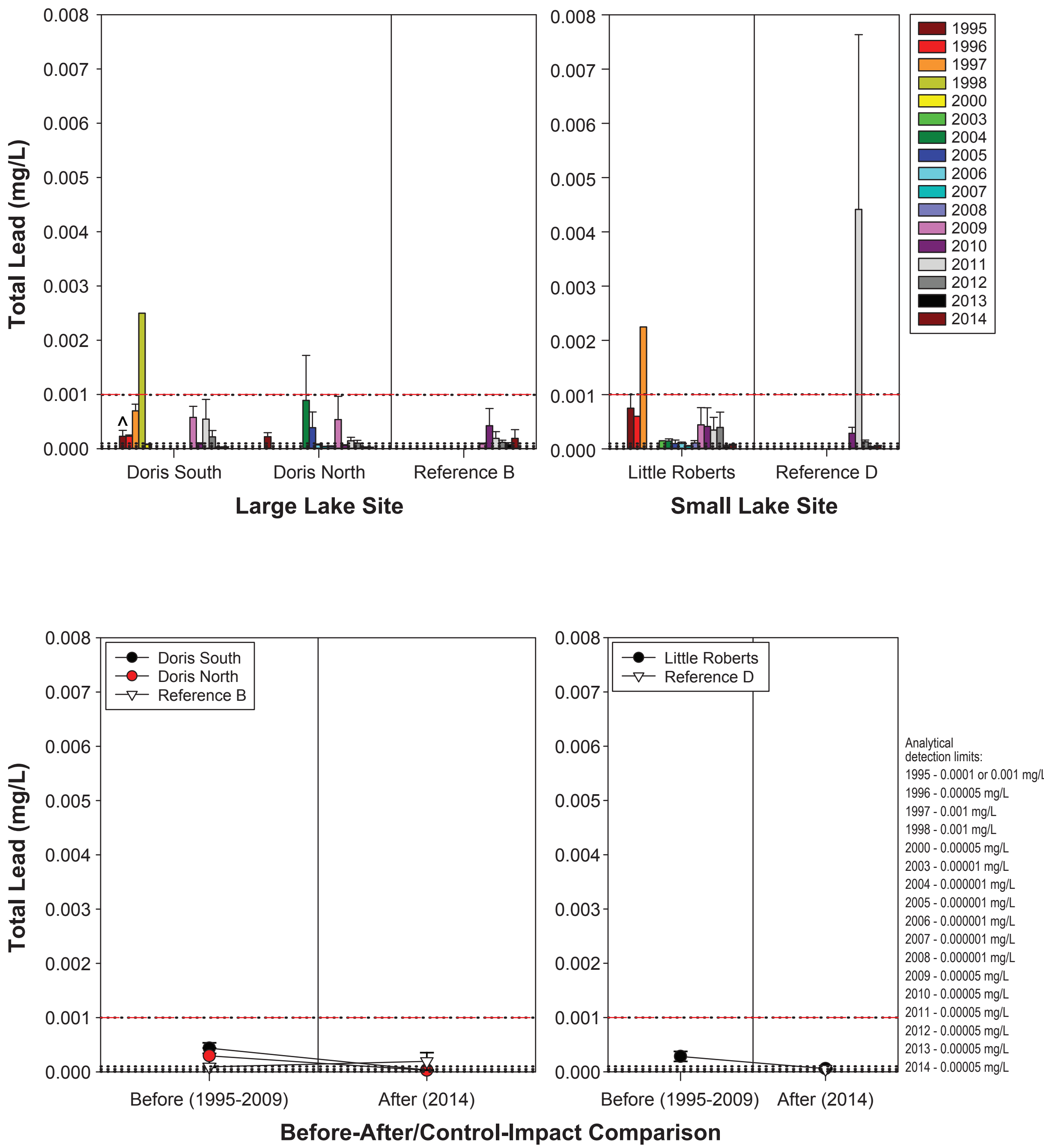
Total Iron Concentration, Lake Sites, Doris North Project, 1995 to 2014

ERM



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed lines represent the CCME freshwater guideline for iron (0.3 mg/L).
Total iron is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of the MMER.

Total Lead Concentration, Lake Sites, Doris North Project, 1995 to 2014



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
The CCME freshwater guideline for lead is hardness dependent.
Red dashed lines represent the minimum CCME freshwater guideline for lead regardless of water hardness (0.001 mg/L).
Total lead is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.

3.3.2.15 Total Mercury

Total mercury is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. All 2014 total mercury concentrations in exposure lakes were similar to concentrations in reference lakes and well below the CCME guideline for inorganic mercury of 0.000026 mg/L (Figure 3.3-33; Appendix A). Mean total mercury concentrations measured in exposure lakes in 2014 were within or lower than the range of baseline concentration. The before-after analysis indicated that there was no difference in means between baseline years and 2014 for Doris Lake North ($p = 0.29$) or Little Roberts Lake ($p = 0.76$). At Doris Lake South, all baseline data were below widely variable detection limits, making comparison to these data difficult. 77% of baseline and 2014 data for Doris Lake South were below analytical detection. The before-after results for Doris Lake South were thus considered unreliable and are not discussed. However, total mercury concentrations in Doris Lake South in 2014 were low and similar to concentrations observed in Reference Lake B. Thus, there was no evidence of Project-related effects for total mercury at Doris Lake South or other exposure lake sites in 2014.

3.3.2.16 Total Molybdenum

Total molybdenum is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. Mean 2014 total molybdenum concentrations were similar among exposure lakes and well below the interim CCME guideline of 0.073 mg/L (Figure 3.3-34). In Doris Lake South and Little Roberts Lake, mean 2014 molybdenum concentrations were within the range of baseline means (Figure 3.3-34). The before-after analysis confirmed that mean 2014 total molybdenum concentrations at these sites were not distinguishable from baseline means ($p = 0.90$ for Doris Lake South and $p = 0.76$ for Little Roberts Lake), suggesting that there was no effect of 2014 Project activities on total molybdenum levels in these exposure sites.

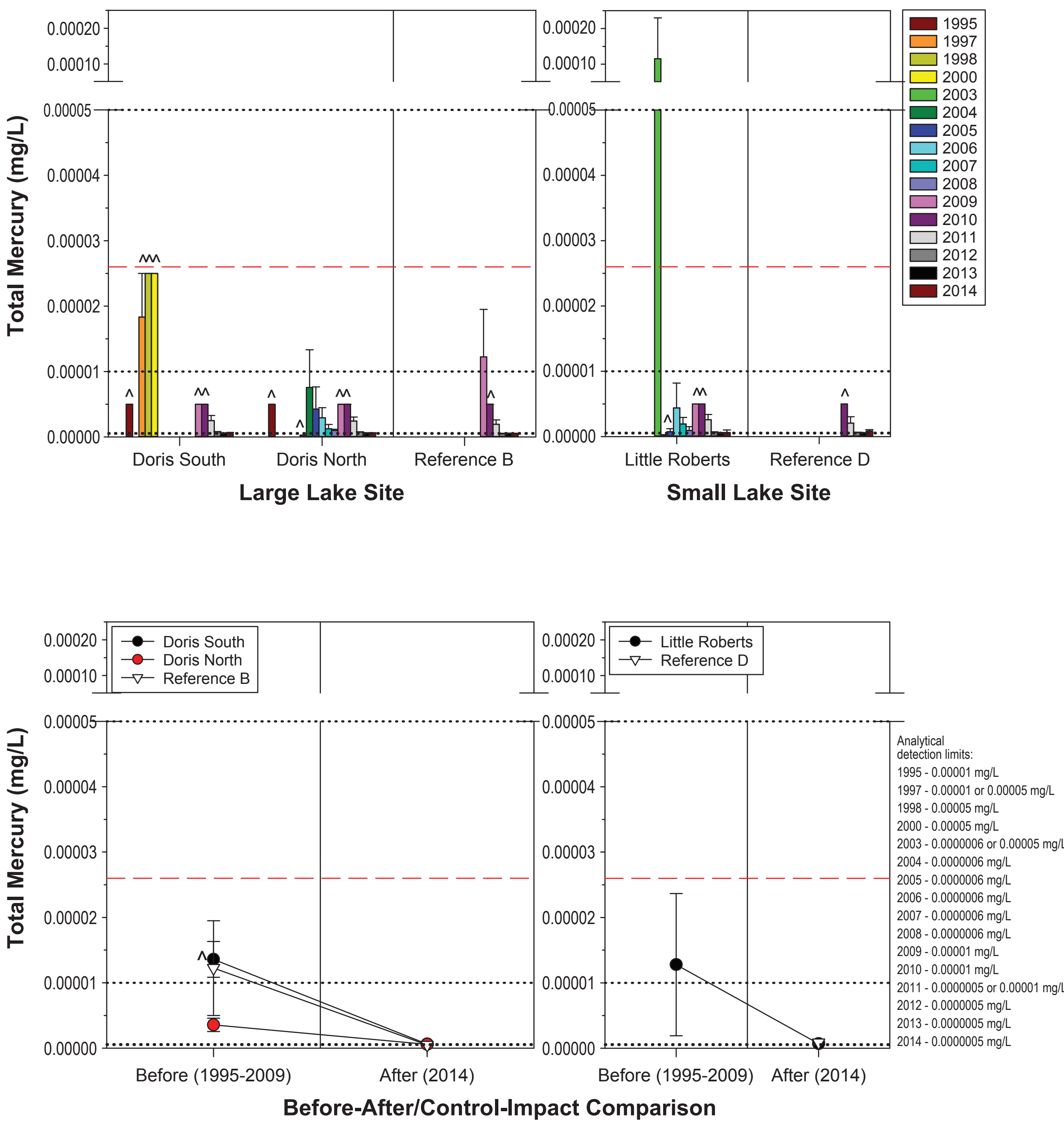
At Doris Lake North, total molybdenum concentrations appeared to have increased slightly over time from 2005 to 2014, though 2014 molybdenum concentrations were the lowest observed since 2010 (Figure 3.3-34). The before-after analysis indicated that there was a significant difference between baseline and 2014 mean concentrations ($p = 0.003$). However, the BACI analysis showed that a parallel change occurred at Reference Lake B ($p = 0.88$), so the increase in total molybdenum concentrations at Doris Lake North was likely unrelated to Project activities.

3.3.2.17 Total Nickel

Total nickel is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. Total nickel concentrations measured in exposure lakes in 2014 were well below the hardness-dependent CCME guideline for nickel and within the range of baseline concentrations (Figure 3.3-35). This suggests that 2014 Project activities did not cause an increase in total nickel concentrations in exposure lakes. The before-after comparison confirmed that mean nickel concentrations did not change significantly in any exposure lake in 2014 compared to baseline years ($p = 0.42$ for Doris Lake South, $p = 0.70$ for Doris Lake North, and $p = 0.89$ for Little Roberts Lake).

Figure 3.3-33

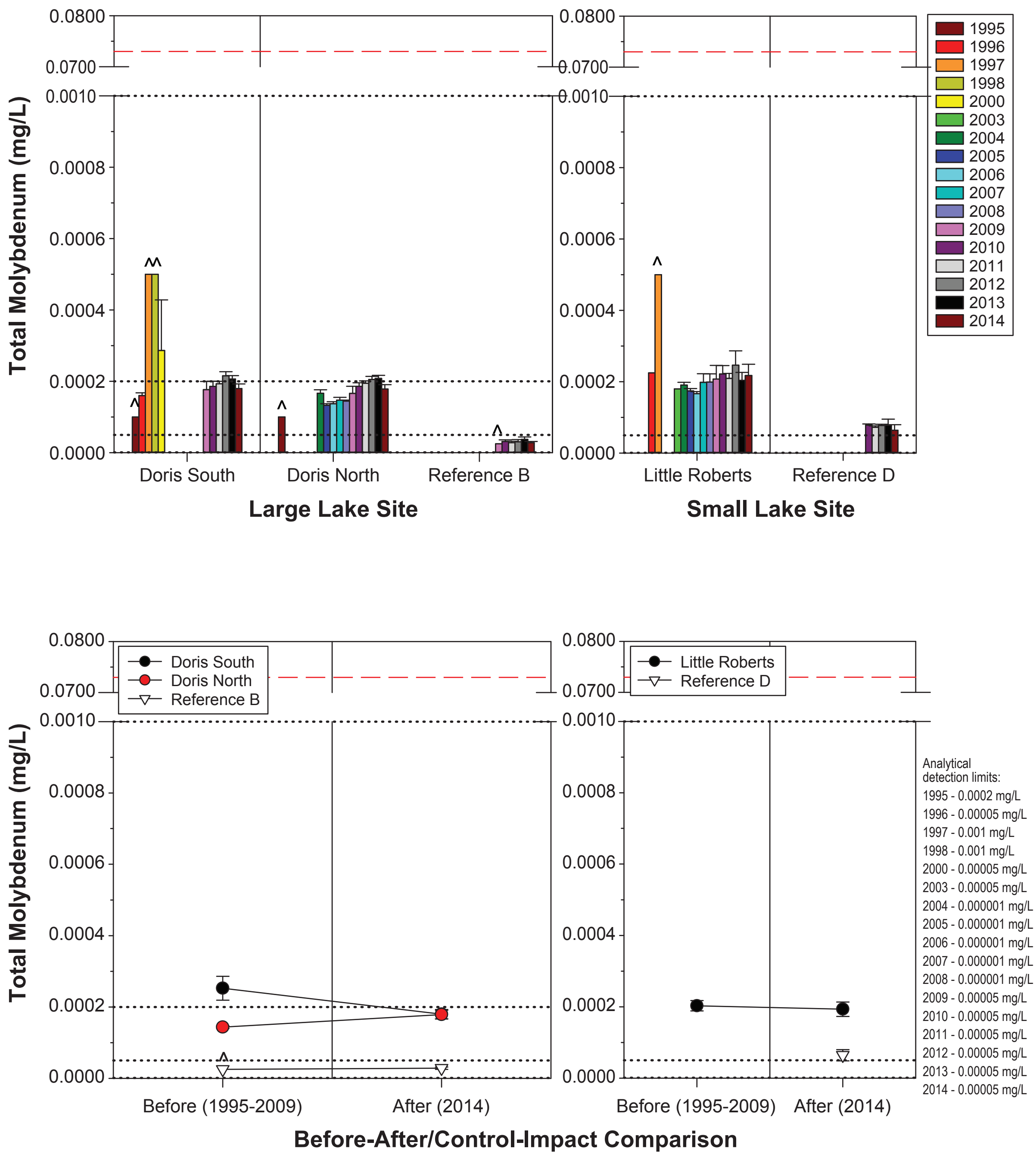
Total Mercury Concentration, Lake Sites, Doris North Project, 1995 to 2014



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed lines represent the CCME freshwater guideline for inorganic mercury (0.000026 mg/L).
Total mercury is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of the MMER.

Figure 3.3-34

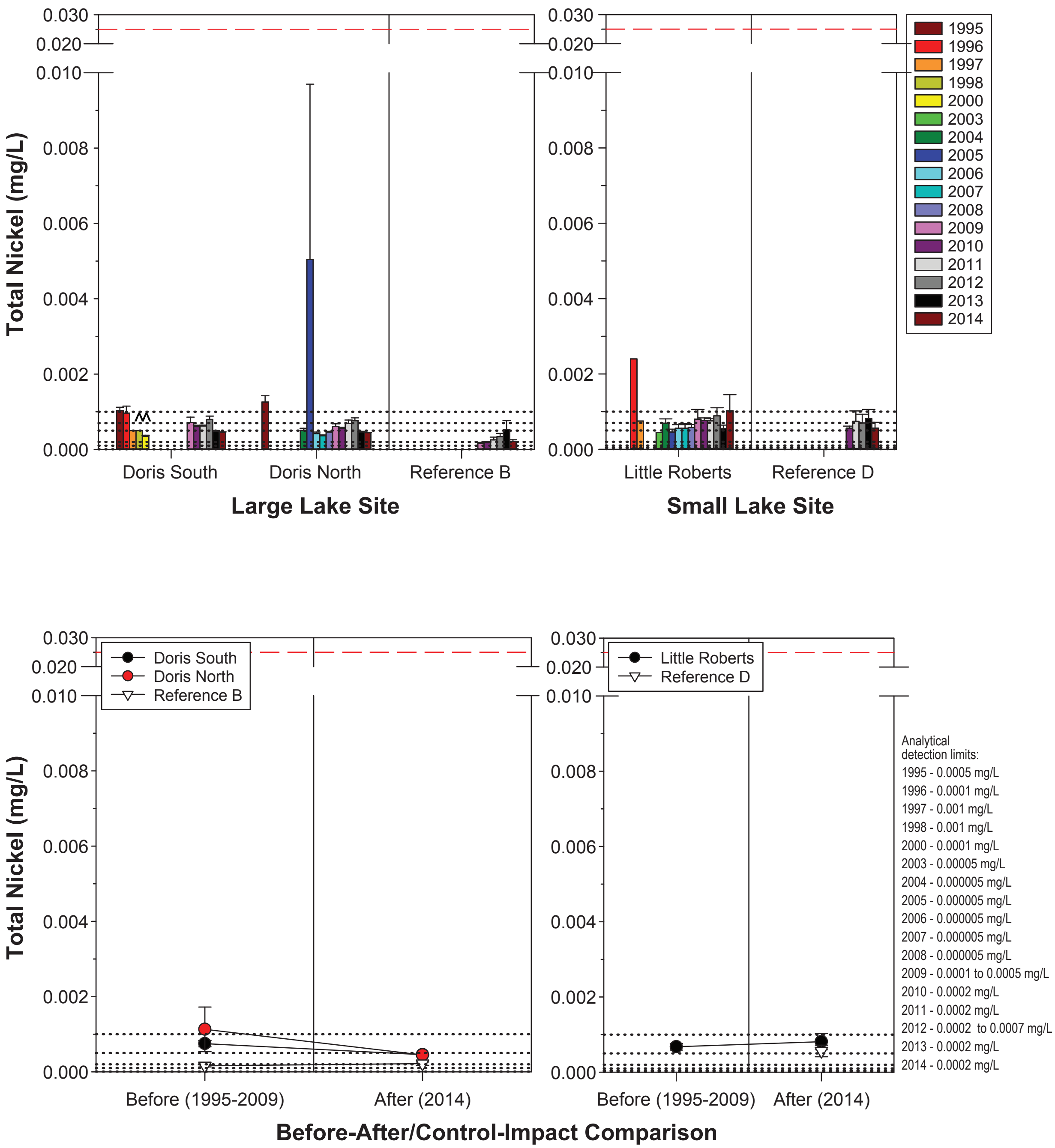
Total Molybdenum Concentration, Lake Sites, Doris North Project, 1995 to 2014



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed lines represent the interim CCME freshwater guideline for molybdenum (0.073 mg/L).
Total molybdenum is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of the MMER.

Figure 3.3-35

Total Nickel Concentration, Lake Sites, Doris North Project, 1995 to 2014



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
The CCME freshwater guideline for nickel is hardness dependent.
Red dashed lines represent the minimum CCME freshwater guideline for nickel regardless of water hardness (0.025 mg/L).
Total nickel is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.

3.3.2.18 Total Zinc

Total zinc is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. In 2014, all total zinc concentrations measured in exposure lakes were below the analytical detection limit of 0.003 mg/L and well below the CCME guideline of 0.03 mg/L (Appendix A; Figure 3.3-36). Therefore, there was no evidence of an increase in zinc in exposure lakes as a result of 2014 Project activities.

3.3.3 Marine

Water quality samples from marine areas were collected from two exposure sites in Roberts Bay (RBW and RBE) and one reference site in Ida Bay (REF-Marine 1) in 2014. Baseline data from 2009 were available for all sites, and additional baseline data from 1996 and 2004 to 2008 were available for site RBE. All 2014 samples were collected at the surface (0 to 1 m depth), so any baseline data collected from near the water-sediment interface were excluded from the baseline dataset used for the effects analyses. Graphs showing water quality trends in marine sites over time are shown in Figures 3.3-37 to 3.3-54; statistical results are presented in Appendix B.

3.3.3.1 pH

pH is a required variable for water quality monitoring as per Schedule 5, s. 7(1)(c) of the MMER. Mean 2014 pH levels in marine exposure and reference sites were always within the recommended marine CCME guideline range of 7.0 to 8.7 (Figure 3.3-37). pH levels measured at RBW and RBE in 2014 were similar to levels measured at REF-Marine 1 and to baseline pH levels (Figure 3.3-37). Marine environments have a high buffering capacity compared to freshwater systems, so pH is relatively insensitive to change. The before-after comparison confirmed that there was no change in marine pH at the exposure sites in 2014 compared to baseline years ($p = 0.44$ for RBW and $p = 0.93$ for RBE). Therefore, there was no apparent effect of 2014 Project activities on marine pH.

3.3.3.2 Total Alkalinity

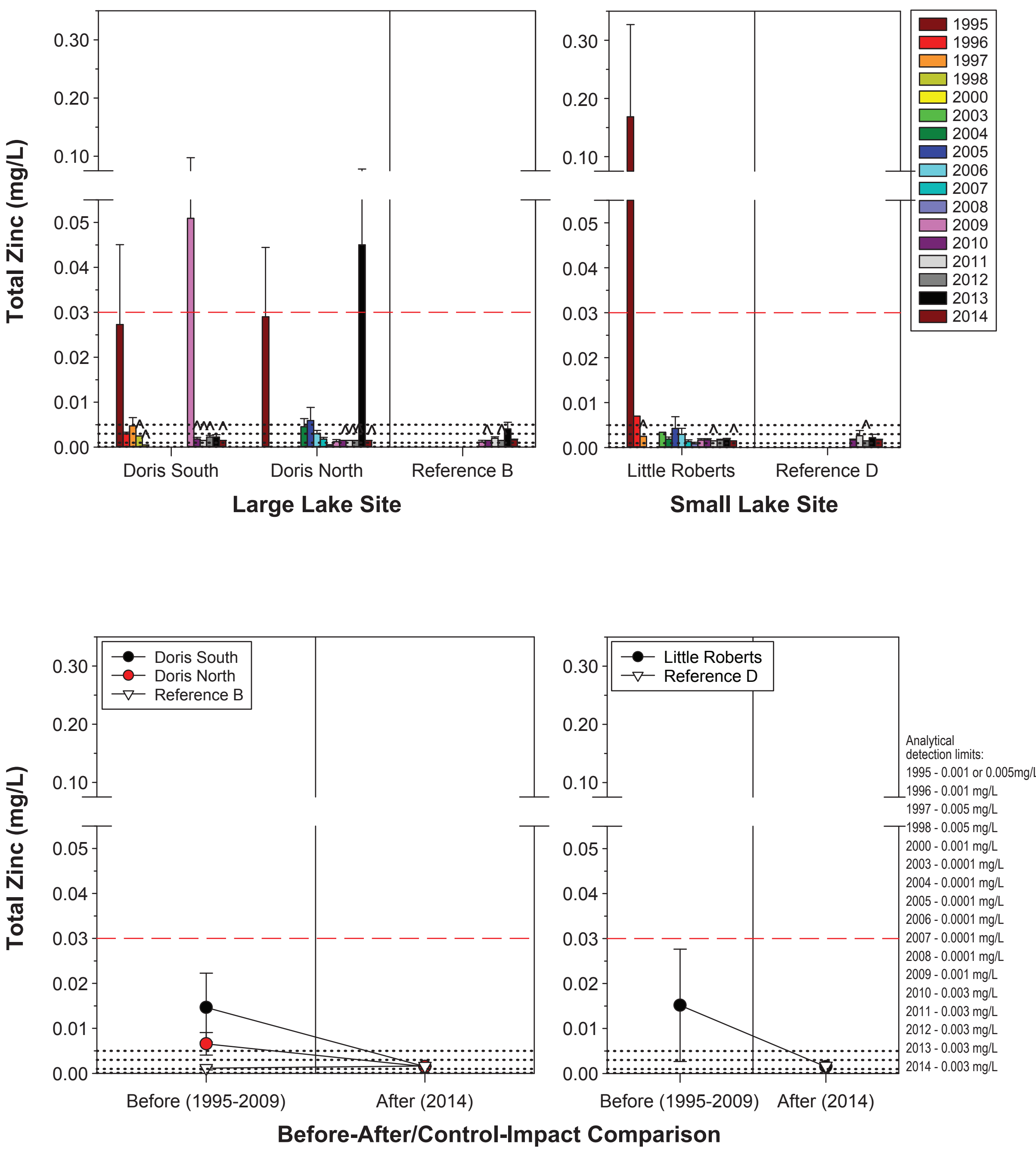
Total alkalinity is a required variable for effluent characterization and water quality monitoring as per Schedule 5, s. 4(1) and s. 7(1)(c) of the MMER. RBE is the only site for which baseline total alkalinity data were available. At this site, the mean 2014 alkalinity was within the range of baseline means (Figure 3.3-38). The before-after comparison indicated that there was no statistically significant change in alkalinity in 2014 at RBE compared to baseline levels ($p = 0.42$). Although no statistical analysis was possible for site RBW, mean 2014 alkalinity was the lowest observed since monitoring began and similar to concentrations observed at the reference site (REF-Marine-1; Figure 3.3-38). Thus, there was no evidence of 2014 Project activities on total alkalinity of the exposure sites.

3.3.3.3 Hardness

Hardness is a required variable for effluent characterization and water quality monitoring as per Schedule 5, s. 4(1) and s. 7(1)(c) of the MMER. Mean hardness (as $CaCO_3$) levels measured in 2014 in Roberts Bay sites were within or lower than the range of baseline hardness levels, and were also similar to the hardness levels measured in Ida Bay (REF-Marine-1; Figure 3.3-39). The before-after comparison confirmed that 2014 hardness levels at RBW and RBE were not distinguishable from baseline levels ($p = 0.90$ for RBW and $p = 0.28$ for RBE), suggesting that there was no effect of 2014 Project activities on the hardness of marine waters at exposure sites.

Figure 3.3-36

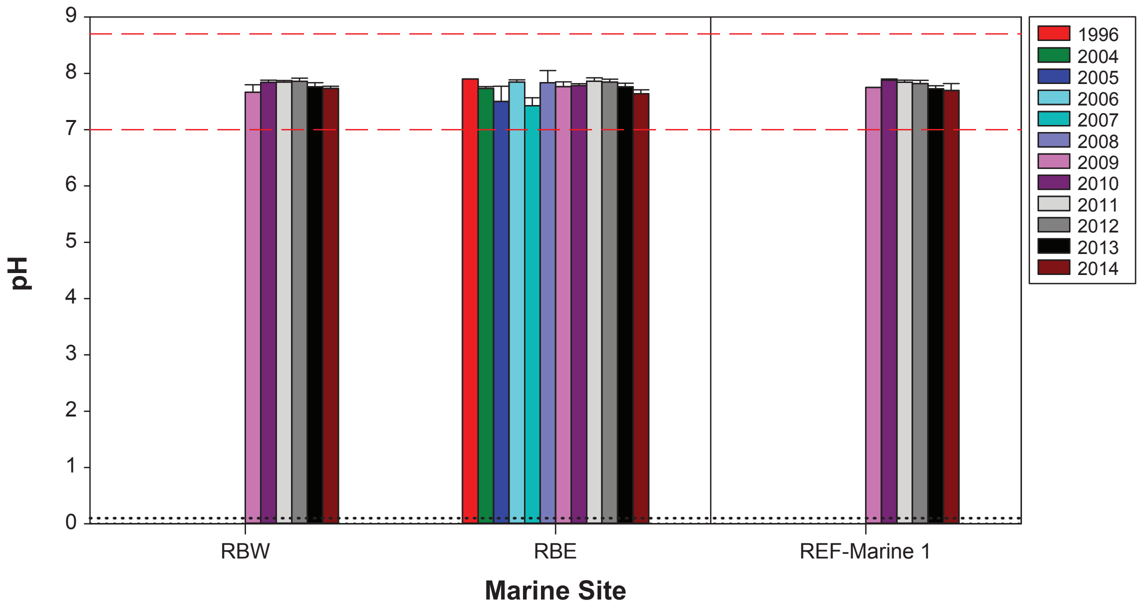
Total Zinc Concentration, Lake Sites, Doris North Project, 1995 to 2014

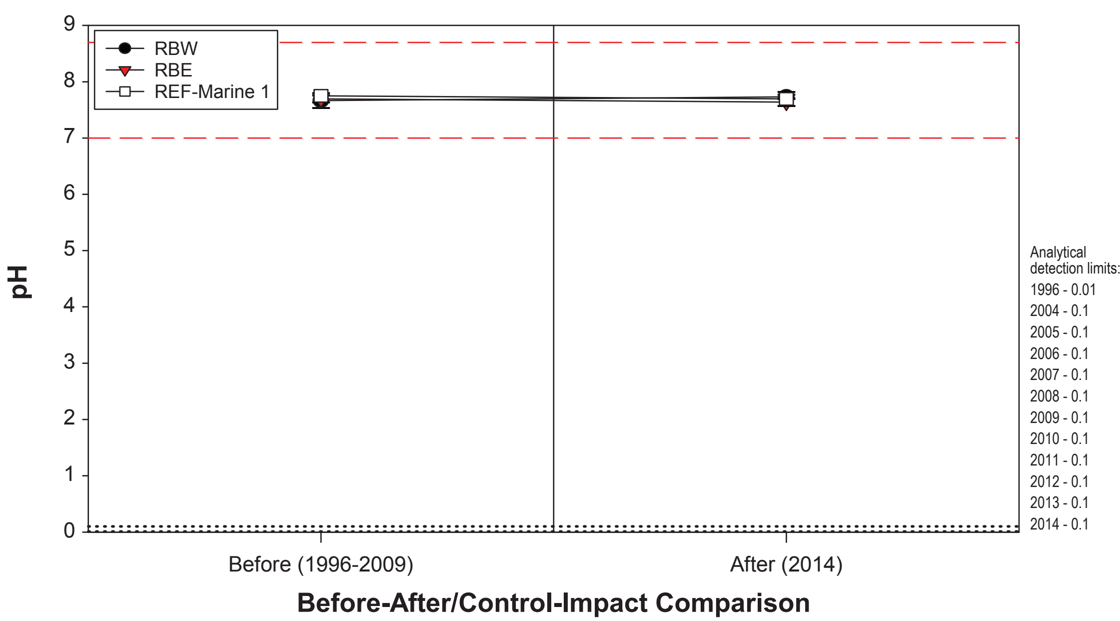


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed lines represent the CCME freshwater guideline for zinc (0.03 mg/L).
Total zinc is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.

Figure 3.3-37

pH, Marine Sites,
Doris North Project, 1996 to 2014

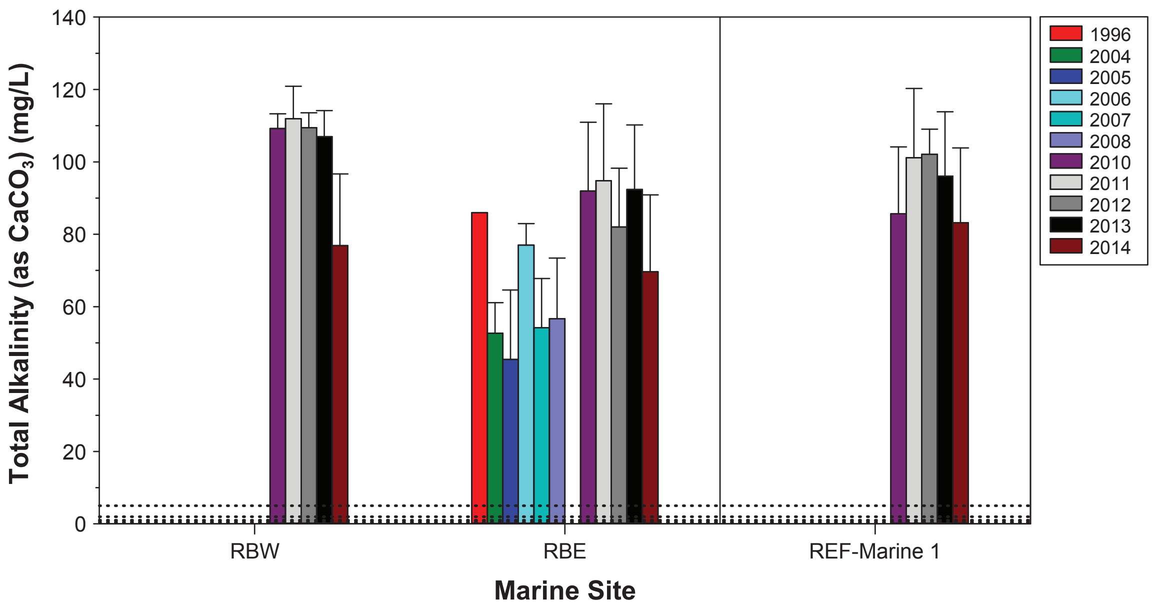


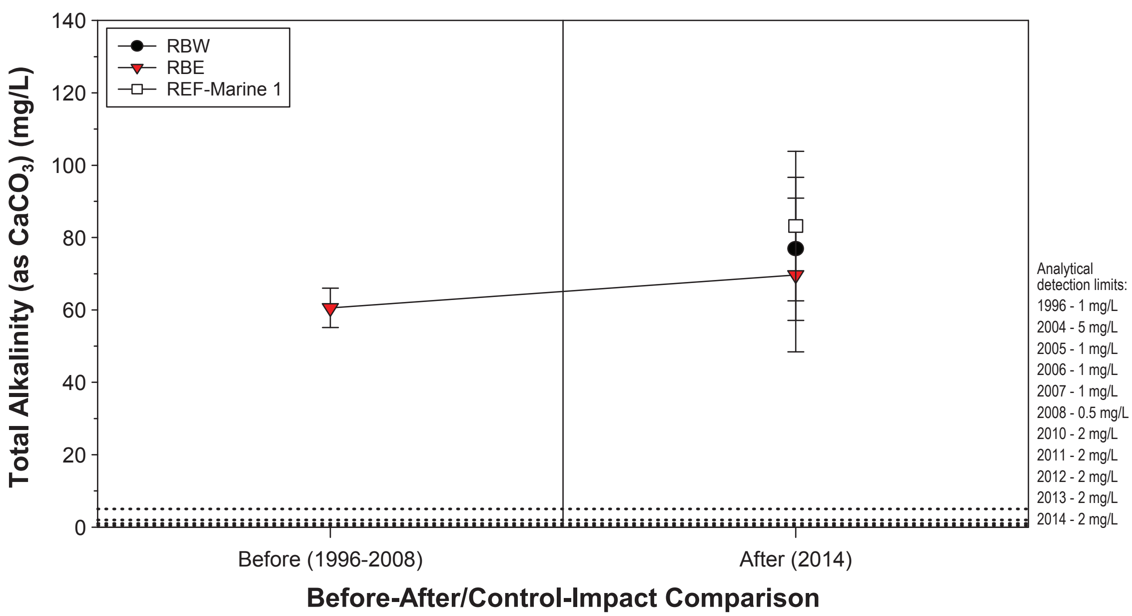


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits.
Red dashed lines represent the CCME marine and estuarine guideline pH range (7.0–8.7).
pH is a required parameter for water quality monitoring as per Schedule 5, s. 7(1)(c) of the MMER.

Total Alkalinity, Marine Sites, Doris North Project, 1996 to 2014

ERM

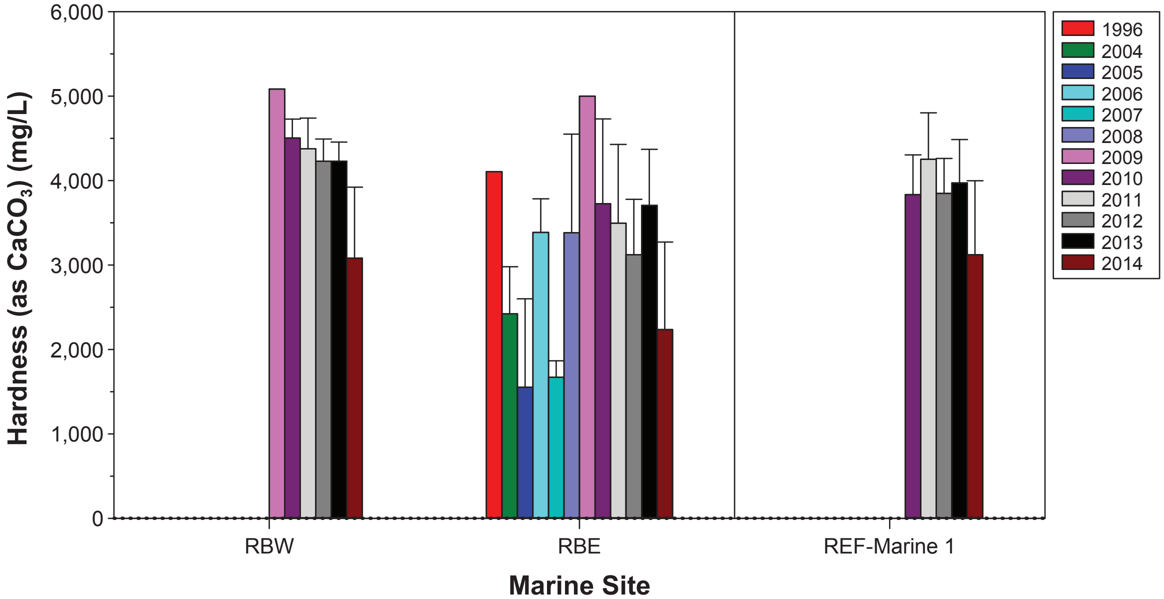


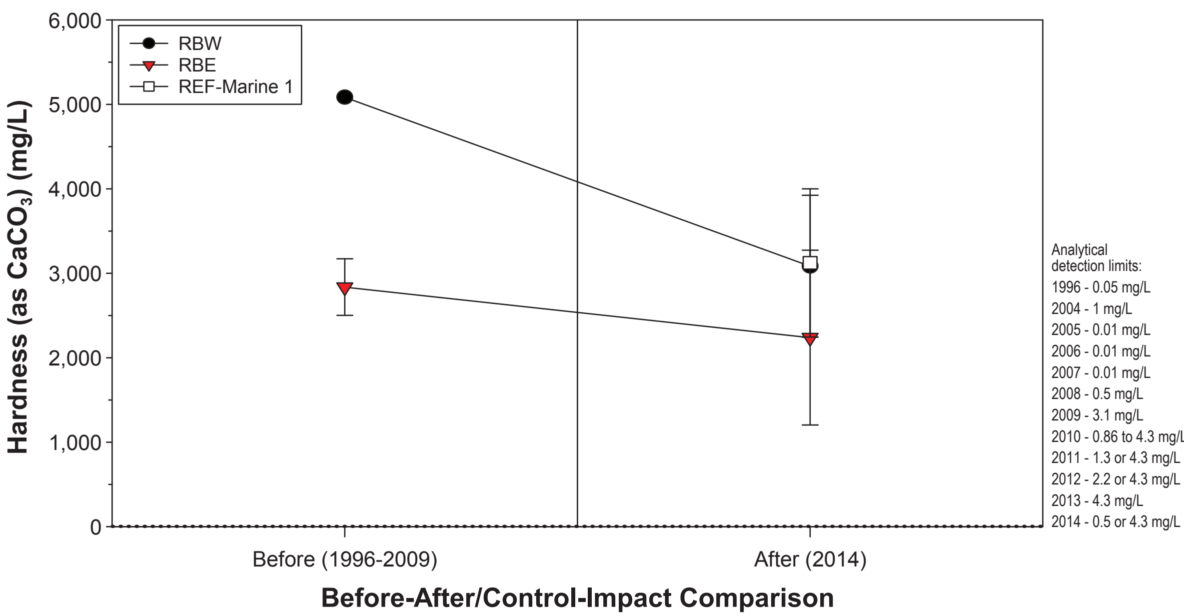


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Total alkalinity is a required parameter for effluent characterization and water quality monitoring as per Schedule 5, s. 4(1) and s. 7(1)(c) of the MMER.

Figure 3.3-39

Hardness, Marine Sites,
Doris North Project, 1996 to 2014





Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits.
Hardness is a required parameter for effluent characterization and water quality monitoring as per Schedule 5, s. 4(1) and s. 7(1)(c) of the MMER.

3.3.3.4 *Total Suspended Solids*

TSS are regulated as deleterious substances in effluents as per Schedule 4 of the MMER. TSS concentrations in the marine environment were highly variable seasonally and inter-annually (Figure 3.3-40 and Appendix A). Mean 2014 TSS concentrations at RBW and RBE were within or lower than the range of baseline means (Figure 3.3-40). The before-after comparison confirmed that the 2014 means were not statistically distinguishable from the baseline means ($p = 0.12$ at RBW and $p = 0.28$ at RBE). Therefore, there was no apparent adverse effect of 2014 Project activities on marine TSS concentrations at exposure sites.

The marine CCME guideline for TSS is dependent upon background levels (for clear-flow waters with background TSS levels below 25 mg/L, a maximum increase of 25 mg/L is allowable for any short-term exposure or 5 mg/L for longer term exposure; CCME 2014a). Because there was no increase in TSS concentrations from background levels at either RBW or RBE, 2014 TSS concentrations in marine exposure sites continued to remain below the CCME guideline.

3.3.3.5 *Total Ammonia*

Total ammonia is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. Total ammonia concentrations in all 2014 Roberts Bay samples were below the analytical detection limit of 0.005 mg ammonia-N/L, except for a single sample collected from RBE that had a total concentration of 0.0051 mg ammonia-N/L (slightly over the detection limit; Figure 3.3-41), suggesting a lack of Project-related effects for total ammonia in 2014. At site RBE, baseline ammonia concentrations were widely variable and were most often higher than 2014 concentrations (Figure 3.3-41). The before-after comparison confirmed that the 2014 mean total ammonia concentration at RBE was not significantly different from the baseline mean ($p = 0.26$). There was no evidence of an effect of 2014 Project activities on total ammonia concentrations at the marine exposure sites.

3.3.3.6 *Nitrate*

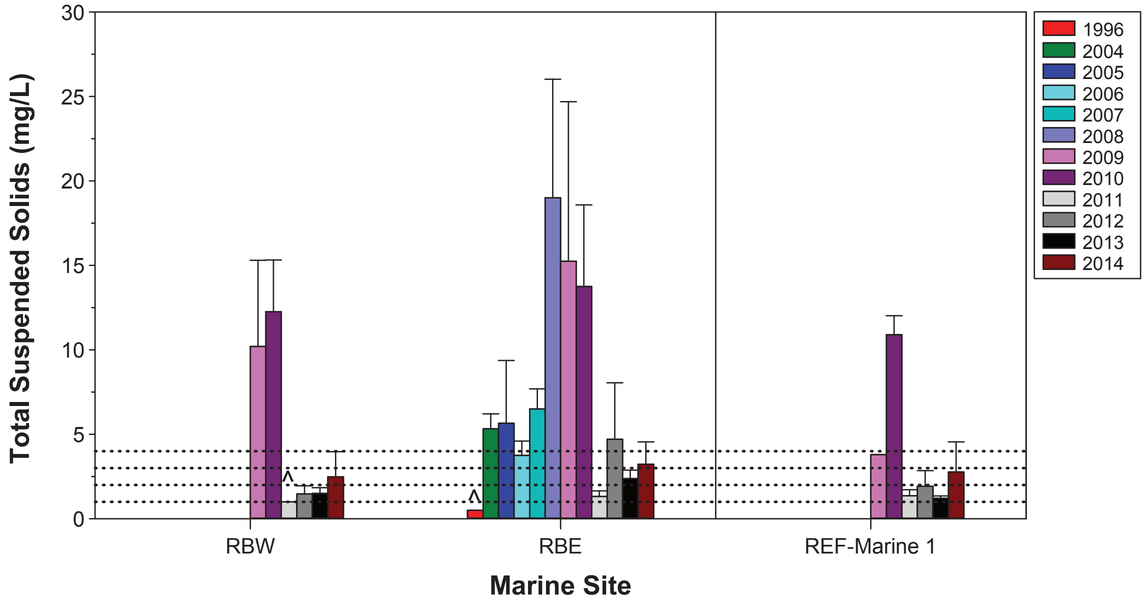
Nitrate is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. All 2014 and baseline nitrate concentrations measured in marine reference and exposure sites were well below the marine CCME guideline of 45 mg nitrate-N/L (Figure 3.3-42). Mean 2014 nitrate concentrations at RBE were within the range of baseline means (Figure 3.3-42). At RBW, the mean 2014 nitrate concentration was above the baseline mean; however, the mean nitrate concentration was similar to that observed at the reference site (REF-Marine-1). For site RBE, 75% of nitrate concentrations in the combined baseline and 2014 dataset were below analytical detection limits, thus the statistical results were considered unreliable and are not discussed. For site RBW, the before-after analysis confirmed that the 2014 and baseline means were not significantly different ($p = 0.56$). Thus, there was no apparent effect of 2014 Project activities on nitrate concentrations in the marine exposure sites.

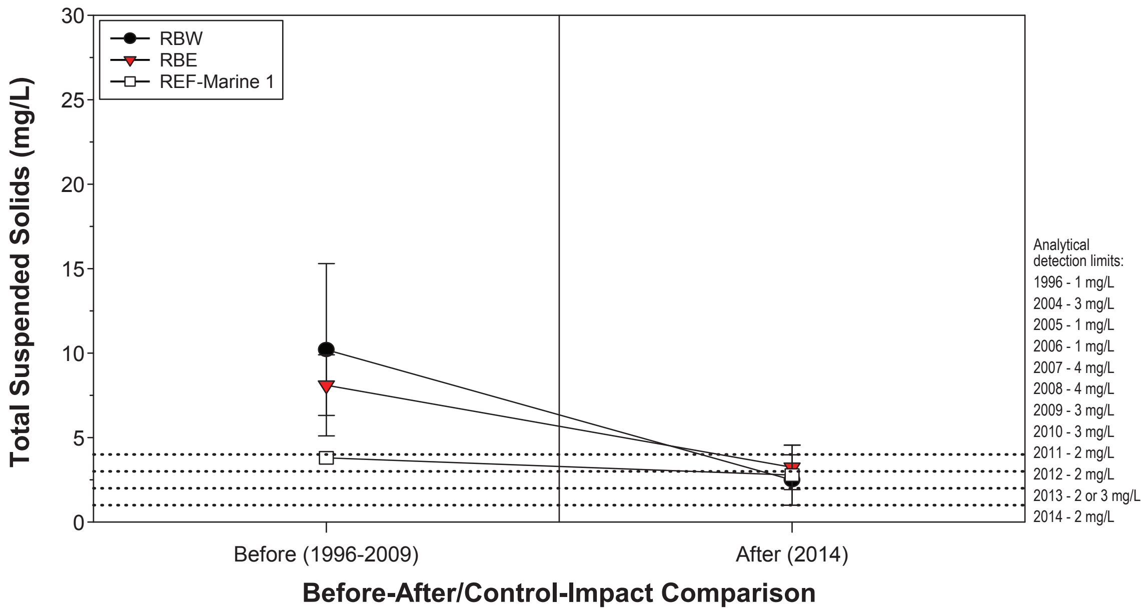
3.3.3.7 *Total Cyanide*

Total cyanide is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. 2014 total cyanide concentrations were all below the detection limit of 0.001 mg/L at all exposure and reference sites (Figure 3.3-43). Therefore, there was no evidence that 2014 Project activities caused an increase in total cyanide concentrations at marine exposure sites.

Figure 3.3-40

Total Suspended Solids Concentration, Marine Sites, Doris North Project, 1996 to 2014

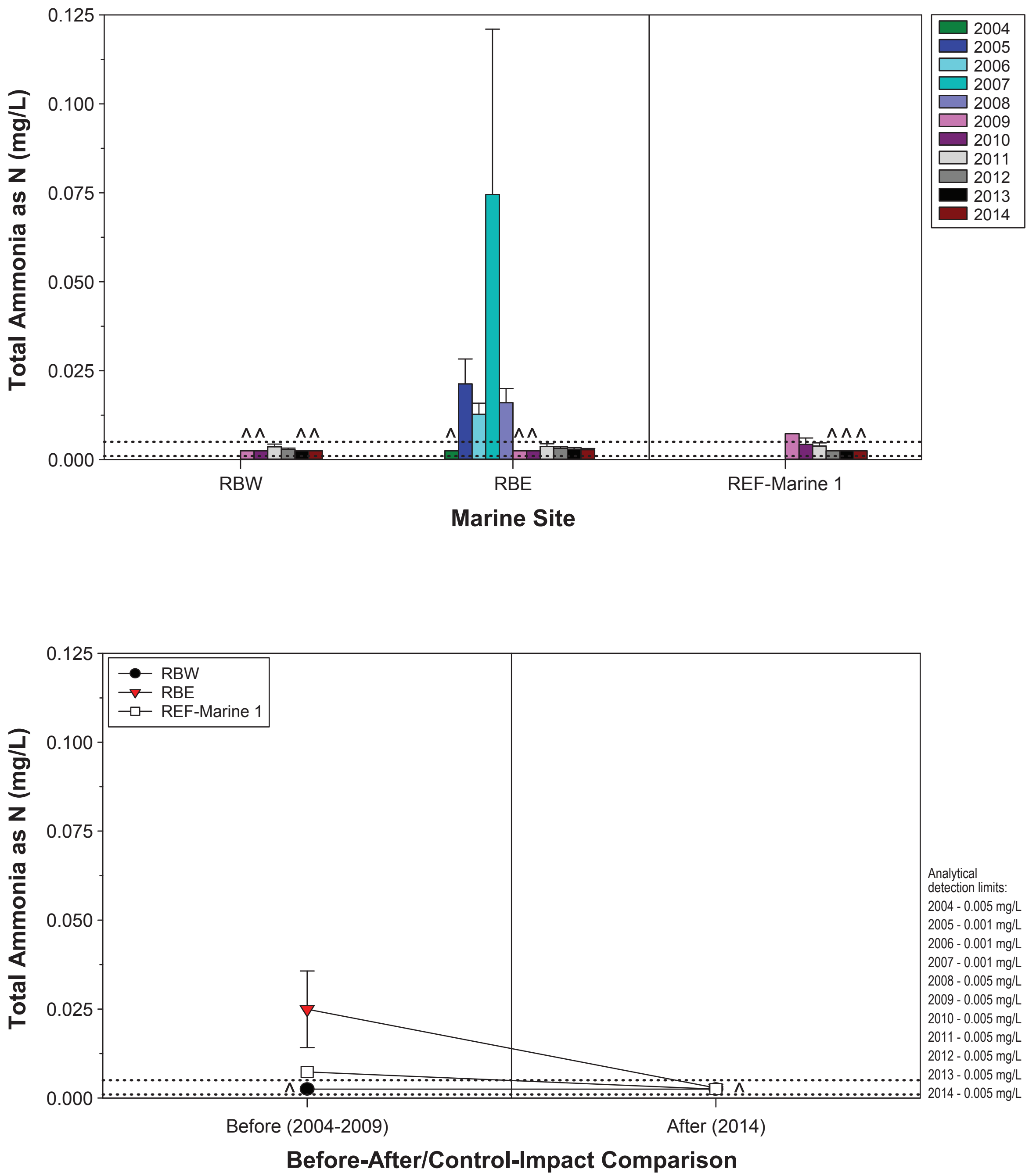




Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
The CCME marine guideline for total suspended solids is dependent upon background levels.
Total suspended solids are regulated as deleterious substances in effluents as per Schedule 4 of the MMER.

Figure 3.3-41

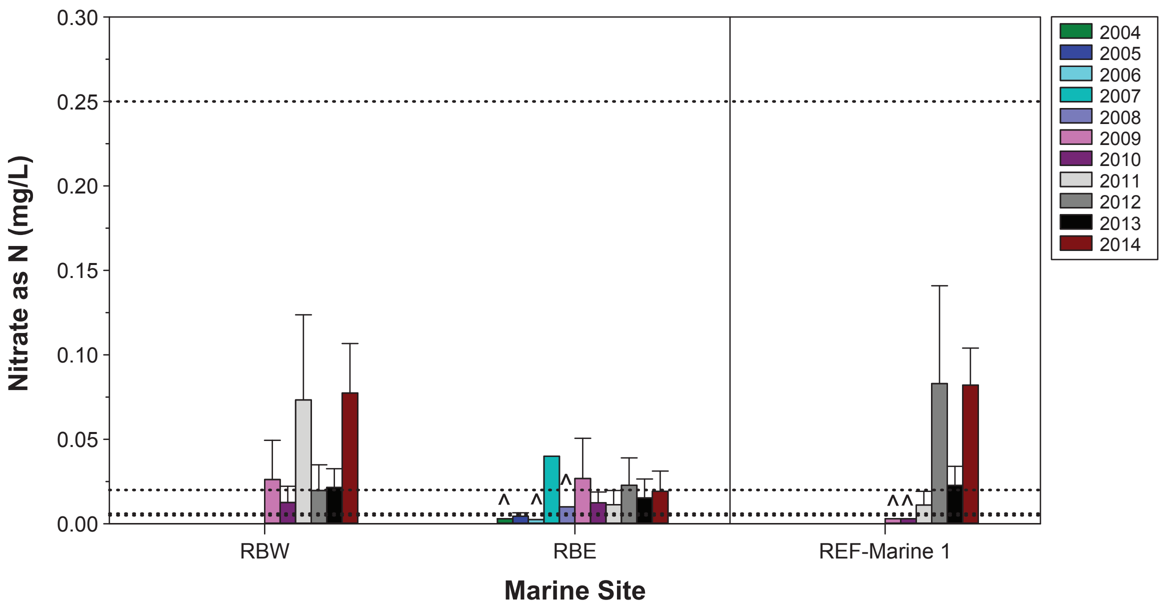
Total Ammonia Concentration, Marine Sites, Doris North Project, 2004 to 2014

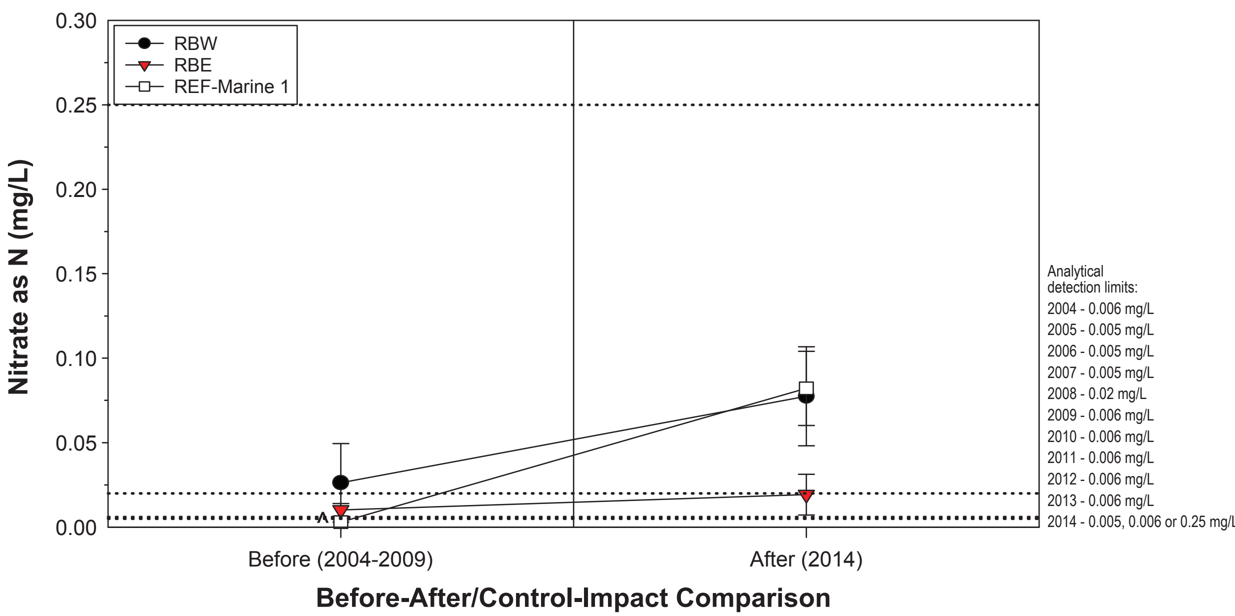


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Sample concentrations that were below the very high detection limit of 5 mg/L were excluded from plots.
^ Indicates that concentrations were below the detection limit in all samples.
Total ammonia is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of the MMER.

Figure 3.3-42

Nitrate Concentration, Marine Sites, Doris North Project, 2004 to 2014

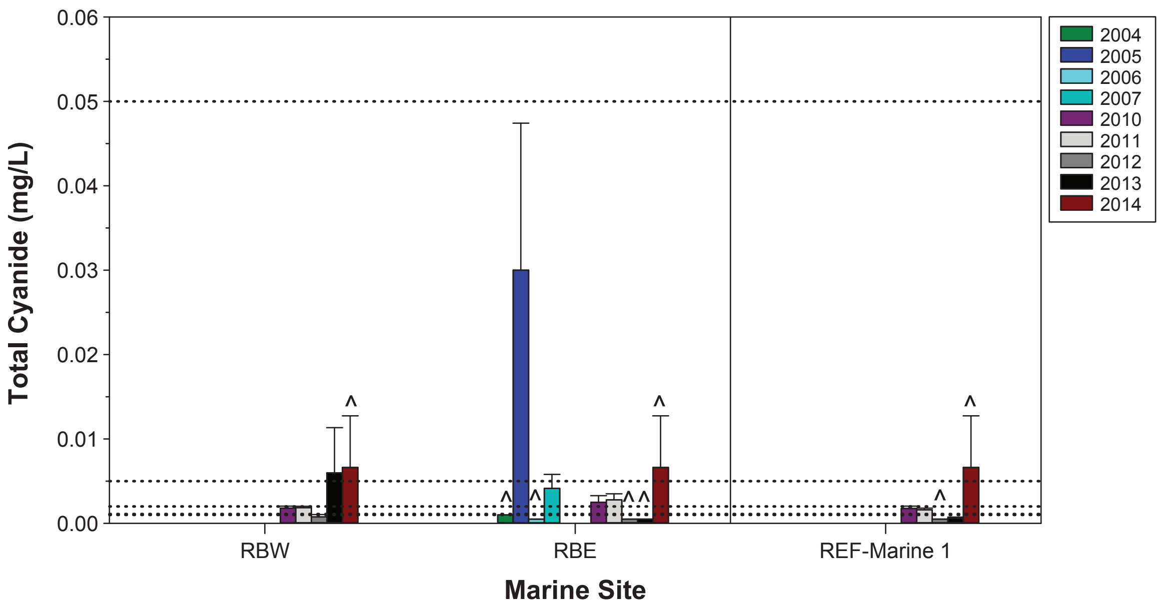


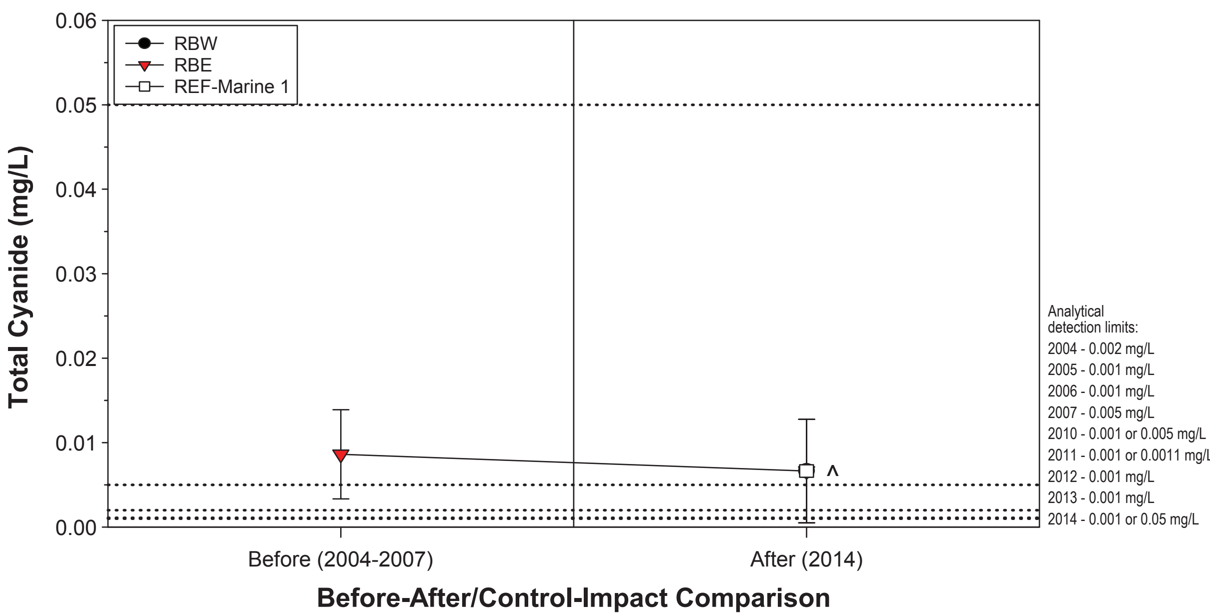


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Sample concentrations that were below the very high detection limits of 0.1, 0.5, or 2.5 mg/L were excluded from plots.
^ Indicates that concentrations were below the detection limit in all samples.
CCME marine guideline for nitrate as N (45 mg/L; long-term concentration) not shown.
Nitrate is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of the MMER.

Total Cyanide Concentration, Marine Sites, Doris North Project, 2004 to 2014

ERM





Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Sample concentrations that were below the very high detection limits of 0.5 or 5 mg/L were excluded from plots.
^ Indicates that concentrations were below the detection limit in all samples.
Total cyanide is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.

3.3.3.8 Radium-226

Radium-226 is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. At all exposure and reference sites all radium-226 concentrations measured in 2014 were below the analytical detection limit of 0.01 Bq/L (Figure 3.3-44). Therefore, there was no evidence of changes in radium-226 concentrations in the marine exposure sites as a result of 2014 Project activities.

3.3.3.9 Total Aluminum

Total aluminum is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. At site RBE, the mean 2014 total aluminum concentration was within the range of baseline means (Figure 3.3-45). At site RBW, the 2014 mean was slightly higher than the 2009 mean (Figure 3.3-45). However, the before-after comparison for both marine exposure sites indicated that the 2014 means were not statistically different from the baseline means ($p = 0.72$ for RBW and $p = 0.67$ for RBE). This suggests that there was no effect of 2014 Project activities on total aluminum concentrations at the marine exposure sites.

3.3.3.10 Total Arsenic

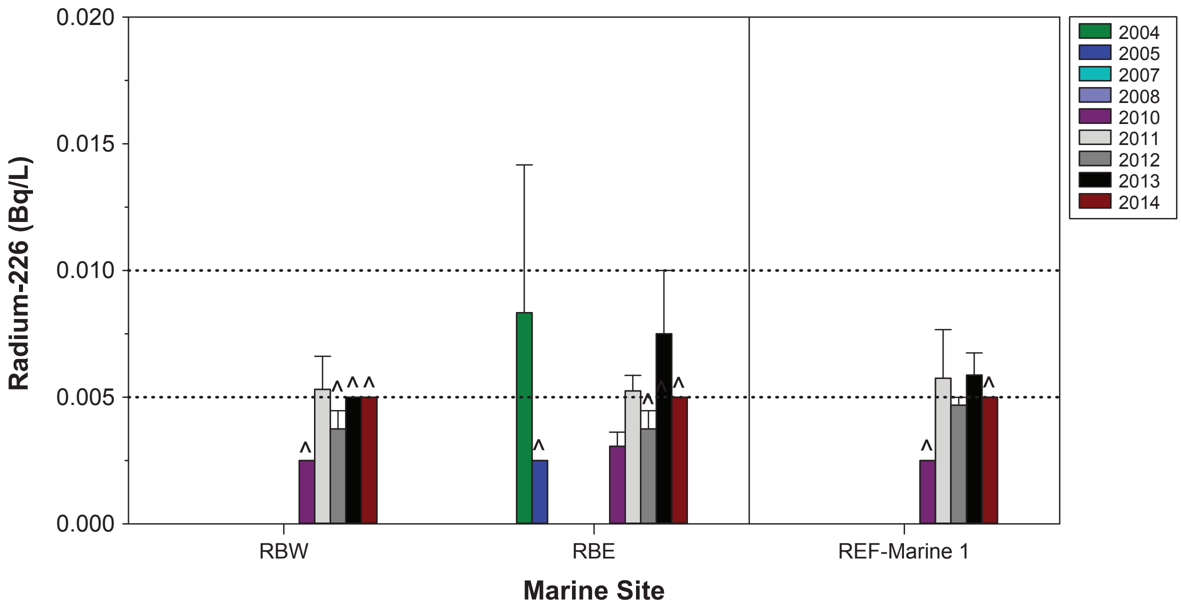
Total arsenic is regulated as a deleterious substance in effluents as per Schedule 44 of the MMER. All total arsenic concentrations measured at marine exposure and reference sites in 2014 were well below the marine CCME guideline of 0.0125 mg/L (Figure 3.3-46). Mean total arsenic concentrations measured at RBW were similar to the baseline concentration measured in 2009. At RBE, the mean 2014 total arsenic concentration was greater than baseline concentrations measured between 2007 and 2009, but lower than the anomalously high arsenic concentrations measured at RBE between 2004 and 2006 (Figure 3.3-46). The 2004 to 2006 data were treated as outliers and removed from the dataset for the statistical analyses to increase the ability of statistical tests to detect differences. The before-after comparisons revealed that the 2014 mean arsenic concentrations at RBW and RBE were not distinguishable from baseline means ($p = 0.73$ for RBW and $p = 0.93$ for RBE). Therefore, the evidence suggested that 2014 Project activities did not affect total arsenic concentrations at the marine exposure sites.

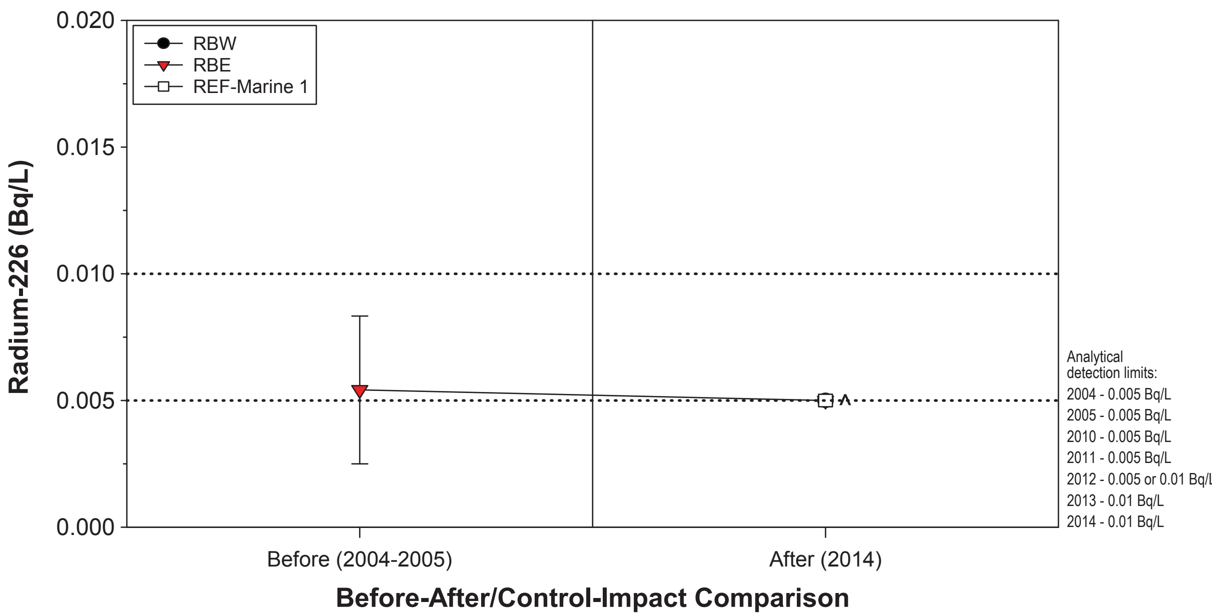
3.3.3.11 Total Cadmium

Total cadmium is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. In 2014, all total cadmium concentrations in samples collected from RBW, RBE, and REF-Marine 1 were below the marine CCME guideline of 0.00012 mg/L (Figure 3.3-47). At the exposure sites, mean 2014 cadmium concentrations were within or lower than the range of baseline means (Figure 3.3-47). Before-after statistical comparisons confirmed that the 2014 and baseline means were not statistically distinguishable ($p = 0.98$ for RBW and $p = 0.82$ for RBE). Therefore, there was no apparent effect of 2014 Project activities on total cadmium concentrations at the marine exposure sites.

Figure 3.3-44

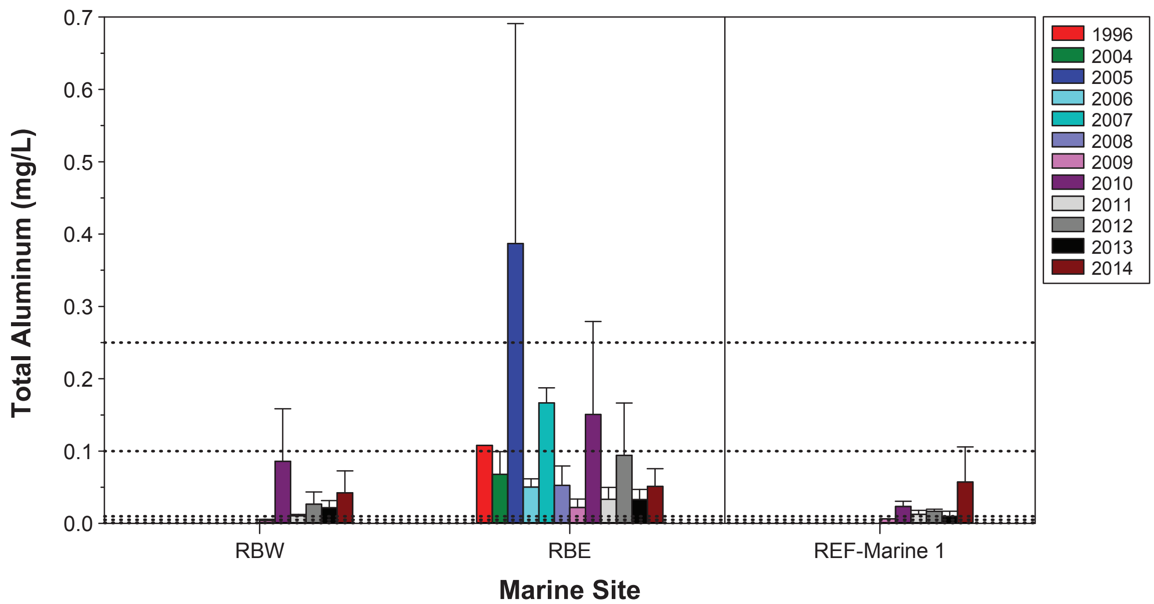
Radium-226 Concentration, Marine Sites, Doris North Project, 2004 to 2014

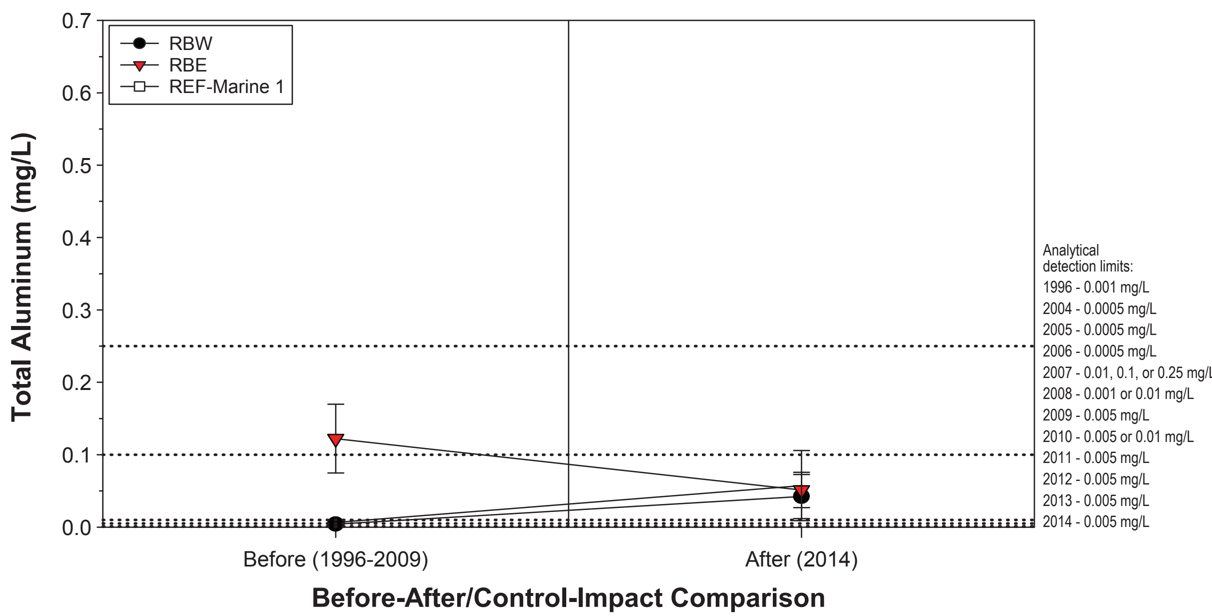




Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Radium-226 is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.

Total Aluminum Concentration, Marine Sites, Doris North Project, 1996 to 2014

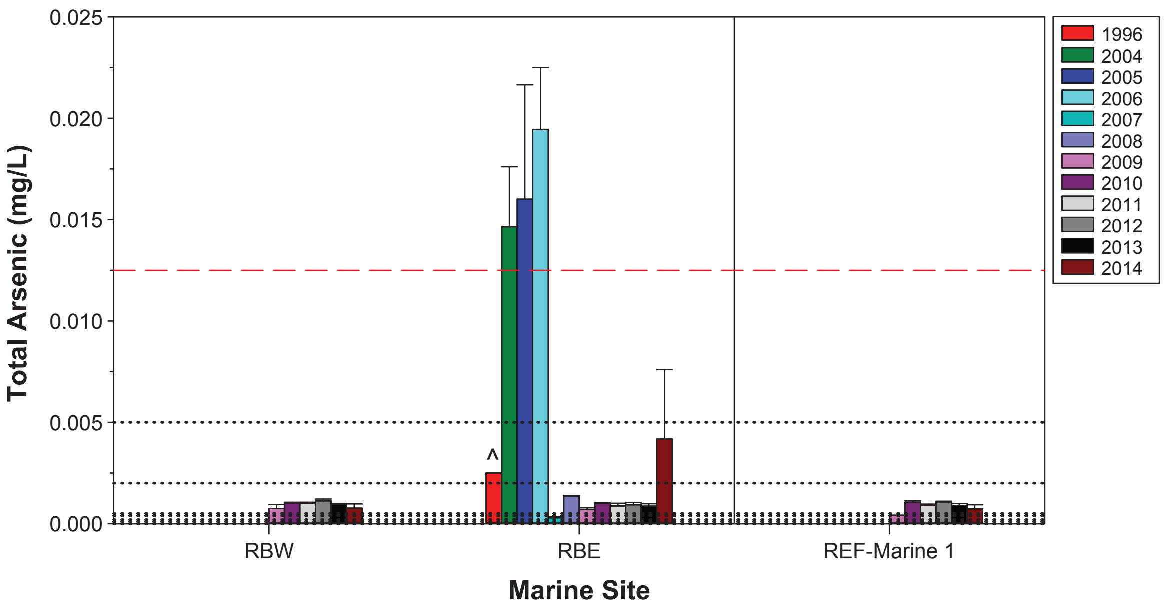


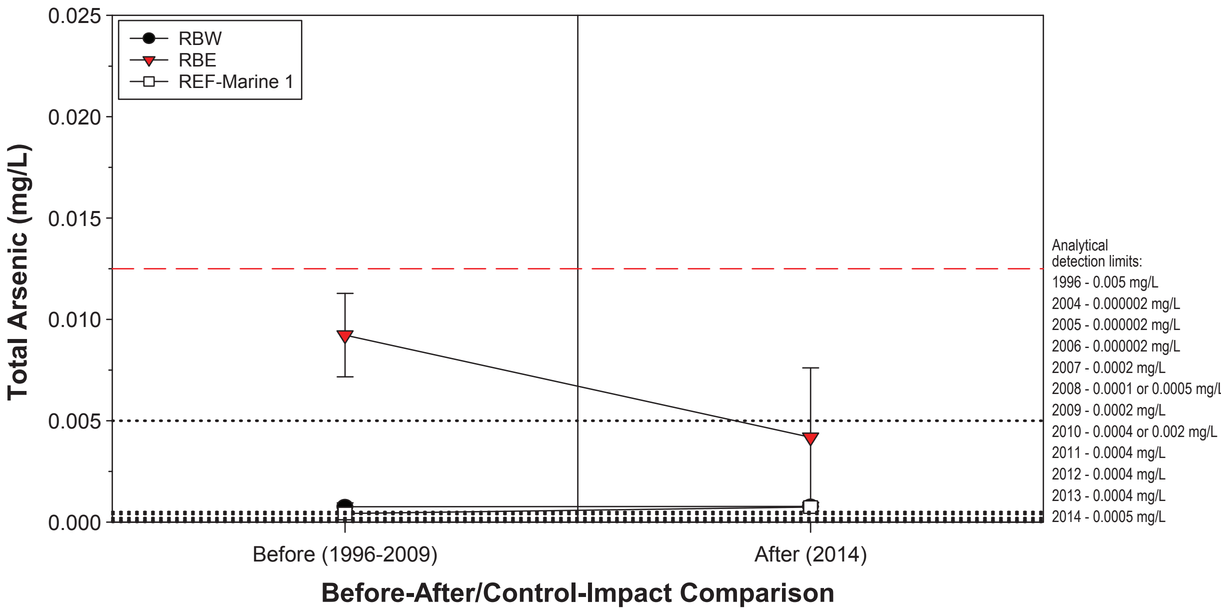


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Total aluminum is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of the MMER.

Figure 3.3-46

Total Arsenic Concentration, Marine Sites, Doris North Project, 1996 to 2014

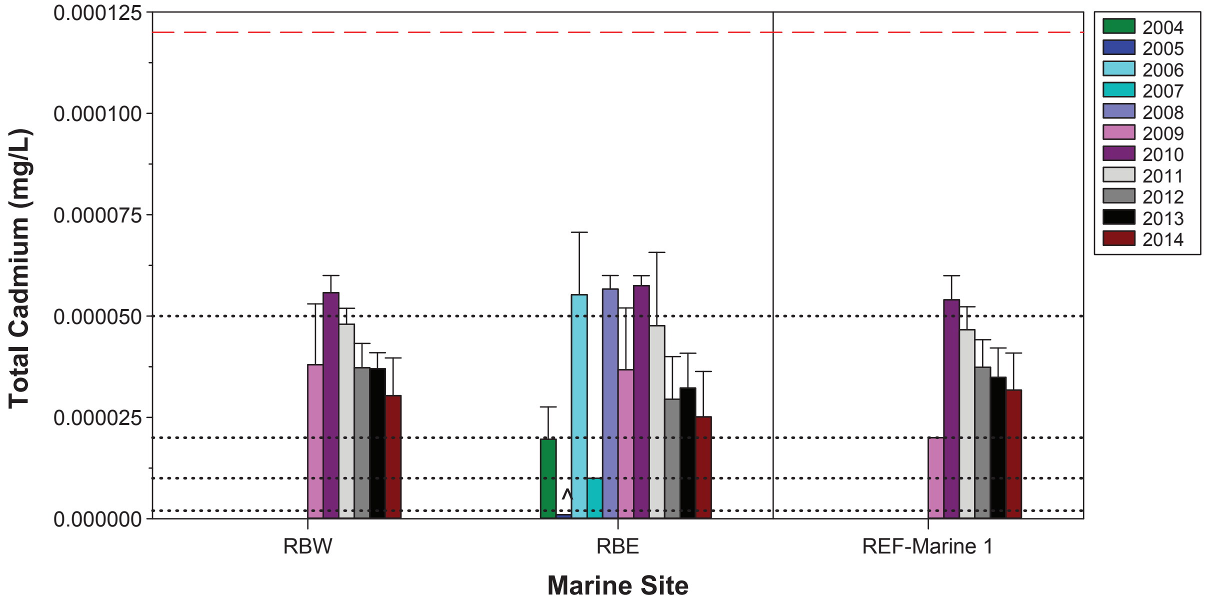


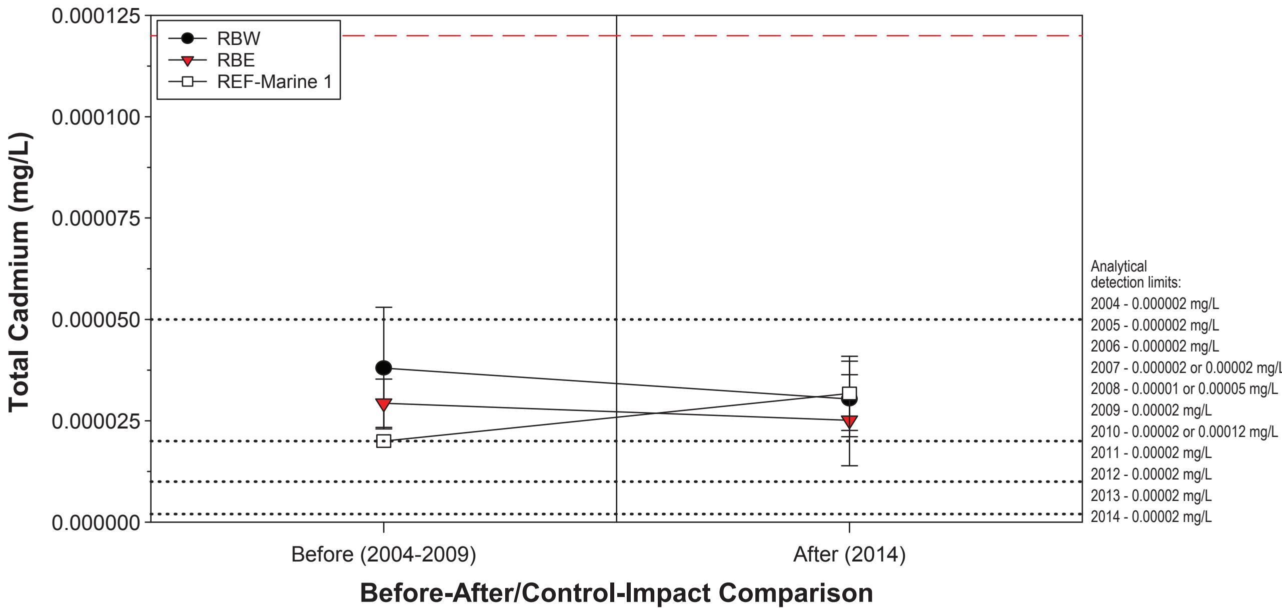


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed lines represent the interim CCME marine guideline for arsenic (0.0125 mg/L).
Total arsenic is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.

Figure 3.3-47

Total Cadmium Concentration, Marine Sites, Doris North Project, 2004 to 2014





Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed lines represent the CCME marine guideline for cadmium (0.00012 mg/L).
The anomalously high total cadmium concentration of 0.00348 mg/L reported for RBE in August 1996 was considered an outlier and was excluded from plots.
Total cadmium is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of the MMER.

3.3.3.12 Total Copper

Total copper is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. From 1996 to 2009, total copper concentrations at RBE were inter-annually variable. The 2014 mean concentration at RBE was within the range of baseline concentrations (Figure 3.3-48). At RBW and REF-Marine-1, 2014 total copper concentrations were similar to the 2010 concentrations (Figure 3.3-48). The before-after comparison showed that for both RBW and RBE, there was no significant difference between baseline and 2014 mean copper concentrations ($p = 0.69$ for RBW and $p = 0.68$ for RBE). Therefore, there was no apparent effect of 2014 Project activities on total copper concentrations at the marine exposure sites.

3.3.3.13 Total Iron

Total iron is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. At site RBE, the mean 2014 total iron concentration was within the range of the widely varying baseline concentrations (Figure 3.3-49). At site RBW, there was a slight increase in the mean iron concentration in 2014 compared to 2009 that also occurred at the reference site (REF-Marine-1) (Figure 3.3-49). For both of these Roberts Bay sites, the before-after analysis showed that 2014 means were not distinguishable from baseline means ($p = 0.73$ for RBW and $p = 0.65$ for RBE), indicating that there was no effect of 2014 Project activities on total iron concentrations at the marine exposure sites.

3.3.3.14 Total Lead

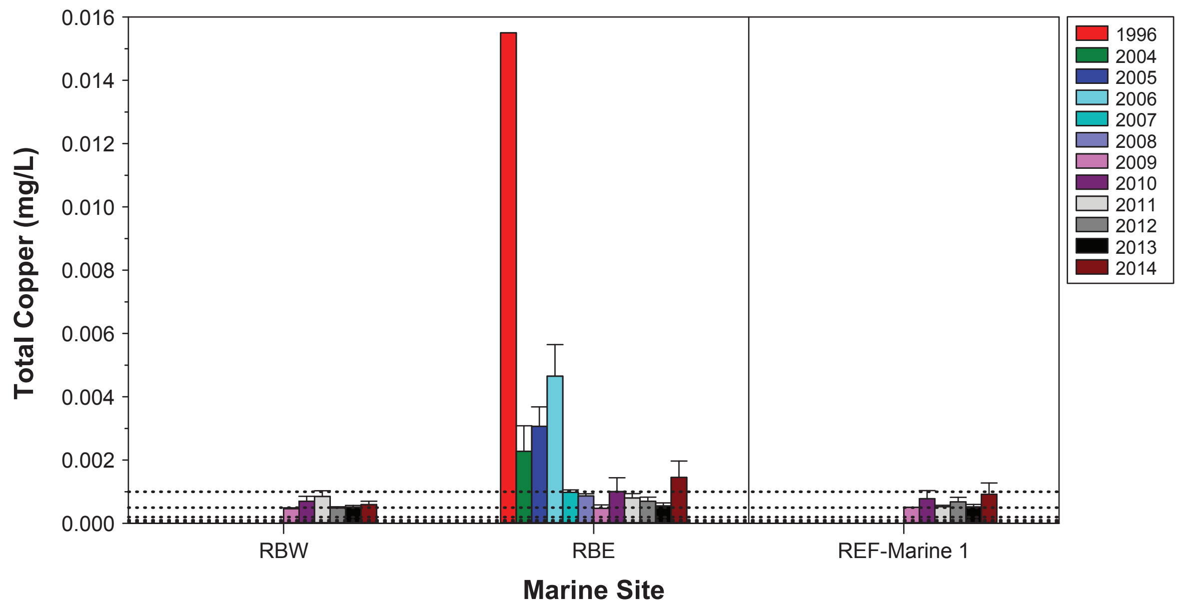
Total lead is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. In 2014, mean total lead concentrations at RBW and RBE were within the range of baseline means and similar to concentrations measured at the reference site (REF-Marine-1; Figure 3.3-50). The before-after analysis confirmed that the 2014 means were not distinguishable from the baseline means ($p = 0.90$ at RBW and $p = 0.69$ at RBE). Thus, there was no apparent effect of 2014 Project activities on total lead concentrations at marine exposure sites.

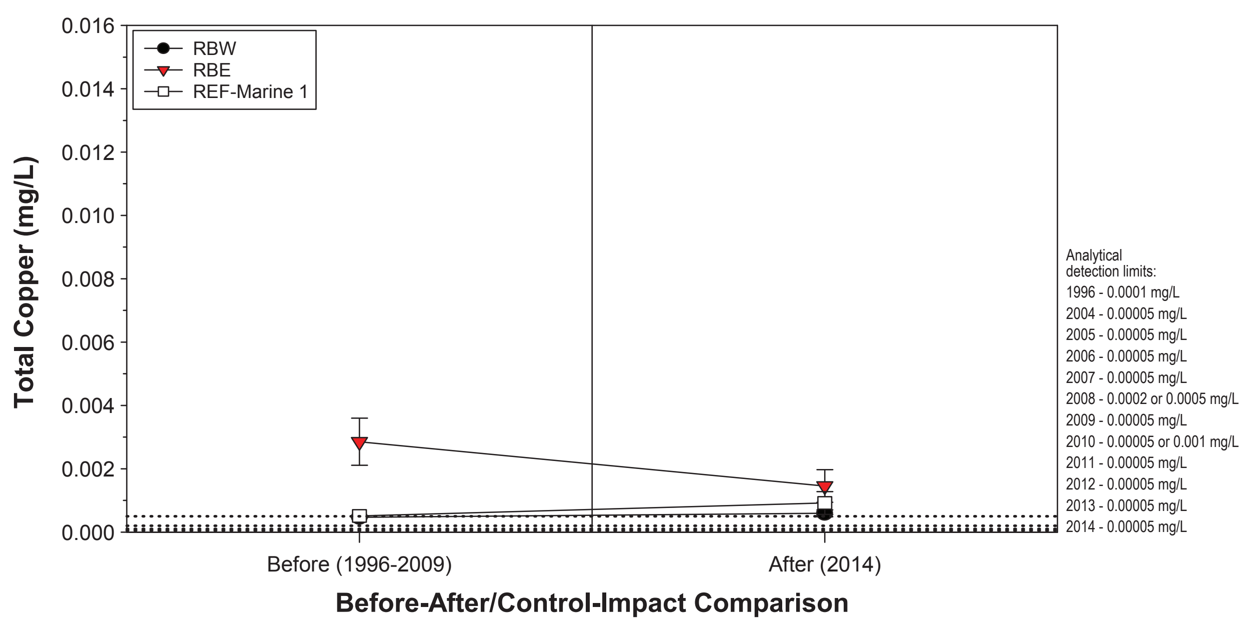
3.3.3.15 Total Mercury

Total mercury is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. In 2014, all total mercury concentrations measured at marine exposure and reference sites were near or below the ultra-low detection limit of 0.0000005 mg/L and well below the interim CCME guideline for inorganic mercury of 0.000016 mg/L (Appendix A). Because 2009 was the only year of baseline data available for RBW and REF-Marine 1, total mercury concentrations appeared to decrease in 2014 compared to 2009, but this was likely an artifact of the higher detection limit achieved for 2009 samples (0.00001 mg/L; Figure 3.3-51) since all 2009 concentrations were below the analytical detection limit. At RBE, where baseline concentrations between 2004 and 2008 were also measured using ultra-low detection limits, the mean 2014 total mercury concentration was within the range of baseline concentrations. The before-after analysis results are not discussed for RBW because a high proportion (> 70%) of concentrations in the combined baseline and 2014 datasets were below analytical detection limits. For RBE, the before-after analysis confirmed that the 2014 mean was not distinguishable from the baseline mean ($p = 0.32$). Thus, there was no apparent effect of 2014 Project activities on total mercury concentrations at the marine exposure sites.

Figure 3.3-48

Total Copper Concentration, Marine Sites, Doris North Project, 1996 to 2014

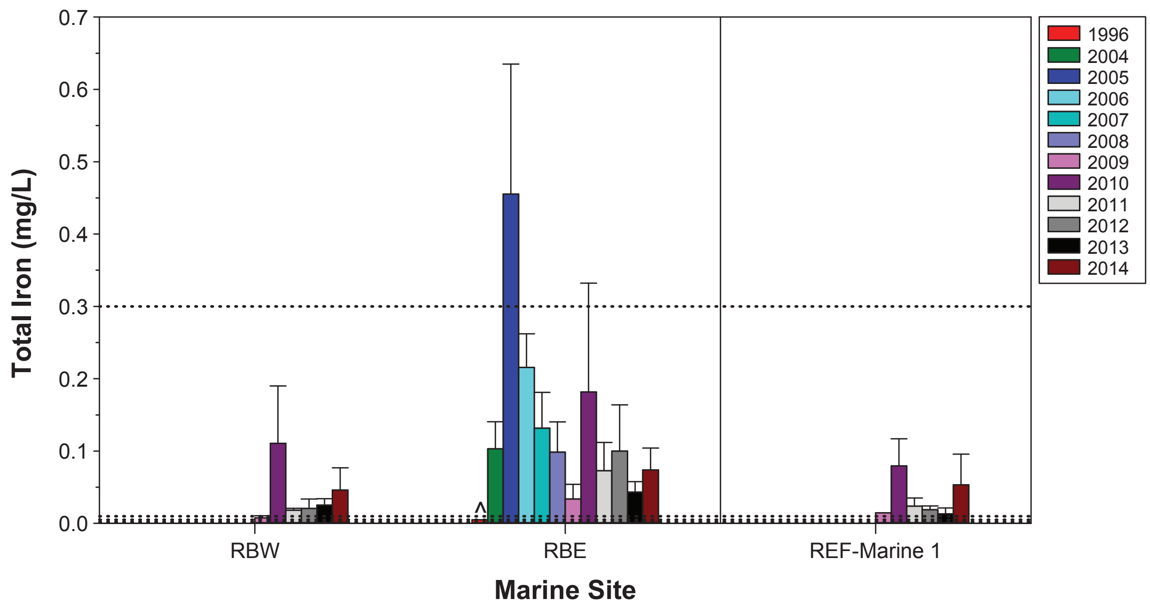


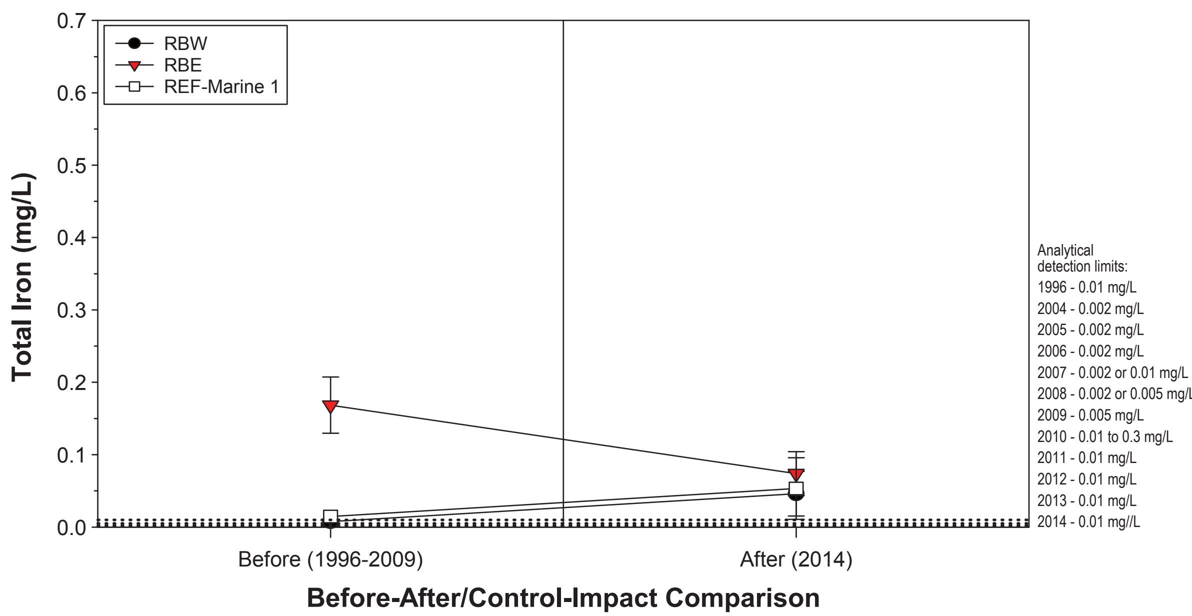


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Total copper is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.

Figure 3.3-49

Total Iron Concentration, Marine Sites, Doris North Project, 1996 to 2014

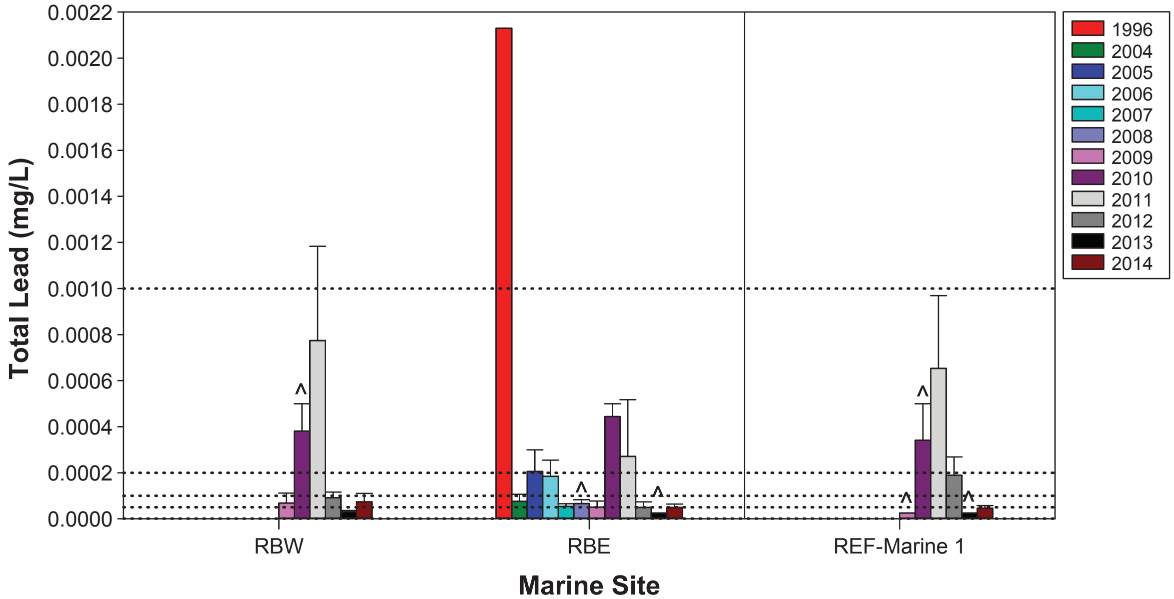


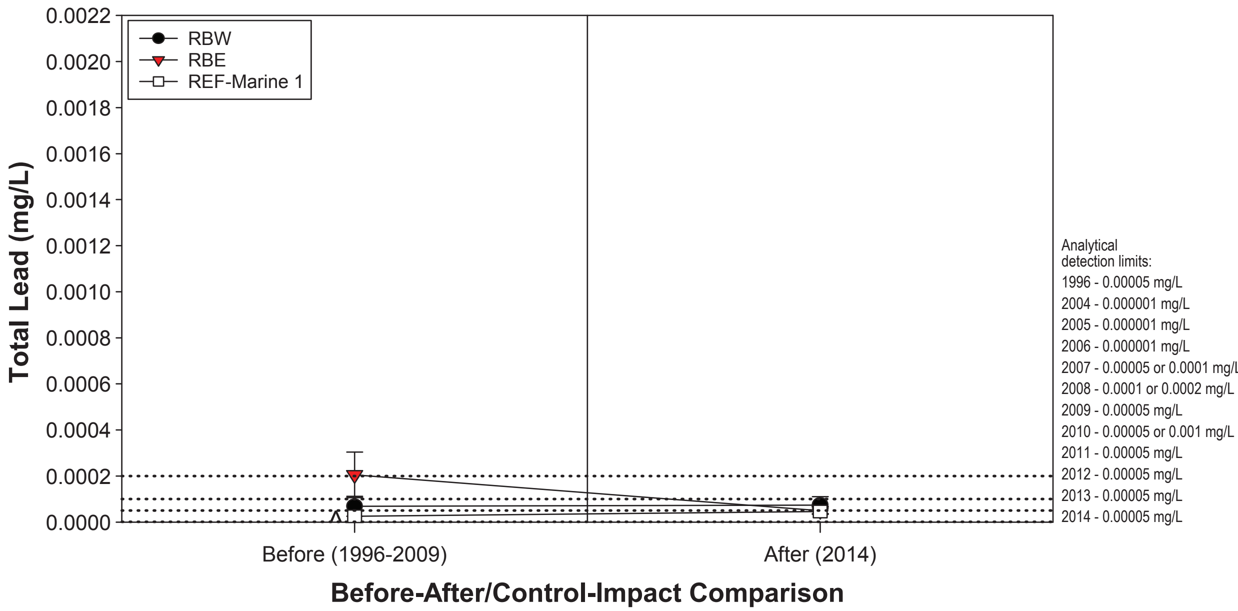


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Total iron is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of the MMER.

Figure 3.3-50

Total Lead Concentration, Marine Sites, Doris North Project, 1996 to 2014

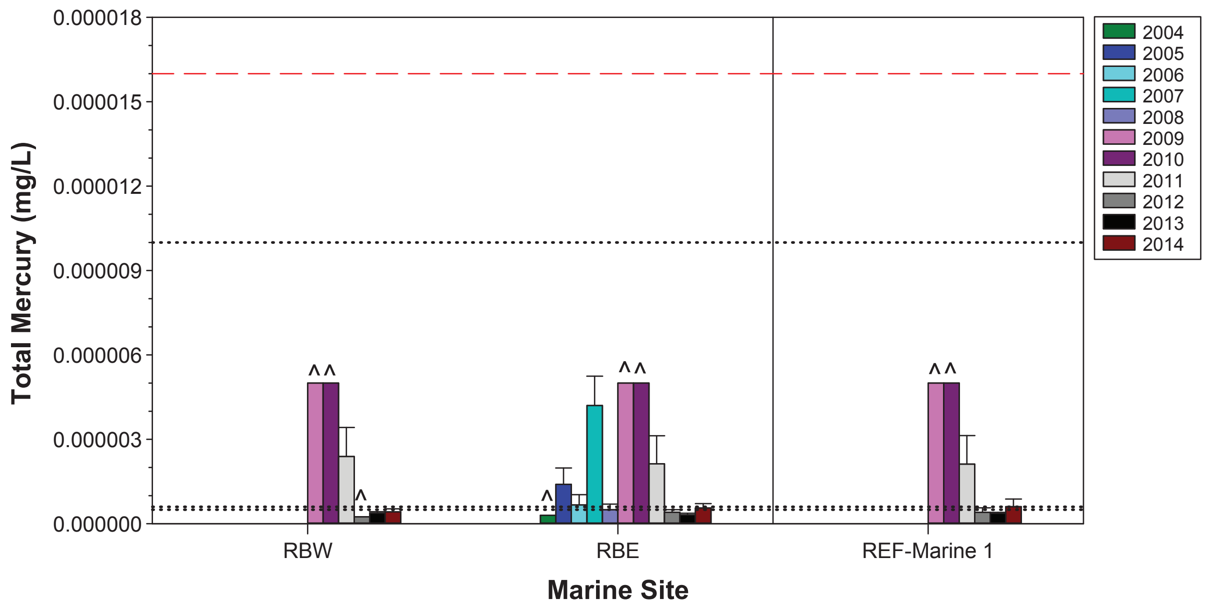


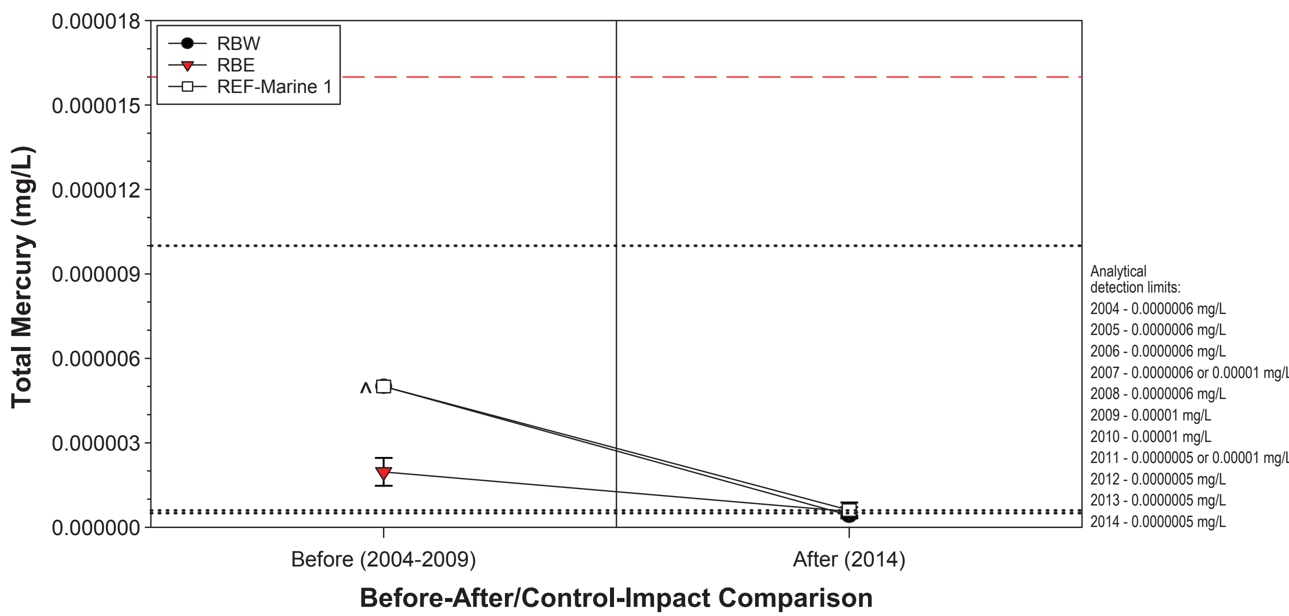


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Total lead is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.

Figure 3.3-51

Total Mercury Concentration, Marine Sites, Doris North Project, 2004 to 2014





Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed lines represent the interim CCME marine guideline for inorganic mercury (0.000016 mg/L).
Total mercury is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of the MMER.

3.3.3.16 Total Molybdenum

Total molybdenum is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. Mean 2014 total molybdenum concentrations at the two marine exposure sites were within or lower than the range of baseline levels (Figure 3.3-52). The before-after comparison confirmed that there was no difference between 2014 mean concentrations and baseline means for the Roberts Bay sites ($p = 0.84$ for RBW and $p = 0.88$ for RBE). Therefore, 2014 Project activities had no apparent effect on total molybdenum concentrations at the marine exposure sites.

3.3.3.17 Total Nickel

Total nickel is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. At site RBW, 2014 total nickel concentrations were similar to 2009 concentrations (Figure 3.3-53), and the before-after analysis confirmed that the 2014 mean was not statistically different from the 2009 mean ($p = 0.92$). At site RBE, the mean 2014 total nickel concentration was lower than the baseline mean (Figure 3.3-53), but the before-after analysis revealed that the baseline and 2014 means were not statistically distinguishable ($p = 0.76$). Therefore, the evidence suggested that there was no effect of 2014 Project activities on total nickel concentrations at the marine exposure sites.

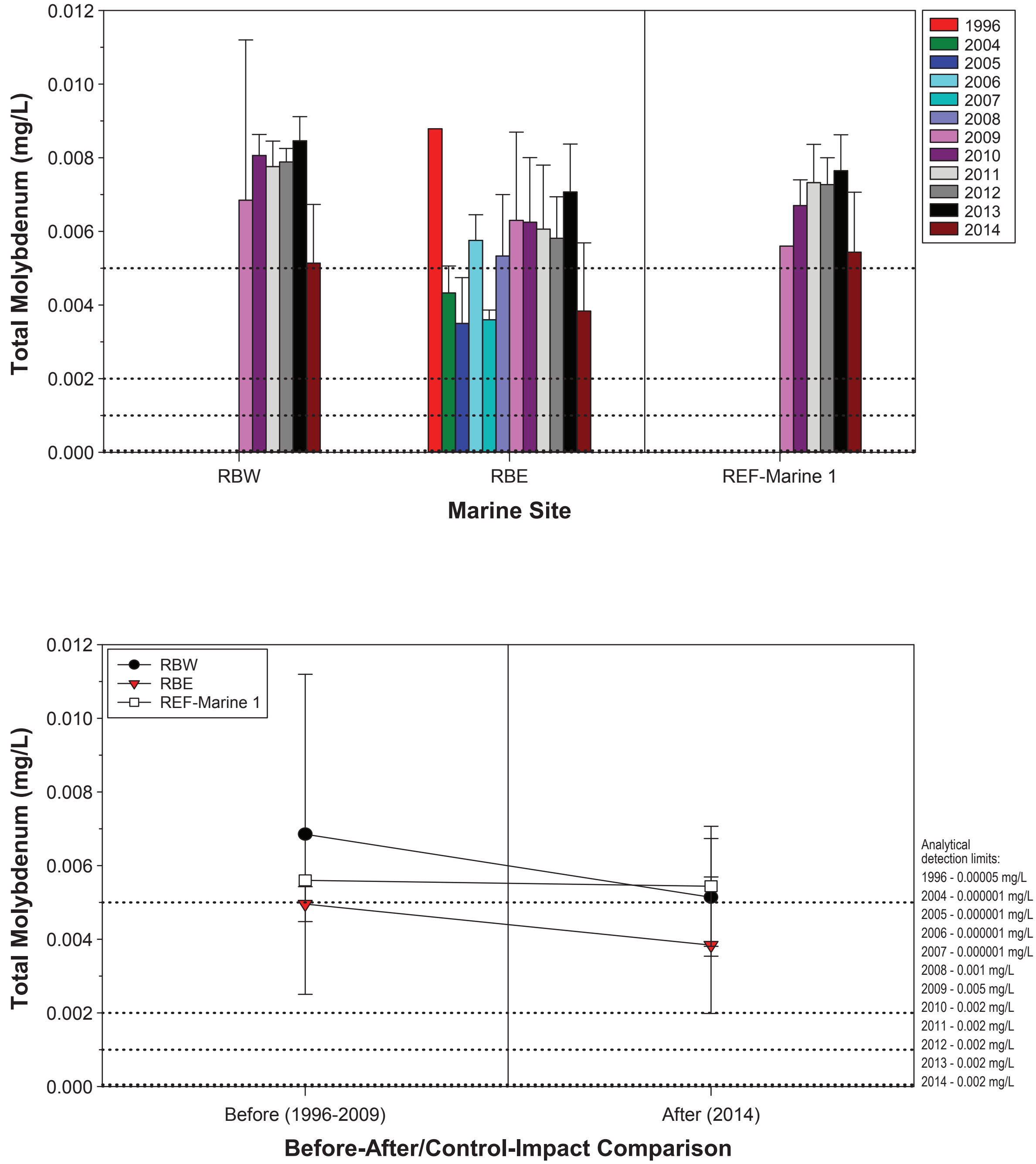
3.3.3.18 Total Zinc

Total zinc is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. At site RBW, the mean total zinc concentration was higher in 2014 than in 2009; while at RBE, the 2014 mean was within the range of means for the baseline years (Figure 3.3-54). The before-after comparison showed that there was no significant difference between baseline and 2014 mean zinc concentrations for either of the Roberts Bay sites ($p = 0.44$ for RBW and $p = 0.83$ for RBE), indicating that 2014 Project activities did not affect zinc concentrations at the marine exposure sites.

3.4 SEDIMENT QUALITY

As per the MMER, Schedule 5, s. 16(a)(iii), sediment samples were collected and analyzed for particle size and TOC content to complement the benthic invertebrate community surveys. In this section, the sediment quality data collected from stream, lake, and marine sites in 2014 were compared against available baseline information as well as reference sites to evaluate whether 2014 Project activities caused changes to these sediment quality variables. Sediment quality variables for which there are CCME sediment quality guidelines for the protection of aquatic life (CCME 2014b) were also evaluated. CCME guidelines for sediments include interim sediment quality guidelines (ISQGs) and probable effects levels (PELs). The more conservative ISQGs are levels below which adverse biological effects are rarely observed. The higher PELs correspond to concentrations above which negative effects would be expected (CCME 2014a). Sediment quality variables were compared to applicable CCME guidelines to determine whether concentrations posed a concern for freshwater and marine aquatic life. Site-specific baseline conditions were considered in addition to CCME guidelines to determine whether any detected changes would result in a potential adverse effect to freshwater and marine life.

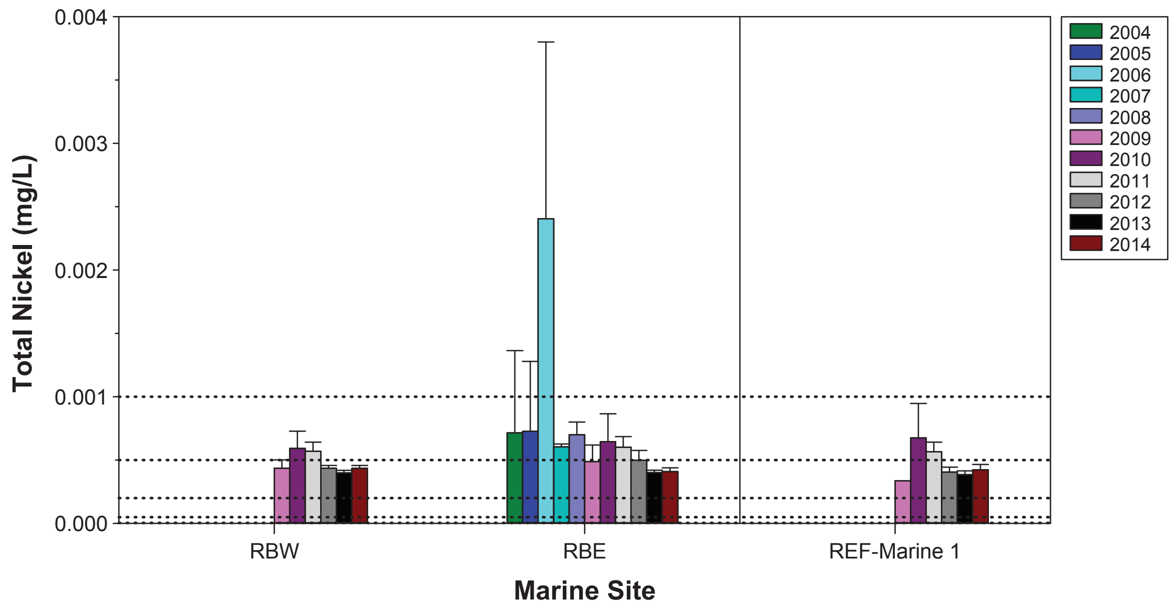
Total Molybdenum Concentration, Marine Sites, Doris North Project, 1996 to 2014

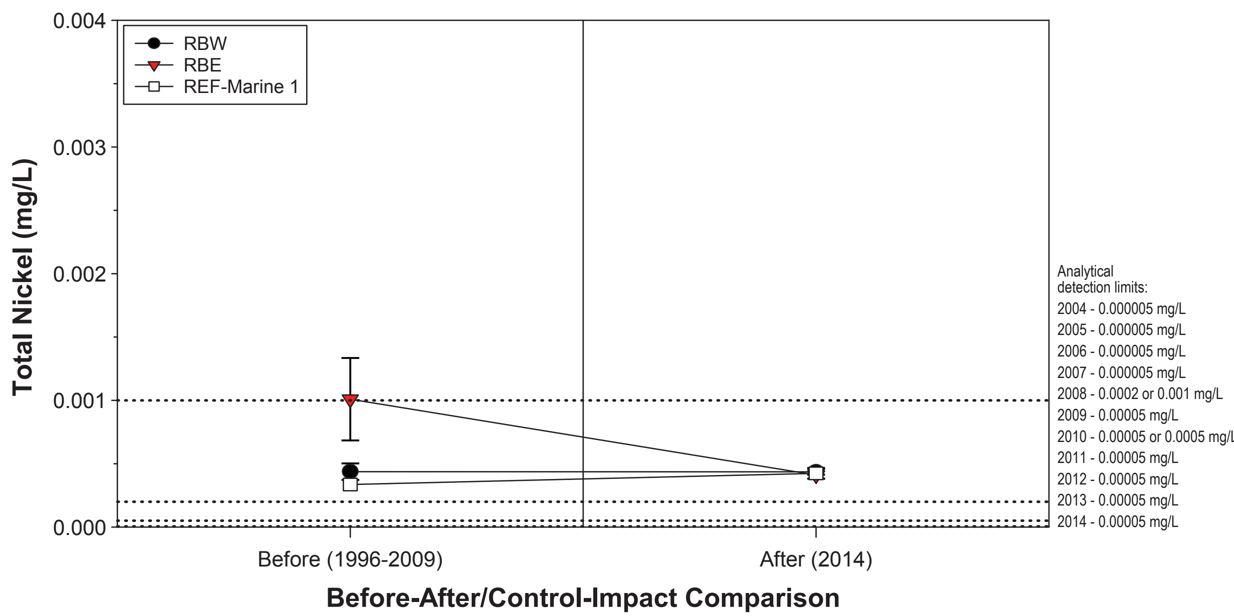


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Total molybdenum is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of the MMER.

Figure 3.3-53

Total Nickel Concentration, Marine Sites, Doris North Project, 2004 to 2014



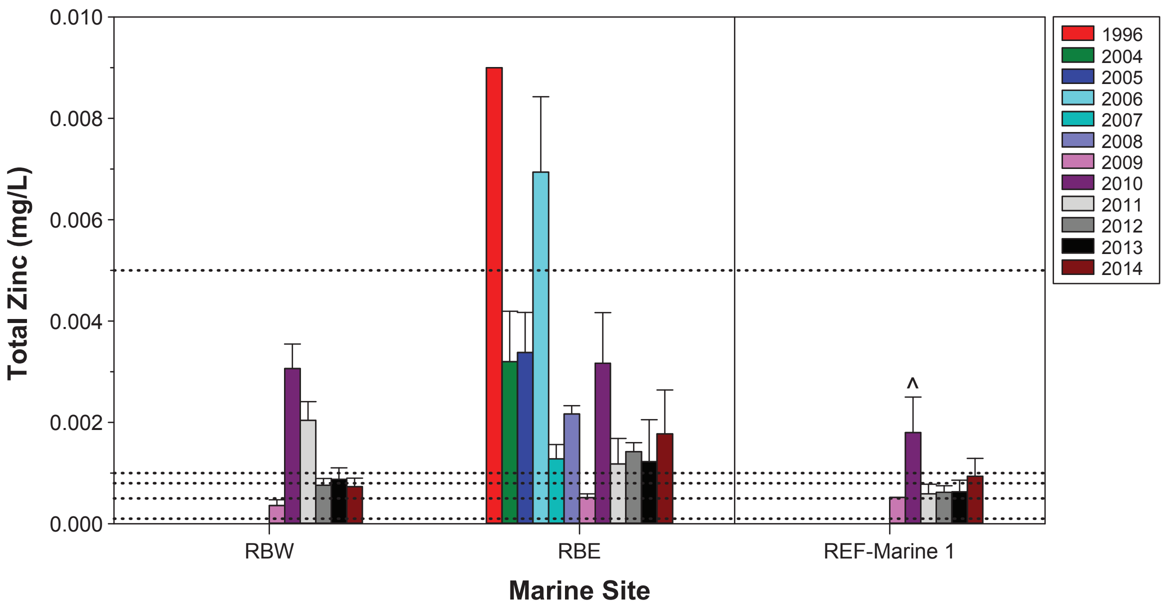


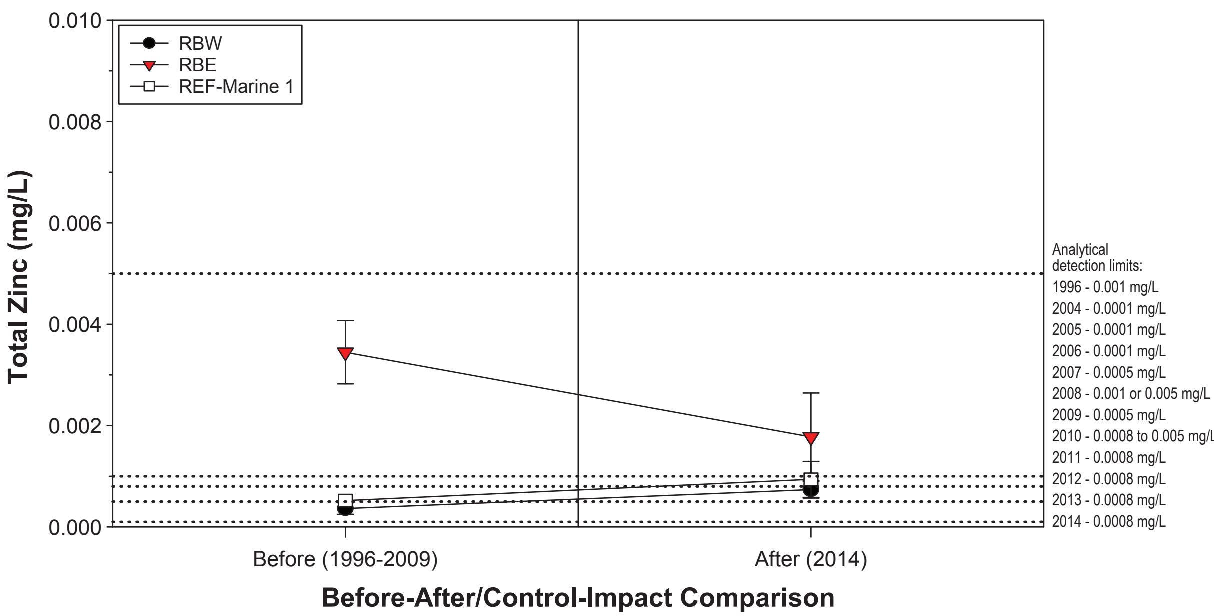
Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
The anomalously high total nickel concentration of 0.0215 mg/L reported for RBE in August 1996 was considered an outlier and was excluded from plots.
Total nickel is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.

Figure 3.3-54

Total Zinc Concentration, Marine Sites, Doris North Project, 1996 to 2014

ERM





Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Total zinc is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.

For both graphical and statistical analyses, a value equal to half the detection limit was substituted for sediment quality samples that were below analytical detection limits. Graphs showing sediment quality trends in AEMP waterbodies over time are shown in Figures 3.4-1 to 3.4-27, and all statistical results are presented in Appendix B.

3.4.1 Streams

Sediment quality samples from streams were collected from three exposure streams (Doris Outflow, Roberts Outflow, and Little Roberts Outflow) and two reference streams (Reference B Outflow and Reference D Outflow). Baseline data for stream sediments are available only from 2009 and only for Doris, Little Roberts, and Reference B Outflows. Data from 2014 were compared to 2009 to identify potential changes to sediment variables. Stream sediment sampling was conducted in August during both years at the sampled sites. For the calculations of annual means for each variable, all analytical results for stream sediment samples collected in a given year were averaged.

3.4.1.1 Particle Size

Particle size is a required sediment variable to complement the benthic invertebrate surveys as per Schedule 5, s. 16(a)(iii) of the MMER. There were some differences in the particle size composition of stream sediments in 2014 compared to 2009 (Figure 3.4-1). This most likely resulted from natural spatial heterogeneity in sediment particle size composition.

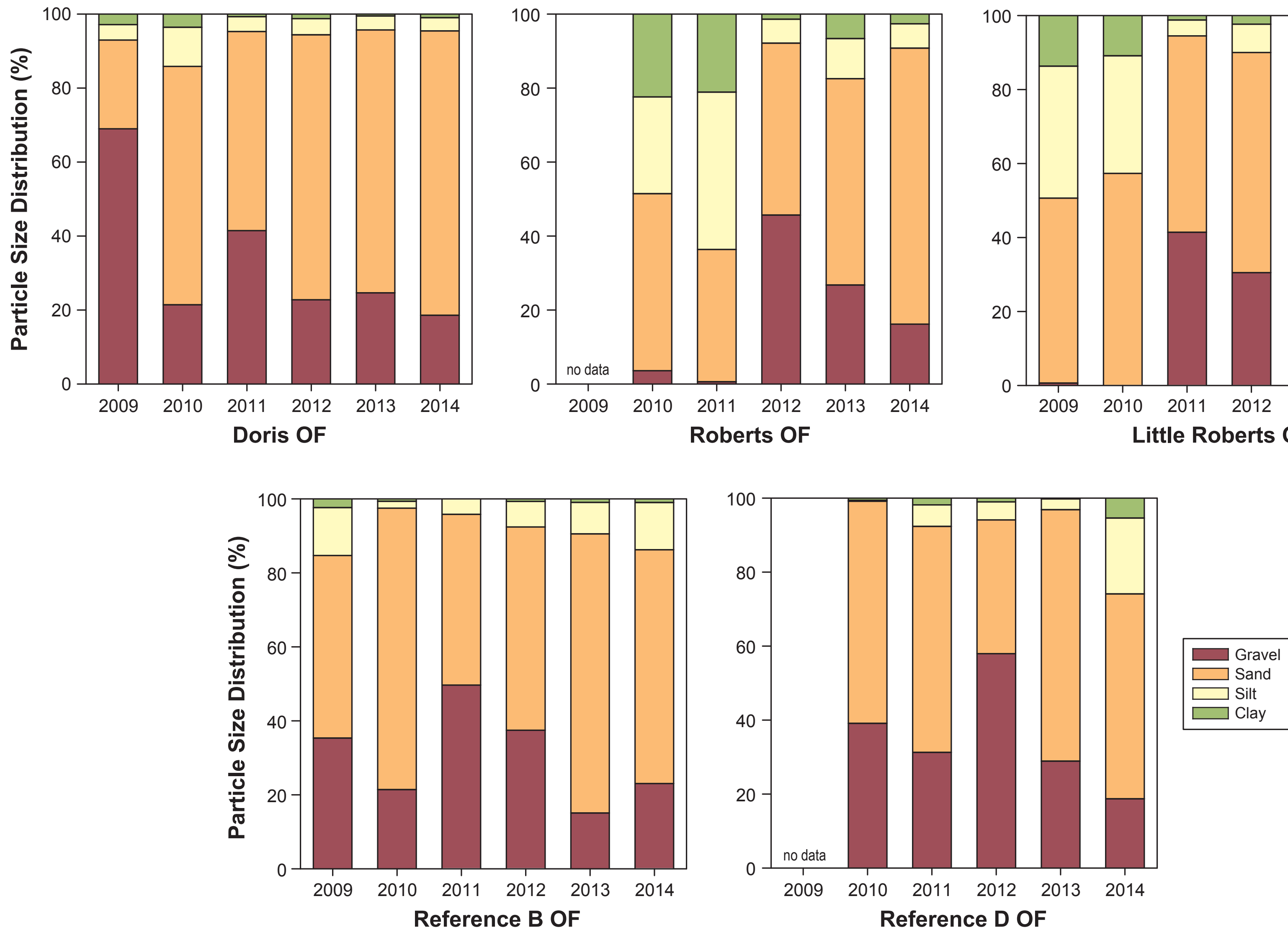
In Doris Outflow, 2014 sediments consisted of a larger proportion of sand and a lower proportion of gravel compared to 2009. The before-after analysis showed that the observed changes in particle size in Doris Outflow sediments were statistically significant ($p = 0.0018$ for gravel and $p = 0.0002$ for sand content). The BACI analysis revealed that there was a marginally non-significant difference between the before and after periods for Doris Outflow and the reference streams for gravel ($p = 0.0479$) and that there was evidence of significant non-parallelism for sand content ($p = 0.0018$).

In Little Roberts Outflow, the gravel and sand content was higher and the clay and silt content was lower in 2014 than 2009 (Figure 3.4-1). The before-after analysis for Little Roberts Outflow showed that the changes in particle size were statistically significant for gravel, sand, silt, and clay ($p = 0.0077$, 0.0014, 0.0007, and 0.0004, respectively). The BACI analysis revealed that these changes were paralleled in the reference streams for gravel and sand content ($p = 0.0961$ and 0.2572, respectively), but there was marginal evidence of a non-parallelism for silt content ($p = 0.0204$) and significant evidence of a non-parallelism for clay content ($p = 0.0013$). No before data exist for Roberts Outflow; however, the observed trends in particle size appeared to be similar to those observed in Little Roberts Outflow.

Variation in sediment particle size composition is unlikely to be related to 2014 Project activities, and probably reflects natural spatial heterogeneity in stream sediments since corresponding Project-related changes in water quality have not been observed (e.g., increases in TSS). However, differences between 2009 and 2014 may complicate the effects analysis because fine sediments are often associated with higher metal and TOC concentrations than coarse sediments (e.g., Lakhan, Cabana, and LaValle 2003; Secrieri and Oaie 2009). This implies, for example, that the shift in sediment particle composition from finer sediments in 2009 (sand, clay, and silt) to coarser sediments (largely sand and gravel) in 2014 samples collected from Little Roberts Outflow could lead to sediment metal and TOC concentrations being lower in 2014 than in 2009 (which was observed for TOC and many metals, as described in the following sections), though this would be unrelated to Project activities.

Figure 3.4-1

Particle Size Distribution, Stream Sediments, Doris North Project, 2009 to 2014



Notes: Stacked bars represent the mean of replicate samples.
Particle size distribution of sediments is a required parameter as part of benthic invertebrate surveys as per Schedule 5, s.16a (iii) of the MMER.

3.4.1.2 Total Organic Carbon

TOC content is a required sediment variable that is meant to support the benthic invertebrate surveys as per Schedule 5, s. 16(a)(iii) of the MMER. In both exposure and reference stream sediments, TOC content was highly variable both inter-annually and among replicates collected within a year (Figure 3.4-2). The before-after comparison showed that the mean 2014 TOC content in Doris Outflow sediments was not distinguishable from the 2009 mean ($p = 0.91$). Although Roberts Outflow TOC concentrations could not be statistically evaluated (because no baseline data were available), the mean 2014 TOC content of Roberts Outflow sediments was within the historical range observed in Reference B Outflow and Reference D Outflow sediments. For Little Roberts Outflow, the before-after comparison showed that the TOC content of sediments decreased significantly in 2014 compared to 2009 ($p = 0.0009$), and the BACI analysis indicated that there was no comparable decrease observed at the reference streams ($p = 0.0013$). This decrease in TOC at Little Roberts Outflow is likely related to the lower proportion of fine sediments in 2014 samples compared to 2009, since TOC concentrations tend to be higher in finer sediments (e.g., Secrieri and Oaie 2009). There is no reason to suspect that 2014 Project activities affected the sediment TOC content of exposure streams.

3.4.1.3 Total Arsenic

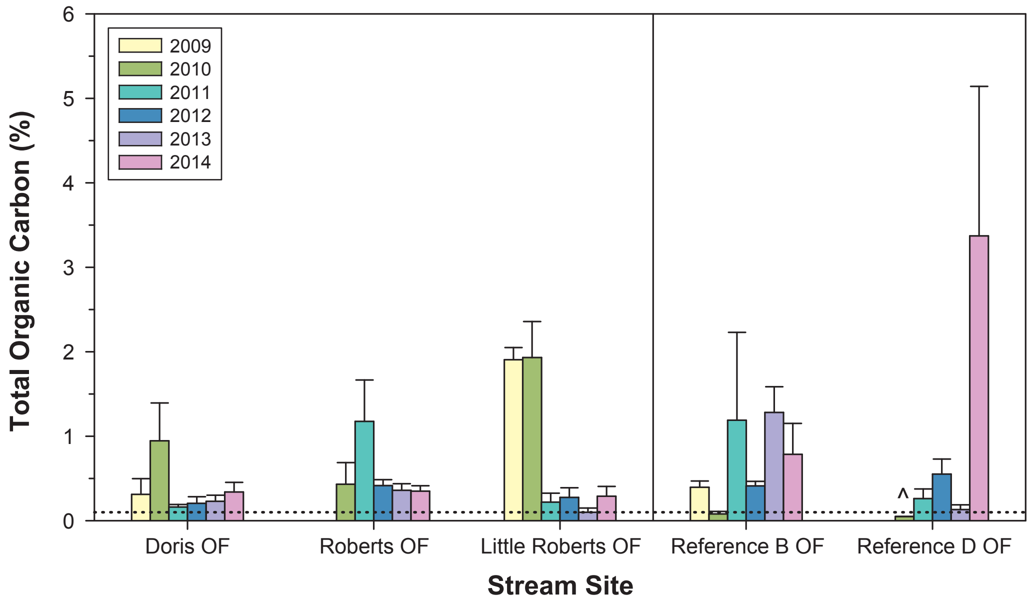
Mean arsenic concentrations in exposure stream sediments in 2014 were within or lower than the baseline range for each stream, and were below the CCME ISQG of 5.9 mg/kg and the PEL of 17 mg/kg (Figure 3.4-3). The before-after comparison showed that there were no significant differences between 2009 and 2014 mean total arsenic concentrations at Doris Outflow ($p = 0.47$) or Little Roberts Outflow ($p = 0.55$). Before-after analysis could not be performed for Roberts Outflow due to a lack of baseline data; however, arsenic concentrations in Roberts Outflow were within the range observed in reference lakes and among the lowest observed to date in Roberts Outflow. Therefore, the evidence suggested that 2014 Project activities did not adversely affect arsenic concentrations in exposure stream sediments.

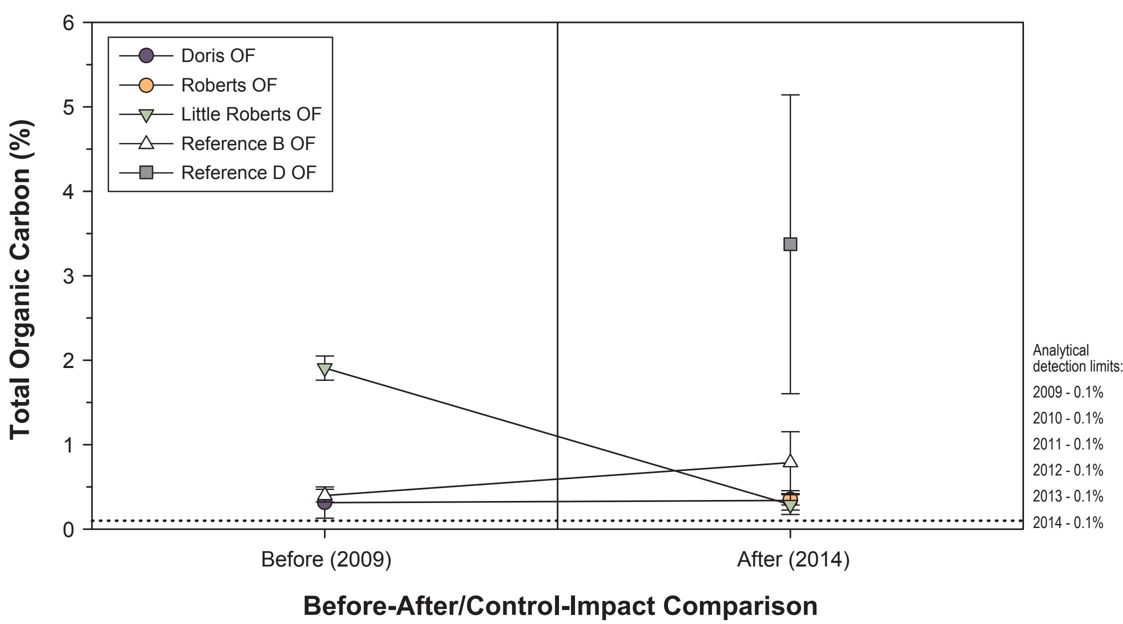
3.4.1.4 Total Cadmium

In Doris, Roberts, and Little Roberts outflows, all 2009 and 2014 sediment cadmium concentrations were below the analytical detection limits of 0.1 mg/kg (2009) or 0.05 mg/kg (2014) with the exception of one replicate sample collected from Little Roberts Outflow. Before-after analyses for Little Roberts Outflow were not considered reliable for cadmium in stream sediments because of the large proportion of data below analytical detection in the combined baseline and 2014 dataset (83%) and are not discussed. Total cadmium concentrations in stream sediments were well below the CCME ISQG of 0.6 mg/kg and the PEL of 3.5 mg/kg (Figure 3.4-4) in all 2014 samples. Therefore, there was no apparent effect of 2014 Project activities on sediment cadmium concentrations in the exposure streams.

Figure 3.4-2

Total Organic Carbon, Stream Sediments, Doris North Project, 2009 to 2014



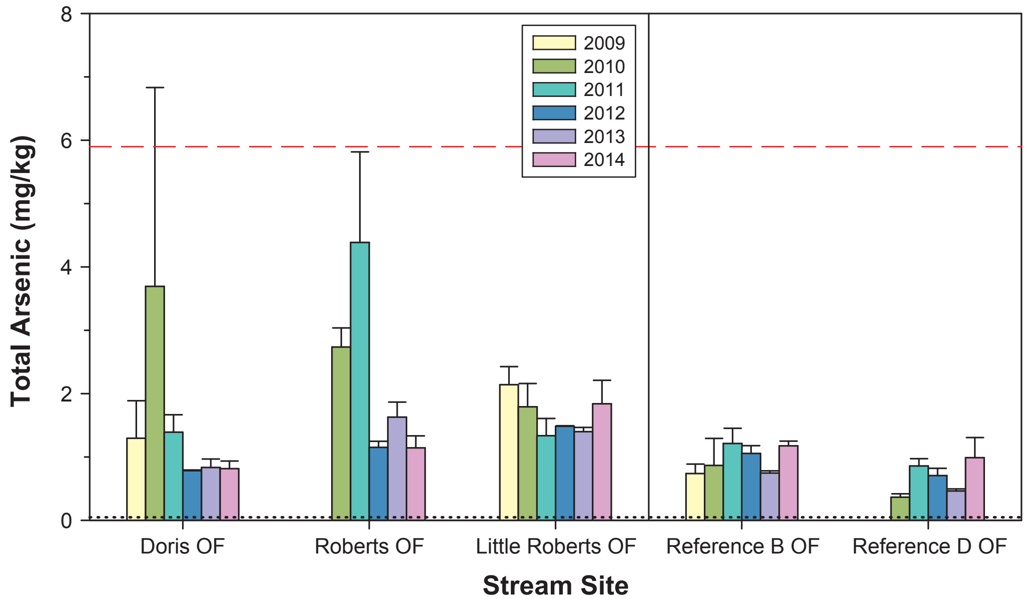


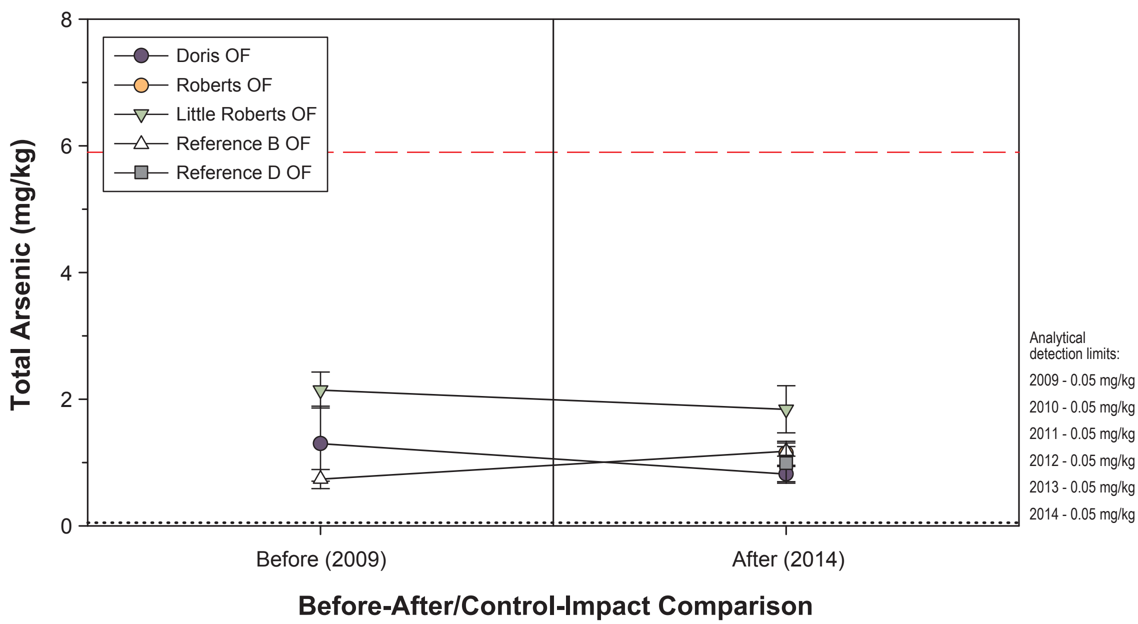
Notes: Error bars represent the standard error of the mean.
Black dotted lines represent the analytical detection limit; values below the detection limit are plotted at half the detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Total organic carbon content of sediments is a required parameter as part of benthic invertebrate surveys as per Schedule 5, s.16a (iii) of the MMER.

Figure 3.4-3

Total Arsenic Concentrations, Stream Sediments, Doris North Project, 2009 to 2014

ERM

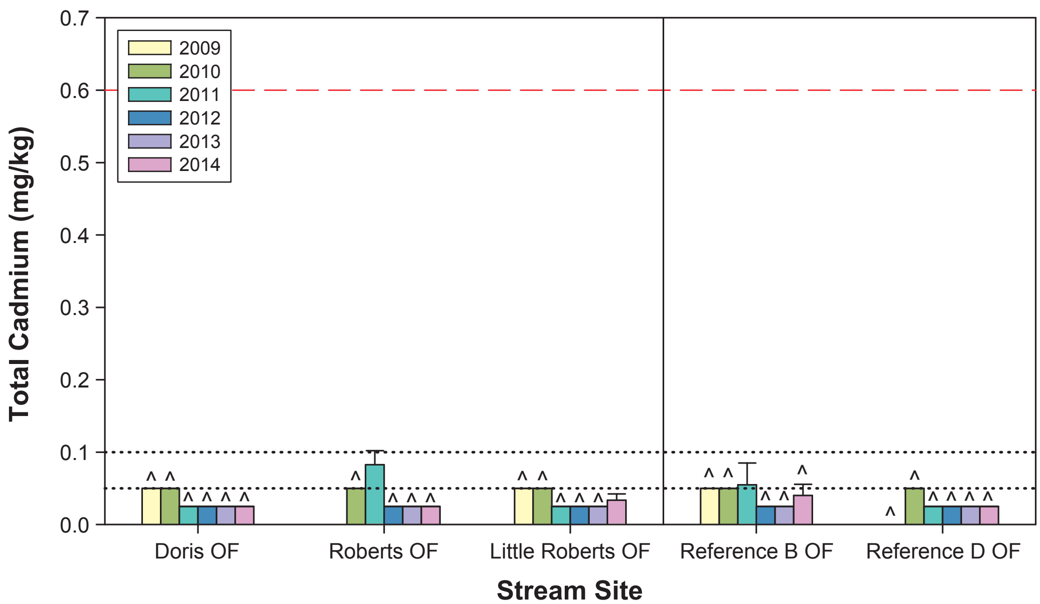


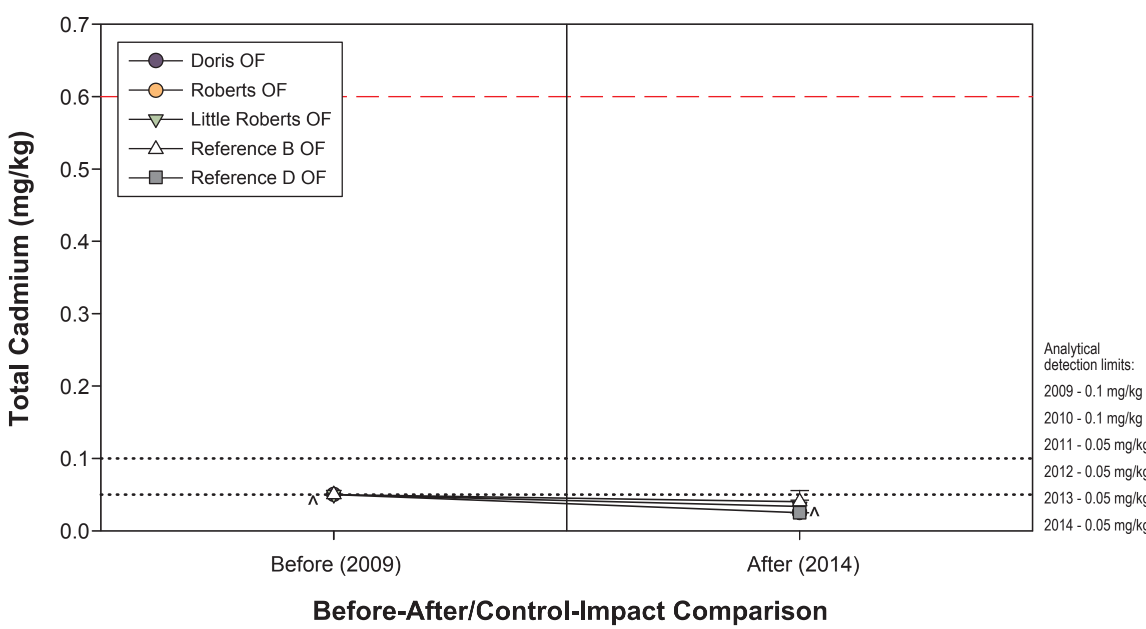


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent the analytical detection limit; values below the detection limit are plotted at half the detection limit.
Red dashed lines represent the CCME freshwater interim sediment quality guideline (ISQG) for arsenic (5.9 mg/kg); the probable effects level (PEL) for arsenic (17 mg/kg) is not shown.

Figure 3.4-4

Total Cadmium Concentrations, Stream Sediments, Doris North Project, 2009 to 2014





Notes: Error bars represent the standard error of the mean.
Black dotted lines represent the analytical detection limit; values below the detection limit are plotted at half the detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed lines represent the CCME freshwater interim sediment quality guideline (ISQG) for cadmium (0.6 mg/kg); the probable effects level (PEL) for cadmium (3.5 mg/kg) is not shown.

3.4.1.5 Total Chromium

Mean chromium concentrations in exposure stream sediments in 2014 were lower than mean baseline concentrations and were below the CCME ISQG of 37.3 mg/kg and the CCME PEL of 90 mg/kg (Figure 3.4-5). Mean 2014 chromium concentrations in Doris Outflow and Little Roberts Outflow sediments were lower than mean 2009 concentrations (Figure 3.4-5). The before-after analysis showed that these decreases were not statistically significant for Doris Outflow ($p = 0.16$) but marginally non-significant for Little Roberts Outflow ($p = 0.02$). The BACI analysis indicated a significant non-parallelism between Little Roberts Outflow and the reference streams during the before and after periods ($p = 0.0002$); however, the change in Little Roberts Outflow was a decline in chromium over time which is of little concern. No baseline data were available for Roberts Outflow; however, chromium concentrations also appeared to have decreased over time at this site (Figure 3.4-5). Thus, there was no apparent effect of 2014 Project activities on sediment chromium concentrations in exposure streams.

3.4.1.6 Total Copper

All sediment copper concentrations measured in 2014 were well below the CCME ISQG of 35.7 mg/kg and the PEL of 197 mg/kg (Appendix A). In both Doris Outflow and Little Roberts Outflow, mean total copper concentrations were slightly lower in 2014 than in 2009 (Figure 3.4-6). However, the before-after analysis indicated that the mean 2014 copper concentrations in Doris Outflow sediments was not distinguishable from the 2009 mean ($p = 0.34$).

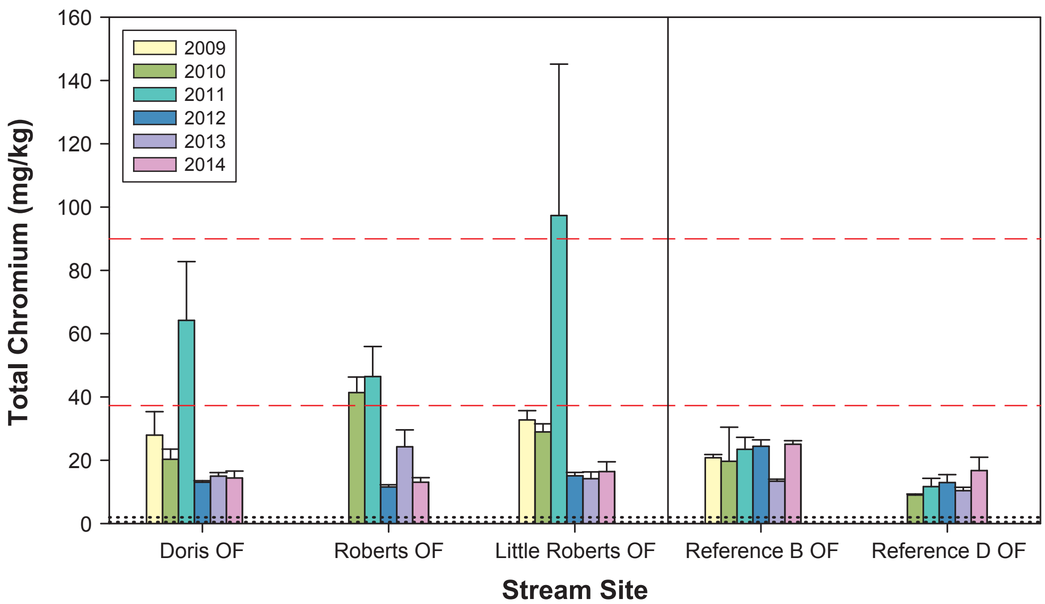
The difference for Little Roberts Outflow was marginally non-significant ($p = 0.02$); however, BACI analysis did not indicate evidence of a non-parallelism in trends for total copper over the before-after period for Little Roberts Outflow relative to the reference streams ($p = 0.14$). There were no baseline data for Roberts Outflow but copper concentrations appear to have generally decreased at this site since 2010, and the 2014 mean copper concentration in Roberts Outflow was the second lowest observed in Roberts Outflow since monitoring began. Therefore, the evidence suggests that 2014 Project activities had no effect on sediment copper concentrations in the exposure streams.

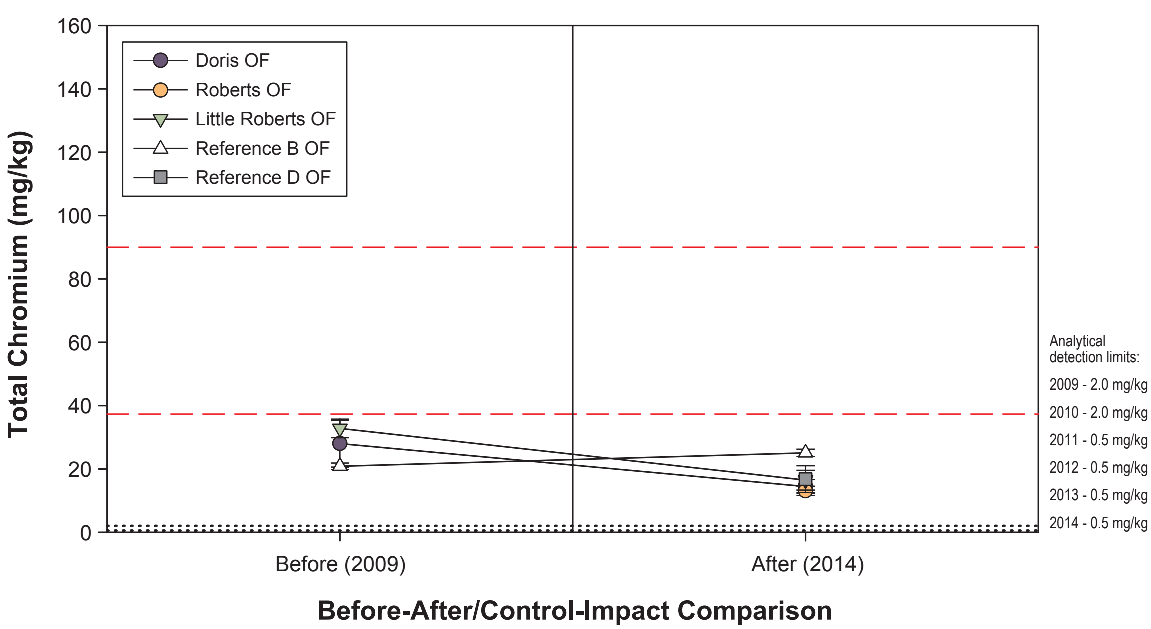
3.4.1.7 Total Lead

2014 lead concentrations in exposure stream sediments were well below the CCME ISQG of 35 mg/kg and the PEL of 91.3 mg/kg (Figure 3.4-7). In both Doris Outflow and Little Roberts Outflow, mean total lead concentrations in sediments were lower in 2014 than in 2009 (Figure 3.4-7). For Doris Outflow, the before-after comparison showed that the 2014 mean lead concentration was not distinguishable from the 2009 mean ($p = 0.38$); however, for Little Roberts Outflow, there was a significant difference in means ($p = 0.0065$). The BACI analysis indicated that the decrease in lead concentration in Little Roberts Outflow sediments was not paralleled at the reference streams ($p = 0.0056$). This decrease in lead concentration is not of environmental concern, and is likely related to the coarser nature of the sediments collected in 2014 compared to the finer sediments collected in 2009. There were no baseline data for Roberts Outflow, but lead concentrations appeared to have generally decreased at this site since 2010 and the 2014 mean lead concentration in Roberts Outflow was the second lowest observed in Roberts Outflow since monitoring began. Thus, there were no apparent adverse effects of 2014 Project activities on lead in exposure stream sediments.

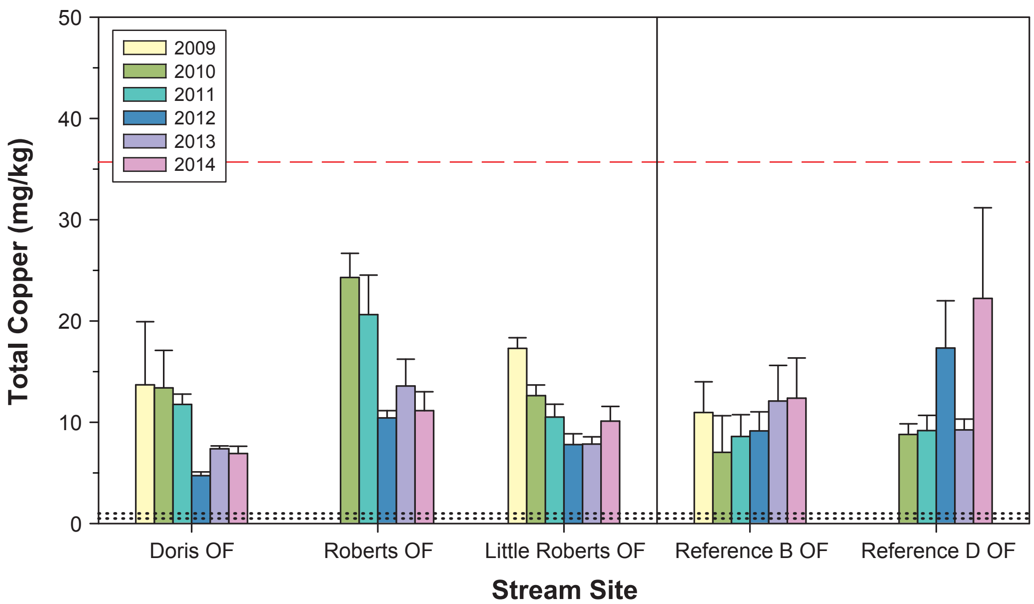
Total Chromium Concentrations, Stream Sediments, Doris North Project, 2009 to 2014

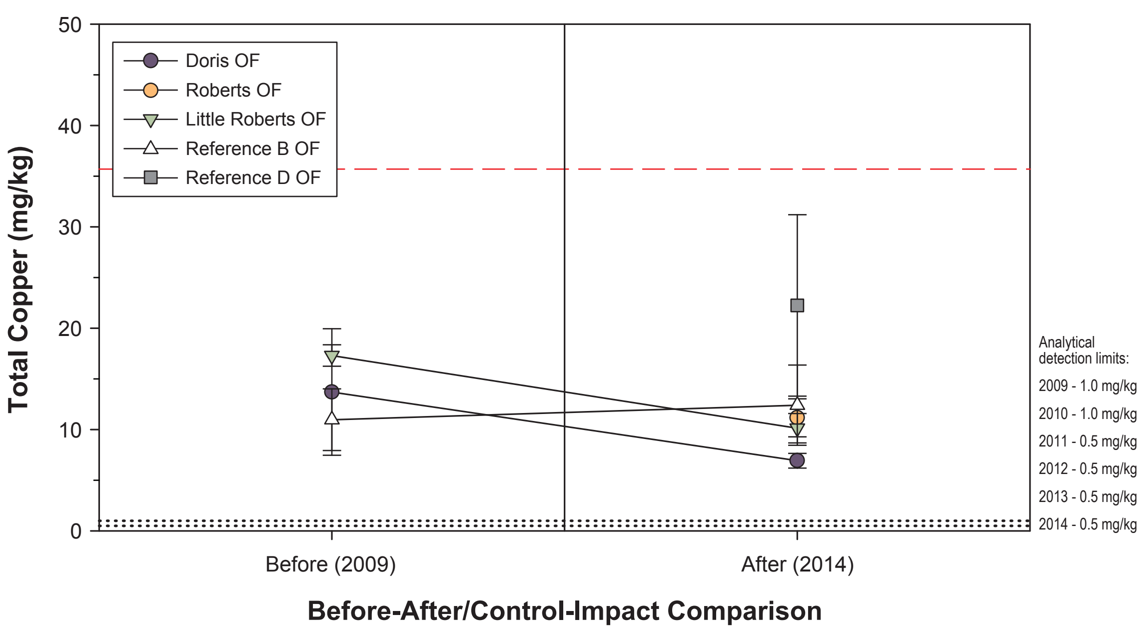
ERM





Notes: Error bars represent the standard error of the mean.
Black dotted lines represent the analytical detection limit; values below the detection limit are plotted at half the detection limit.
Red dashed lines represent the CCME freshwater interim sediment quality guideline (ISQG) for chromium (37.3 mg/kg) and the probable effects level (PEL) for chromium (90 mg/kg).

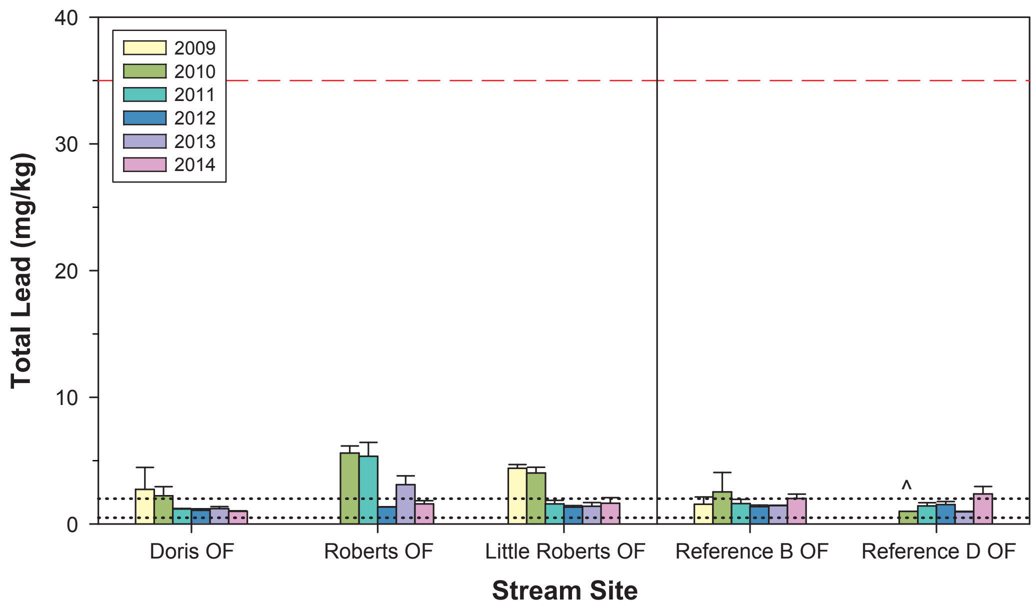


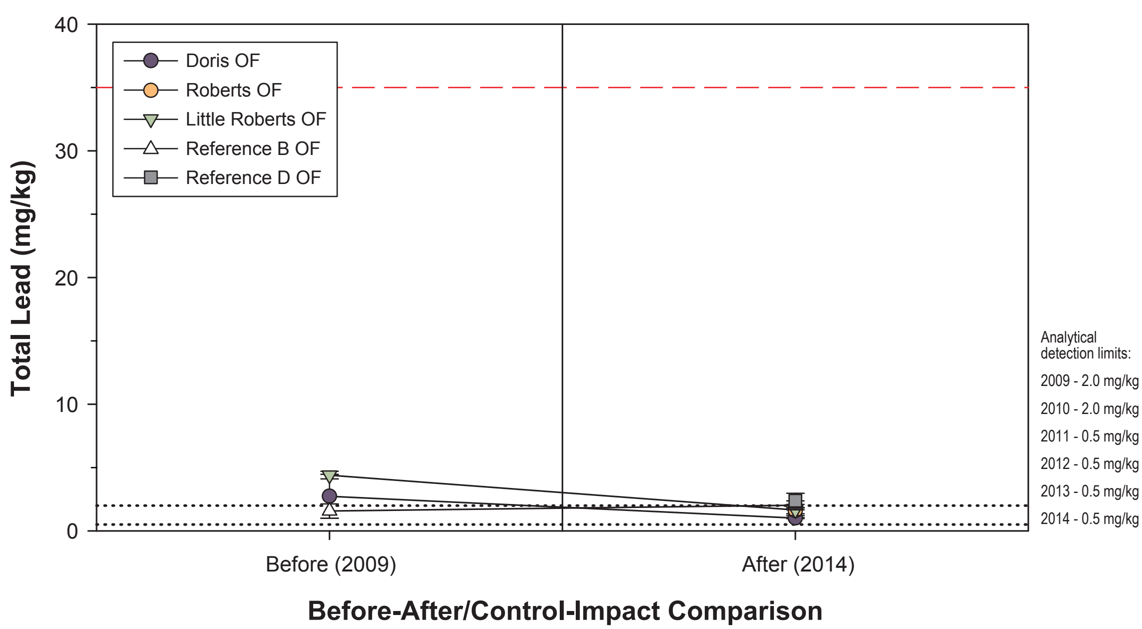


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent the analytical detection limit; values below the detection limit are plotted at half the detection limit.
Red dashed lines represent the CCME freshwater interim sediment quality guideline (ISQG) for copper (35.7 mg/kg); the probable effects level (PEL) for copper (197 mg/kg) is not shown.

Figure 3.4-7

Total Lead Concentrations, Stream Sediments, Doris North Project, 2009 to 2014





Notes: Error bars represent the standard error of the mean.
Black dotted lines represent the analytical detection limit; values below the detection limit are plotted at half the detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed lines represent the CCME freshwater interim sediment quality guideline (ISQG) for lead (35 mg/kg); the probable effects level (PEL) for lead (91.3 mg/kg) is not shown.

3.4.1.8 Total Mercury

2014 total mercury concentrations measured in Doris Outflow and Little Roberts Outflow sediments were below the analytical detection limit of 0.005 mg/kg in all samples and there was no evidence of an effect of 2014 Project activities on sediment mercury levels in these streams. The mean 2014 concentration at Roberts Outflow was similar to, but lower than, the concentration measured in Reference Lake B and Reference Lake D sediments. At all exposure sites, total mercury concentrations in sediments were well below the CCME ISQG of 0.17 mg/kg and the PEL of 0.486 mg/kg (Figure 3.4-8). Statistical analysis could not be performed for Roberts Outflow because there were no baseline data; however, total mercury concentrations appeared to be stable over time in this stream and in 2014 the mean concentration was lower than that measured in either reference stream. Consequently, there was no apparent effect of 2014 Project activities on total mercury concentrations in the sediments of exposure streams.

3.4.1.9 Total Zinc

In all three exposure streams, 2014 zinc concentrations in sediments were well below the CCME ISQG of 123 mg/kg and the PEL of 315 mg/kg (Figure 3.4-9). Graphical analysis suggests that the 2014 mean concentrations were lower than 2009 means in both Doris Outflow and Little Roberts Outflow (Figure 3.4-9). The before-after comparison indicated that the mean 2014 zinc concentration in Doris Outflow sediments was not distinguishable from the 2009 mean ($p = 0.26$); however, the difference was marginally non-significant for Little Roberts Outflow ($p = 0.02$).

The BACI analysis indicated a significant non-parallelism between Little Roberts Outflow and the reference streams during the before and after periods ($p = 0.0008$); however, the change in Little Roberts Outflow sediments was a decline in zinc over time which is of little concern. There were no baseline data for Roberts Outflow, but zinc concentrations also appeared to have decreased at this site since 2010, and the 2014 mean zinc concentration in Roberts Outflow was the second lowest observed in Roberts Outflow since monitoring began. Thus, there was no evidence that 2014 Project activities adversely affected zinc concentrations in exposure stream sediments.

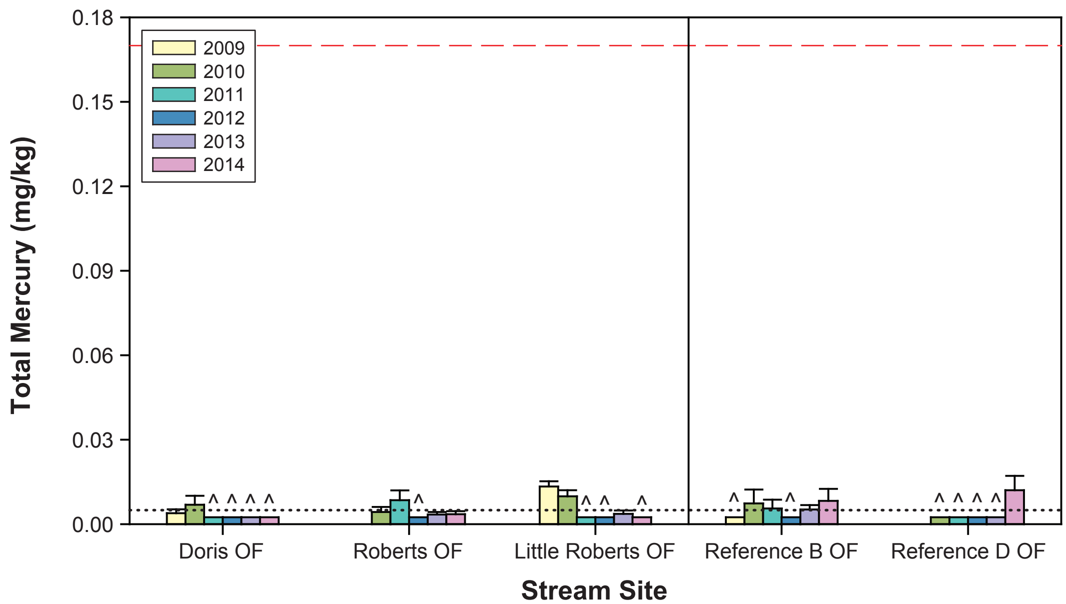
3.4.2 Lakes

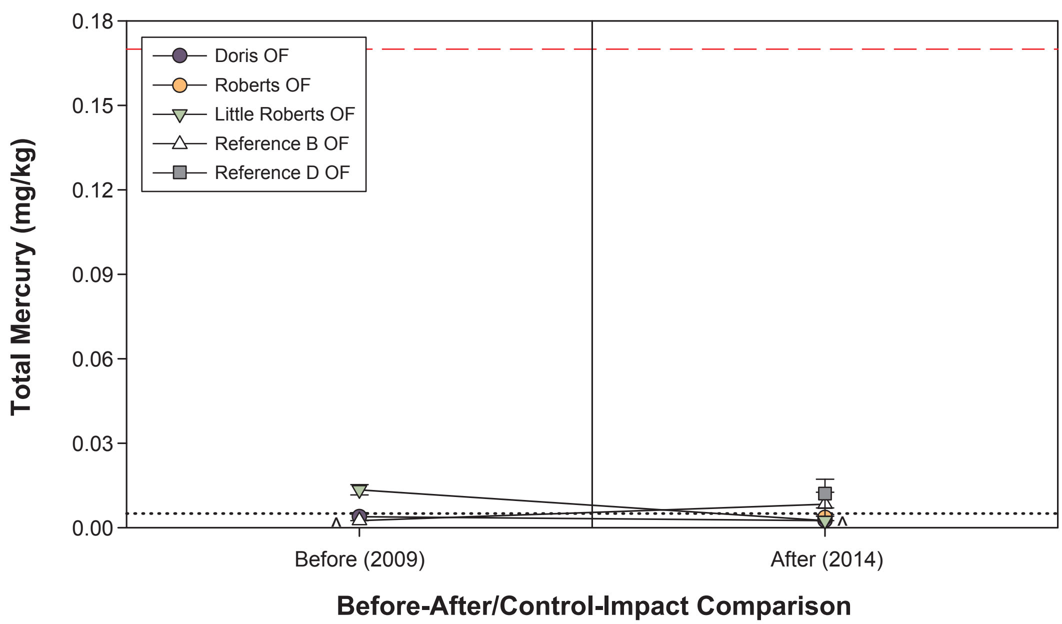
Sediment quality samples were collected from three exposure sites (Doris Lake North, Doris Lake South, and Little Roberts Lake) and two reference sites (Reference Lake B and Reference Lake D) in 2014. Sediment samples have been collected in the Doris North area since 1996. However, most of the historical data were not directly comparable to 2014 data because of differences in sampling locations, depth strata, and sampling methodology (Appendix B).

Sediment quality data from 1997 and 2009 were used for before-after comparisons for Doris Lake South and Little Roberts Lake, and data from 2009 were used for before-after comparisons for Doris Lake North. 1997 sediment sampling was conducted in July, while 2009 and 2014 sediment sampling was conducted in August. No baseline sediment quality data were available for the reference lakes; therefore, no BACI analyses were possible for the lake exposure sites. For the calculations of annual means for each variable, all analytical results for lake sediment samples collected in a given year were averaged.

Figure 3.4-8

Total Mercury Concentrations, Stream Sediments, Doris North Project, 2009 to 2014



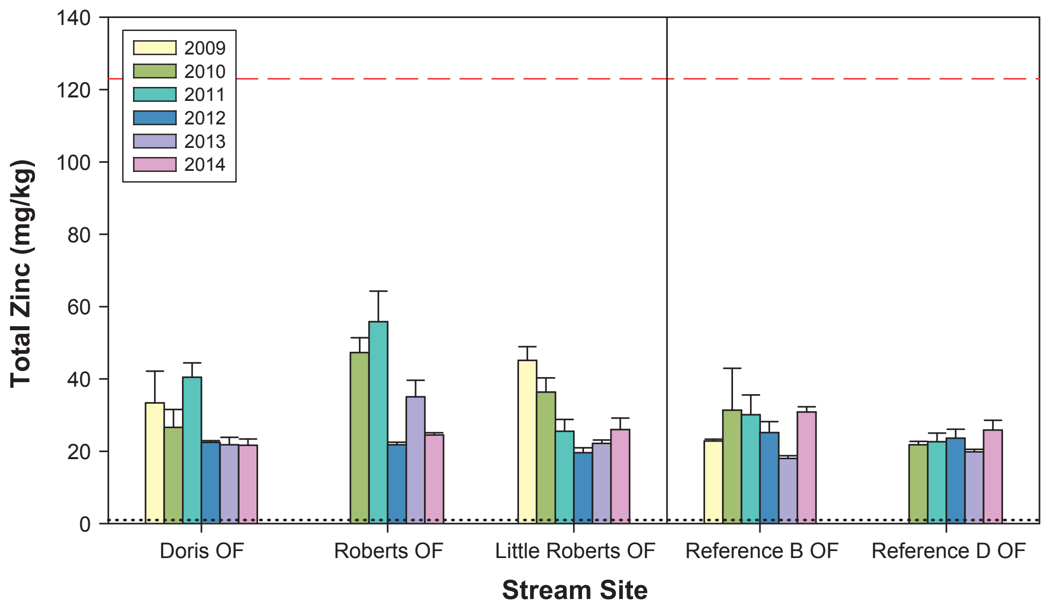


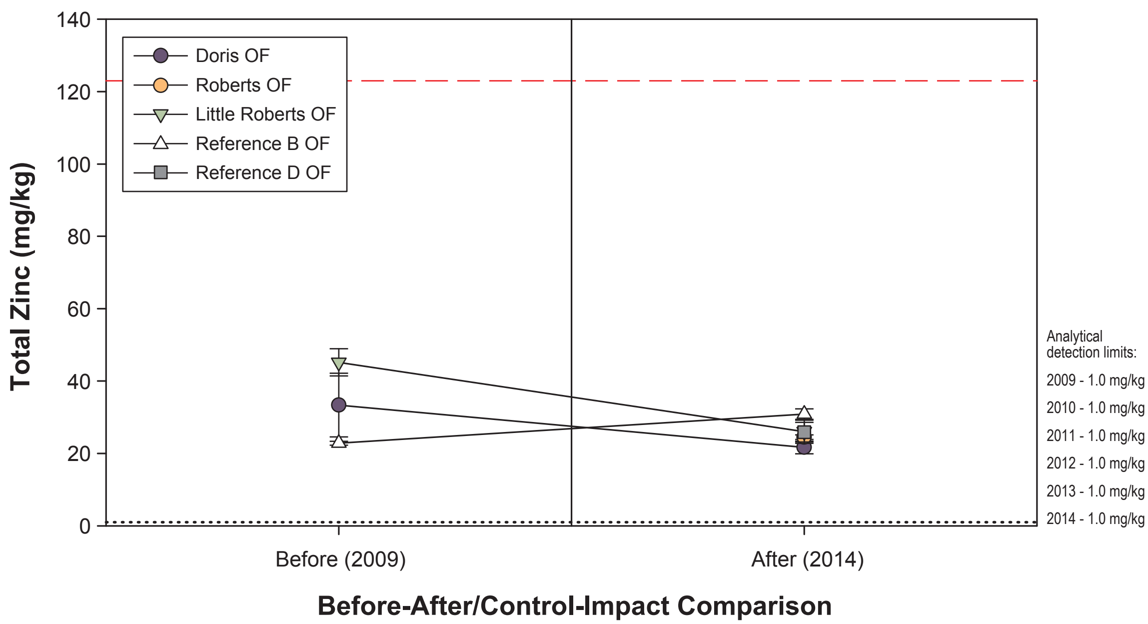
Analytical detection limits:
2009 - 0.005 mg/kg
2010 - 0.005 mg/kg
2011 - 0.005 mg/kg
2012 - 0.005 mg/kg
2013 - 0.005 mg/kg
2014 - 0.005 mg/kg

Notes: Error bars represent the standard error of the mean.
Black dotted lines represent the analytical detection limit; values below the detection limit are plotted at half the detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed lines represent the CCME freshwater interim sediment quality guideline (ISQG) for mercury (0.17 mg/kg); the probable effects level (PEL) for mercury (0.486 mg/kg) is not shown.

Figure 3.4-9

Total Zinc Concentrations, Stream Sediments, Doris North Project, 2009 to 2014





Notes: Error bars represent the standard error of the mean.
Black dotted lines represent the analytical detection limit; values below the detection limit are plotted at half the detection limit.
Red dashed lines represent the CCME freshwater interim sediment quality guideline (ISQG) for zinc (123 mg/kg); the probable effects level (PEL) for zinc (315 mg/kg) is not shown.

3.4.2.1 Particle Size

Consistent with previous years, exposure and reference lakes were dominated by fine sediments (silt and clay) in 2014 (Figure 3.4-10). In the three exposure lakes, the particle size composition was generally similar between 2009 and 2014. However, the before-after analysis indicated that the silt content increased significantly ($p = 0.0049$) while the clay content decreased significantly ($p = 0.0078$) in 2014 compared to 2009 in sediment samples collected from Doris Lake South.

For Little Roberts Lake, the before-after analysis indicated that the silt content increased significantly ($p = 0.0004$) while the sand content decreased significantly ($p= 0.0002$) in 2014 compared to 2009. There was also a marginally non-significant decrease in clay content in Little Roberts Lake ($p = 0.0329$). Before-after analyses for gravel are not discussed as they were considered unreliable due to the high proportion of the baseline and 2014 dataset that were below analytical detection limits. A visual examination of the time series of data available for gravel did not indicate any obvious differences over time for the exposure lakes (Figure 3.4-10).

In Doris Lake North, no statistically significant changes in the particle size composition were detected from 2009 to 2014 ($p = 0.0682$, 0.1042, and 0.2285 for sand, silt, and clay content, respectively).

BACI analyses could not be performed due to a lack of pre-construction data for reference lakes. However, variation in sediment particle size composition was likely unrelated to 2014 Project activities, and probably reflected natural spatial heterogeneity in lake sediments.

3.4.2.2 Total Organic Carbon

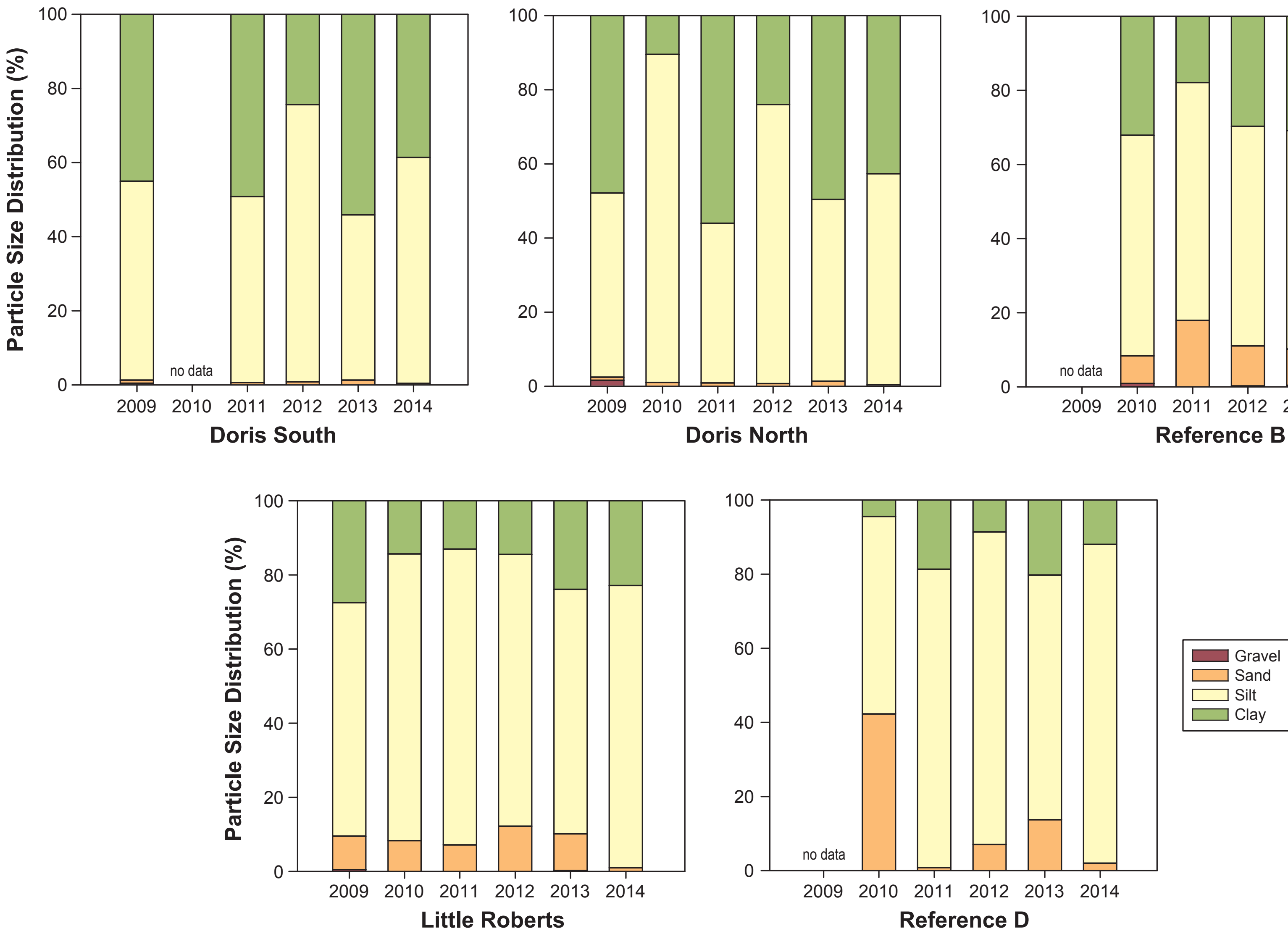
Mean 2014 TOC levels in Doris Lake South and Doris Lake North were slightly higher than baseline TOC levels. In Little Roberts Lake sediments mean 2014 TOC levels were within the range of baseline (Figure 3.4-11). The before-after comparison concluded that there was a significant difference between mean baseline and mean 2014 TOC level in Doris Lake North ($p = 0.0065$) but not in Doris Lake South ($p = 0.74$) or Little Roberts Lake ($p = 0.82$). No BACI analysis could be performed because no baseline data exists for the reference lakes. However, the statistical analyses for Doris Lake North are based on comparison of 2014 data to one year of baseline data (2009) and the plots of historical data do not show a steadily increasing trend at this site over time. Additionally, the difference between 2009 and 2014 means for Doris North is quite small (0.19%) and is likely related to natural variability rather than Project effects. Therefore, there was likely no effect of 2014 Project activities on the TOC content of exposure lakes.

3.4.2.3 Total Arsenic

As observed in baseline years, mean 2014 arsenic concentrations in Doris Lake South sediments and Doris Lake North sediments were higher than the CCME ISQG of 5.9 mg/kg. Doris Lake South sediment arsenic concentrations were also above the PEL of 17 mg/kg (Figure 3.4-12). The mean 2014 arsenic concentration in Little Roberts Lake sediments was lower than both the CCME ISQG and PEL guidelines (Figure 3.4-12). Mean 2014 arsenic concentrations in the exposure lake sediments were greater than baseline means in Doris Lake South and Little Roberts Lake, but lower than the baseline mean in Doris Lake North (Figure 3.4-12).

Figure 3.4-10

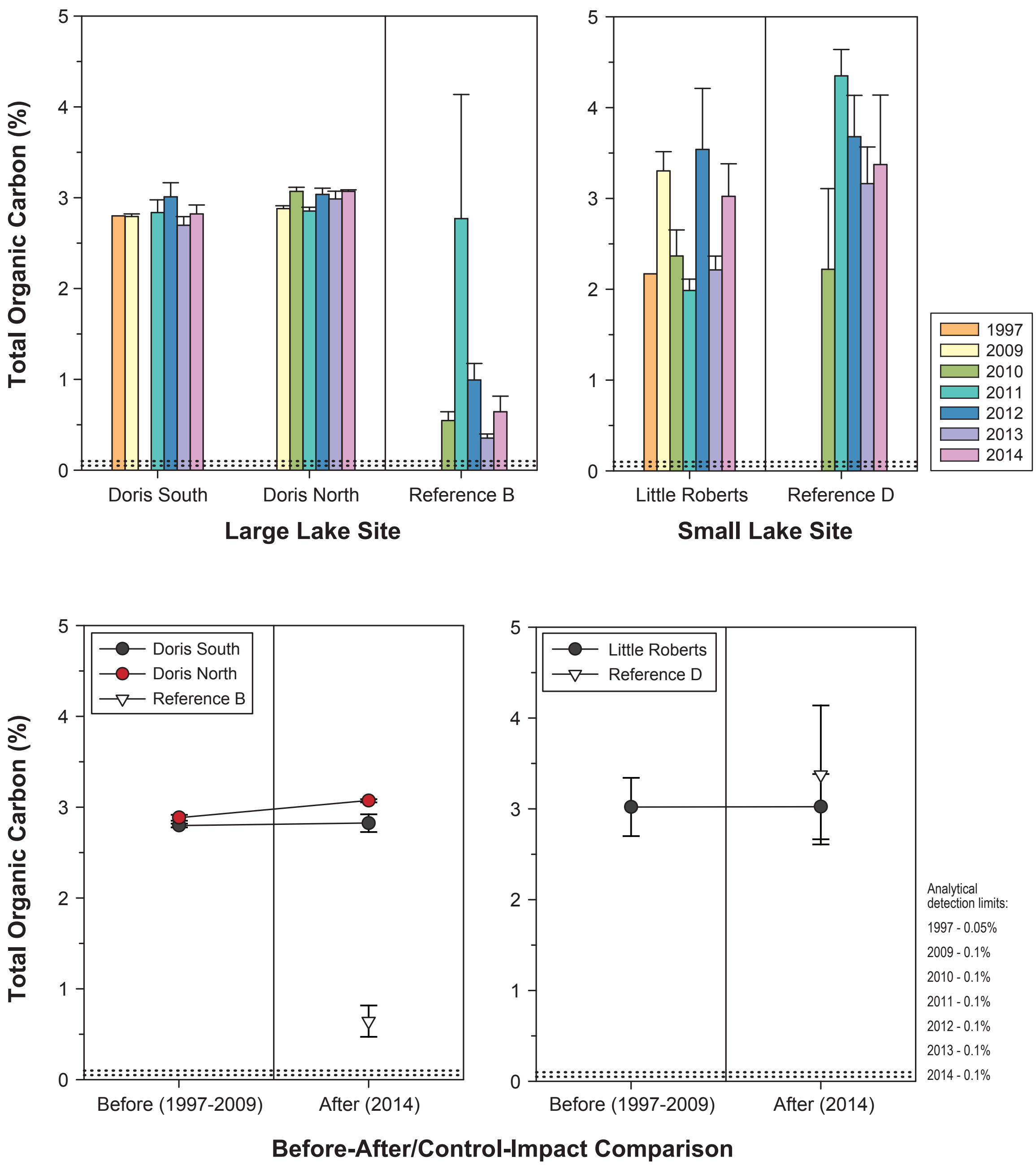
Particle Size Distribution, Lake Sediments, Doris North Project, 2009 to 2014



Notes: Stacked bars represent the mean of replicate samples.
Particle size distribution of sediments is a required parameter as part of benthic invertebrate surveys as per Schedule 5, s.16a (iii) of the MMER.

Figure 3.4-11

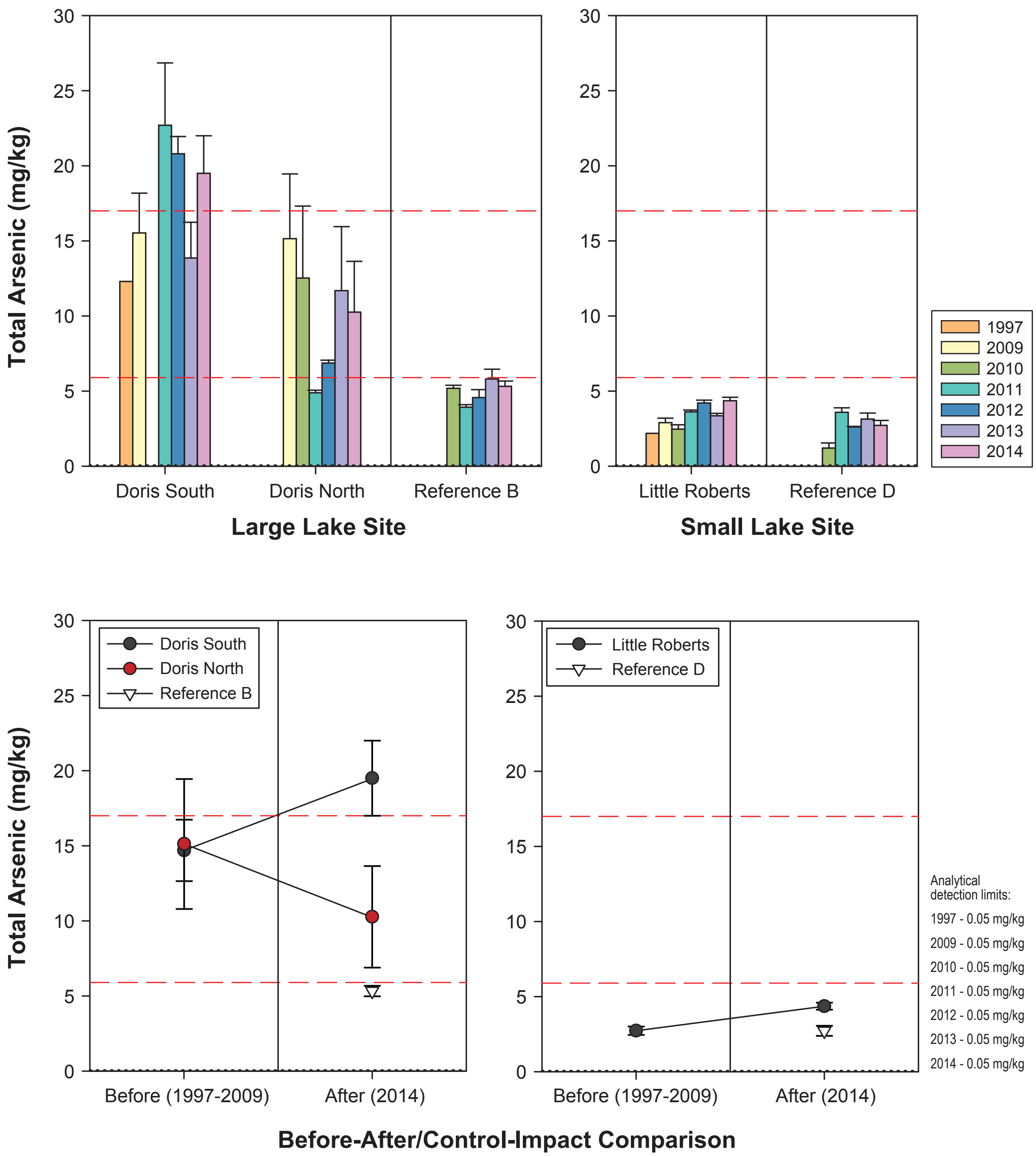
Total Organic Carbon, Lake Sediments, Doris North Project, 1997 to 2014



Notes: Error bars represent the standard error of the mean of replicates.
Dotted lines represent the analytical detection limit; values below the detection limit are plotted at half the detection limit.
Total organic carbon content of sediments is a required parameter as part of benthic invertebrate surveys as per Schedule 5, s.16a (iii) of the MMER.

Figure 3.4-12

Total Arsenic Concentrations, Lake Sediments, Doris North Project, 1997 to 2014



Notes: Error bars represent the standard error of the mean of replicates.
Dotted lines represent the analytical detection limit; values below the detection limit are plotted at half the detection limit.
Red dashed lines represent the CCME freshwater interim sediment quality guideline (ISQG) for arsenic (5.9 mg/kg) and the probable effects level (PEL) for arsenic (17 mg/kg).

The before-after comparison indicated that 2009 and 2014 mean arsenic levels were not distinguishable for either Doris Lake South or Doris Lake North (p = 0.135 and p = 0.42, respectively), but that the increase from 2009 to 2014 for Little Roberts Lake was statistically significant (p = 0.0019). Figure 3.4-12 indicated a slight increasing trend for Little Roberts Lake over time; however, 2014 concentrations remained comparable to reference lake concentrations and the mean 2014 arsenic concentration in Little Roberts Lake sediments was lower than both the CCME ISQG and PEL guidelines (Figure 3.4-12). It is not clear whether the observed increase in arsenic concentrations in Little Roberts Lake is a Project effect or due to natural variability but there is no known Project-related source of arsenic contamination to exposure lakes and the concentration of arsenic has remained less than the CCME ISQG guideline through time in Little Roberts Lake; therefore a Project-related effect was deemed unlikely. No project-related effects were found for total arsenic in Doris Lake South or Doris Lake North.

3.4.2.4 Total Cadmium

Mean 2014 cadmium concentrations in Doris Lake South and Little Roberts Lake sediments were within the range of baseline means, while the mean 2014 cadmium concentration in Doris Lake North sediments was slightly lower than the 2009 mean (Figure 3.4-13). All 2014 mean cadmium concentrations in exposure and reference lake sediments were below the CCME ISQG of 0.6 mg/kg and the PEL of 3.5 mg/kg (Figure 3.4-13). Based on the before-after analysis, there were no significant changes in mean sediment cadmium concentrations between baseline years and 2014 in the exposure lakes (p = 0.80 for Doris Lake South, p = 0.03 for Doris Lake North, and p = 0.73 for Little Roberts Lake). The result for Doris Lake North (p = 0.03) was considered marginally non-significant but the change was a decline over time which is of little concern. Thus, 2014 Project activities had no apparent adverse effect on cadmium concentrations in the exposure lake sediments.

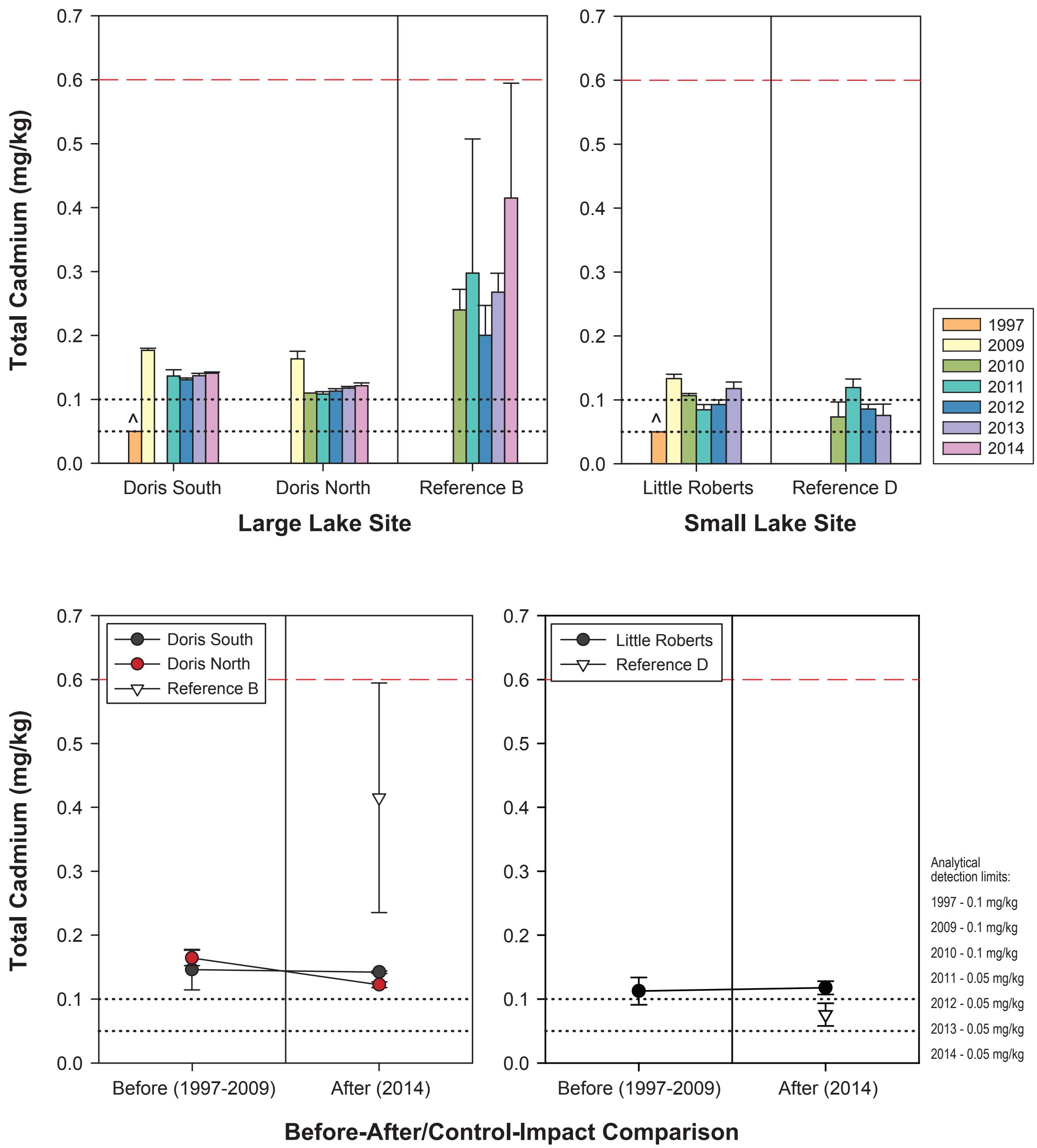
3.4.2.5 Total Chromium

Mean 2014 chromium concentrations in Doris Lake South and Little Roberts Lake sediments were within the range of baseline concentrations; in Doris Lake North, total chromium concentrations in 2014 were slightly higher than baseline (2009) concentrations. Sediment chromium concentrations were naturally high in the exposure and reference lake sediments, as all baseline and 2014 concentrations were above the CCME ISQG of 37.3 mg/kg, but below the CCME PEL of 90 mg/kg, with the exception of Doris Lake South sediments in 1997 which were also above the CCME PEL (Figure 3.4-14).

In the exposure lakes, mean 2014 sediment chromium concentrations were similar to baseline concentrations, and the before-after analysis confirmed that there was no difference in means between baseline years and 2014 for any exposure lake (p = 0.56 for Doris Lake South, p = 0.30 for Doris Lake North, and p = 0.83 for Little Roberts Lake). Therefore, there was no evidence of an effect of 2014 Project activities on total chromium concentrations in exposure lake sediments.

Figure 3.4-13

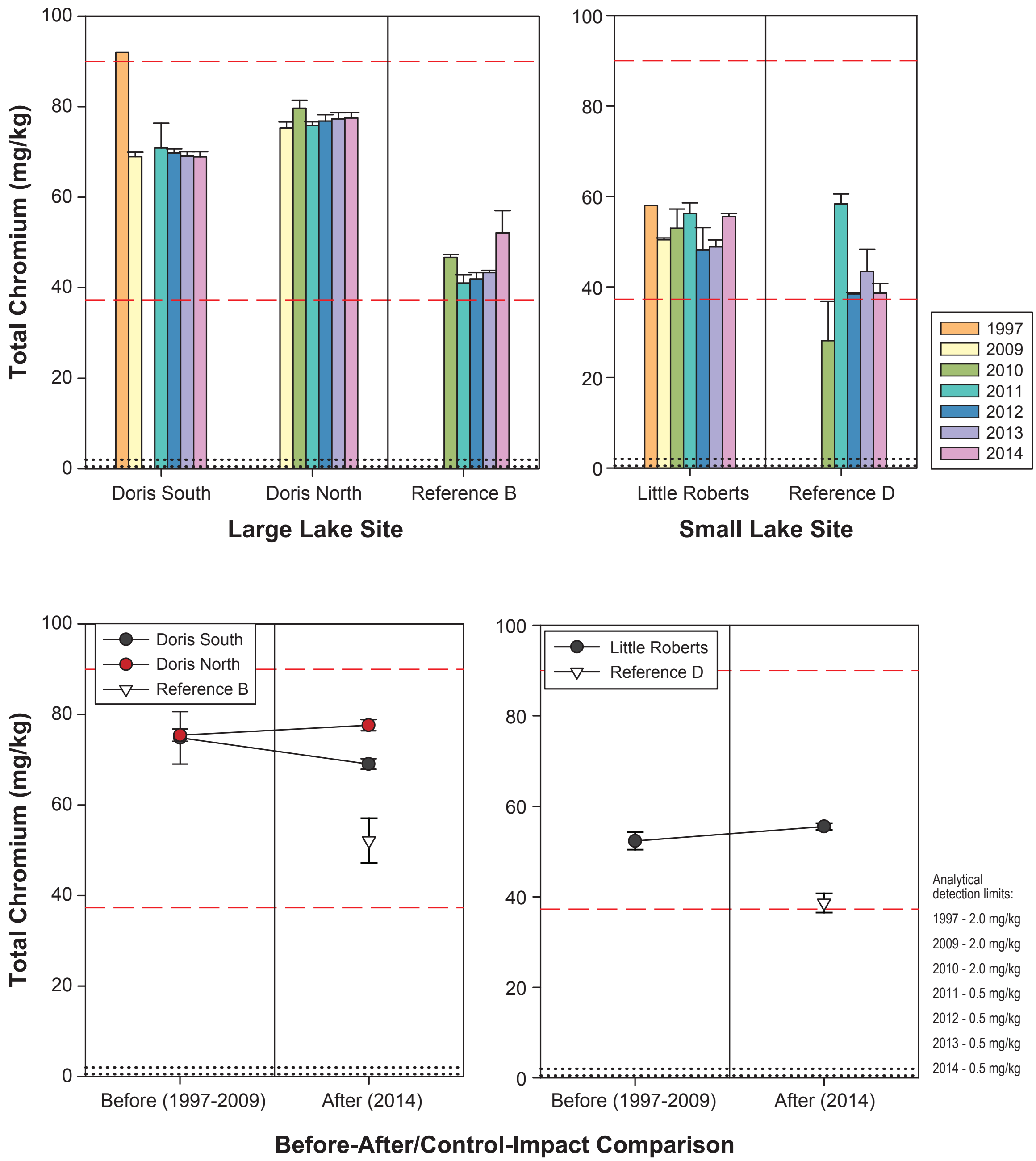
Total Cadmium Concentrations, Lake Sediments, Doris North Project, 1997 to 2014



Notes: Error bars represent the standard error of the mean of replicates.
Dotted lines represent the analytical detection limit; values below the detection limit are plotted at half the detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed lines represent the CCME freshwater interim sediment quality guideline (ISQG) for cadmium (0.6 mg/kg); the probable effects level (PEL) for cadmium (3.5 mg/kg) is not shown.

Figure 3.4-14

Total Chromium Concentrations, Lake Sediments, Doris North Project, 1997 to 2014



Notes: Error bars represent the standard error of the mean of replicates.
Dotted lines represent the analytical detection limit; values below the detection limit are plotted at half the detection limit.
Red dashed lines represent the CCME freshwater interim sediment quality guideline (ISQG) for chromium (37.3 mg/kg) and the probable effects level (PEL) for chromium (90 mg/kg).

3.4.2.6 Total Copper

Mean baseline and 2014 copper concentrations in sediments were slightly higher than the CCME ISQG of 35.7 mg/kg in both Doris Lake South and Doris Lake North, but were well below the PEL of 197 mg/L. In Little Roberts Lake, mean baseline and 2014 concentrations were below both the ISQG and PEL guidelines (Figure 3.4-15). At all three exposure lake sites, graphical analysis showed that mean 2014 sediment copper concentrations were within the range of, or lower than, baseline means (Figure 3.4-15).

The before-after analysis indicated that this decrease was statistically significant for Doris Lake South ($p < 0.0001$) and Doris Lake North sediments ($p = 0.003$), but that there was no significant difference between the baseline and the 2014 mean for Little Roberts Lake sediments ($p = 0.79$). A decrease in total copper concentrations in Doris Lake South and North sediments is not of concern; therefore, the evidence suggests that 2014 Project activities did not adversely affect copper concentrations in the sediments of exposure lakes.

3.4.2.7 Total Lead

Mean sediment lead concentrations in 2014 were within or lower than the baseline range for all exposure lakes and well below the CCME ISQG of 35 mg/kg and the PEL of 91.3 mg/kg (Figure 3.4-16). The before-after comparison showed that the mean 2014 lead concentrations at the exposure lakes were not significantly different from the baseline means ($p = 0.05$ for Doris Lake South; $p = 0.014$ for Doris Lake North; and $p = 0.795$ for Little Roberts Lake). The results for Doris Lake South and Doris Lake North were marginally non-significant. BACI analyses could not be performed due to the lack of baseline data for sediments in reference lakes; however, the change in the sediment lead concentration in Doris Lake South was a decline over time which is of little concern. Thus, the evidence suggests that 2014 Project activities did not adversely affect lead concentrations in the sediments of exposure lakes.

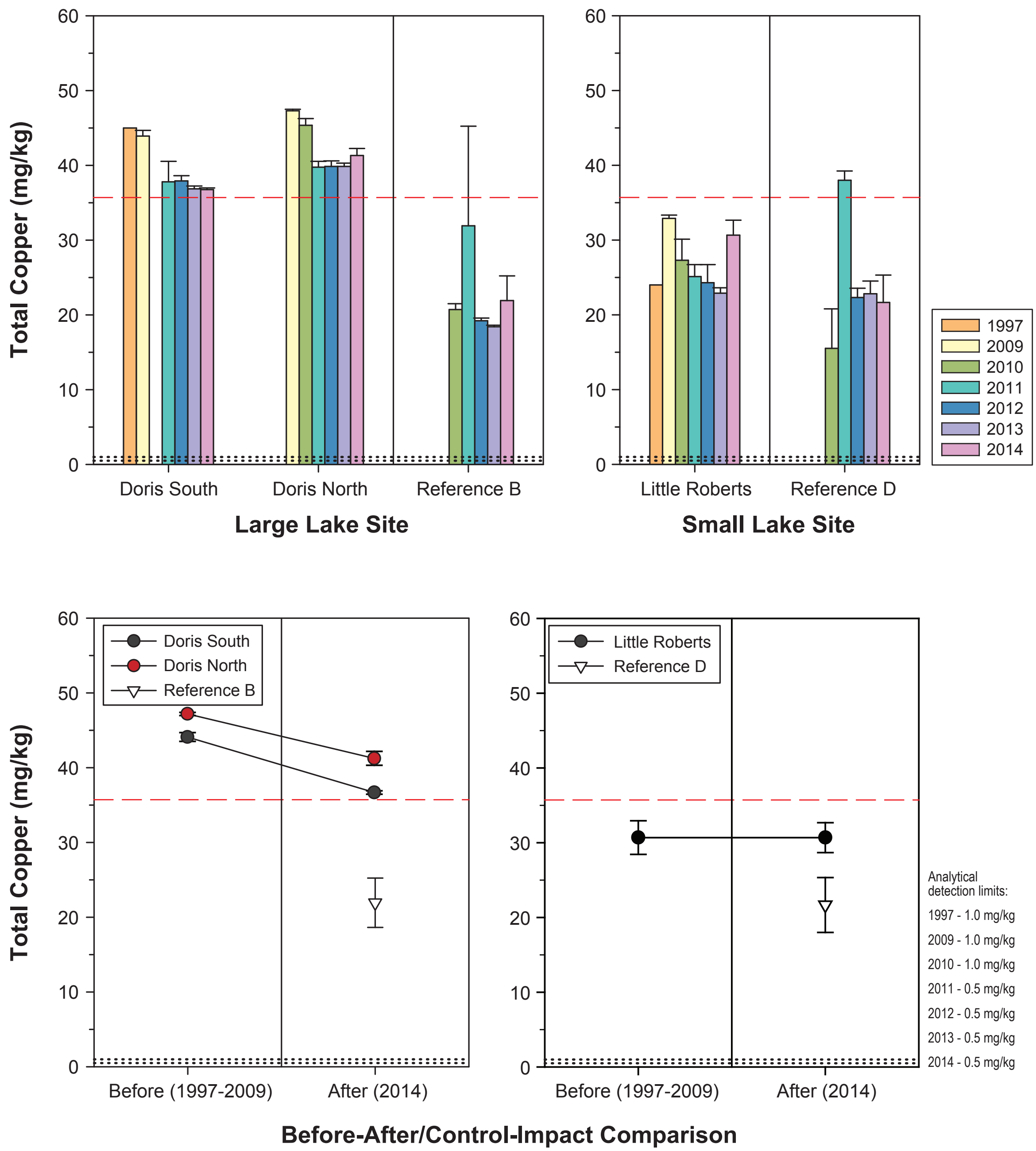
3.4.2.8 Total Mercury

In all exposure lakes, sediment mercury concentrations measured in 2014 were similar to or lower than baseline concentrations, and were well below the CCME ISQG of 0.17 mg/kg and the PEL of 0.486 mg/kg (Figure 3.4-17). The before-after comparison confirmed that the 2014 mean mercury concentration was not significantly different from the baseline mean for any exposure lake ($p = 0.76$ for Doris Lake South, $p = 0.12$ for Doris Lake North, and $p = 0.77$ for Little Roberts Lake). Thus, there was no indication that 2014 Project activities affected sediment mercury concentrations in exposure lakes.

3.4.2.9 Total Zinc

Mean 2014 zinc concentrations in the sediments of Doris Lake South and Doris Lake North were similar between baseline years and 2014; mean 2014 concentrations in Little Roberts Lake were notably higher than baseline concentrations. In exposure lakes, 2014 zinc concentrations were always below the CCME ISQG of 123 mg/kg and the PEL of 315 mg/kg (Figure 3.4-18).

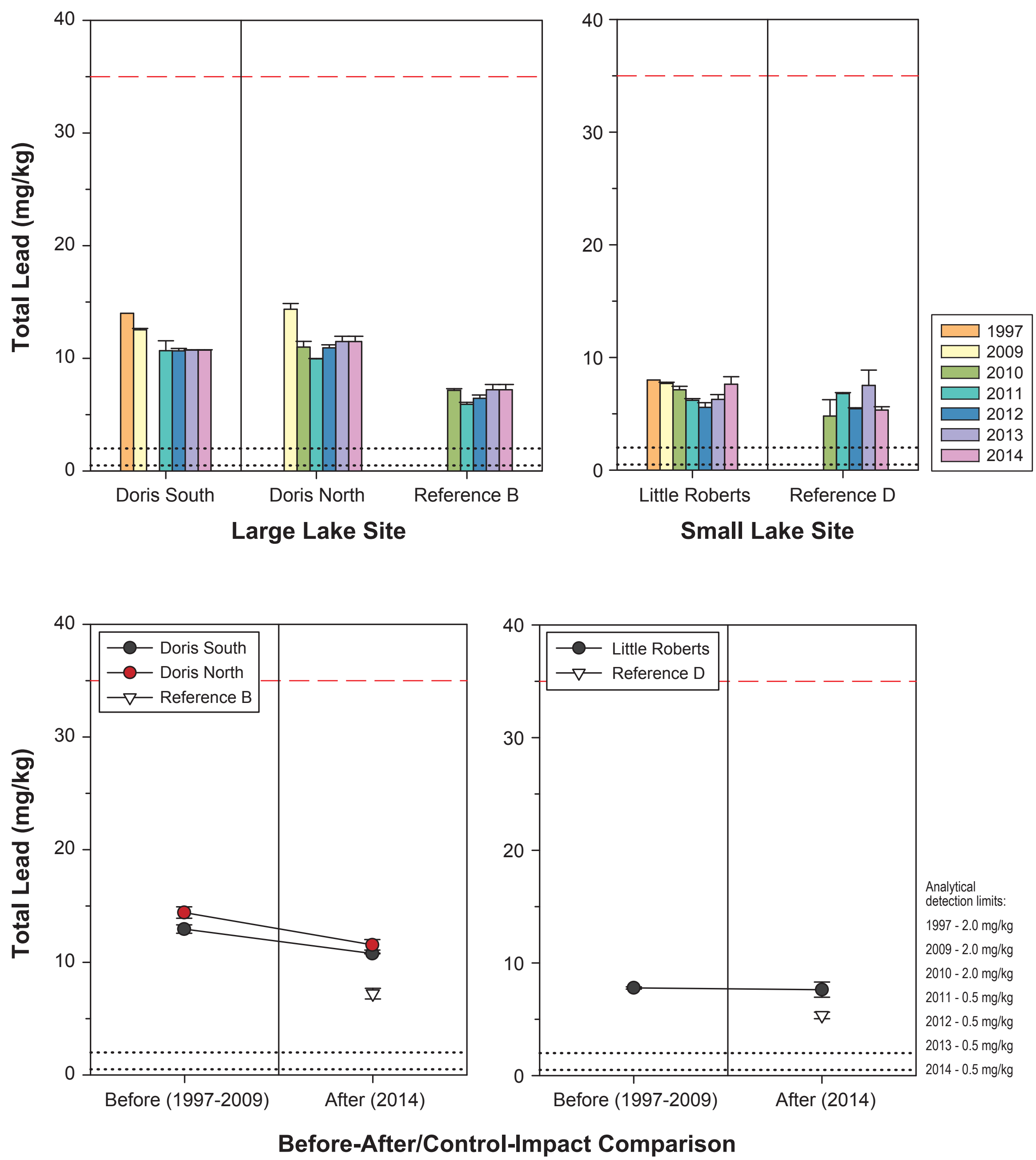
Total Copper Concentrations, Lake Sediments, Doris North Project, 1997 to 2014



Notes: Error bars represent the standard error of the mean of replicates.
Dotted lines represent the analytical detection limit; values below the detection limit are plotted at half the detection limit.
Red dashed lines represent the CCME freshwater interim sediment quality guideline (ISQG) for copper (35.7 mg/kg); the probable effects level (PEL) for copper (197 mg/kg) is not shown.

Figure 3.4-16

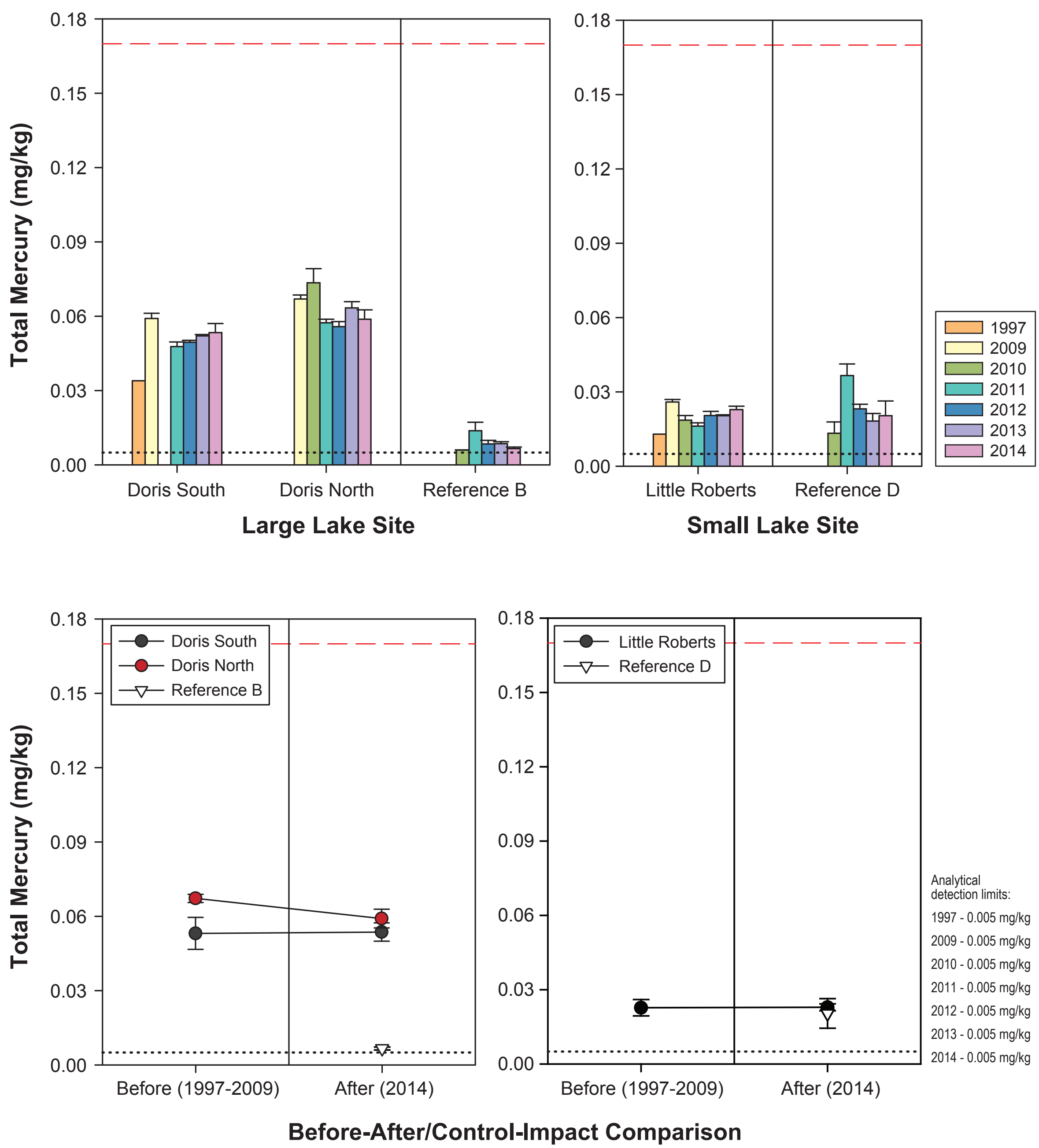
Total Lead Concentrations, Lake Sediments, Doris North Project, 1997 to 2014



Notes: Error bars represent the standard error of the mean of replicates.
Dotted lines represent the analytical detection limit; values below the detection limit are plotted at half the detection limit.
Red dashed lines represent the CCME freshwater interim sediment quality guideline (ISQG) for lead (35 mg/kg); the probable effects level (PEL) for lead (91.3 mg/kg) is not shown.

Figure 3.4-17

Total Mercury Concentrations, Lake Sediments, Doris North Project, 1997 to 2014

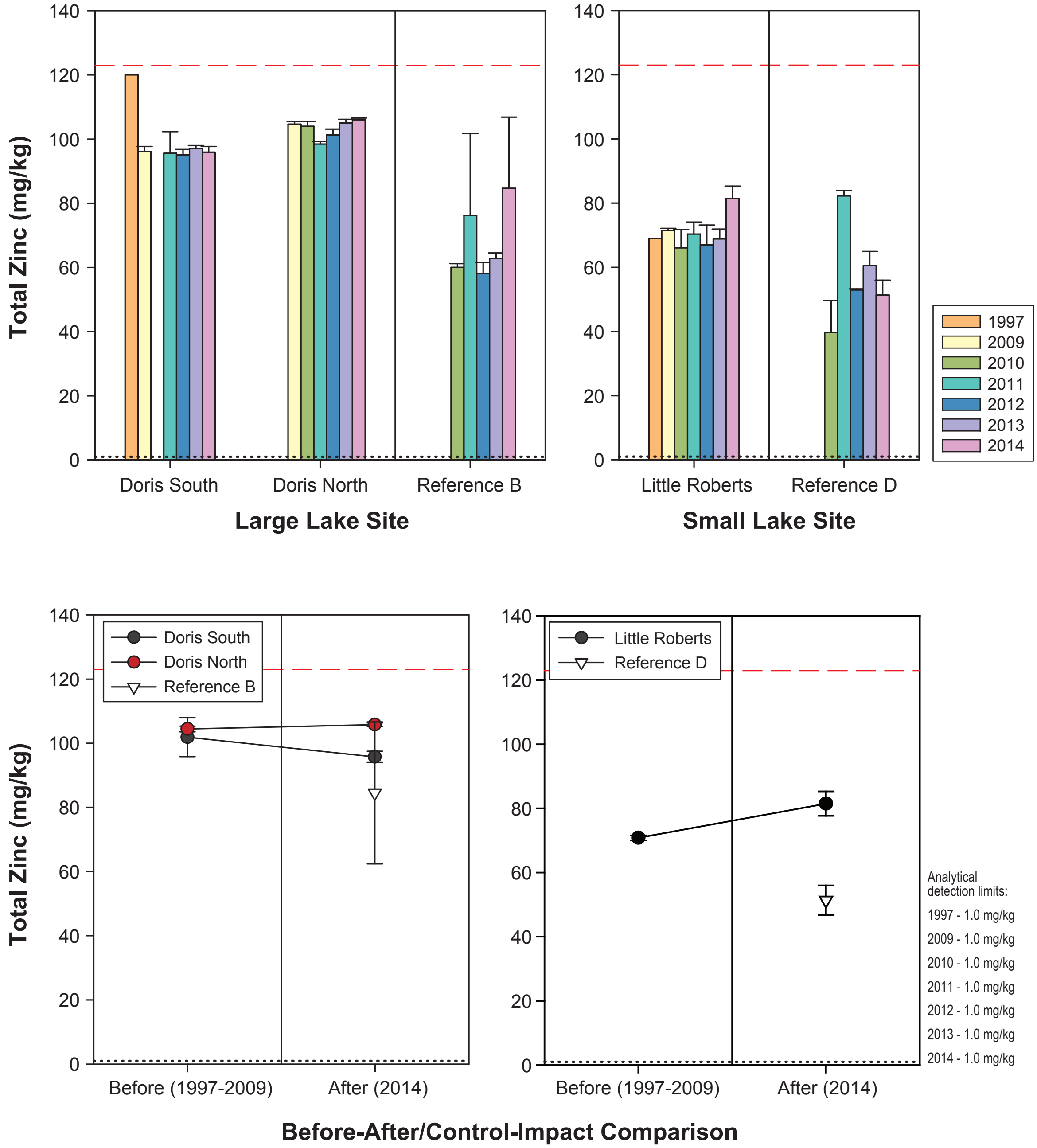


Notes: Error bars represent the standard error of the mean of replicates.
Dotted lines represent the analytical detection limit; values below the detection limit are plotted at half the detection limit.
Red dashed lines represent the CCME freshwater interim sediment quality guideline (ISQG) for mercury (0.17 mg/kg); the probable effects level (PEL) for mercury (0.486 mg/kg) is not shown.

Figure 3.4-18

Total Zinc Concentrations, Lake Sediments, Doris North Project, 1997 to 2014

ERM



Notes: Error bars represent the standard error of the mean of replicates.
Dotted lines represent the analytical detection limit; values below the detection limit are plotted at half the detection limit.
Red dashed lines represent the CCME freshwater interim sediment quality guideline (ISQG) for zinc (123 mg/kg); the probable effects level (PEL) for zinc (315 mg/kg) is not shown.

The before-after analysis confirmed that there was no significant difference between baseline and 2014 means for Doris Lake ($p = 0.56$ for Doris Lake South and $p = 0.27$ for Doris Lake North), and that the difference observed in Little Roberts Lake was significant ($p = 0.001$). However, there was no obvious increasing trend in zinc concentrations in Little Roberts Lake and no known Project-related source of potential increases in zinc in Little Roberts Lake. Therefore, the higher concentrations observed in 2014 for Little Roberts Lake likely resulted from natural variability potentially related to the increase in fine sediments observed at this site. Thus, there were no apparent adverse effects of 2014 Project activities on zinc concentrations in exposure lake sediments.

3.4.3 Marine

Sediment quality samples from the marine environment were collected from two exposure sites in Roberts Bay (RBW and RBE) and one reference site in Ida Bay (REF-Marine 1). Baseline sediment quality data were collected in Roberts Bay in 1997, 2002, and 2009. However, not all of the baseline data were directly comparable to the 2014 samples, either because they were not collected in the immediate vicinity of the AEMP sampling sites or because they were collected from different depth strata than 2014 samples (Appendix B). There were no suitable baseline data available for RBE, but there was one year of baseline data available for RBW (2002) and REF-Marine 1 (2009).

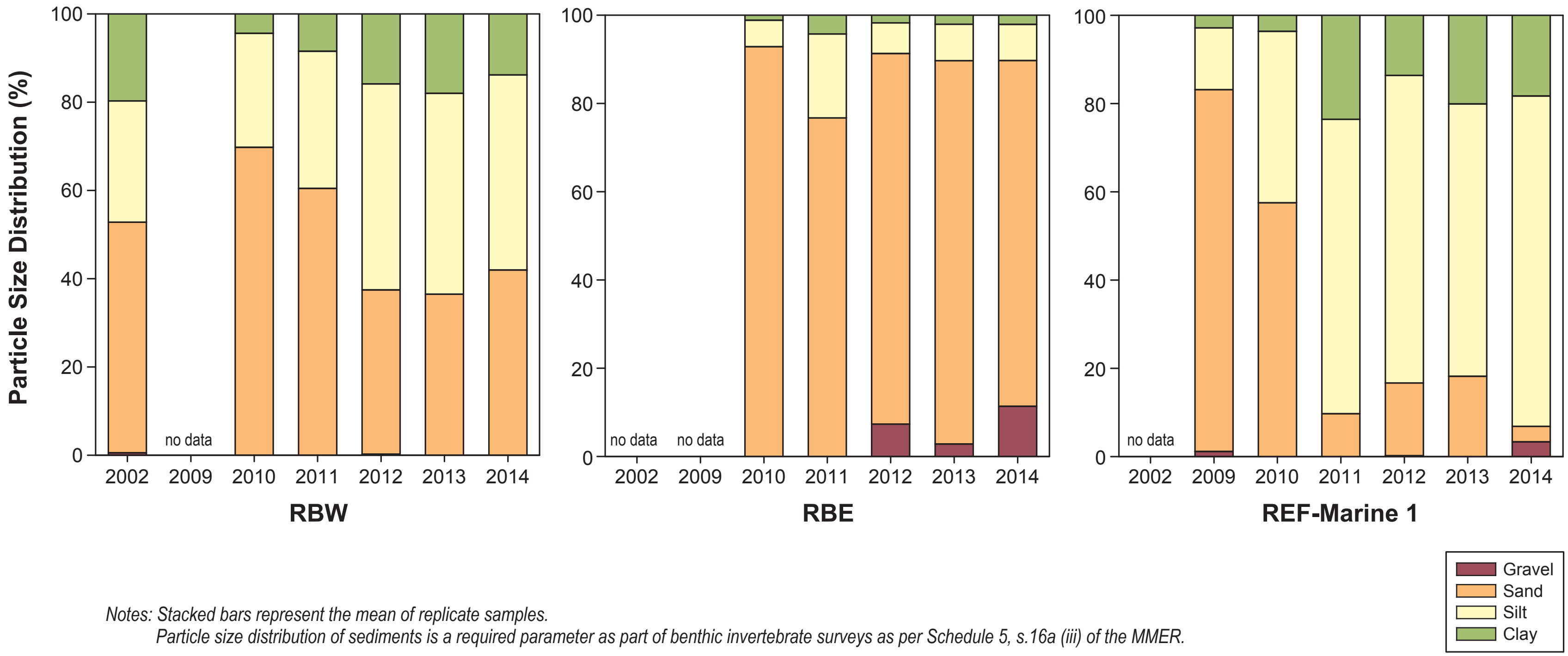
Because the available baseline data were from two different years, a change in any variable at the exposure site, RBW, from 2002 to 2014 could not be directly compared to the change at the reference station, REF-Marine 1, between 2009 and 2014. Any change at REF-Marine 1 could only be used to show the inherent inter-annual variability that occurs in sediment variables. Also, caution must be exercised when interpreting changes at RBW because there was a ten-year gap between the collection of before and after data. No BACI analysis was possible for RBW because there were too few degrees of freedom in the before period and no before-after or BACI analyses could be performed for RBE because there was no suitable baseline sediment data collected near this exposure site.

3.4.3.1 Particle Size

In 2014, sediments at sites RBW consisted mainly of sand and silt, whereas sediments at REF-Marine 1 consisted mainly of silt and clay (Figure 3.4-19). The before-after comparison showed that the silt content increased significantly in 2014 sediment samples compared to baseline samples at both RBW ($p = 0.0002$) and REF-Marine 1 ($p < 0.0001$), while the clay content decreased significantly ($p = 0.0098$) at RBW and increased significantly ($p = 0.0014$) at REF-Marine 1. At REF-Marine 1 the sand content also decreased significantly in 2014 ($p = 0.0001$) and a smaller, marginally non-significant, decrease was observed at RBW ($p = 0.02226$). Before-after analyses could not be performed for RBE due to a lack of baseline data; however, RBE sediments at this site were generally coarser than RBW or REF-Marine-1 sediments (mainly gravel, sand, and silt). There was some damage to the Roberts Bay jetty in 2013 that was repaired during the winter of 2013/2014 that could have contributed to changes in particle size composition and sediment quality in a localized area. However, the similarity between RBW and REF-Marine 1 with respect to increases in silt content, and increases in sediment metal and TOC concentrations from baseline years to 2014 suggests that the observed changes at RBW were naturally occurring and unrelated to the jetty damage or other Project activities. The changes in sediment particle size composition and quality may have been due to regional re-distribution of sediments following a strong storm event that occurred in July 2013 (which was responsible for damaging the jetty), or these changes could also be the product of spatial sediment heterogeneity.

Figure 3.4-19

Particle Size Distribution, Marine Sediments, Doris North Project, 2002 to 2014



Notes: Stacked bars represent the mean of replicate samples.
Particle size distribution of sediments is a required parameter as part of benthic invertebrate surveys as per Schedule 5, s.16a (iii) of the MMER.

The observed changes in particle size composition towards finer sediments at RBW and REF-Marine-1 has important implications for the before-after comparisons of sediment quality variables because metal and TOC concentrations tend to be higher in fine sediments than in coarse sediments (e.g., Lakhan, Cabana, and LaValle 2003; Secrieri and Oaie 2009). As described in the following sections, mean concentrations of TOC and most evaluated metals increased significantly at both RBW and REF-Marine 1 in 2014 compared to baseline years, and this increase was likely associated with the higher proportion of fine sediments in the 2014 sediment samples.

3.4.3.2 Total Organic Carbon

The mean TOC content in sediments from RBW increased from below the detection limit of 0.5% in 2002 to 0.59% 2014 (Figure 3.4-20), and the before-after comparison indicated that this increase was statistically significant ($p < 0.0001$). An increase in the mean TOC from 0.20% in 2009 to 1.6% in 2014 was also observed at REF-Marine 1, and the before-after comparison indicated that the difference was significantly different ($p = 0.002$). Although a BACI analysis could not be performed to directly compare the before-after trend at RBW to the trend at the reference site (because there were too few degrees of freedom), graphical analysis suggests that the increasing trends were similar at both sites (Figure 3.4-20). This increase in TOC at both RBW and REF-Marine 1 was likely related to the higher proportion of fine sediments in 2014 samples collected from these sites compared to 2009 samples, because fine sediments tend to contain higher concentrations of TOC (Secrieri and Oaie 2009). Sediment samples from the sand-dominated RBE contained very little TOC, with all concentrations near or below the detection limit of 0.1% and lower than the TOC content in samples from either RBW or REF-Marine 1. Thus, there was no evidence that 2014 Project activities had any effect on the proportion of TOC in exposure site sediments.

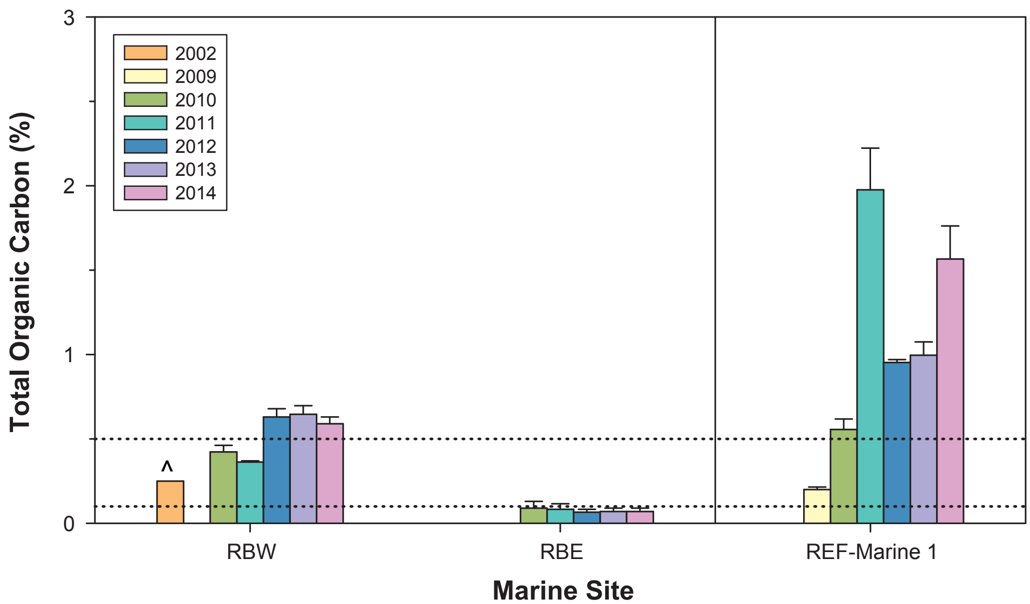
3.4.3.3 Total Arsenic

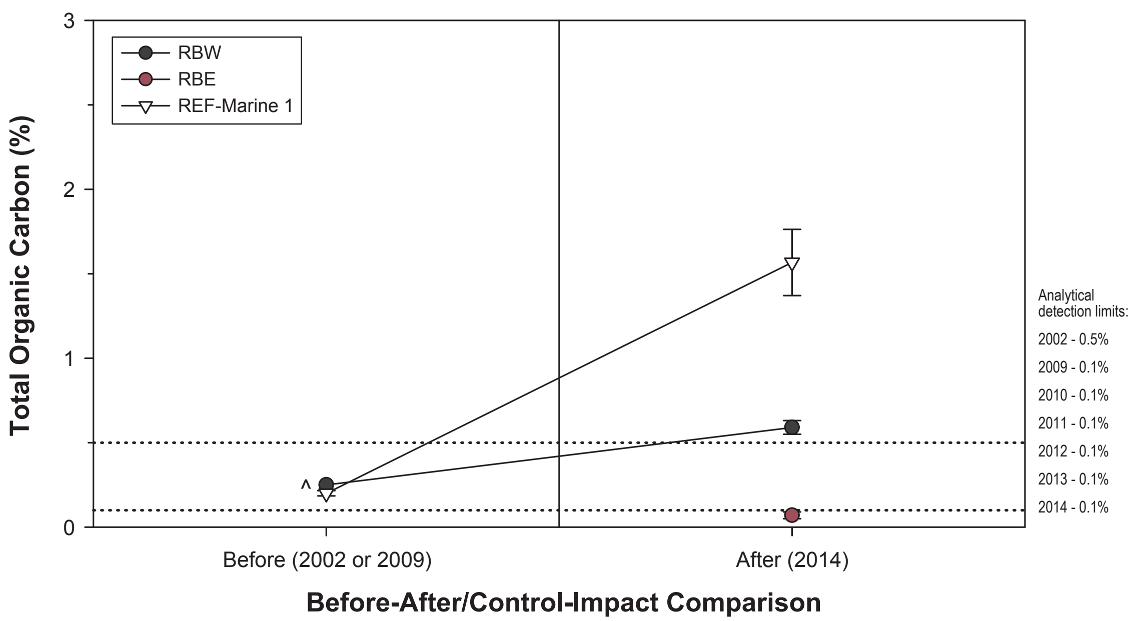
Mean arsenic concentrations in sediments from RBW increased significantly from 1.9 mg/kg in 2002 to 4.05 mg/kg in 2014 (before-after: $p < 0.0001$; Figure 3.4-21). However, mean arsenic concentrations also increased significantly at REF-Marine 1, from 0.60 mg/kg in 2009 to 4.73 mg/kg in 2014 ($p = 0.0005$). In both cases, the increase in sediment arsenic concentrations was likely related to the significant increase in the proportion of fine sediments in the samples, since fine sediments tend to have higher affinities for metals. This suggests that the change in arsenic concentrations that occurred in sediments from RBW in 2014 was unrelated to Project activities.

At RBE, the mean 2014 arsenic concentration in sediments (1.15 mg/kg) was equal to or lower than the mean 2010, 2011, 2012, or 2013 concentration and lower concentrations than for most years at RBW and REF-Marine-1 (Figure 3.4-21). All 2014 concentrations were well below the CCME ISQG of 7.24 mg/kg and the PEL of 41.6 mg/kg. Thus, there was no evidence that 2014 Project activities affected sediment arsenic concentrations at the marine exposure sites.

Figure 3.4-20

Total Organic Carbon, Marine Sediments, Doris North Project, 2002 to 2014

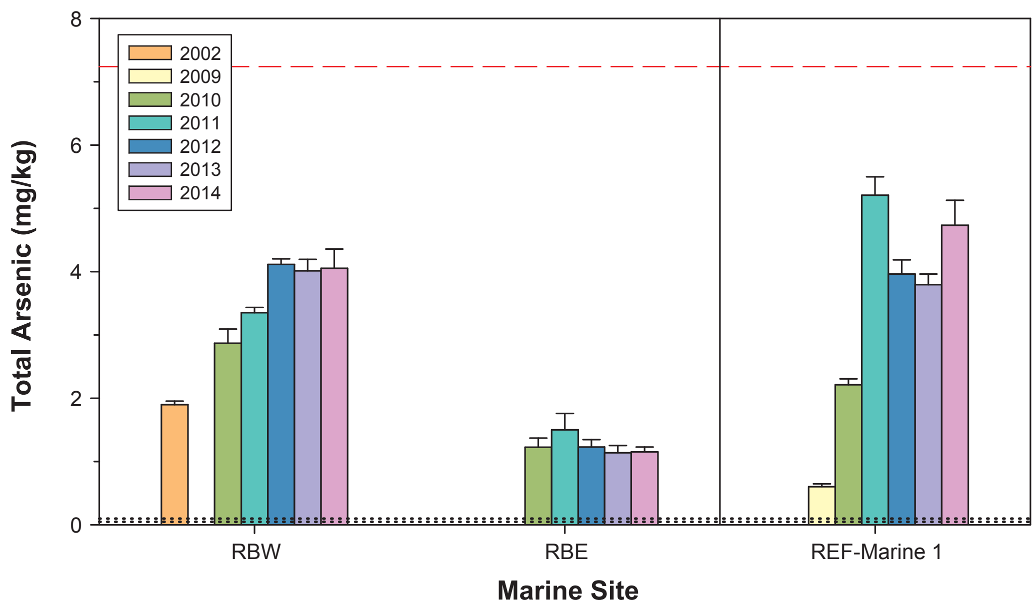


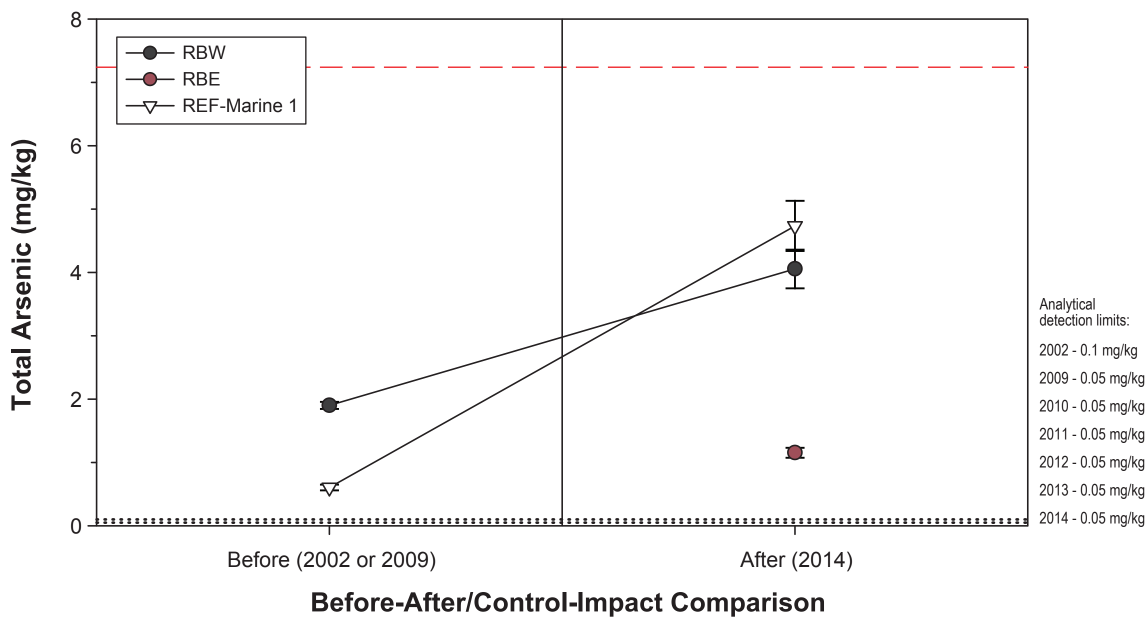


Notes: Error bars represent the standard error of the mean.
Dotted lines represent analytical detection limits; values below the detection limit are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Total organic carbon content of sediments is a required parameter as part of benthic invertebrate surveys as per Schedule 5, s.16a (iii) of the MMER.

Figure 3.4-21

Total Arsenic Concentrations, Marine Sediments, Doris North Project, 2002 to 2014





Notes: Error bars represent the standard error of the mean.
Dotted lines represent analytical detection limits; values below the detection limit are plotted at half the applicable detection limit.
Red dashed lines represent the CCME marine and estuarine interim sediment quality guideline (ISQG) for arsenic (7.24 mg/kg); the probable effects level (PEL) for arsenic (41.6 mg/kg) is not shown.

3.4.3.4 *Total Cadmium*

Total cadmium concentrations were below the analytical detection limit (< 0.05 mg/kg) in all sediment samples collected from RBW and RBE in 2014 (Figure 3.4-22). All 2014 concentrations were also well below the CCME ISQG of 0.7 mg/kg and the PEL of 4.2 mg/kg. Therefore, there was no indication that 2014 Project activities had an effect on cadmium concentrations in sediments at the marine exposure sites.

3.4.3.5 *Total Chromium*

Mean chromium concentrations in RBW sediments increased significantly from 18.2 mg/kg in 2002 to 29.3 mg/kg in 2014 (before-after: $p < 0.0013$; Figure 3.4-23). A significant increase from 9.4 mg/kg in 2009 to 30.5 mg/kg in 2014 (before-after: $p = 0.0001$) also occurred in sediments from REF-Marine 1 (Figure 3.4-23). In both cases, the increase in sediment chromium concentrations was likely related to the significant increase in the proportion of fine sediments in the samples, since fine sediments tend to have higher affinities for metals. This suggested that the change in chromium concentrations that occurred in sediments from RBW in 2014 was unrelated to Project activities.

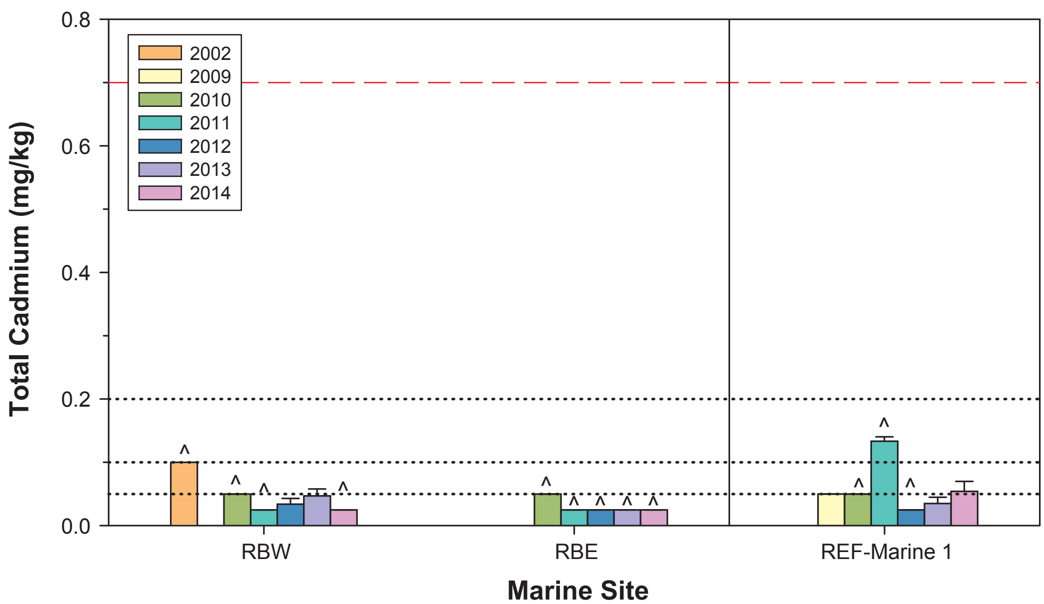
No baseline data were available for comparison at RBE, but the mean 2014 chromium concentration in sediments (13.2 mg/kg) was lower than the mean 2014 concentrations in sediments from the other exposure and reference sites and concentrations at RBE appeared to be consistent through time (Figure 3.4-23). All 2014 concentrations were below the CCME ISQG of 52.3 mg/kg and the PEL of 160 mg/kg. Thus, there was no evidence of an effect of 2014 Project activities on sediment chromium concentrations at the marine exposure sites in Roberts Bay.

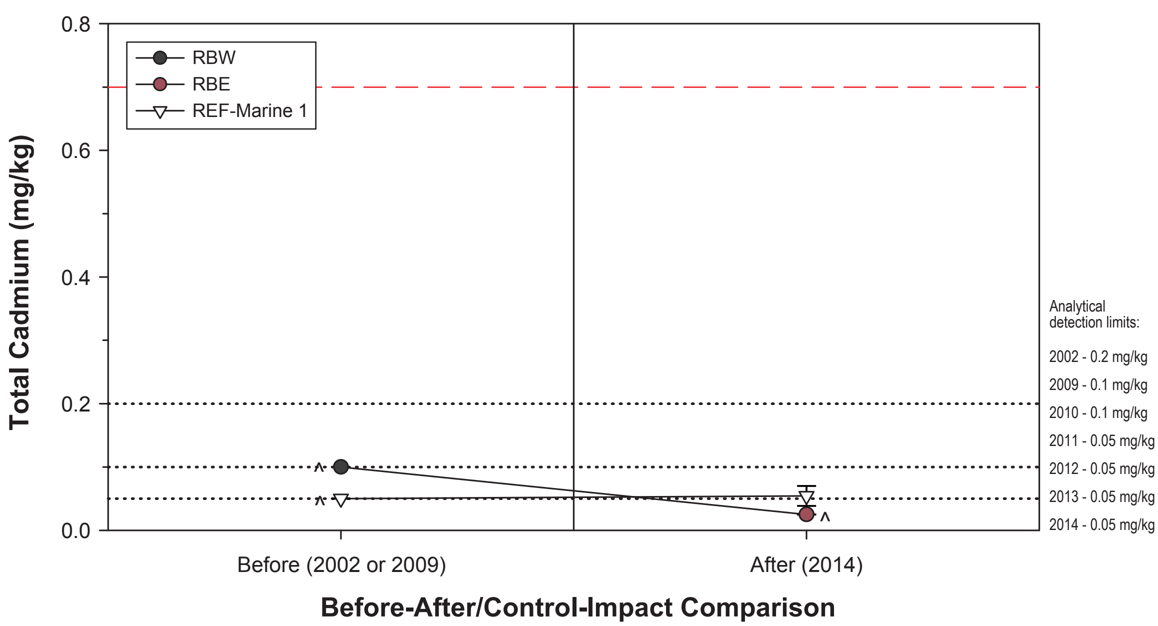
3.4.3.6 *Total Copper*

Mean copper concentrations in sediments from RBW increased from 8.4 mg/kg in 2002 to 19.2 mg/kg in 2014, which was above the CCME ISQG of 18.7 mg/kg, but below the PEL of 108 mg/kg. (Figure 3.4-24).

This increase was statistically significant ($p < 0.0008$) based on the before-after analysis. However, mean copper concentrations also increased significantly at REF-Marine 1 from 4.9 mg/kg in 2009 to 12.2 in 2014 ($p = 0.0004$). In both cases, the increase in sediment copper concentrations was likely related to the significant increase in the proportion of fine sediments in the samples, since fine sediments tend to have higher affinities for metals. This suggested that the increase in copper concentrations that occurred in sediments from RBW in 2014 was unrelated to Project activities.

There were no baseline data for RBE, but the mean 2014 copper concentration in sediments (7.5 mg/kg) was lower than mean concentrations in sediments from the other exposure and reference sites, which is consistent with the coarser nature of the sediment at RBE (Figure 3.4-24). Concentrations at RBE also consistent appeared to decrease slightly over time. Therefore, there was no indication that 2014 Project activities affected sediment copper concentrations at the marine exposure sites.

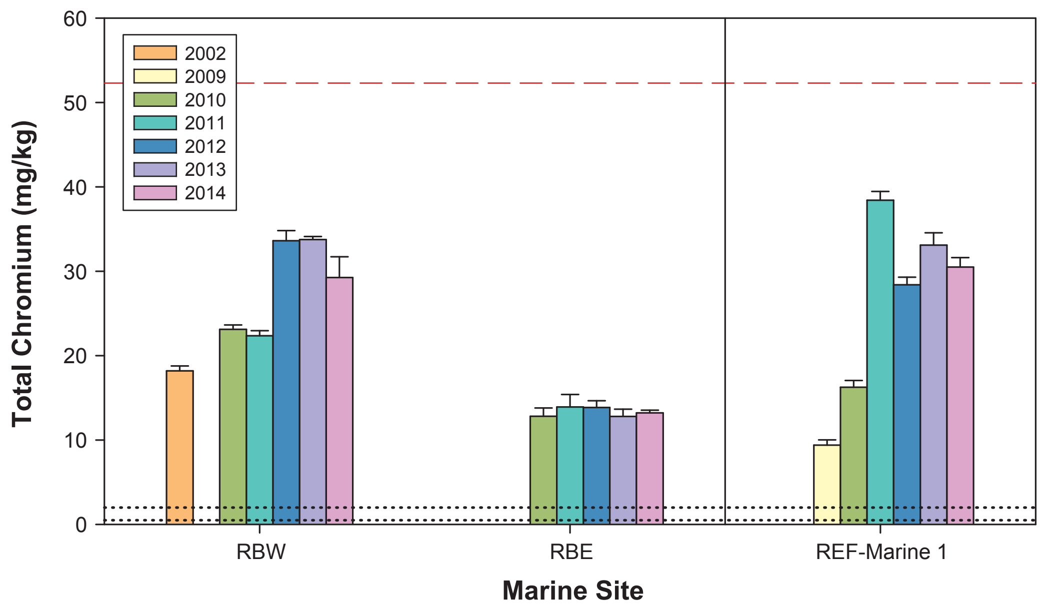


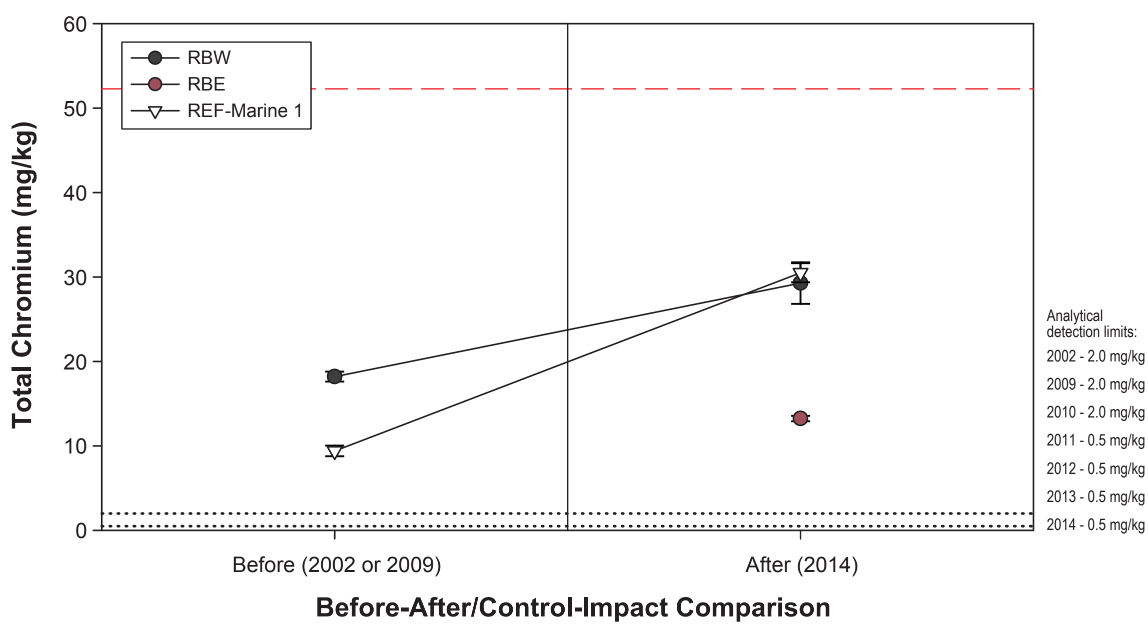


Notes: Error bars represent the standard error of the mean.
Dotted lines represent analytical detection limits; values below the detection limit are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed lines represent the CCME marine and estuarine interim sediment quality guideline (ISQG) for cadmium (0.7 mg/kg); the probable effects level (PEL) for cadmium (4.2 mg/kg) is not shown.

Figure 3.4-23

Total Chromium Concentrations, Marine Sediments, Doris North Project, 2002 to 2014

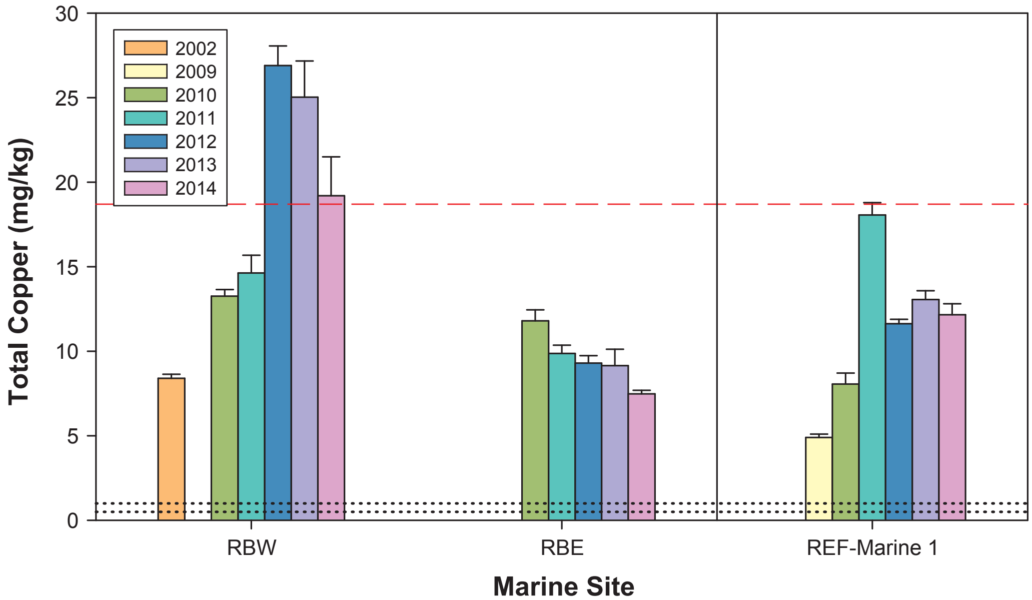


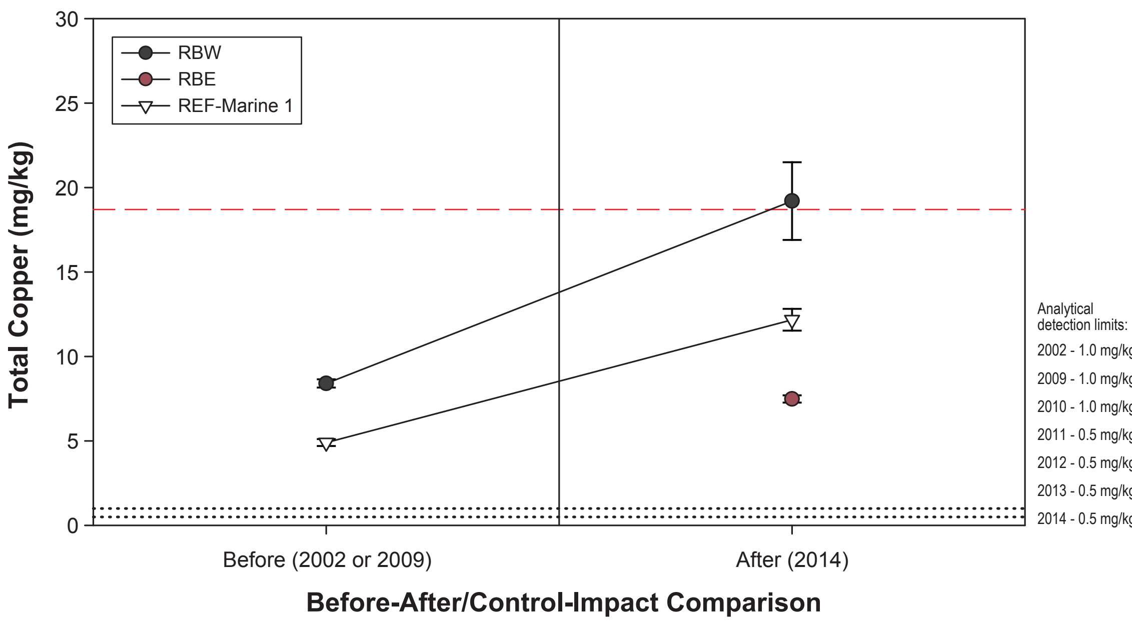


Notes: Error bars represent the standard error of the mean.
Dotted lines represent analytical detection limits; values below the detection limit are plotted at half the applicable detection limit.
Red dashed lines represent the CCME marine and estuarine interim sediment quality guideline (ISQG) for chromium (52.3 mg/kg); the probable effects level (PEL) for chromium (160 mg/kg) is not shown.

Figure 3.4-24

Total Copper Concentrations, Marine Sediments, Doris North Project, 2002 to 2014





Notes: Error bars represent the standard error of the mean.
Dotted lines represent analytical detection limits; values below the detection limit are plotted at half the applicable detection limit.
Red dashed lines represent the CCME marine and estuarine interim sediment quality guideline (ISQG) for copper (18.7 mg/kg); the probable effects level (PEL) for copper (108 mg/kg) is not shown.

3.4.3.7 Total Lead

All 2014 sediment lead concentrations at the marine sites were well below the CCME ISQG of 30.2 mg/kg and the PEL of 112 mg/kg (Figure 3.4-25). The mean 2014 lead concentration in RBW sediments (3.8 mg/kg) was higher than the 2002 mean (2.6 mg/kg; Figure 3.4-25), and the before-after analysis showed a marginally non-significant difference between the 2014 and 2002 mean lead concentrations ($p = 0.04$). A similar increase was observed at site REF-Marine 1 ($p < 0.0001$). In both cases, the increase in sediment lead concentrations was likely related to the significant increase in the proportion of fine sediments in the samples, since fine sediments tend to have higher affinities for metals. This suggested that the increase in lead concentrations that occurred in sediments from RBW in 2014 was unrelated to Project activities.

Although no before data exist for RBE, as observed for all other sediment metal concentrations, sediments from RBE had the lowest mean 2014 concentration of lead (1.3 mg/kg; Figure 3.4-25) compared to the other marine sites, and concentrations were generally consistent across time from 2010 to 2014. Thus, there was no apparent effect of 2014 activities on sediment lead concentrations at the marine exposure sites.

3.4.3.8 Total Mercury

Mean total mercury concentrations in RBW sediments increased from 0.0060 mg/kg in 2002 to 0.0069 mg/kg in 2014 (Figure 3.4-26); however, the before-after analysis found that the 2002 and 2014 means were not significantly different ($p = 0.71$). Although no baseline data exist for site RBE, mercury concentrations were near or below the analytical detection limit of 0.005 mg/kg. Therefore, there was no indication that 2014 Project activities had any effect on mercury concentrations in sediments at the marine exposure sites. Total mercury concentrations in all exposure and reference site samples collected in 2014 were well below the CCME ISQG of 0.13 mg/kg and the PEL of 0.7 mg/kg.

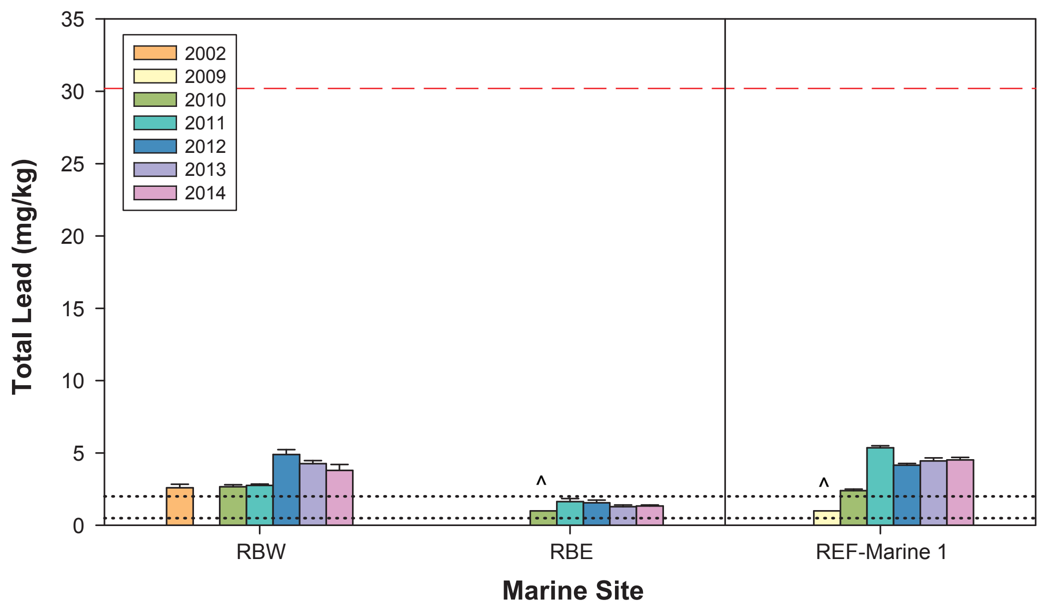
3.4.3.9 Total Zinc

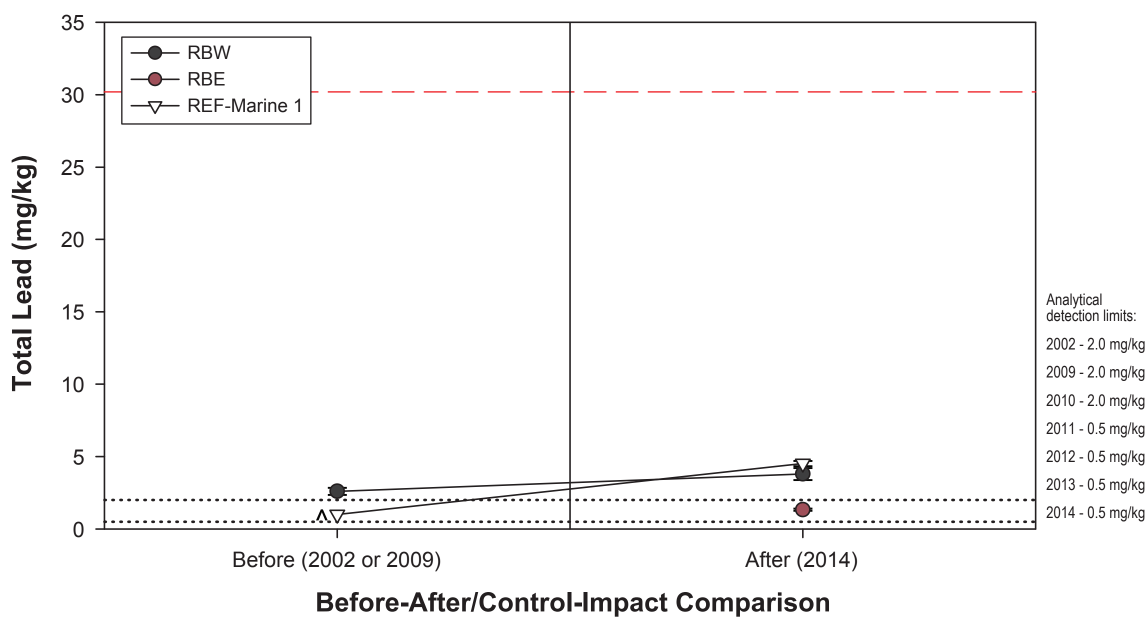
The mean 2014 zinc concentration (31.3 mg/kg) in sediments from RBW was higher than the 2002 mean (20.6 mg/kg; Figure 3.4-27), and the before-after analysis revealed a marginally non-significant difference between the means ($p = 0.0104$). A similar pattern was observed for REF-Marine 1 ($p = 0.0002$; Figure 3.4-27).

Although no before data were available for RBE, sediments from RBE had the lowest mean 2014 concentration of zinc (14.5 mg/kg) compared to the other marine sites and zinc concentrations at RBE also appeared to be consistent through time (Figure 3.4-27). The relatively lower zinc concentrations observed at RBE is consistent with the coarser nature of the sediments at this site. All 2014 sediment zinc concentrations measured in samples from the marine sites were well below the CCME ISQG of 124 mg/kg and the PEL of 271 mg/kg (Figure 3.4-27). Thus, there was no apparent effect of 2014 Project activities on sediment zinc concentrations at the marine exposure sites.

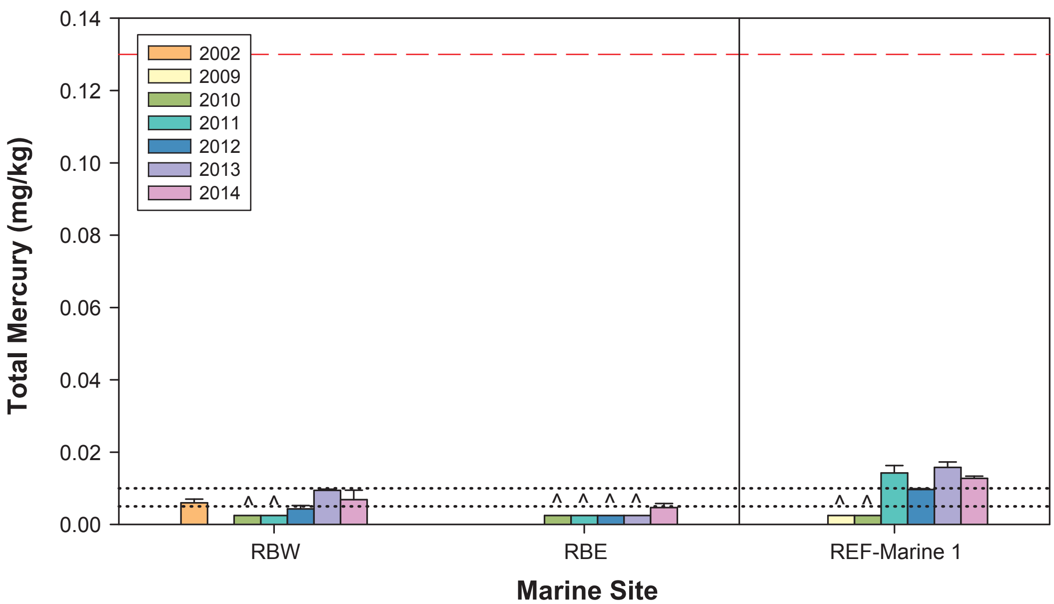
Figure 3.4-25

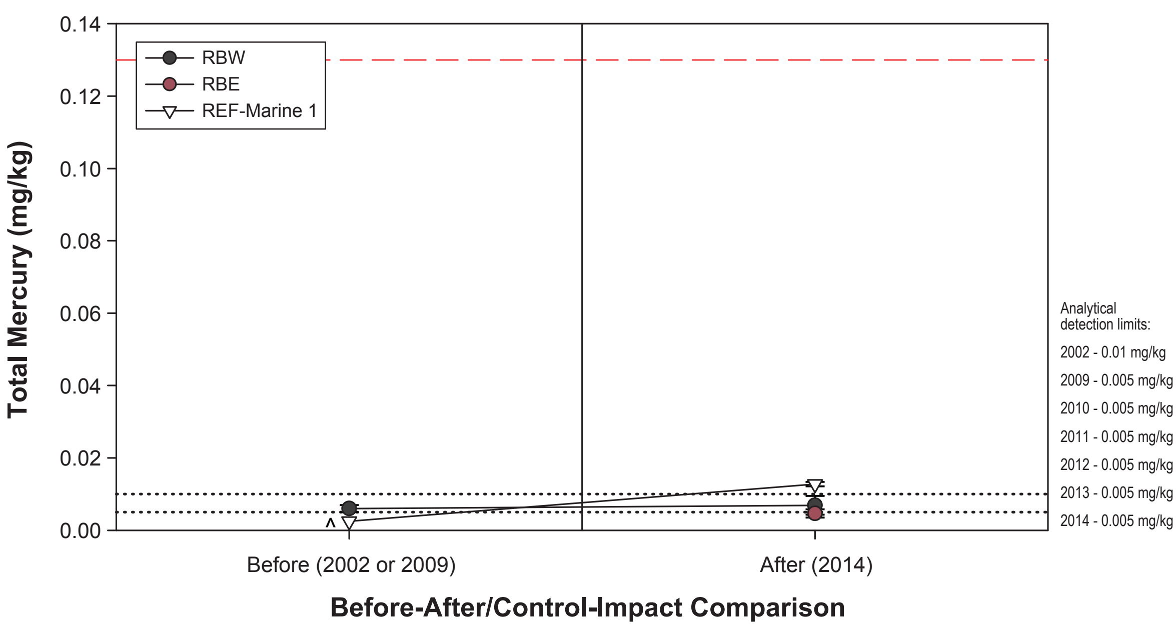
Total Lead Concentrations, Marine Sediments, Doris North Project, 2002 to 2014





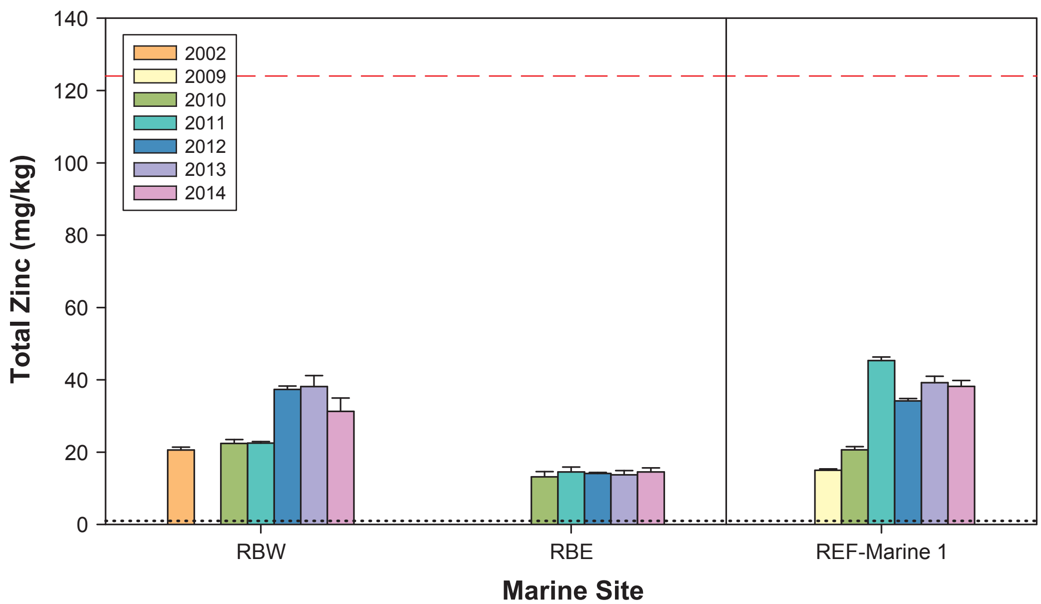
Notes: Error bars represent the standard error of the mean.
Dotted lines represent analytical detection limits; values below the detection limit are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed lines represent the CCME marine and estuarine interim sediment quality guideline (ISQG) for lead (30.2 mg/kg); the probable effects level (PEL) for lead (112 mg/kg) is not shown.

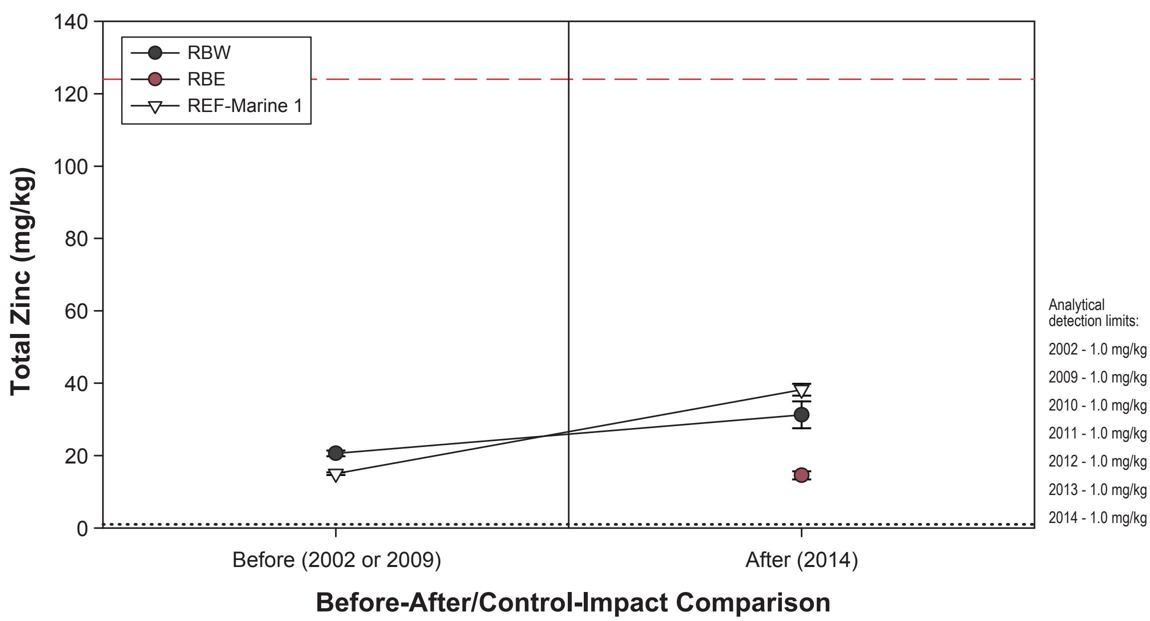




Notes: Error bars represent the standard error of the mean.
Dotted lines represent analytical detection limits; values below the detection limit are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed lines represent the CCME marine and estuarine interim sediment quality guideline (ISQG) for mercury (0.13 mg/kg); the probable effects level (PEL) for mercury (0.7 mg/kg) is not shown.

Total Zinc Concentrations, Marine Sediments, Doris North Project, 2002 to 2014





Notes: Error bars represent the standard error of the mean.
Dotted lines represent analytical detection limits; values below the detection limit are plotted at half the applicable detection limit.
Red dashed lines represent the CCME marine and estuarine interim sediment quality guideline (ISQG) for zinc (124 mg/kg); the probable effects level (PEL) for zinc (271 mg/kg) is not shown.

3.5 PRIMARY PRODUCERS

Primary producer biomass (as chlorophyll *a*) samples were collected in streams, lakes, and the marine environment to assess potential changes due to eutrophication or toxicity. Historical primary producer (phytoplankton and periphyton) biomass sampling has been conducted in the Project area since 1996. The main criteria for the selection of relevant baseline periphyton and phytoplankton biomass data for inclusion in the effects analysis were the proximity of baseline sampling sites to 2014 sampling sites and the use of comparable sampling methodologies.

Graphical analyses, before-after comparisons, and BACI analyses (where possible) were all used to determine whether there were changes in primary producer biomass in the Project area. For all graphical and statistical analyses, replicate samples collected on the same date were averaged prior to analysis. The complete results of all statistical methods and analyses are provided in Appendix B.

3.5.1 Stream Periphyton Biomass

Stream periphyton biomass samples were collected from three exposure streams (Doris, Roberts, and Little Roberts outflows) and two reference streams (Reference B and Reference D outflows). Baseline data for stream periphyton biomass that were comparable to 2014 data in terms of sampling locations and methodologies were available from 1997, 2000, and 2009 for Doris Outflow, and from 2009 for Little Roberts and Reference B Outflows (Appendix B). No baseline data were available for Roberts Outflow or Reference D Outflow, so before-after and BACI analyses could not be performed for these streams. Also, there were too few degrees of freedom in the before period for Little Roberts and Reference B outflows, so before-after analyses could not be performed for periphyton data from these streams; however, there were sufficient degrees of freedom to conduct a BACI analysis.

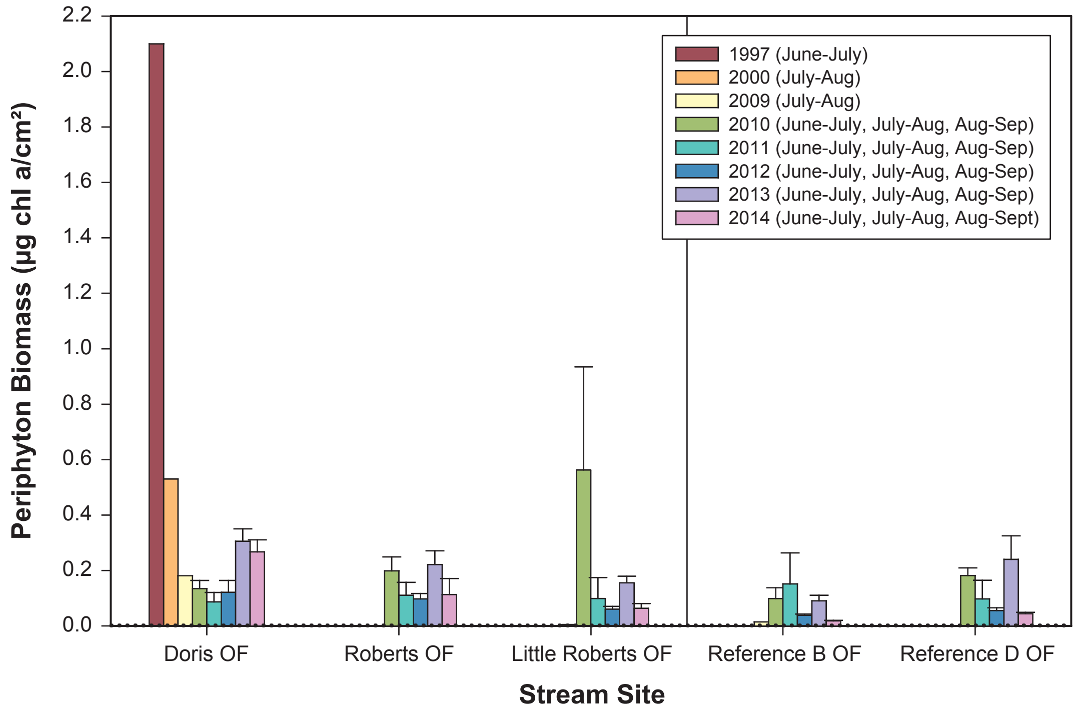
Periphyton biomass was highly variable over time, particularly at Doris Outflow, where several years of baseline data were available (Figure 3.5-1). Chlorophyll *a* concentrations at this stream site decreased by an order of magnitude between 1997 and 2009, before the commencement of any Project activities. This degree of natural variability makes it difficult to isolate trends from natural background variability. Mean 2014 periphyton biomass concentrations at Doris Outflow were intermediate to 2000 and 2009 mean biomass levels, and the before-after analysis confirmed that there was no significant difference between the baseline mean biomass and the 2014 mean biomass at this site ($p = 0.19$).

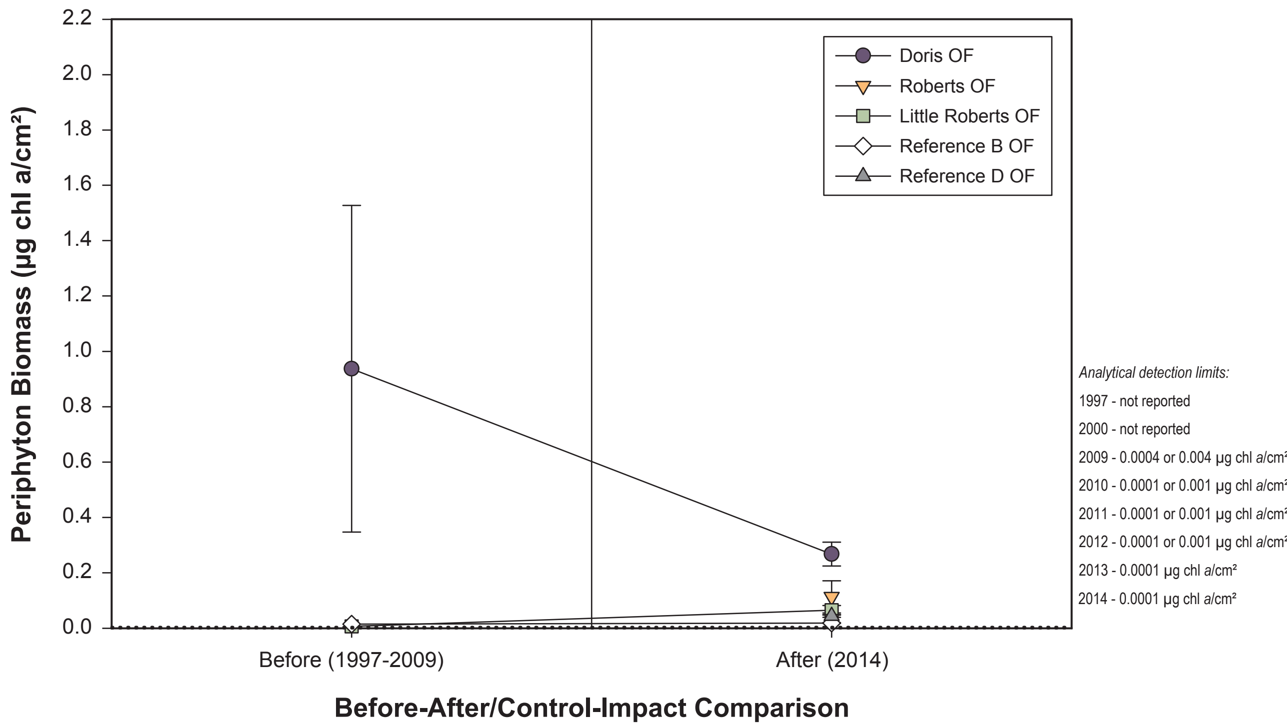
At Little Roberts Outflow, 2014 periphyton biomass concentrations were within the range of historical observations (Figure 3.5-1). Although a before-after analysis could not be performed, the BACI analysis indicated that there was some evidence that the before-after trend at Little Roberts Outflow did not parallel the before-after trend for the reference streams (p = marginally non-significant; 0.0305). However, graphical analysis indicated that trends were similar between Little Roberts Outflow and reference streams. Additionally, there were no Project related changes in water quality in Little Roberts Outflow that would have resulted in a change in periphyton biomass. Thus, the difference in biomass levels at Little Roberts Outflow between 2009 and 2014 was likely unrelated to Project activities.

The mean periphyton biomass level at Roberts Outflow in 2014 was within the range of biomass levels measured in previous years and in the reference streams. Therefore, there was no indication that Project activities had any effect on periphyton biomass levels in exposure streams.

Figure 3.5-1

Periphyton Biomass (as Chlorophyll *a*), Stream Sites, Doris North Project, 1997 to 2014





Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits.
The anomalously high periphyton biomass of 194.4 µg chl a/cm² reported for Doris Outflow in July-August 1997 was considered an outlier and was excluded from plots and statistical analyses.

3.5.2 Lake Phytoplankton Biomass

Phytoplankton biomass samples were collected from three exposure lake sites (Doris Lake South, Doris Lake North, and Little Roberts Lake) and two reference lake sites (Reference Lake B and Reference Lake D) in 2014. Baseline data for lake phytoplankton biomass that were comparable to 2014 data in terms of sampling locations and methodologies were available from 1997, 2000, and 2009 for Doris Lake South, 1997 and 2009 for Little Roberts Lake, and 2009 for Doris Lake North and Reference Lake B (Appendix B). No baseline data were available for Reference Lake D, so a BACI analysis could not be performed for Little Roberts Lake.

At the exposure lake sites Doris South and Little Robert Lake, mean 2014 phytoplankton biomass concentrations were within the range of baseline means, at Doris North mean 2014 biomass was lower than 2009 baseline levels (Figure 3.5-2). However, the before-after analysis confirmed that the mean 2014 biomass level was not significantly different from the mean baseline level at any exposure lake site ($p = 0.89$ for Doris Lake South, $p = 0.28$ for Doris Lake North, and $p = 0.71$ for Little Roberts Lake). Thus, there was no apparent effect of 2014 Project activities on phytoplankton biomass in exposure lakes.

3.5.3 Marine Phytoplankton Biomass

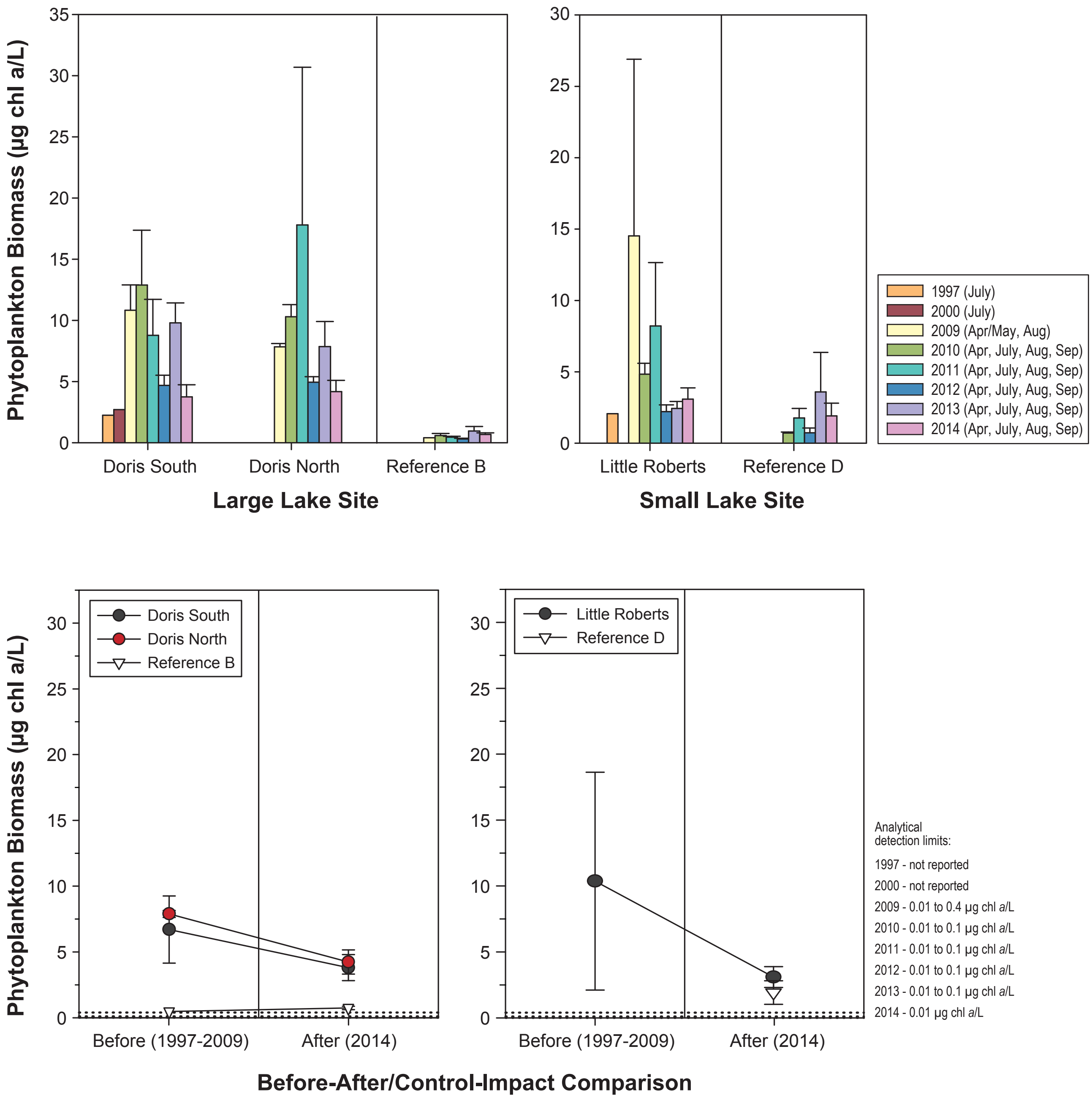
Phytoplankton biomass samples from marine areas were collected from two exposure sites in Roberts Bay (RBW and RBE) and one reference site in Ida Bay (REF-Marine 1) in 2014. Historical phytoplankton biomass data have been collected in Roberts Bay since 2006. However, only baseline data from 2009 were considered comparable to 2014 data. Historical data collected between 2006 and 2008 were excluded because of differences in sampling methodology (Appendix B). Baseline data from 2009 were available for all marine exposure and reference sites.

Marine phytoplankton biomass concentrations were lower at all sites in 2009 than in 2014 (Figure 3.5-3). Mean phytoplankton biomass concentrations measured in 2009 were below the detection limit (< 0.04 µg chl *a*/L) at both RBE and RBW and slightly above the detection limit at REF-Marine 1 (0.045 µg chl *a*/L). In 2014, mean biomass concentrations at the marine sites were: 0.47 µg chl *a*/L at RBW, 1.93 µg chl *a*/L at RBE, and 1.19 µg chl *a*/L at REF-Marine 1 (Figure 3.5-3).

The apparent increase in biomass concentrations between 2009 and 2014 may be related to natural seasonal differences in biomass levels, as samples collected in 2009 were collected only during one month (August) compared to four months in 2014 (April, July, August, and September). Furthermore, there was no significant increase in nitrate concentration at the exposure sites, which is the natural limiting nutrient in Roberts Bay. Although, it was not possible to perform before-after analysis on marine phytoplankton data (there were too few degrees of freedom to fit the model; Appendix B), the BACI analysis indicated that the 2009 to 2014 trends observed at the exposure sites were parallel to the 2009 to 2014 trend observed at the reference site ($p = 0.43$ for RBW and $p = 0.71$ for RBE). Therefore, the evidence suggested that the increases in phytoplankton biomass at RBW and RBE were likely unrelated to 2014 Project activities.

Figure 3.5-2

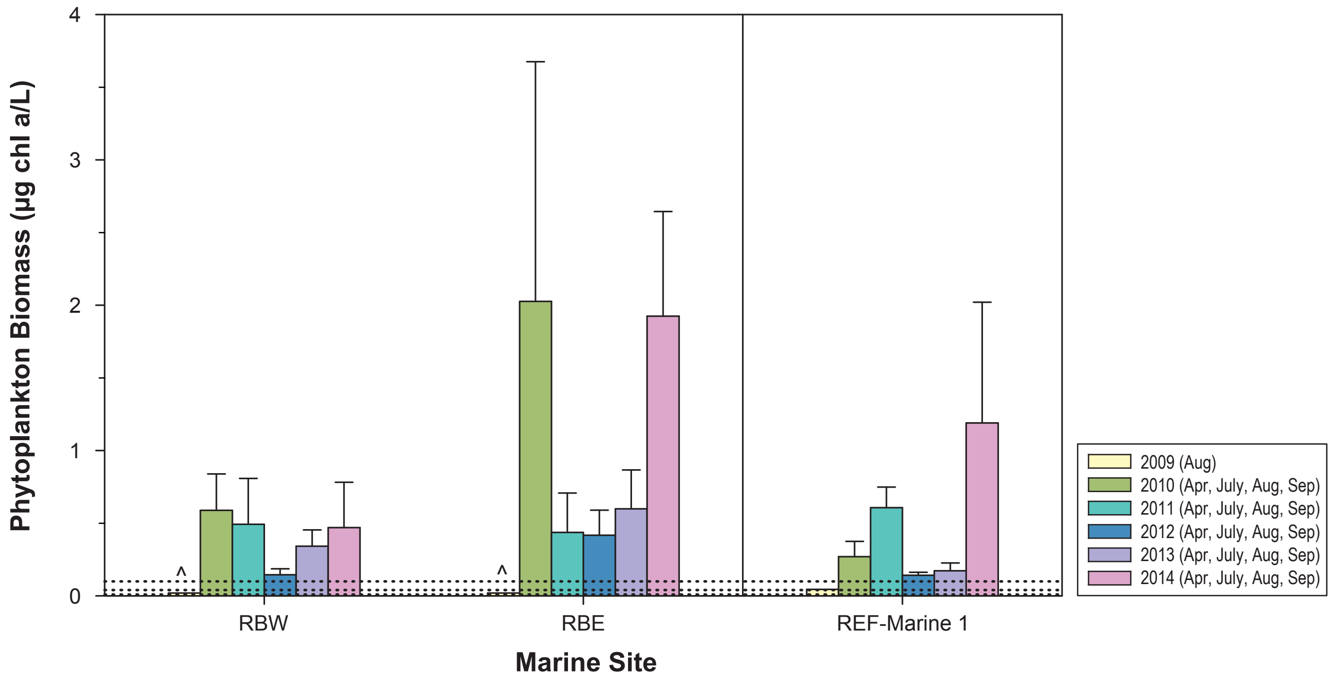
Phytoplankton Biomass (as Chlorophyll *a*), Lake Sites, Doris North Project, 1997 to 2014

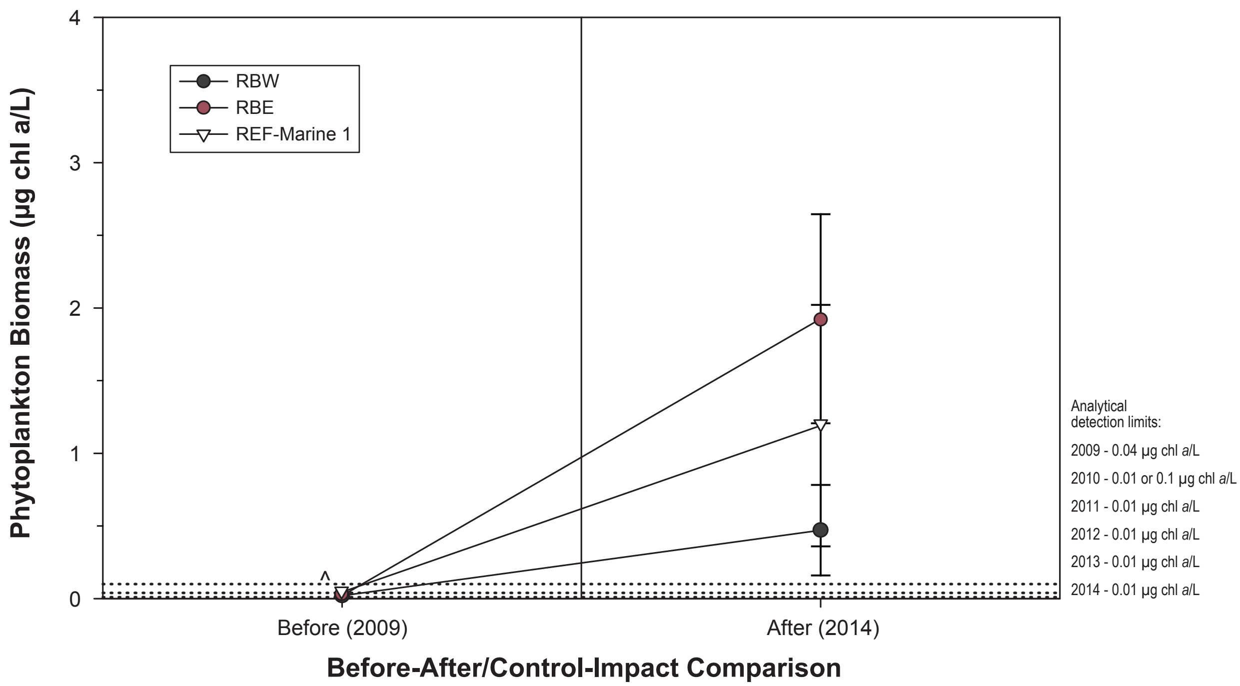


Notes: Error bars represent the standard error of the mean of replicates.
Dotted lines represent the analytical detection limit.

Figure 3.5-3

Phytoplankton Biomass (as Chlorophyll *a*), Marine Sites, Doris North Project, 2009 to 2014





Notes: Error bars represent the standard error of the mean.
Dotted lines represent analytical detection limits; values below the detection limit are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.

3.6 BENTHOS

As required in Schedule 5 of the MMER, benthic invertebrate community surveys were conducted in 2014 at stream, lake, and marine sites, and the data gathered were used to calculate benthos density, evenness (Simpson's Evenness Index), taxa richness, and a similarity index (Bray-Curtis Index). Simpson's Diversity Index, which incorporates taxa richness and evenness, was also calculated. The level of taxonomic resolution used to calculate community descriptors was family-level, as recommended in the EEM guidance document (Environment Canada 2011). All summary statistics for these community descriptors are provided in Appendix A.

The effects analysis for benthos required a different approach than that used for the other evaluated variables because of the lack of comparable baseline data for benthos. The method used to collect benthos samples from 2010 to 2014 involved the pooling of three subsamples for each of five replicate samples; therefore, data collected since 2010 were not considered comparable to baseline data (as replicates collected during baseline studies were not composite samples). Instead of employing before-after or BACI comparisons for benthos data, an impact level-by-time analysis was used, whereby the benthos trends at exposure sites between 2010 and 2014 were compared to the 2010 to 2014 trends at reference sites to determine if there was evidence of non-parallelism over time. The results of the effects analysis of effects for benthos are discussed below, and complete statistical methodology and results are presented in Appendix B.

3.6.1 Stream Benthos

3.6.1.1 Density

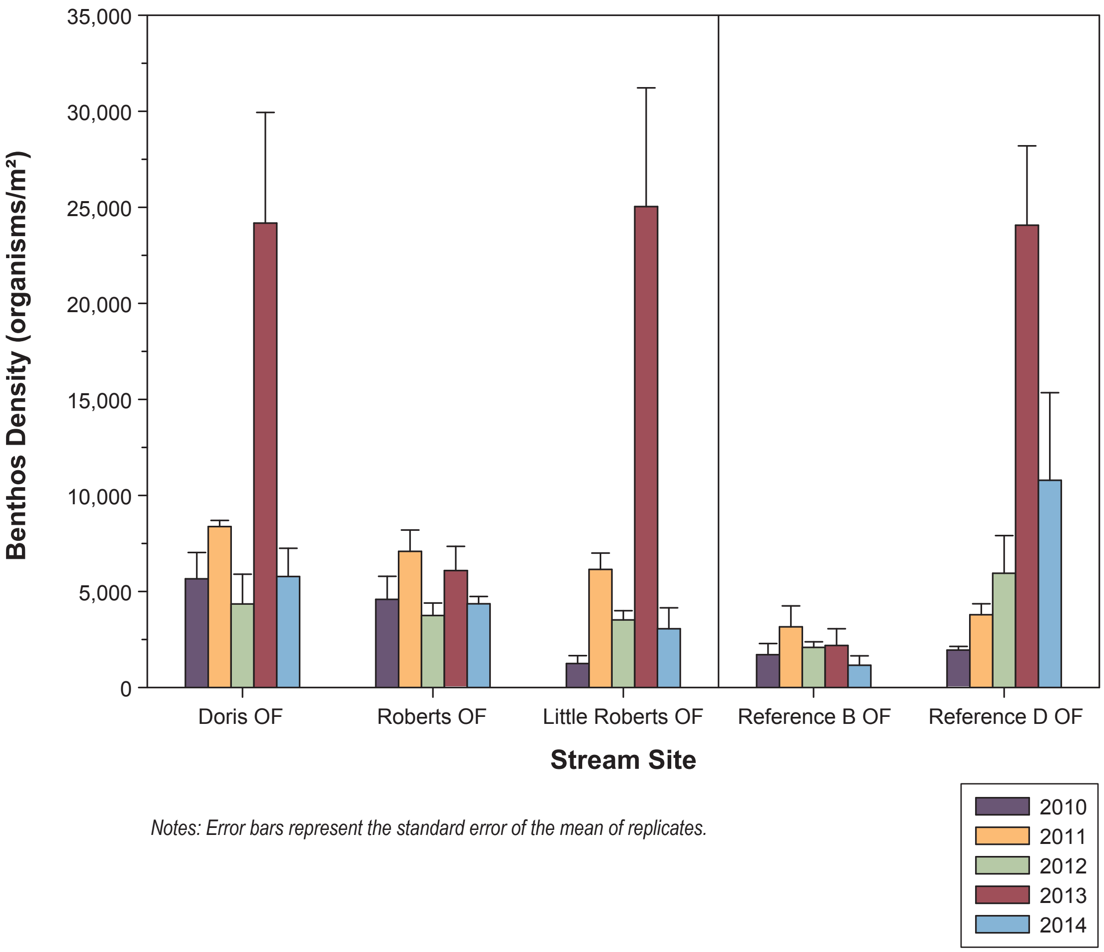
At all sites except Reference B Outflow, mean benthic invertebrate density in 2014 was within the range of densities recorded from 2010 to 2013. The 2014 density in Reference B Outflow was slightly lower than densities recorded for 2010 to 2013 (Figure 3.6-1). There was no evidence of significant non-parallelism between the reference streams and Doris or Roberts outflows ($p = 0.15$ and 0.09, respectively), but there was evidence of a marginally non-significant difference between the reference streams and Little Roberts Outflow ($p = 0.03$). Despite the marginally non-significant result for Little Roberts Outflow, graphical analysis indicated that the non-parallelism in density between Little Roberts Outflow and the reference streams was a natural phenomenon and was unlikely related to Project activities. The 2014 benthos density at Little Roberts Outflow was well within the range observed at other exposure and reference sites. Thus, the evidence suggested that there were no adverse effects of 2014 Project activities on stream benthos densities at exposure sites.

3.6.1.2 Community Richness, Evenness, and Diversity

2014 benthos family richness was generally similar to previous years in all exposure and reference streams (Figure 3.6-2), although slightly higher in Roberts Outflow and Little Roberts Outflow in 2014 than in any of the previous years. Nonetheless, there was no evidence of non-parallelism in trends between the exposure streams and the reference streams ($p = 0.23$ for Doris Outflow, $p = 0.43$ for Roberts Outflow, and $p = 0.37$ for Little Roberts Outflow).

Figure 3.6-1

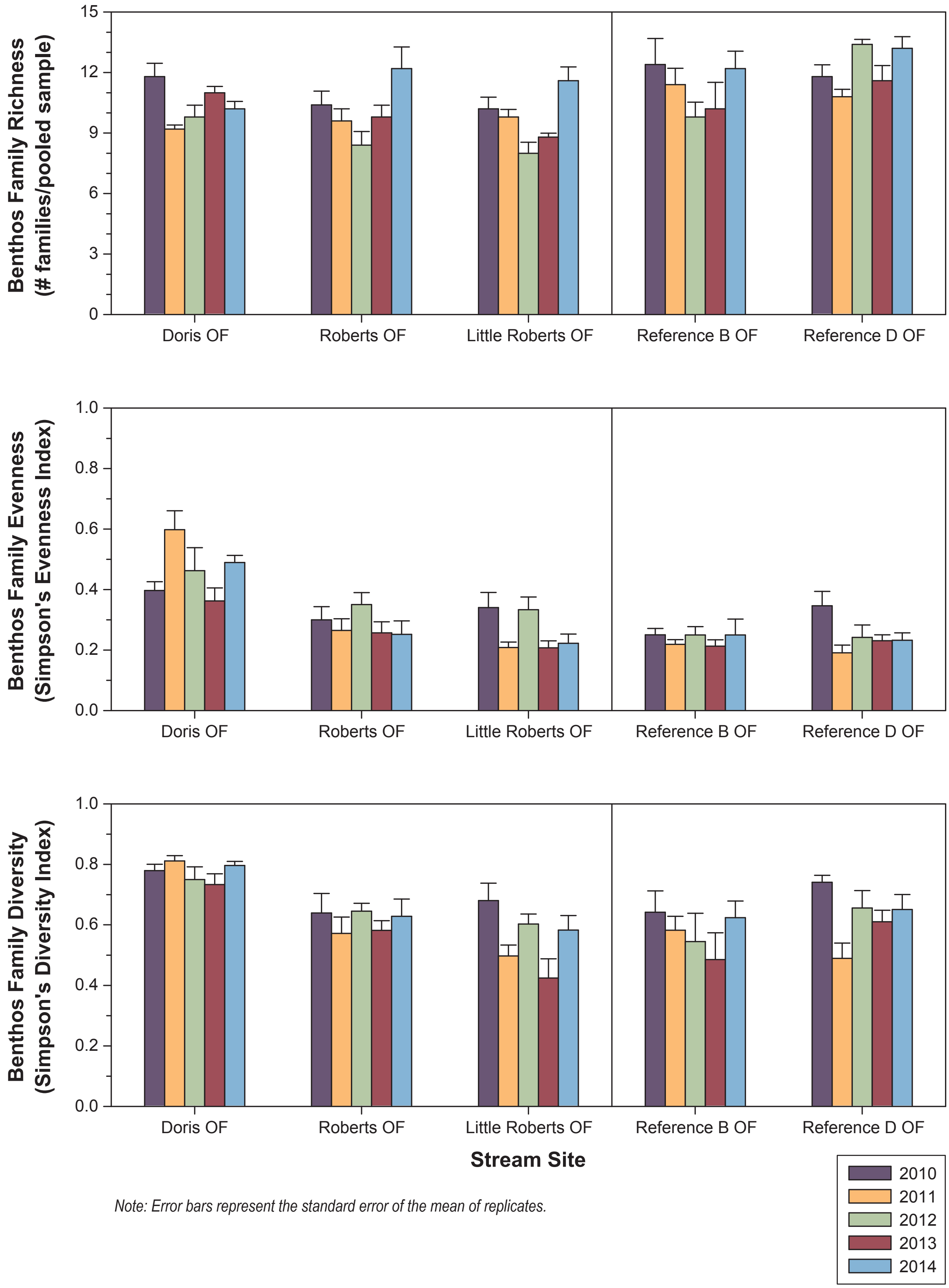
Benthos Density, Stream Sites, Doris North Project, 2010 to 2014



Notes: Error bars represent the standard error of the mean of replicates.

Figure 3.6-2

Benthos Richness, Evenness, and Diversity, Stream Sites, Doris North Project, 2010 to 2014



Note: Error bars represent the standard error of the mean of replicates.

Mean 2014 benthos Simpson's Evenness was similar to mean evenness observed in previous years at all exposure and reference streams (Figure 3.6-2). However, at Doris Outflow, there was evidence of non-parallelism with the reference streams ($p = 0.0005$). This likely resulted from relatively greater variability in evenness at Doris Outflow compared to reference streams (Figure 3.6-2). As in previous years, 2014 evenness was consistently higher at Doris OF compared to the other streams. Together, the evidence suggests that there was no adverse effect of 2014 Project activities on evenness at this site. At the other exposure streams, there was no evidence of non-parallelism in evenness trends relative to the reference streams ($p = 0.44$ for Roberts Outflow and $p = 0.31$ for Little Roberts Outflow).

Trends in the Simpson's Diversity Index between 2010 and 2014 were similar between exposure and reference streams and values were similar to those observed in previous years (Figure 3.6-2; $p = 0.36$ for Doris Outflow, $p = 0.85$ for Roberts Outflow, and $p = 0.75$ for Little Roberts Outflow), suggesting that there were no Project effects on benthic community diversity in the exposure streams in 2014.

3.6.1.3 Bray-Curtis Index

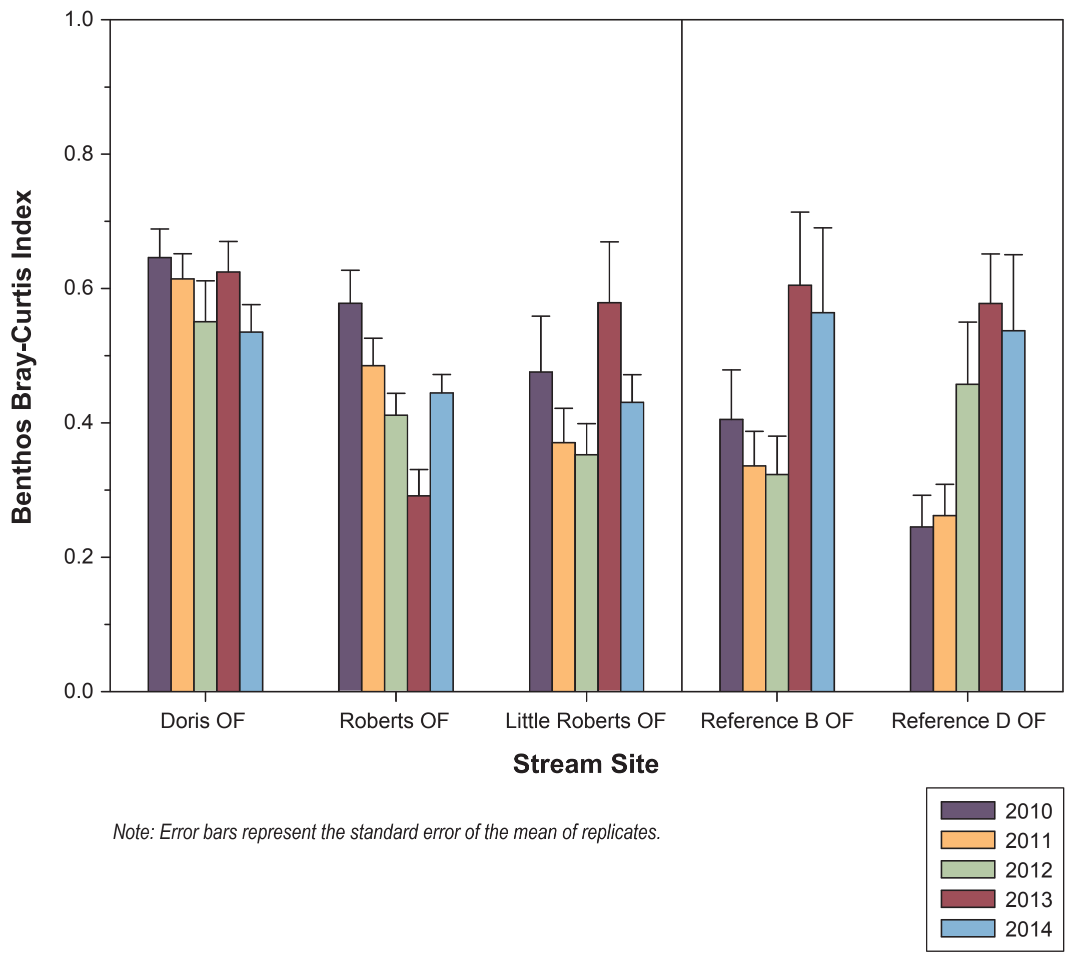
The Bray-Curtis Index, a measure of the percentage of difference between an exposure site benthos community composition and the median reference benthos community composition, was generally similar among sites in 2014 (Figure 3.6-3). Roberts Outflow and Little Roberts Outflow tended to have lower 2014 Bray-Curtis indices compared to other sites, suggesting that the community composition at these sites were the most similar to the median reference community composition (Figure 3.6-3). Roberts Outflow exhibited evidence of a significant non-parallelism over time relative to the reference streams ($p = <0.0002$). There was no evidence of non-parallelism compared to reference streams for Little Roberts Outflow ($p = 0.32$), and marginally non-significant evidence for Doris Outflow ($p = 0.02$). The results for Roberts and Doris outflows were likely due to the Bray-Curtis Indices for these streams exhibiting declines through time while the Bray Curtis Indices for the reference streams increased in the last two years (Figure 3.6-3). However, the decreasing trend in the Bray-Curtis Index at Roberts Outflow and Doris Outflow suggested that benthic communities at these streams were becoming more similar to reference communities through time and is therefore of little concern. Moreover, the 2014 Bray-Curtis values for Roberts Outflow and Doris Outflow were similar to those observed at all other sites. Thus, the evidence suggests that there has been no effect of Project activities on benthic community composition at exposure sites through time.

3.6.2 Lake Benthos

At Doris Lake South, 2010 data were collected from a shallow site, whereas 2011 to 2014 data were collected from a deep site in the southern section of Doris Lake. Therefore, 2010 data were excluded from the analyses.

Figure 3.6-3

Benthos Bray-Curtis Index, Stream Sites, Doris North Project, 2010 to 2014



Note: Error bars represent the standard error of the mean of replicates.

3.6.2.1 Density

Benthic invertebrate density was consistently higher at the shallow lake sites (Little Roberts Lake and Reference Lake D) than at the deep lake sites (Doris Lake South, Doris Lake North, and Reference Lake B) between 2010 and 2014 (Figure 3.6-4). There was evidence of non-parallelism in density trends over time between all exposure and reference lakes ($p = <0.0001$ for Doris Lake South, $p = 0.0014$ for Doris Lake North, and $p = 0.0001$ for Little Roberts Lake). Densities at Doris Lake South and Doris Lake North were greater in 2014 than in previous years, whereas densities in Reference B Lake were lower, likely resulting in the non-parallelism compared to reference sites which have remained relatively stable through time (Figure 3.6-4).

Overall the results indicated a potential increase in lake benthos density in Doris Lake and a potential decrease in Little Roberts Lake; however, the data were highly variable and there was no evidence of Project-related changes in key environmental drivers of benthos density (e.g., nutrient availability) in these lakes. There were also no Project-related changes in water, sediment quality or phytoplankton biomass observed in these lakes in 2014 thus indicating that any changes in benthos density were unlikely to be Project-related.

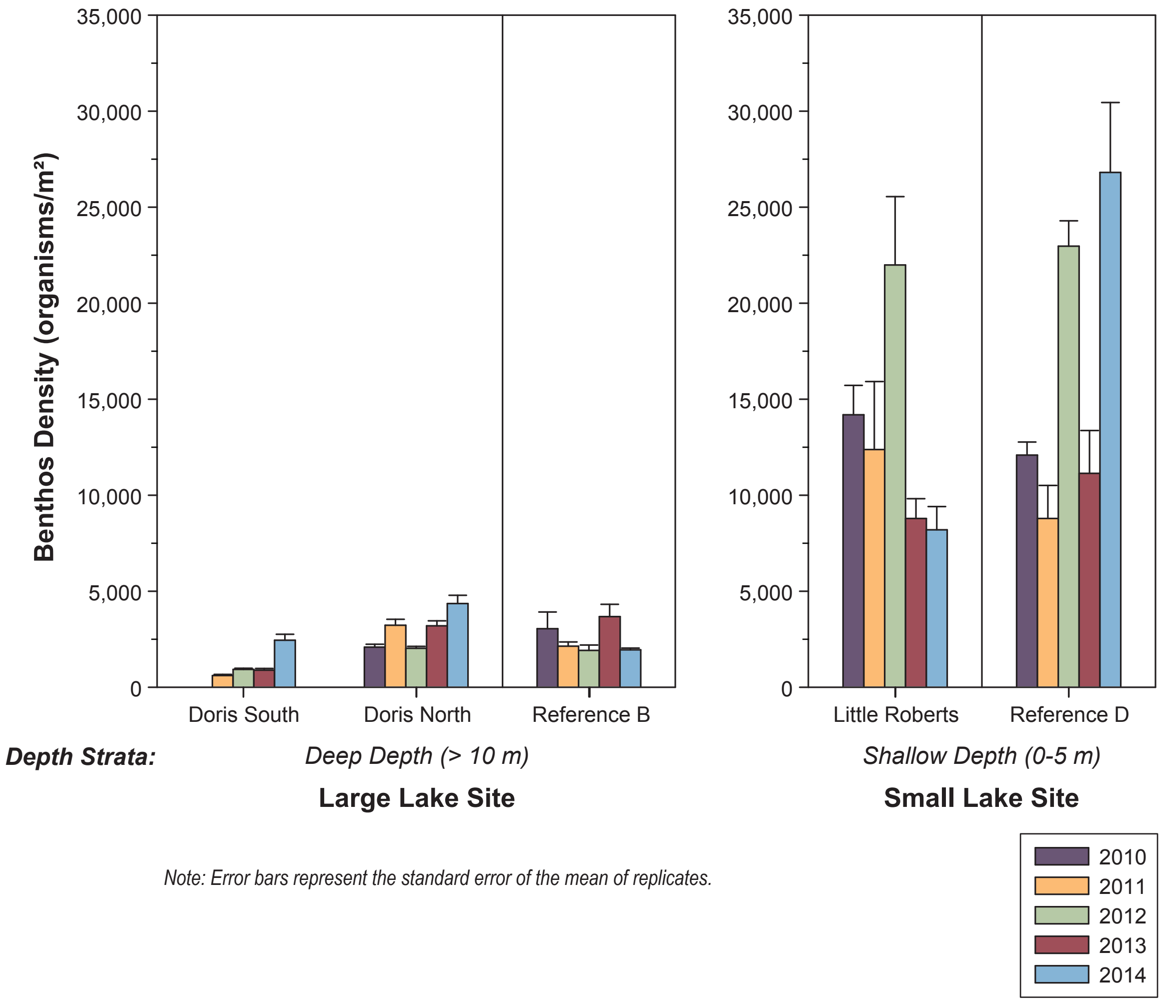
3.6.2.2 Community Richness, Evenness, and Diversity

Benthos family richness tended to be higher at the shallow lakes sites (Little Roberts Lake and Reference Lake D) than at the deep lake sites (Doris Lake South, Doris Lake North, and Reference Lake B; Figure 3.6-5). Family richness was relatively similar over time at each site, although there was some evidence of non-parallelism in trends for Doris Lake South and Little Roberts Lake relative to reference lakes ($p = 0.04$ for Doris Lake South, $p = 0.17$ for Doris Lake North, and $p = 0.02$ for Little Roberts Lake). A closer examination of the data indicated that there was a small increase in family richness over time at Doris Lake South and that mean richness observed in 2014 for both Doris Lake South and Little Roberts Lake were both well within the range observed in the reference lakes (Figure 3.6-5). Thus any differences between exposure and reference lake family richness was likely due to natural variability and is unlikely a Project-related effect.

For exposure and reference lakes, the mean 2014 Simpson's Evenness Index calculated for the benthos community was generally similar to the evenness calculated in previous years, though 2014 evenness was notably higher at Doris Lake North and lower at Reference Lake D compared to previous years (Figure 3.6-2). There was no evidence of non-parallelism in Doris Lake compared to reference lakes ($p = 0.05$ for Doris Lake South and $p = 0.48$ for Doris Lake North). However, there was evidence of non-parallelism in Little Roberts Lake compared to Reference Lake D ($p = 0.004$). Evenness was relatively stable through time in Little Roberts Lake, whereas a decrease was observed in Reference D Lake (Figure 3.6-5). Since the non-parallelism resulted from the decrease in Reference D Lake rather than a change over time in Little Roberts Lake, no adverse effects of 2014 Project activities on evenness were detected at this site.

Figure 3.6-4

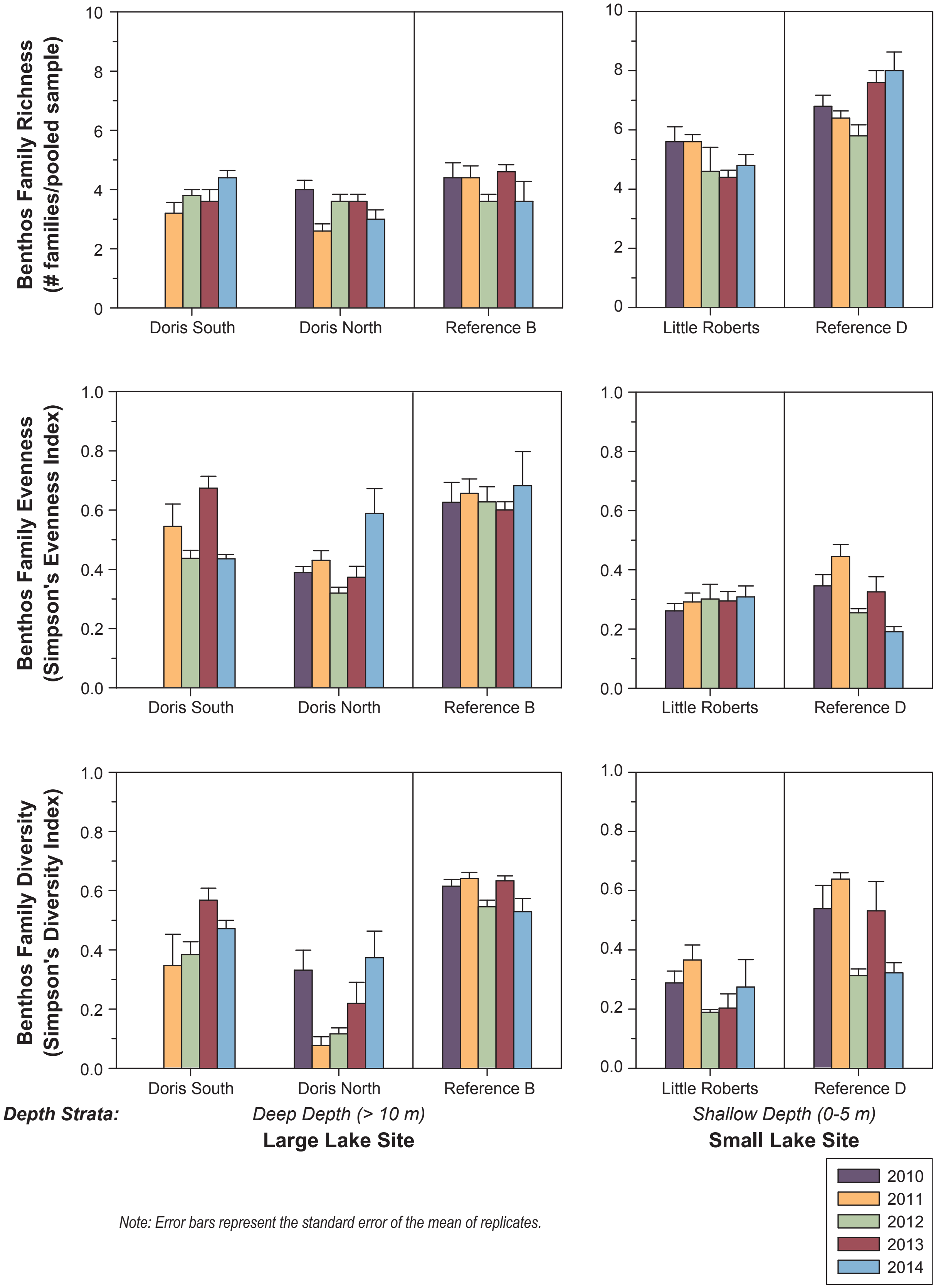
Benthos Density, Lake Sites, Doris North Project, 2010 to 2014



Note: Error bars represent the standard error of the mean of replicates.

Figure 3.6-5

Benthos Richness, Evenness, and Diversity, Lake Sites, Doris North Project, 2010 to 2014



Note: Error bars represent the standard error of the mean of replicates.

The mean Simpson's Diversity indices in exposure and reference lakes in 2014 were similar to mean diversity indices calculated for previous years with the exception of Doris Lake North, where mean diversity was greater than recent previous years (Figure 3.6-5). There was evidence of non-parallelism in trends between Doris North and reference lakes ($p = 0.0015$), but not for Doris Lake South ($p = 0.07$) or Little Roberts Lake ($p = 0.11$). Since diversity had generally increased since 2011 and mean 2014 diversity was similar to mean 2010 diversity in Doris Lake North, no Project-related negative effects were detected at Doris North. Thus, there were no apparent effects of 2014 Project activities on benthos diversity in the exposure lakes.

3.6.2.3 Bray-Curtis Index

The Bray-Curtis Index was highly inter-annually variable at the large lake exposure sites Doris Lake South and Doris Lake North (Figure 3.6-6). There was evidence of non-parallelism in the Bray-Curtis Index over time at both Doris Lake South and Doris Lake North (both $p < 0.0001$) relative to the trend at Reference Lake B. However, the non-parallelism was likely driven by an apparent decrease in the Bray-Curtis Index at Reference B, while the index remained relatively stable through time at the exposure sites (Figure 3.6-6). Thus, no Project-related effects were detected at large lake sites in 2014.

For Little Roberts Lake, the mean 2014 Bray-Curtis Index of 0.54 was slightly greater than previous years (Figure 3.6-6) but there was no evidence of non-parallelism between the trend for Little Roberts Lake and the trend for Reference Lake D ($p = 0.08$). Therefore, no Project-related effects on the Bray-Curtis Index were detected in this lake in 2014.

3.6.3 Marine Benthos

As recommended in the EEM guidance document (Environment Canada 2011), the marine benthos community was analyzed for the whole community (adults and juveniles) as well as for the adult community in isolation because juvenile benthos can respond differently to environmental disturbances than adult benthos.

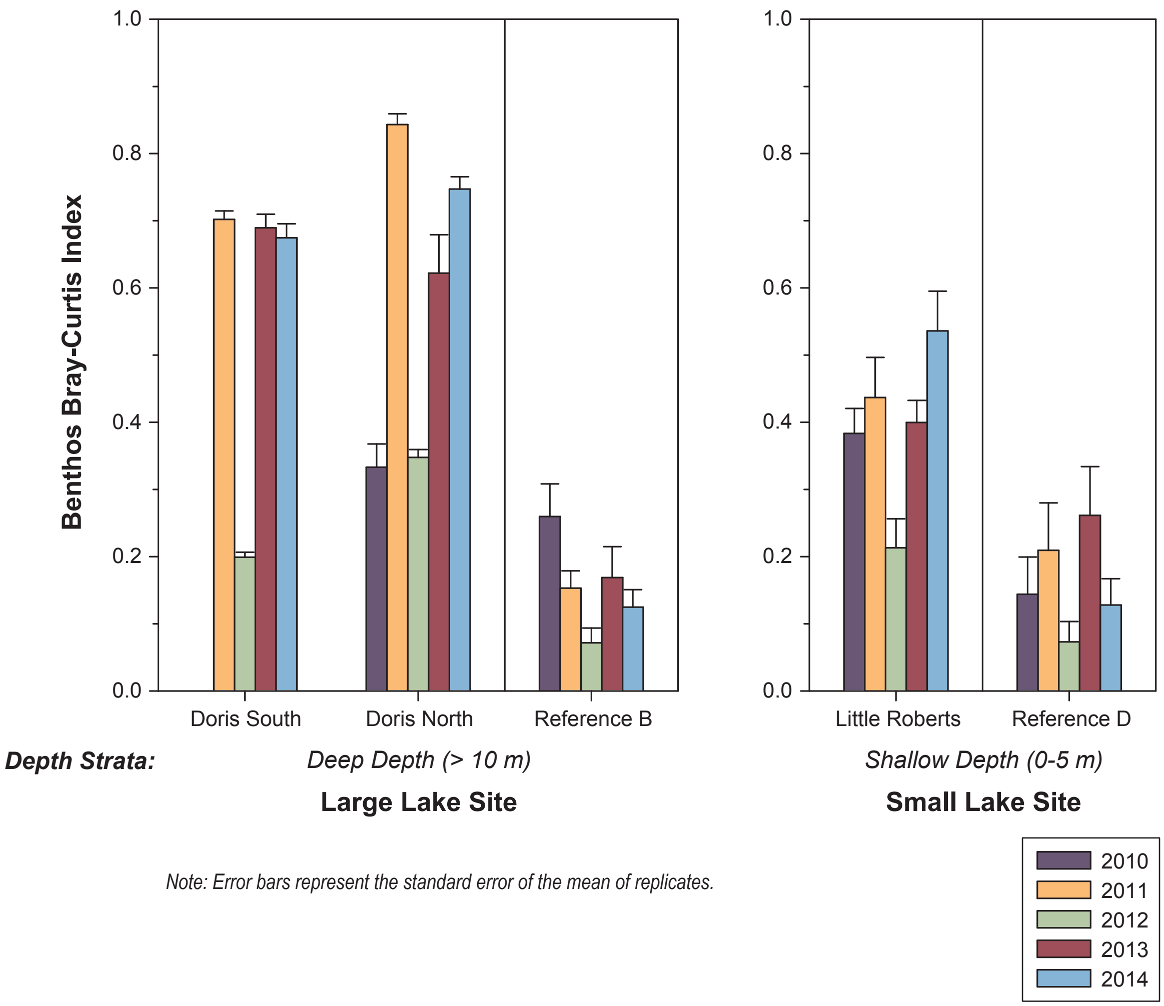
3.6.3.1 Density

Between 2011 and 2014, mean whole community as well as mean adult benthos densities were similar between marine sites RBW and REF-Marine 1, but comparatively low at site RBE (Figure 3.6-7). In both the whole community and the adult subset, there was evidence of non-parallelism in the 2010 to 2014 benthos density trends between RBW and REF-Marine 1 (both $p < 0.0001$). Whole community 2010 to 2014 density trends between RBE and REF-Marine 1 were parallel ($p = 0.46$); however, adult densities showed evidence of non-parallelism over time at RBE compared to REF-Marine 1 ($p < 0.0001$).

For RBW, the observed non-parallelism in trends with the reference site was largely driven by the relatively high densities observed in 2010 compared to later years at RBW and the correspondingly low 2010 density at the reference site compared to later years coupled with an increasing trend at the reference site. There were no apparent Project-related changes to water quality, sediment quality or primary producer biomass, despite some jetty erosion in 2013. Therefore, the decrease in benthos density at RBW was unlikely to be related to Project activities, though a Project-related effect cannot be entirely ruled out.

Figure 3.6-6

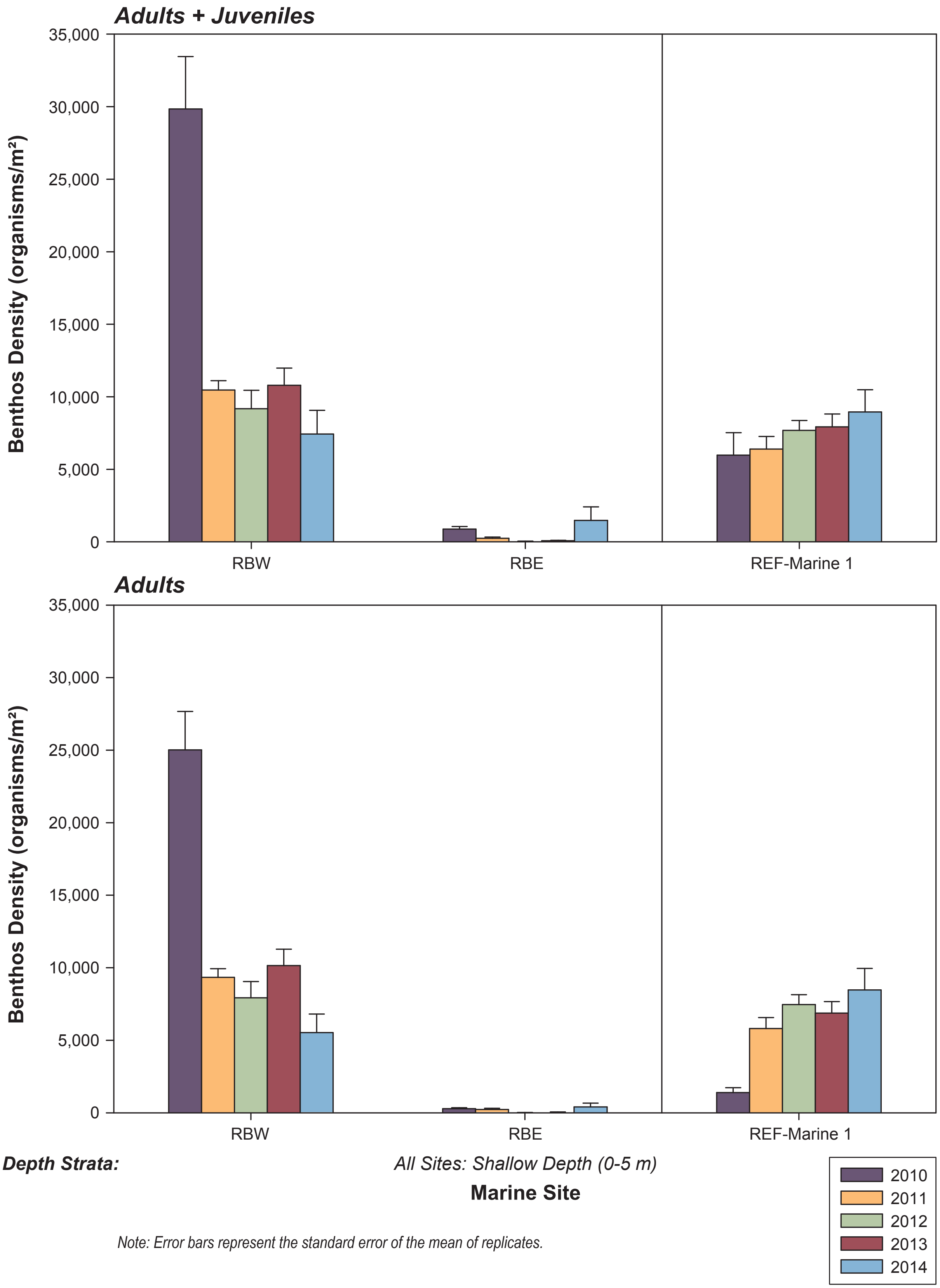
Benthos Bray-Curtis Index, Lake Sites, Doris North Project, 2010 to 2014



Note: Error bars represent the standard error of the mean of replicates.

Figure 3.6-7

Benthos Density, Marine Sites, Doris North Project, 2010 to 2014



Note: Error bars represent the standard error of the mean of replicates.

For RBE, adult densities appear to have been relatively consistent over time, from 2010 to 2014; therefore, the observed non-parallelism with the reference site was likely related to the apparent increasing trend over time observed at REF-Marine-1. Given that there have been no Project-related changes in water quality, sediment quality or primary producer biomass, it is unlikely that non-parallelism in density compared to the reference site was related to Project activities.

3.6.3.2 Community Richness, Evenness, and Diversity

In both the whole community and the adult only datasets, mean 2014 family richness was within the range observed in previous years at both exposure and reference sites (Figures 3.6-8a and 3.6-8b). However, there was evidence of significant non-parallelism in the trends in benthos family richness between REF-Marine 1 and the exposure sites (RBW whole community: $p = 0.0047$, adults: $p = 0.0014$; RBE whole community: $p = <0.0001$, adults: $p = <0.0001$). Because 2014 richness was among the highest observed to date at all sites, but remained in the range of historical values observed at all sites, the evidence suggested that there were no adverse effects of Project activities on benthos family richness at the exposure sites.

In both the whole community and adult datasets, family evenness and diversity were inter-annually variable at all marine sites (Figures 3.6-8a and 3.6-8b). The impact level-by-time analysis showed that there was evidence of significant non-parallelism in the 2010 to 2014 evenness and diversity trends between the exposure sites and the reference site for the adult dataset (evenness: $p < 0.0001$ for RBW, and $p = 0.0068$ for RBE; diversity: $p = 0.0001$ for RBW, and $p = 0.0001$ for RBE). For the whole community dataset there was evidence of significant non-parallelism between RBW and the reference site for evenness and evidence of a marginally non-significant difference between RBE and the reference site ($p = < 0.0001$ for RBW and $p = 0.0454$ for RBE). There was also significant evidence of non-parallelism between RBE and the reference site for whole community diversity ($p = 0.0003$). Differences in trends were marginally non-significant for whole benthos community diversity at RBW compared to REF-Marine 1 ($p = 0.0381$).

At site RBW, whole community and adult benthos family richness, evenness, and diversity in 2014 were among the highest levels observed and within the range of values observed in previous years. At site RBE, richness, evenness, and diversity were all within the range of values observed historically when error was taken into account. Given that there were no apparent Project-related changes to the water quality, sediment quality, or primary producer biomass that could have affected benthos richness, evenness or diversity in 2014, it was unlikely that observed changes in these variables were related to Project activities.

3.6.3.3 Bray-Curtis Index

The benthos Bray-Curtis Index measured for each marine site in 2014 fell within the range of previous years for both the whole community dataset and the adult subset (Figure 3.6-9). However, there was significant evidence of non-parallelism in the Bray-Curtis Index over time for both the whole community ($p = 0.0037$ for RBW, and $p = 0.0001$ for RBE) and the adult datasets ($p < 0.0001$ for RBE). The differences in trends in the Bray-Curtis Index for the adult only dataset at RBW compared to REF-Marine 1 was marginally non-significant ($p = 0.014$).

Figure 3.6-8a

Benthos Richness, Evenness, and Diversity, Marine Sites, Doris North Project, 2010 to 2014

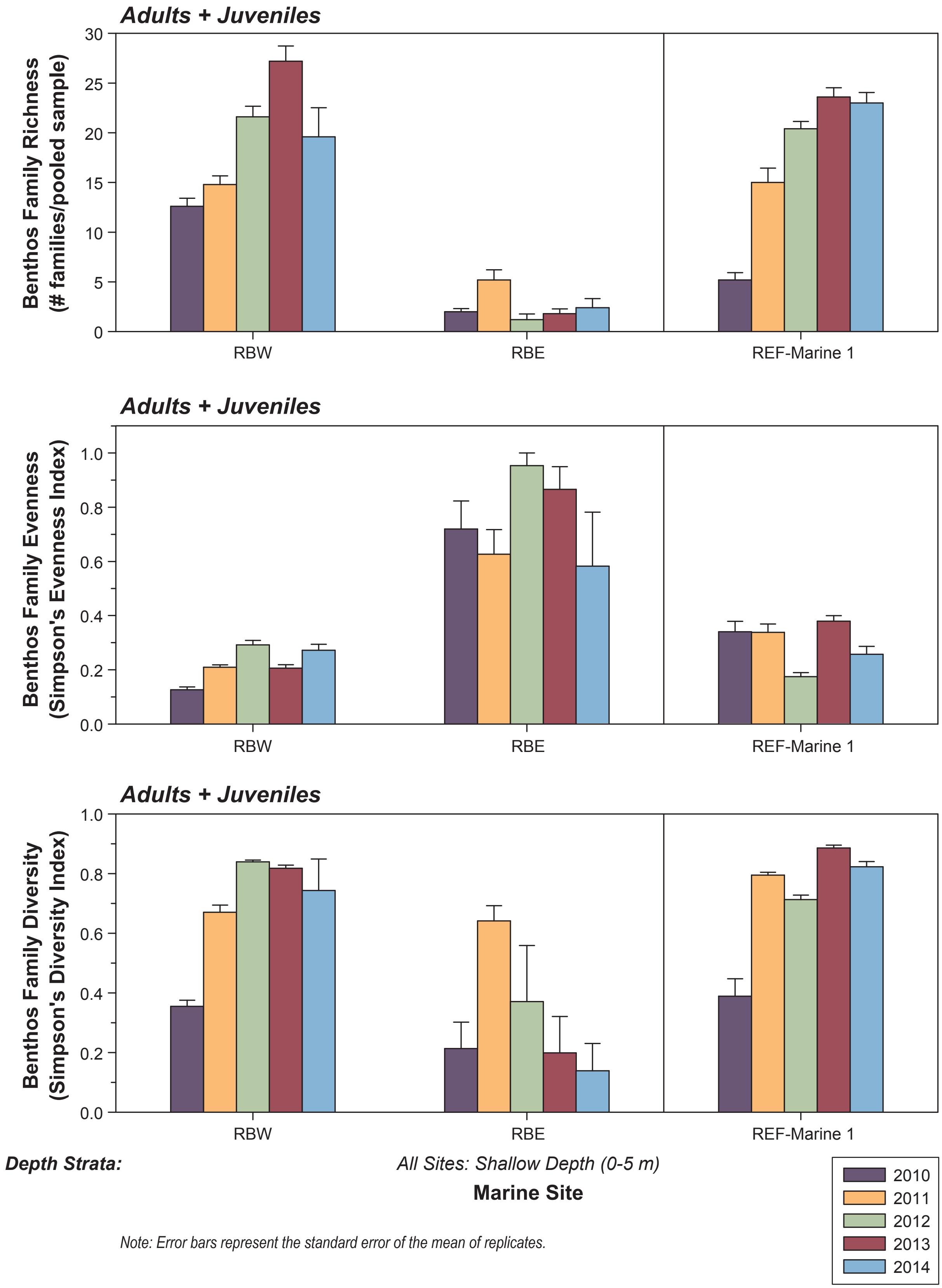
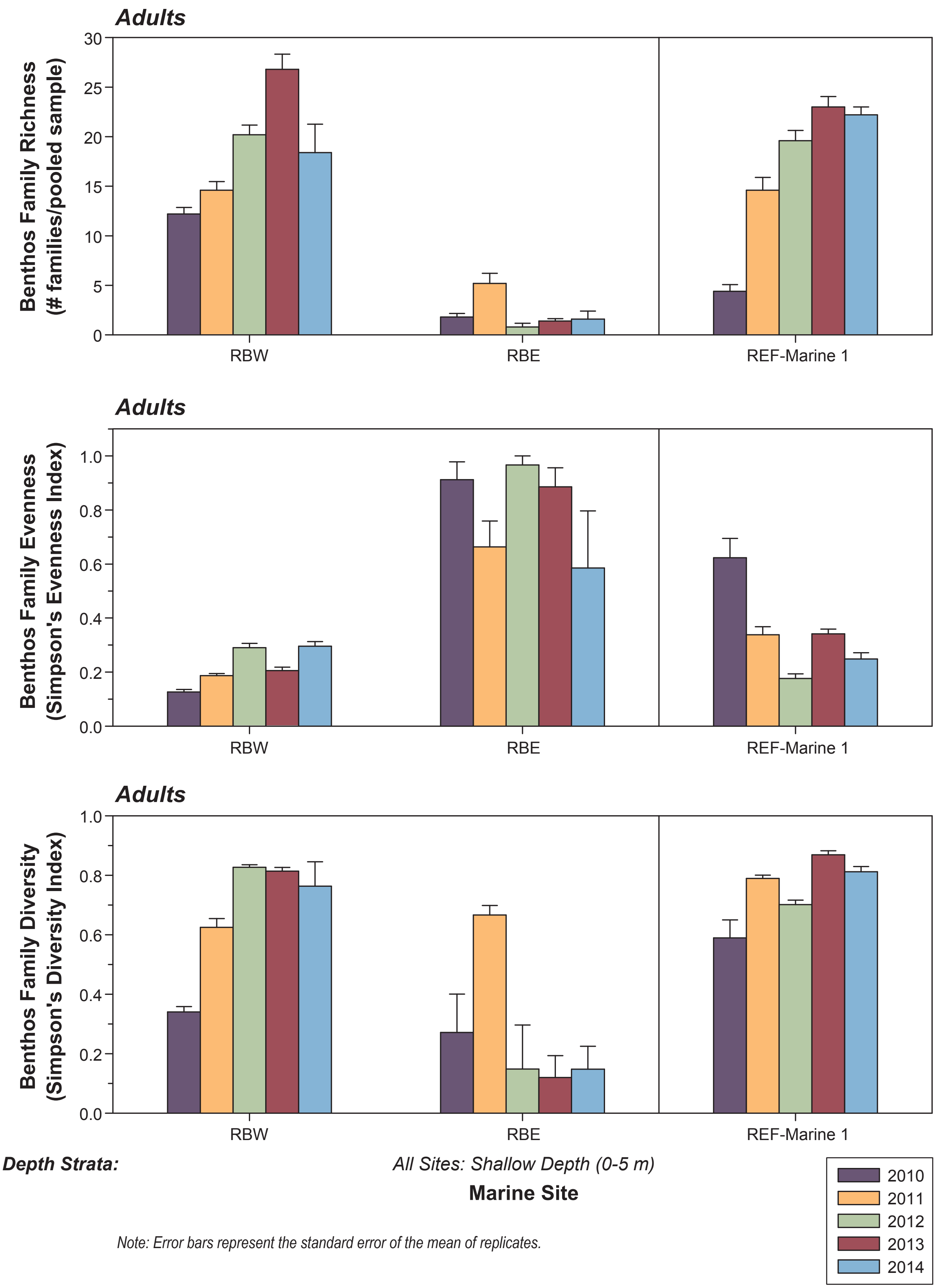


Figure 3.6-8b

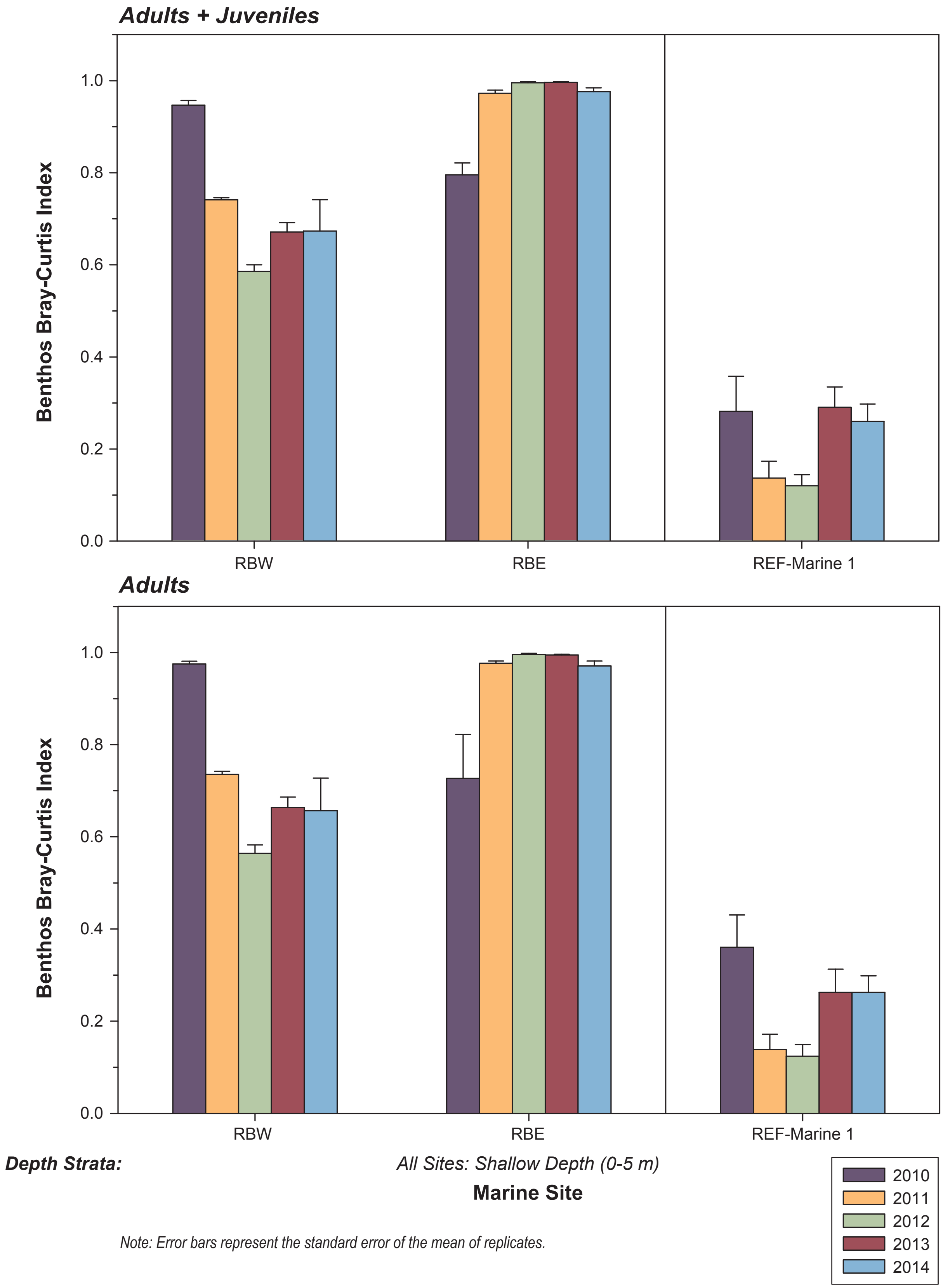
Benthos Richness, Evenness, and Diversity, Marine Sites, Doris North Project, 2010 to 2014



Note: Error bars represent the standard error of the mean of replicates.

Figure 3.6-9

Benthos Bray-Curtis Index, Marine Sites, Doris North Project, 2010 to 2014



At site RBW, the whole community and adult Bray-Curtis indices were within the range of previous years and had, if anything, became more similar to reference communities through time. Thus, there was no evidence that jetty erosion in 2013 adversely affected the benthos community at this site. At site RBE, the 2014 Bray-Curtis indices for both the whole community and the adults were within range of previous years, and there were no apparent Project-related changes to water quality, sediment quality, or primary producer biomass that could have affected the community composition of benthic invertebrates; therefore, it was unlikely that non-parallelism in the Bray-Curtis Index compared to the reference site was related to Project activities.

4. SUMMARY OF EFFECTS ANALYSIS

The effects analysis employed graphical and statistical methods to identify potential effects to the aquatic environment that may have resulted from Project activities in 2014. When historical information was available, before (baseline, 1995-2009 or 2010) and after (evaluation year, 2014) data for specific variables were first compared at each of the exposure sites to determine whether there was a discernible change in evaluated variables in 2014 compared to baseline years. If there was a change, before-after trends in the exposure sites were compared to those at the reference sites (BACI design) to determine if parallel changes occurred (no effect) or if the change differed between the exposure and reference waterbodies (potential effect). Graphical analysis was used to supplement statistical methods and to aid in the interpretation of temporal trends. Professional judgment was always employed when statistical or graphical methods indicated potential effects for specific variables to determine whether the effect resulted from natural processes or Project activities.

4.1 STREAMS

A summary of the 2014 effects analysis for the AEMP exposure streams is presented in Table 4.1-1. There was sufficient historical information to evaluate potential Project-related effects on water and sediment quality, periphyton biomass, and the benthic invertebrate community. Overall, there were no apparent Project-related effects on any of the evaluated variables in exposure streams.

Mean 2014 water quality concentrations in exposure streams were all below CCME guidelines, with the exception of total aluminum. However, the total aluminum guideline was also frequently exceeded in all exposure streams during baseline years. Of the 18 water quality variables that were evaluated, none changed significantly from baseline to 2014 in the exposure streams. Marginally non-significant changes (i.e., $p = 0.01$ to 0.05) were observed for some parameters; however, there was no evidence of a Project related effect in any of these instances. Therefore, there were no apparent adverse effects of 2014 Project activities on the water quality of the exposure streams.

Mean 2014 sediment quality concentrations in AEMP exposure streams were all below CCME ISQGs and PELs. At Doris and Little Roberts outflows, there were some differences in the particle size composition of sediment samples collected in 2014 compared to the particle size composition of baseline samples. Variation in sediment particle size composition was likely unrelated to 2014 Project activities, and probably reflects natural spatial heterogeneity in stream sediments. At Little Roberts Outflow, sediments in 2014 contained significantly lower concentrations of TOC, lead, and mercury than did baseline sediments. There was also some evidence that chromium, copper and zinc concentrations in Little Roberts Outflow had declined. These decreases were likely attributable to the significant decrease in the proportion of fine sediments in 2014 samples compared to baseline samples, since fine sediments tend to be associated with higher concentrations of TOC and metals than coarse sediments (e.g., Lakhan, Cabana, and LaValle 2003; Secrieri and Oaie 2009). Decreases in sediment metal concentrations are not of concern. Therefore, there were no apparent adverse effects of 2014 Project activities on the sediment quality of exposure streams.

There was no significant indication that 2014 Project activities affected periphyton biomass in the exposure streams. The BACI result for the comparison of Little Roberts Outflow to the reference streams was marginally non-significant but the observations were deemed to be unrelated to Project activities.

There was no evidence of Project-related effects on benthos density, richness, evenness or diversity in exposure streams despite significant evidence of non-parallelism in trends in benthos family evenness between Doris Outflow and the reference streams and marginally non-significant evidence of non-parallelism in trends of benthos density between Little Roberts Outflow and the reference streams. Trends in the Bray-Curtis Index differed significantly between Roberts Outflow and Doris Outflow and the reference streams, likely because the Bray-Curtis Index has declined through time in Roberts Outflow and Doris Outflow but has increased in the last two years in the reference streams. This suggested that benthos communities in Roberts Outflow and Doris Outflow have become more similar to reference communities through time, which is of little concern. Thus, there were no apparent adverse effects of 2014 Project activities on stream benthos communities.

4.2 LAKES

Table 4.2-1 presents the summary of the 2014 effects analysis for the AEMP exposure lakes. There was sufficient historical information to evaluate potential Project-related effects on under-ice dissolved oxygen concentrations, Secchi depth, water and sediment quality, phytoplankton biomass, and the benthic invertebrate community. Overall, there were no apparent Project-related effects on any of the evaluated variables in the AEMP exposure lakes.

There was no evidence of an effect of 2014 Project activities on either under-ice dissolved oxygen concentrations or Secchi depths in the exposure lakes. At both Doris Lake sites, dissolved oxygen concentrations throughout the water column were greater than the CCME guideline for cold-water, early life stages (9.5 mg/L). In 2014, dissolved oxygen concentrations in Little Roberts were relatively low and below the CCME freshwater cold-water guideline for non-early life stages (6.5 mg/L), but fell within the wide range of baseline measurements. Thus, no adverse changes to 2014 winter dissolved oxygen concentrations were detected in exposure lakes.

Mean 2014 water quality concentrations in exposure lakes were less than CCME guidelines with the exception of total iron in Little Roberts Lake. In Little Roberts Lake, the mean 2014 total iron concentration was greater than CCME guideline of 0.3 mg/L due to elevated under-ice concentrations, most likely due to sample contamination. Open-water total iron concentrations in Little Roberts Lake were below the CCME guideline. There was evidence of a significant change between baseline years and 2014 in water hardness (increase) at Doris Lake South and Little Roberts Lake, and in the concentrations of total arsenic (decrease) and total molybdenum (increase) at Doris Lake North. However, in three of these four instances, the BACI analysis showed that parallel changes from baseline years to 2014 occurred at the reference lakes. Thus, these three changes were likely unrelated to 2014 Project activities. BACI analysis could not be performed for Little Roberts Lake for water hardness because there were no baseline data for Reference Lake D. Although hardness was elevated in Little Roberts Lake under-ice, open-water season concentrations were within the range of baseline means. Combined, the evidence does not suggest a Project-related effect for hardness in Little Roberts Lake.

Table 4.1-1. Summary of Evaluation of Effects, AEMP Streams, Doris North Project, 2014

Variable	Method of Evaluation	Within Waterbody Before-After Difference (BA analysis)[a]					Before-After Trend Relative to Reference Sites (BACI analysis)[a]			Conclusion of Effect[b, c]		
		Doris OF	Roberts OF	Little Roberts OF	Reference B OF	Reference D OF	Doris OF	Roberts OF	Little Roberts OF	Doris OF	Roberts OF	Little Roberts OF
Water Quality												
pH	GA, BA	No difference	No difference	No difference	No difference	-	□	□	□	No effect	No effect	No effect
Alkalinity, Total	GA, BA	No difference	No difference	No difference	No difference	-	□	□	□	No effect	No effect	No effect
Hardness	GA, BA	No difference	No difference	No difference	Marginal	-	□	□	□	No effect	No effect	No effect
Total Suspended Solids	GA, BA	No difference	No difference	No difference	-	-	□	□	□	No effect	No effect	No effect
Ammonia (as N)	GA, BA	No difference	No difference	No difference	-	-	□	□	□	No effect	No effect	No effect
Nitrate (as N)	GA, BA	-	-	-	No difference	-	-	-	-	No effect	No effect	No effect
Cyanide, Total	GA	-	-	-	-		-	-	-	No effect	No effect	No effect
Radium-226	GA	-	-	-	-	-	-	-	-	No effect	No effect	No effect
Aluminum, Total	GA, BA	No difference	No difference	No difference	Marginal	-	□	□	□	No effect	No effect	No effect
Arsenic , Total	GA, BA	No difference	Marginal	No difference	Marginal	-	□	No difference	□	No effect	No effect	No effect
Cadmium, Total	GA	-	-	No difference	-	-	-	-	□	No effect	No effect	No effect
Copper, Total	GA, BA	No difference	No difference	No difference	No difference	-	□	□	□	No effect	No effect	No effect
Iron , Total	GA, BA	No difference	No difference	No difference	No difference	-	□	□	□	No effect	No effect	No effect
Lead, Total	GA, BA	No difference	No difference	No difference	-	-	□	□	□	No effect	No effect	No effect
Mercury, Total	GA, BA	-	Marginal	No difference	**Decrease**	-	-	**Significant difference**	□	No effect	No effect[d]	No effect
Molybdenum, Total	GA, BA	Marginal	No difference	No difference	-	-	No difference	□	□	No effect	No effect	No effect
Nickel, Total	GA, BA	No difference	No difference	No difference	No difference	-	□	□	□	No effect	No effect	No effect
Zinc, Total	GA	No difference	No difference	No difference	-	-	□	□	□	No effect	No effect	No effect
Sediment Quality												
% Gravel (>2 mm)	GA, BA, BACI	**Decrease**	-	**Increase**	No difference	-	Parallel	-	Parallel	No effect	No effect	No effect
% Sand (2.0 mm - 0.063 mm)	GA, BA, BACI	**Increase**	-	**Increase**	No difference	-	**Non-parallel**	-	Parallel	No effect[d]	No effect	No effect
% Silt (0.063 mm - 4 µm)	GA, BA, BACI	No difference	-	**Decrease**	No difference	-	□	-	Parallel	No effect	No effect	No effect
% Clay (<4 µm)	GA, BA, BACI	No difference	-	**Decrease**	No difference	-	□	-	**Non-parallel**	No effect	No effect	No effect[d]
Total Organic Carbon	GA, BA, BACI	No difference	-	**Decrease**	No difference	-	□	-	**Non-parallel**	No effect	No effect	No effect[d]
Arsenic	GA, BA	No difference	-	No difference	No difference	-	□	-	□	No effect	No effect	No effect
Cadmium	GA	-	-	-	-	-	-	-	-	No effect	No effect	No effect
Chromium	GA, BA	No difference	-	Marginal	Marginal	-	□	-	**Marginal**	No effect	No effect	No effect[d]
Copper	GA, BA	No difference	-	Marginal	No difference	-	□	-	Parallel	No effect	No effect	No effect
Lead	GA, BA, BACI	No difference	-	**Decrease**	No difference	-	□	-	**Non-parallel**	No effect	No effect	No effect[d]
Mercury	GA, BA, BACI	-	-	**Decrease**	No difference	-	-	-	**Non-parallel**	No effect	No effect	No effect[d]
Zinc	GA, BA	No difference	-	Marginal	**Increase**	-	□	-	**Marginal**	No effect	No effect	No effect[d]
Periphyton												
Biomass	GA, BA, BACI	No difference	-		-	-	□	-	Marginal	No effect	No effect	No effect[d]
							2010 to 2014 Trend Relative to Reference Sites (Impact Level-by-Time analysis)[a]					
Benthic Invertebrates												
Total Density	GA, ILBT	-	-	-	-	-	Parallel	Parallel	Marginal	No effect	No effect	No effect[d]
Family Richness	GA, ILBT	-	-	-	-	-	Parallel	Parallel	Parallel	No effect	No effect	No effect
Simpson's Evenness Index	GA, ILBT	-	-	-	-	-	**Non-parallel**	Parallel	Parallel	No effect[d]	No effect	No effect
Simpson's Diversity Index	GA, ILBT	-	-	-	-	-	Parallel	Parallel	Parallel	No effect	No effect	No effect
Bray-Curtis Index	GA, ILBT	-	-	-	-	-	Marginal	**Non-parallel**	Parallel	No effect[d]	No effect[d]	No effect

Notes:

GA - Graphical analysis; BA - Before-After analysis; BACI - Before-After-Control-Impact analysis; ILBT - Impact Level-by-Time analysis

[a] *Statistically significant difference at p<0.01 to avoid Type I errors. P-values of 0.01 to 0.05 were considered marginally non-significant (labelled as marginal in table).*

[b] *Conclusion of effect is based on graphical analysis, statistical analyses, and professional judgment.*

[c] *For water pH, water alkalinity, water hardness, sediment total organic carbon, sediment particle size, periphyton biomass, and benthos community descriptors, a change in any direction is considered to be an effect. For winter dissolved oxygen concentrations, only a decrease is considered to be an effect. For all remaining variables, only an increase is considered to be an effect.*

[d] *Although there was a significant or marginal difference, this change was not attributed to Project activities.*

For both the BACI and the ILBT analyses, a differential increase or decrease in exposure site variables over time relative to the reference sites (i.e., a non-parallel effect) may indicate a Project-related effect.

Dash (-) indicates that statistical analysis was not possible because of missing data (i.e., no historical data available), the high proportion of nondetectable concentrations, too few degrees of freedom for the analysis, or the lack of variation in a variable over time (having no measure of variation causes F-statistic to be infinite).

Square (□) indicates that BACI results are not reported because the within waterbody before-after comparison shows that there was no significant difference between baseline and 2014 means.

Table 4.2-1. Summary of Evaluation of Effects, AEMP Lakes, Doris North Project, 2014

Variable	Method of Evaluation	Within Waterbody Before-After Difference (BA analysis)[a]					Before-After Trend Relative to Reference Site (BACI analysis)[a]			Conclusion of Effect[b, c]		
		Doris South	Doris North	Reference B	Little Roberts	Reference D	Doris South	Doris North	Little Roberts	Doris South	Doris North	Little Roberts
Physical Limnology												
Winter Dissolved Oxygen	GA	-	-	-	-	-	-	-	-	No effect	No effect	No effect
Secchi Depth	GA, BA	No difference	No difference	-	No difference	-	☐	☐	-	No effect	No effect	No effect
Water Quality												
pH	GA, BA	No difference	No difference	No difference	No difference	-	☐	☐	-	No effect	No effect	No effect
Alkalinity, Total	GA, BA	No difference	No difference	No difference	No difference	-	☐	☐	-	No effect	No effect	No effect
Hardness	GA, BA, BACI	**Increase**	Marginal	Marginal	**Increase**	-	Parallel	No difference	-	No effect	No effect	No effect[d]
Total Suspended Solids	GA, BA	No difference	No difference	-	No difference	-	☐	☐	-	No effect	No effect	No effect
Ammonia (as N)	GA, BA	No difference	No difference	No difference	No difference	-	☐	☐	-	No effect	No effect	No effect
Nitrate (as N)	GA, BA	No difference	No difference	No difference	No difference	-	☐	☐	-	No effect	No effect	No effect
Cyanide, Total	GA	-	-	-	-	-	-	-	-	No effect	No effect	No effect
Radium-226	GA	-	-	-	-	-	-	-	-	No effect	No effect	No effect
Aluminum, Total	GA, BA	No difference	No difference	No difference	No difference	-	☐	☐	-	No effect	No effect	No effect
Arsenic , Total	GA, BA, BACI	No difference	**Decrease**	Marginal	No difference	-	☐	Parallel	-	No effect	No effect	No effect
Cadmium, Total	GA	-	-	-	-	-	☐	☐	-	No effect	No effect	No effect
Copper, Total	GA, BA	No difference	No difference	No difference	No difference	-	☐	☐	-	No effect	No effect	No effect
Iron , Total	GA, BA	No difference	No difference	No difference	No difference	-	☐	☐	-	No effect	No effect	No effect
Lead, Total	GA, BA	No difference	No difference	No difference	No difference	-	☐	☐	-	No effect	No effect	No effect
Mercury, Total	GA, BA, BACI	-	No difference	**Decrease**	No difference	-	Parallel	☐	-	No effect	No effect	No effect
Molybdenum, Total	GA, BA, BACI	No difference	**Increase**	-	No difference	-	☐	Parallel	-	No effect	No effect	No effect
Nickel, Total	GA, BA	No difference	No difference	No difference	No difference	-	☐	☐	-	No effect	No effect	No effect
Zinc, Total	GA	No difference	No difference	-	No difference	-	☐	☐	-	No effect	No effect	No effect
Sediment Quality												
% Gravel (>2 mm)	GA	-	-	-	-	-	-	-	-	No effect	No effect	No effect
% Sand (2.0 mm - 0.063 mm)	GA, BA	No difference	No difference	-	**Decrease**	-	-	-	-	No effect	No effect	No effect[d]
% Silt (0.063 mm - 4 µm)	GA, BA	**Increase**	No difference	-	**Increase**	-	-	-	-	No effect[d]	No effect	No effect[d]
% Clay (<4 µm)	GA, BA	**Decrease**	No difference	-	Marginal	-	-	-	-	No effect[d]	No effect	No effect[d]
Total Organic Carbon	GA, BA	No difference	**Increase**	-	No difference	-	-	-	-	No effect	No effect[d]	No effect
Arsenic	GA, BA	No difference	No difference	-	**Increase**	-	-	-	-	No effect	No effect	No effect[d]
Cadmium	GA, BA	Marginal	No difference	-	No difference	-	-	-	-	No effect[d]	No effect	No effect
Chromium	GA, BA	No difference	No difference	-	No difference	-	-	-	-	No effect	No effect	No effect
Copper	GA, BA	**Decrease**	**Decrease**	-	No difference	-	-	-	-	No effect[d]	No effect[d]	No effect
Lead	GA, BA	Marginal	Marginal	-	No difference	-	-	-	-	No effect[d]	No effect[d]	No effect
Mercury	GA, BA	No difference	No difference	-	No difference	-	-	-	-	No effect	No effect	No effect
Zinc	GA, BA	No difference	No difference	-	**Increase**	-	-	-	-	No effect	No effect	No effect[d]
Phytoplankton												
Biomass	GA, BA	No difference	No difference	-	No difference	-	☐	☐	-	No effect	No effect	No effect
							2010 to 2014 Trend Relative to Reference Sites (Impact Level-by-Time analysis)[a]					
Benthic Invertebrates												
Total Density	GA, ILBT	-	-	-	-	-	**Non-parallel**	**Non-parallel**	**Non-parallel**	No effect[d]	No effect[d]	No effect[d]
Family Richness	GA, ILBT	-	-	-	-	-	Marginal	Parallel	Marginal	No effect[d]	No effect	No effect[d]
Simpson's Evenness Index	GA, ILBT	-	-	-	-	-	Parallel	Parallel	**Non-parallel**	No effect	No effect	No effect[d]
Simpson's Diversity Index	GA, ILBT	-	-	-	-	-	Parallel	**Non-parallel**	Parallel	No effect	No effect[d]	No effect
Bray-Curtis Index	GA, ILBT	-	-	-	-	-	**Non-parallel**	**Non-parallel**	Parallel	No effect[d]	No effect[d]	No effect

Notes:

GA - Graphical analysis; BA - Before-After analysis; BACI - Before-After-Control-Impact analysis; ILBT - Impact Level-by-Time analysis

[a] *Statistically significant difference at p<0.01 to avoid Type I errors. P-values of 0.01 to 0.05 were considered marginally non-significant (labelled as marginal in table).*

[b] *Conclusion of effect is based on graphical analysis, statistical analyses, and professional judgment.*

[c] *For water pH, water alkalinity, water hardness, sediment total organic carbon, sediment particle size, periphyton biomass, and benthos community descriptors, a change in any direction is considered to be an effect. For winter dissolved oxygen concentrations, only a decrease is considered to be an effect. For all remaining variables, only an increase is considered to be an effect.*

[d] *Although there was a significant or marginal difference, this change was not attributed to Project activities.*

For both the BACI and the ILBT analyses, a differential increase or decrease in exposure site variables over time relative to the reference sites (i.e., a non-parallel effect) may indicate a Project-related effect.

Dash (-) indicates that statistical analysis was not possible because of missing data (i.e., no historical data available), the high proportion of nondetectable concentrations, too few degrees of freedom for the analysis, or the lack of variation in a variable over time (having no measure of variation causes F-statistic to be infinite).

Square (☐) indicates that BACI results are not reported because the within waterbody before-after comparison shows that there was no significant difference between baseline and 2014 means.

Marginally non-significant changes were also observed for some water quality parameters however there was no evidence of a Project related effect in any of these instances.

Mean 2014 sediment quality concentrations were generally below CCME ISQGs, except for total arsenic at Doris Lake South, total chromium at all exposure and reference sites, and total copper at Doris Lake North and Doris Lake South. The total arsenic PEL was also exceeded at Doris Lake South. At Doris Lake South and Little Roberts Lake, there were some differences in the particle size composition in the sediment samples collected in 2014 compared to the particle size composition of baseline samples. Variation in sediment particle size composition was likely unrelated to 2014 Project activities, and probably reflects natural spatial heterogeneity in lake sediments. There was evidence of a decrease between baseline years and 2014 in copper concentrations in sediments from Doris Lake South and Doris Lake North, as well as an increase in TOC in Doris Lake North, and an increase in arsenic and zinc concentrations in Little Roberts Lake. However, decreases in sediment heavy metal concentrations are not of environmental concern and increases in metal concentrations in Little Roberts Lake were likely related to the non-Project-related increase in the proportion of fine sediments observed in that lake. Marginally non-significant changes (i.e., $p = 0.01$ to 0.05) were also observed for some sediment quality parameters however there was no evidence of a Project related effect in any of these instances. Therefore, there were no apparent adverse effects of 2014 Project activities on the sediment quality of exposure lakes.

There was no indication of a Project-related effect on 2014 phytoplankton biomass in the exposure lakes.

There was evidence of significant non-parallelism in the 2010 to 2014 benthos density trends for all exposure lakes relative to reference lakes, Simpson's Evenness Index between Little Roberts Lake and Reference D Lake, Simpson's Diversity Index between Doris Lake North and Reference B Lake, and the Bray-Curtis Index between Doris Lake South, Doris Lake North, and Reference Lake D. Overall the results indicated a potential increase in lake benthos density in Doris Lake and a potential decrease in Little Roberts Lake, however, the data were highly variable and there was no evidence of Project-related changes in key environmental drivers of benthos density (e.g., nutrient availability) in these lakes. There were also no Project-related changes in water, sediment quality or phytoplankton biomass observed in these lakes in 2014 thus indicating that any changes in benthos density were unlikely to be Project-related. The non-parallelism in evenness at Little Roberts Lake compared to Reference Lake D resulted from a decrease in Reference D Lake rather than a change over time in Little Roberts Lake. Thus, no adverse effects of 2014 Project activities on evenness were detected at this site. The non-parallelism in diversity at Doris Lake North was unlikely to be a project-related effect since mean 2014 diversity was similar to mean 2010 diversity in Doris Lake North. The Bray-Curtis Index was highly inter-annually variable at the large lake exposure sites Doris Lake South and Doris Lake North and the non-parallelism at these sites relative to the trend in Reference Lake B was likely driven by an apparent decrease in the Bray-Curtis Index at Reference B, while the index remained relatively stable through time at the exposure sites. Thus, no Project-related effects were detected at lake sites for the Bray-Curtis Index in 2014. 2010 to 2014 trends in family richness at exposure lakes paralleled (Doris Lake North) or showed marginally non-significant differences (Doris Lake South and Little Roberts Lake) compared to the trends observed for the reference lakes. These differences were deemed to be due to natural variability and no effects of 2014 Project activities on benthos family richness were found.

4.3 MARINE

Table 4.3-1 presents the summary of the 2014 effects analysis for the AEMP marine exposure sites. There was sufficient historical information to evaluate potential Project-related effects on under-ice dissolved oxygen concentrations, water and sediment quality, phytoplankton biomass, and the benthic invertebrate community. Overall, there were no apparent Project-related effects on any of the evaluated variables in the marine exposure sites.

There was no evidence of an effect of 2014 Project activities on under-ice dissolved oxygen concentrations at the marine exposure sites in Roberts Bay, and 2014 concentrations remained above the CCME interim guideline for the minimum concentration of dissolved oxygen in marine and estuarine waters (8.0 mg/L).

At the marine exposure sites, mean 2014 concentrations of the 18 evaluated water quality variables were all below CCME guidelines. No statistically significant (or marginally non-significant) changes in water quality from baseline years to 2014 were observed for exposure sites. Therefore, there no adverse, Project-related effects on water quality were detected at the marine exposure sites in Roberts Bay in 2014.

At site RBW, near the jetty, and at the reference site REF-Marine 1, there were some differences in the particle size composition of the sediment samples collected in 2014 compared to the particle size composition of samples collected in 2002 or 2009. Overall there was an increase in the proportion of fine sediment (silt and/or clay). As expected, this shift to finer sediments in 2014 had important implications for TOC content and some evaluated metal concentrations (arsenic, chromium, and copper), which increased significantly at both RBW and REF-Marine 1 in 2014 compared to baseline years. Mercury and zinc concentrations also increased significantly at REF-Marine-1, and there were marginally non-significant decreases in lead and zinc at RBW. The similarity between RBW and REF-Marine 1 with respect to increases in silt content, and increases in sediment TOC content and metal concentrations from baseline years to 2014 suggests that the observed changes at RBW were naturally occurring and unrelated to the damage to the jetty that occurred in 2013, the jetty repair in the winter of 2013/2014, or other Project activities. The changes in sediment particle size composition and quality may be the product of spatial heterogeneity. All evaluated sediment quality variables in marine exposure sites had concentrations less than CCME ISQGs and PELs, with the exception of the total copper concentration at RBW, which was greater than the ISQG, but less than the PEL.

There was no indication of a Project-related effect on phytoplankton biomass at the marine exposure sites.

In the whole benthos community (adults and juveniles), significant non-parallelisms were detected for all evaluated benthos community descriptors at RBW and RBE relative to the REF-Marine 1, except for the whole community benthos Simpson's Diversity Index at RBW, and density and Simpson's Evenness Index at RBE. Marginally non-significant differences in trends were also found between RBW and REF-Marine 1 for whole community benthos Simpson's Diversity Index and between RBE and REF-Marine 1 for whole community benthos Simpson's Evenness Index.

Table 4.3-1. Summary of Evaluation of Effects, AEMP Marine Sites, Doris North Project, 2014

		Within Waterbody Before-After Difference (BA analysis)[a]			Before-After Trend Relative to Reference Site (BACI analysis)[a]		Conclusion of Effect[b, c]	
Variable	Method of Evaluation	Roberts Bay West (RBW)	Roberts Bay East (RBE)	Ida Bay (REF-Marine 1)	Roberts Bay West (RBW)	Roberts Bay East (RBE)	Roberts Bay West (RBW)	Roberts Bay East (RBE)
Physical Oceanography								
Winter Dissolved Oxygen	GA	-	-	-	-	-	No effect	No effect
Water Quality								
pH	GA, BA	No difference	No difference	No difference	☐	☐	No effect	No effect
Alkalinity, Total	GA, BA	No difference	No difference	-	-	-	No effect	No effect
Hardness	GA, BA	No difference	No difference	-	-	-	No effect	No effect
Total Suspended Solids	GA, BA	No difference	No difference	No difference	☐	☐	No effect	No effect
Ammonia (as N)	GA, BA	-	No difference	-	-	☐	No effect	No effect
Nitrate (as N)	GA, BA	No difference	-	No difference	☐	☐	No effect	No effect
Cyanide, Total	GA	-	-	-	-	-	No effect	No effect
Radium-226	GA	-	-	-	-	-	No effect	No effect
Aluminum, Total	GA, BA	No difference	No difference	No difference	☐	☐	No effect	No effect
Arsenic , Total	GA, BA	No difference	No difference	No difference	☐	☐	No effect	No effect
Cadmium, Total	GA, BA	No difference	No difference	No difference	☐	☐	No effect	No effect
Copper, Total	GA, BA	No difference	No difference	No difference	☐	☐	No effect	No effect
Iron , Total	GA, BA	No difference	No difference	No difference	☐	☐	No effect	No effect
Lead, Total	GA, BA	No difference	No difference	No difference	☐	☐	No effect	No effect
Mercury, Total	GA, BA	-	No difference	Marginal	-	☐	No effect	No effect[d]
Molybdenum, Total	GA, BA	No difference	No difference	No difference	☐	☐	No effect	No effect
Nickel, Total	GA, BA	No difference	No difference	No difference	☐	☐	No effect	No effect
Zinc, Total	GA, BA	No difference	No difference	No difference	☐	☐	No effect	No effect
Sediment Quality								
% Gravel (>2 mm)	GA, BA	-	-	No difference	-	-	No effect	No effect
% Sand (2.0 mm - 0.063 mm)	GA, BA	Marginal	-	**Decrease**	-	-	No effect[d]	No effect[d]
% Silt (0.063 mm - 4 µm)	GA, BA	**Increase**	-	**Increase**	-	-	No effect[d]	No effect[d]
% Clay (<4 µm)	GA, BA	**Decrease**	-	**Increase**	-	-	No effect[d]	No effect[d]
Total Organic Carbon	GA, BA	**Increase**	-	**Increase**	-	-	No effect[d]	No effect[d]
Arsenic	GA, BA	**Increase**	-	**Increase**	-	-	No effect[d]	No effect[d]
Cadmium	GA	-	-	No difference	-	-	No effect	No effect
Chromium	GA, BA	**Increase**	-	**Increase**	-	-	No effect[d]	No effect[d]
Copper	GA, BA	**Increase**	-	**Increase**	-	-	No effect[d]	No effect[d]
Lead	GA, BA	Marginal	-	**Increase**	-	-	No effect[d]	No effect[d]
Mercury	GA, BA	No difference	-	**Increase**	-	-	No effect	No effect[d]
Zinc	GA, BA	Marginal	-	**Increase**	-	-	No effect[d]	No effect[d]

(continued)

Table 4.3-1. Summary of Evaluation of Effects, AEMP Marine Sites, Doris North Project, 2014 (completed)

		Within Waterbody Before-After Difference (BA analysis)[a]			Before-After Trend Relative to Reference Site (BACI analysis)[a]		Conclusion of Effect[b, c]	
Variable	Method of Evaluation	Roberts Bay West (RBW)	Roberts Bay East (RBE)	Ida Bay (REF-Marine 1)	Roberts Bay West (RBW)	Roberts Bay East (RBE)	Roberts Bay West (RBW)	Roberts Bay East (RBE)
Phytoplankton								
Biomass	GA, BACI	-	-	-	Parallel	Parallel	No effect	No effect
					2010 to 2014 Trend Relative to Reference Sites (Impact Level-by-Time analysis)[a]			
Benthic Invertebrates (Adults + Juveniles)								
Total Density	GA, ILBT	-	-	-	**Non-parallel**	Parallel	No effect[d]	No effect
Family Richness	GA, ILBT	-	-	-	**Non-parallel**	**Non-parallel**	No effect[d]	No effect[d]
Simpson's Evenness Index	GA, ILBT	-	-	-	**Non-parallel**	Marginal	No effect[d]	No effect[d]
Simpson's Diversity Index	GA, ILBT	-	-	-	Marginal	**Non-parallel**	No effect[d]	No effect[d]
Bray-Curtis Index	GA, ILBT	-	-	-	**Non-parallel**	**Non-parallel**	No effect[d]	No effect[d]
Benthic Invertebrates (Adults)								
Total Density	GA, ILBT	-	-	-	**Non-parallel**	**Non-parallel**	No effect[d]	No effect[d]
Family Richness	GA, ILBT	-	-	-	**Non-parallel**	**Non-parallel**	No effect[d]	No effect[d]
Simpson's Evenness Index	GA, ILBT	-	-	-	**Non-parallel**	**Non-parallel**	No effect[d]	No effect[d]
Simpson's Diversity Index	GA, ILBT	-	-	-	**Non-parallel**	**Non-parallel**	No effect[d]	No effect[d]
Bray-Curtis Index	GA, ILBT	-	-	-	Marginal	**Non-parallel**	No effect[d]	No effect[d]

Notes:

GA - Graphical analysis; BA - Before-After analysis; BACI - Before-After-Control-Impact analysis; ILBT - Impact Level-by-Time analysis

[a] *Statistically significant difference at p<0.01 to avoid Type I errors. P-values of 0.01 to 0.05 were considered marginally non-significant (labelled as marginal in table).*

[b] *Conclusion of effect is based on graphical analysis, statistical analyses, and professional judgment.*

[c] *For water pH, water alkalinity, water hardness, sediment total organic carbon, sediment particle size, phytoplankton biomass, and benthos community descriptors, a change in any direction is considered to be an effect. For winter dissolved oxygen concentrations, only a decrease is considered to be an effect. For all remaining variables, only an increase is considered to be an effect.*

[d] *Although there was a significant or marginal difference, this change was not attributed to Project activities.*

For both the BACI and the ILBT analyses, a differential increase or decrease in exposure site variables over time relative to the reference sites (i.e., a non-parallel effect) may indicate a Project-related effect.

Dash (-) indicates that statistical analysis was not possible because of missing data (i.e., no historical data available), the high proportion of nondetectable concentrations, too few degrees of freedom for the analysis, or the lack of variation in a variable over time (having no measure of variation causes F-statistic to be infinite).

Square (☐) indicates that BACI results are not reported because the within waterbody before-after comparison shows that there was no significant difference between baseline and 2014 means.

For the adult subset, significant non-parallelisms were detected for all evaluated benthos community descriptors at both RBW and RBE, with the exception of the Bray-Curtis Index at RBW. Marginally non-significant differences in trends between RBW and REF-Marine 1 were also found in the adult subset for the Bray-Curtis Index.

Most 2014 benthos community descriptors were within range of previous years, and there was no indication that benthos communities in 2014 at RBW or RBE were adversely effected by Project activities (i.e., there was no evidence of an increase in the Bray-Curtis Index or of a decrease in density, richness, or evenness in 2014 compared to previous years). There were no apparent Project-related changes to the water quality, sediment quality or primary producer biomass at either exposure site, despite some jetty erosion in 2013. Thus, non-parallelisms in trends in the benthos communities were likely attributable to the high inter-annual variability.

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Definitions of the acronyms and abbreviations used in this reference list can be found in the Glossary and Abbreviations section.

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Appendix A

2014 Data Report

APPENDIX A. 2014 DATA REPORT

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APPENDIX A. 2014 DATA REPORT

A.1 OVERVIEW OF REPORT

This report presents the complete dataset as well as summary graphs and tables of the results of the 2014 Program for the Project. The 2014 Program included the following: physical profiles of temperature, dissolved oxygen, and salinity (marine sites only); Secchi depths; water quality; sediment quality; primary producer biomass; and benthic invertebrate (benthos) taxonomy and density. Details of the sampling methodology and data analysis are provided in the main body of the report. Figure A.1-1 provides an overview of sampling sites included in the 2014 Program and Figures A.1-2 to A.1-7 show detailed maps of each lake and marine sampling site, including sampling details and bathymetric contours (if available).

Figure A.1-1
AEMP Sampling Locations, Doris North Project, 2014

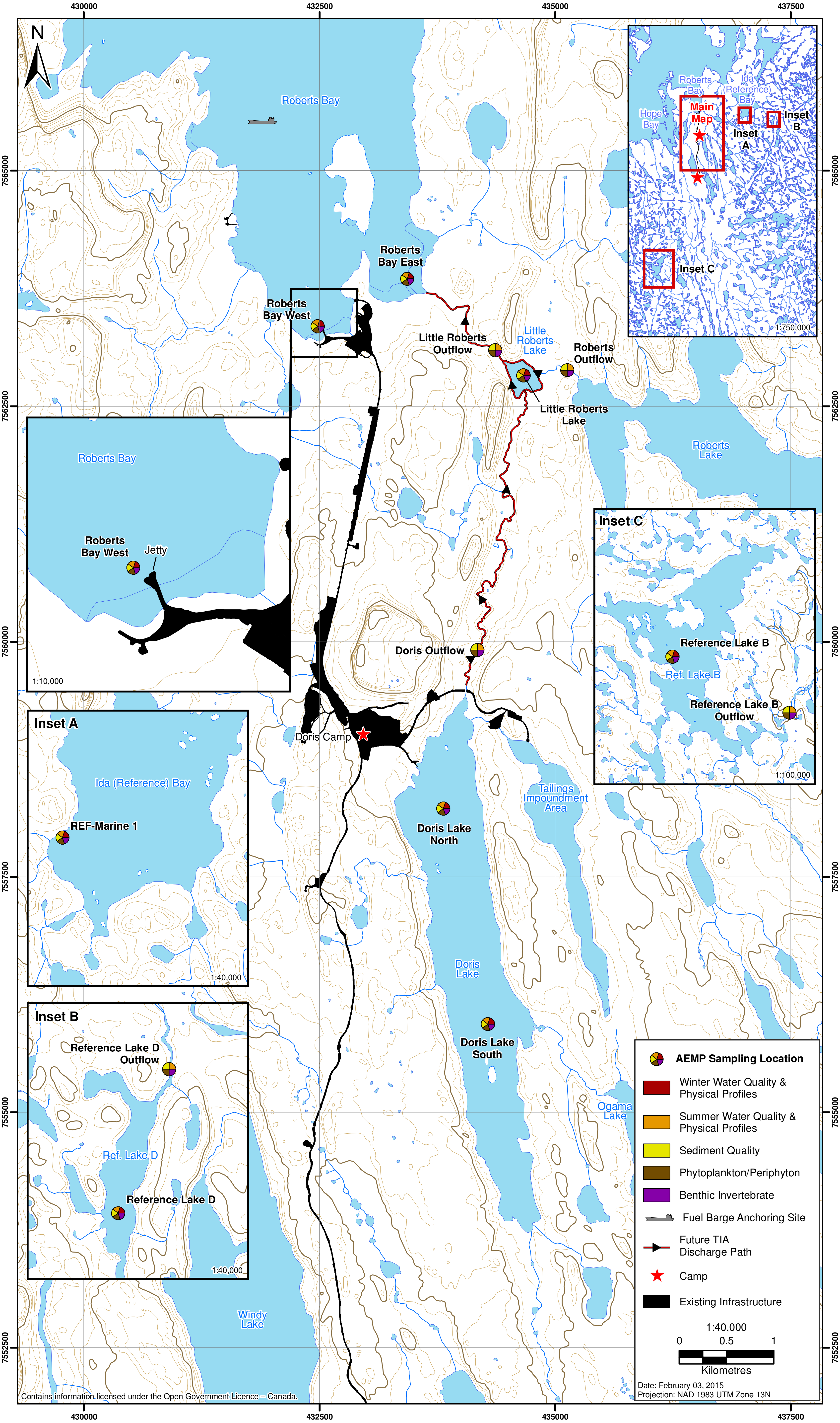

Figure A.1-2
Sampling Locations in Doris Lake, Doris North Project, 2014