Figure 2.2-2
Sediment Quality Sampling Stations, Doris Project, 1996 to 2016

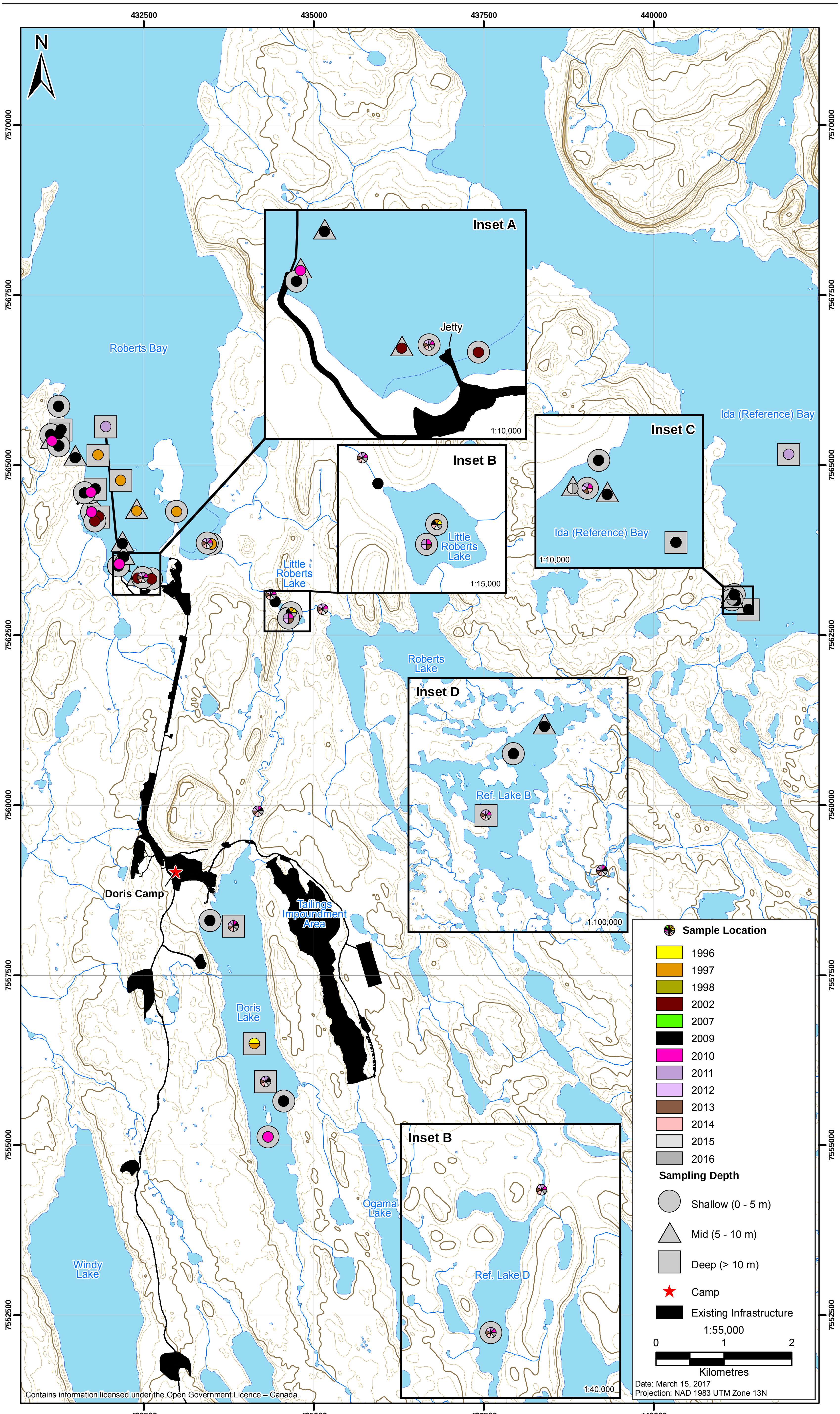
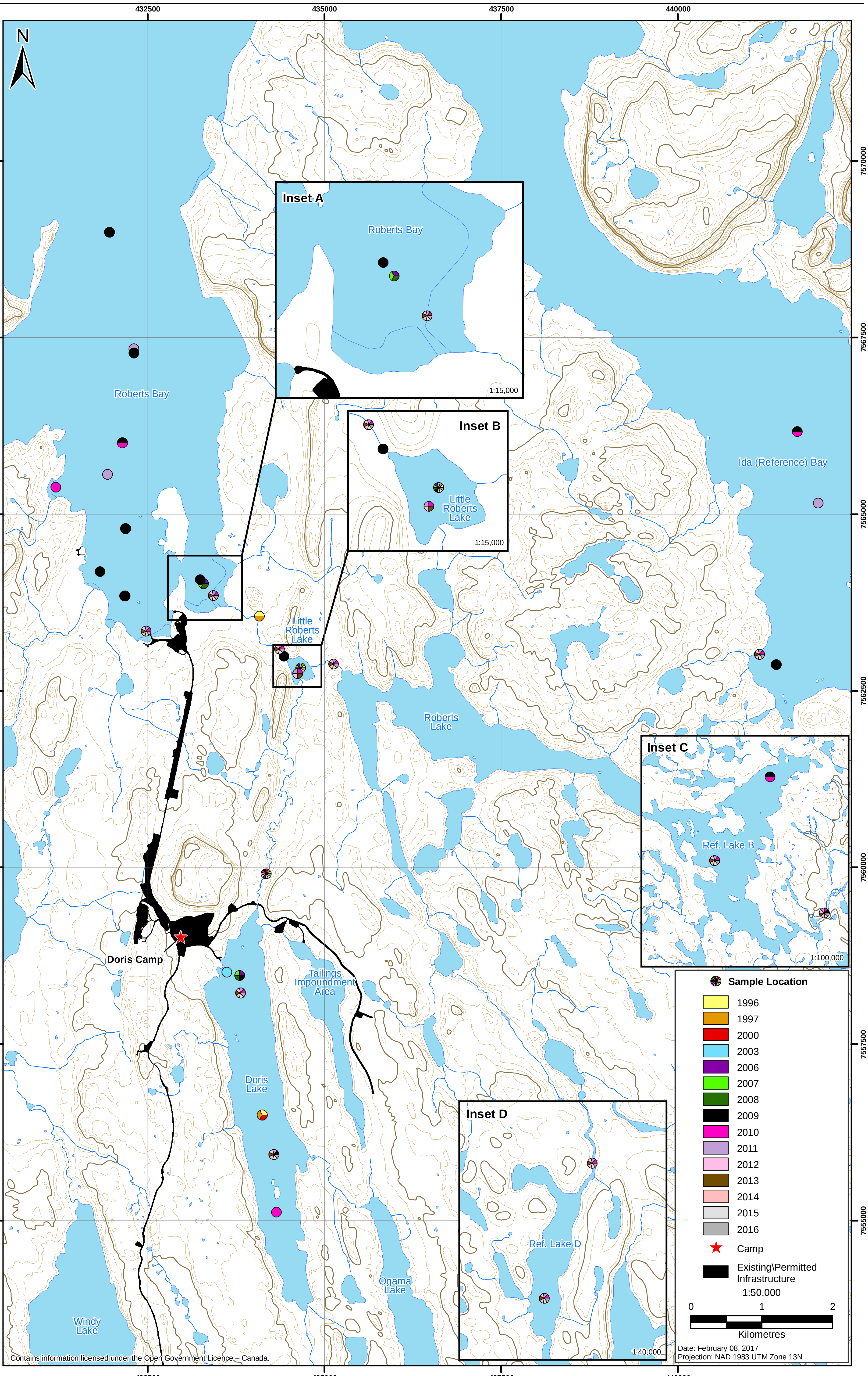


Figure 2.2-3
Phytoplankton and Periphyton Sampling Stations, Doris Project, 1996 to 2016



For Doris Lake South, historical phytoplankton biomass data collected in 1997 and 2000 were excluded from some previous AEMP reports because the 1997 and 2000 sampling site was more than 1 km away to the north of the 2010 Doris Lake South sampling site (Figure 2.2-3). However, the Doris Lake South sampling site was moved slightly further to the north in 2011, and approximately 500 m away from the 1997 and 2000 sampling site. Therefore, these historical data were considered comparable to the 2016 phytoplankton biomass data and were included in the 2016 effects analysis for Doris Lake South.

<u>Effects Analysis</u>

Graphical analysis of annual mean phytoplankton or periphyton biomass and the comparison of before-after means at the exposure sites to before-after means at the reference sites were used to identify trends and to supplement the results of the statistical analyses.

For each waterbody, a before-after comparison between the mean baseline biomass and 2016 mean biomass was conducted (provided that baseline data were available). A mixed model ANOVA was used for this before-after comparison. This model included fixed effects of *period* (before vs. after) and *season*, and a random effect of *year* to account for variability in primary producer data. For the *period* effect, data were grouped into one of two periods: *before* the start of construction (1996 to 2009) or *after* the start of construction (2016). For the *season* effect, samples were grouped into one of four seasons depending on the date of sample collection to account for within-year variability in biomass levels: 1) April or May (under-ice), 2) July, 3) August, and 4) September. A significance level of 0.05 was used when reviewing the results.

The interpretation of the before-after analyses, the conditions under which a subsequent BACI analyses was conducted, the BACI methodology, and the interpretation and presentation of the BACI results are described in Section 2.2.2.2. Details specific to the phytoplankton and periphyton analyses are described below.

For lake and marine phytoplankton biomass, the change from before to after for each exposure site was compared against the change at the corresponding reference site using a BACI analysis. For stream periphyton biomass, the before-after trend for each exposure site was compared against the trend obtained using data from both reference streams (Reference B Outflow and Reference D Outflow) for the BACI analysis. Although no baseline data were available for Reference D Outflow, data collected from this site in 2016 contributed some information on the year-effect, which improved the precision of the BACI analysis.

All phytoplankton and periphyton biomass replicates collected on the same date were treated as pseudo-replicates and were averaged prior to graphical and statistical analysis.

2.2.2.6 Benthos

<u>Data Selection</u>

Benthos data have been collected since 1996 in the Project area (Figure 2.2-4). Prior to 2010, historical benthos sampling consisted of collecting one to five replicates per site with no composite sampling. Starting in 2010, this approach was changed to accommodate the EEM methodologies as required under the Type A Water Licence for the Doris Project.

The 2010 to 2016 sampling procedure required the pooling of three subsamples per replicate, and the collection of five replicates per site. Because the pooling of subsamples for each replicate affects sample variability, as well as various diversity components (e.g., richness and evenness), baseline (1995 to 2009) benthos data were not considered comparable to data collected from 2010 to 2016.

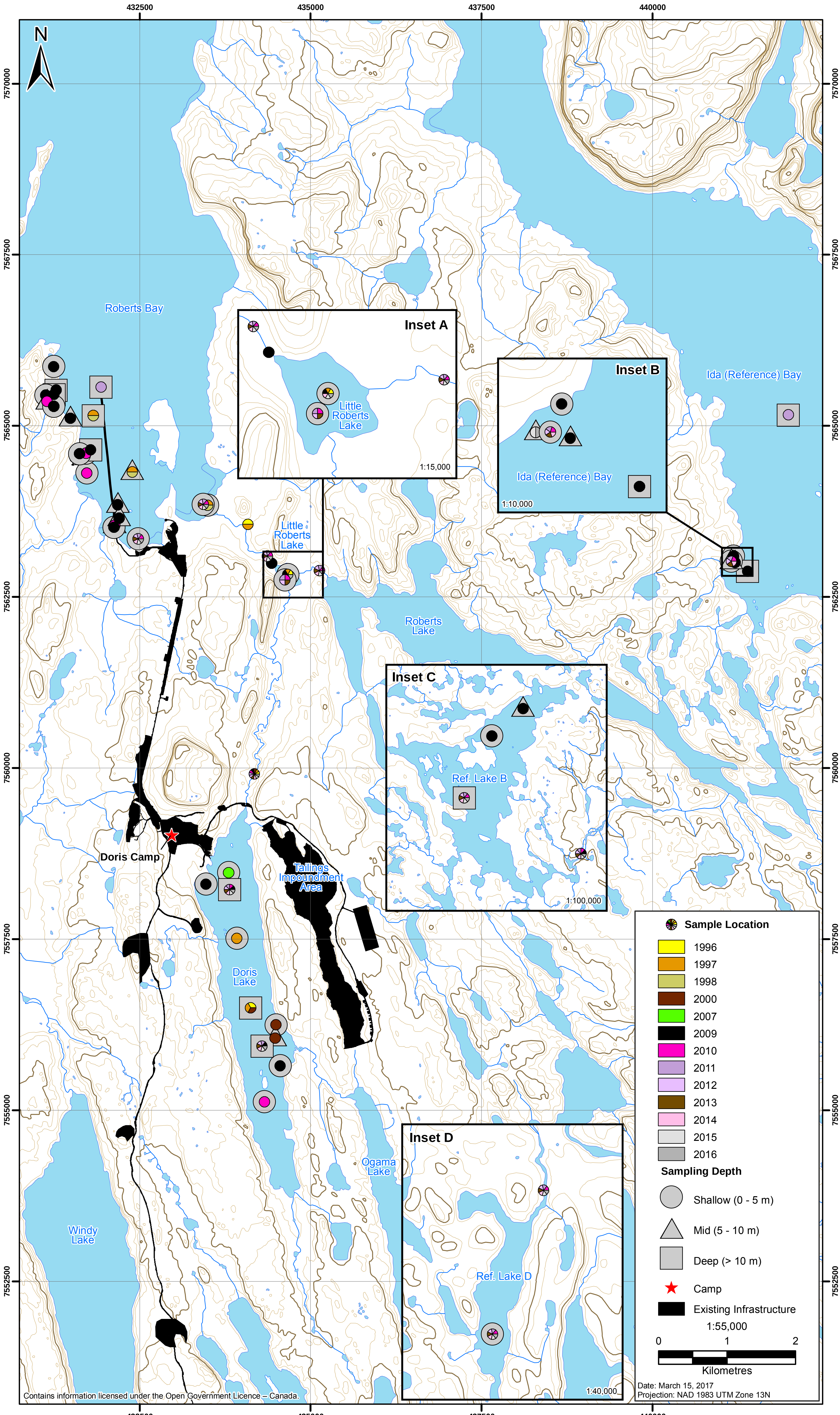
Effects Analysis

Because of methodological differences, no suitable baseline benthos data were available for comparison against 2016 data; therefore, neither before-after nor BACI analyses were possible for benthos data. The absence of appropriate baseline data for benthos complicates the determination of potential effects of the Project on benthos community descriptors. Comparing reference site data to exposure site data is not an ideal approach because of the potential natural differences between sites that are unrelated to Project activities. A preferred approach recommended by Wiens and Parker (1995) is an impact level-by-time analysis, where the benthos changes at exposure sites are compared to the changes at reference sites to determine if there is evidence of non-parallelism over time (in this case, from 2010 to 2016). Because of the limited data available, evidence of non-parallelism between 2010 and 2016 may simply indicate patchiness in the environment or natural yearly variation and does not necessarily imply a Project-related effect. As more years of data become available, trends (if present) would become more apparent.

For lake and marine benthos data, the 2010 to 2016 trend for each exposure site was compared against the trend at the corresponding reference site using an impact level-by-time analysis. For stream benthos data, the 2010 to 2016 trend for each exposure site was compared against the 2010 to 2016 trend obtained using data from both reference streams (Reference B Outflow and Reference D Outflow).

The impact level-by-time model included a *year* effect, a *class* effect, and a *year*class* interaction term. The *year* effect describes any inter-annual variation observed across the region, while the *class* effect describes differences between the reference and exposure sites. The *year*class* interaction term is the key term in the analysis–this term describes the effect of non-parallelism over time between the two classes of sites. A significance level of 0.05 was used when reviewing the results. For the 2016 analysis, tables showing the modelling coefficients for each exposure site analysis were also presented in Appendix B in order to assess the magnitude of the *year* effect, *class* effect, and *year*class* interaction. The magnitude and direction of the *year*class* coefficients were used to determine whether any annual trends are apparent in the *year*class* interaction term, which could imply a Project-related effect.

Figure 2.2-4
Benthic Invertebrate Sampling Stations, Doris Project, 1996 to 2016



3. EVALUATION OF EFFECTS

3.1 UNDER-ICE DISSOLVED OXYGEN

Potential effects of the Project on lake and marine dissolved oxygen concentrations were evaluated using under-ice dissolved oxygen concentrations, since concentrations are typically lowest during this period and pose the greatest concern for aquatic life. Minimum oxygen levels are required for critical life stages of fish and other freshwater and marine organisms (CCME 2016b). Ice cover usually forms in October or November in the Doris region, and under-ice oxygen profiles were collected in April 2016. The formation of ice cover in November 2015 isolated lakes, streams, and Roberts Bay from any atmospheric inputs such as dust that could have been generated by Project activities between November 2015 and June/July 2016. Therefore, the water column that was profiled in April 2016 reflects activities from 2015 rather than 2016.

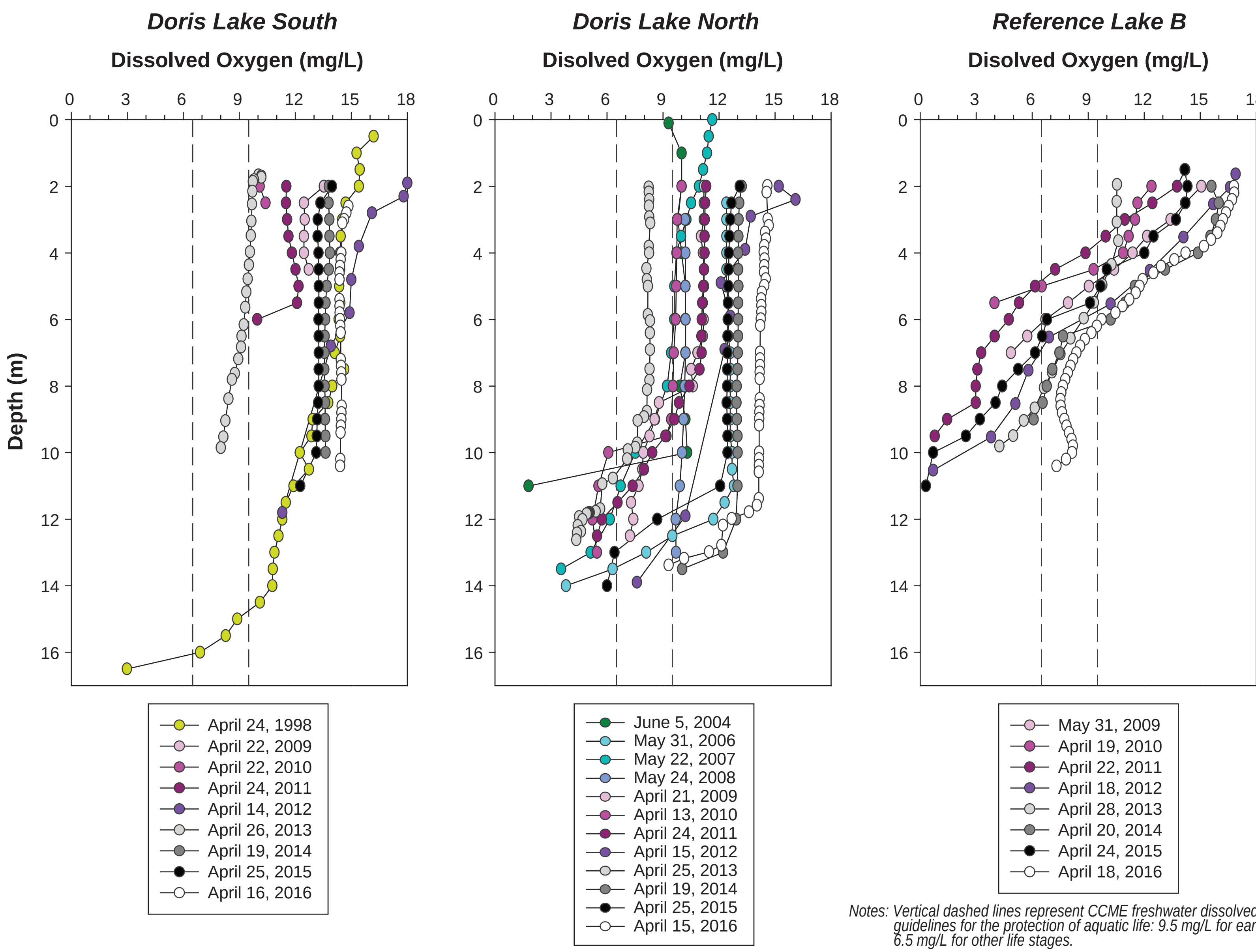
Figures 3.1-1a, 3.1-1b, and 3.1-2 present the 2016 and historical under-ice dissolved oxygen profiles for lake and marine sites. 2016 under-ice profiles were collected in mid-April, and historical under-ice profiles were collected between mid-April and early June.

3.1.1 Lakes

April 2016 dissolved oxygen concentrations at Doris Lake South and North were similar to or higher than concentrations recorded during baseline years (Figure 3.1-1a). In Doris Lake South, dissolved oxygen concentrations in April 2016 were relatively consistent throughout the water column, averaging 14.5 mg/L (Figure 3.1-1a), and were always above the CCME guideline for freshwater cold-water early life stages (9.5 mg/L; Figure 3.1-1a). In Doris Lake North, April 2016 dissolved oxygen concentrations averaged 14.3 mg/L in the upper 11 m of the water column, and decreased to a minimum of 9.3 mg/L at 13.3 m depth, which is just below the CCME guideline of 9.5 mg/L (Figure 3.1-1a). A decrease in under-ice dissolved oxygen concentrations at depth is a common phenomenon in seasonally stratified lakes, and has been observed nearly every year since 2004 in Doris Lake North (Figure 3.1-1a). During baseline years, the under-ice oxygen minimum at Doris Lake North ranged from 1.8 to 9.7 mg/L, so the minimum of 9.3 mg/L in 2016 is at the upper end of this range (Figure 3.1-1a). In Reference Lake B, 2016 under-ice dissolved oxygen concentrations were also relatively high throughout the water column compared to previous years (Figure 3.1-1a). There continues to be no evidence of adverse effects of Project activities on under-ice dissolved oxygen concentrations in Doris Lake.

Figure 3.1-1a

Winter Dissolved Oxygen Concentrations at Large Lake Sites, Doris Project, 1998 to 2016

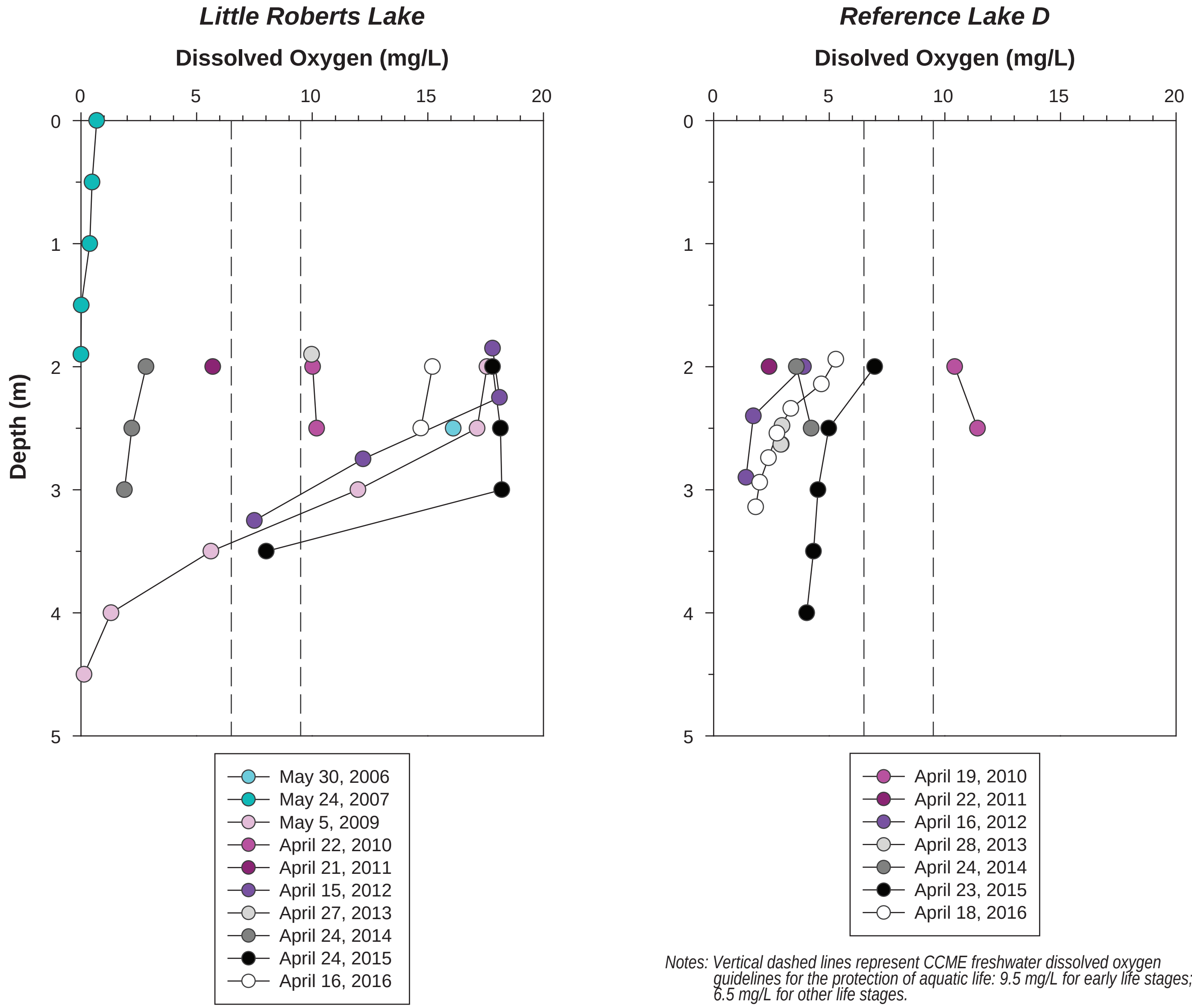


Notes: Vertical dashed lines represent CCME freshwater dissolved oxygen guidelines for the protection of aquatic life: 9.5 mg/L for early life stages; 6.5 mg/L for other life stages.

Figure 3.1-1b

Winter Dissolved Oxygen Concentrations at Small Lake Sites, Doris Project, 2006 to 2016

ERM

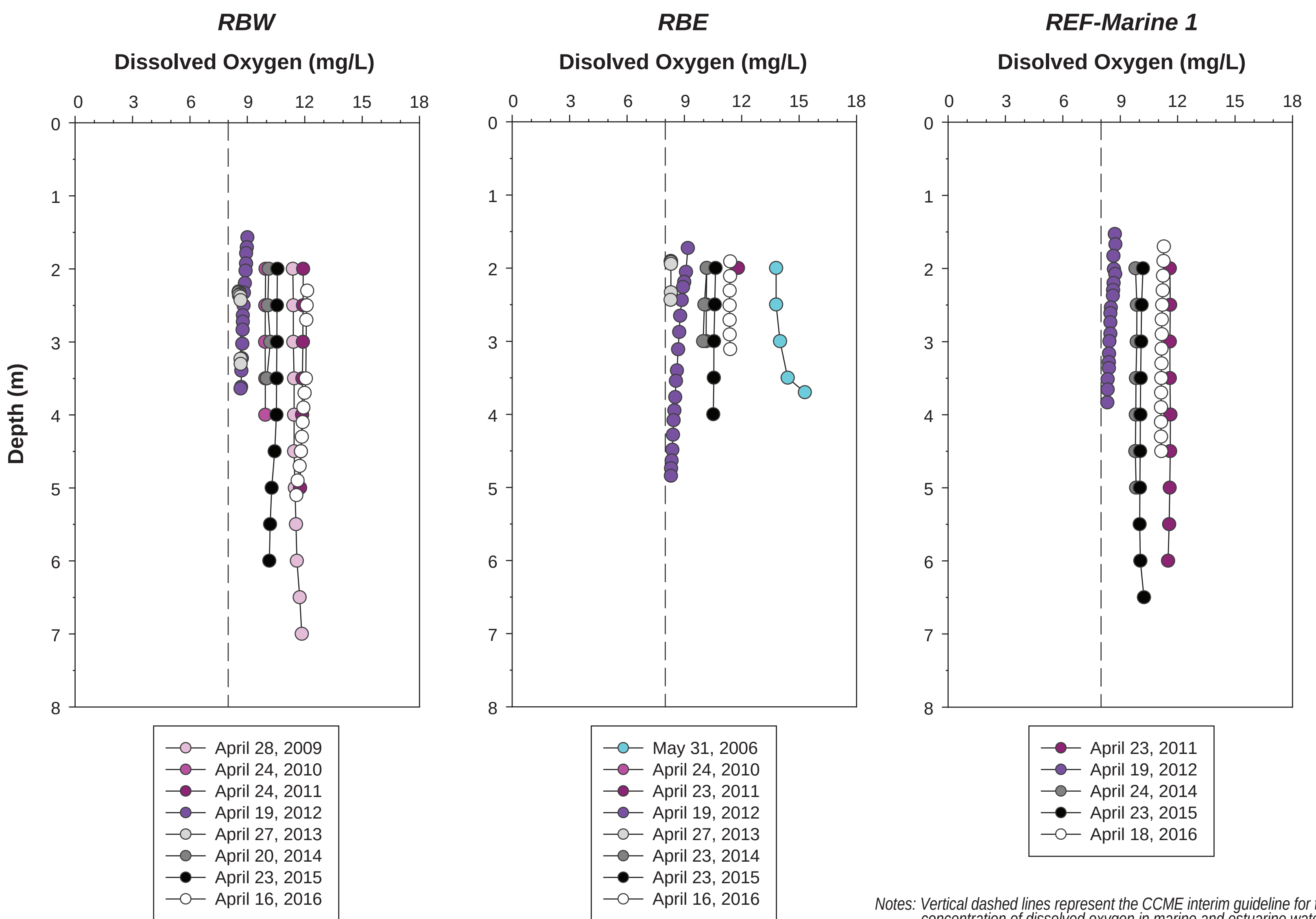


Notes: Vertical dashed lines represent CCME freshwater dissolved oxygen guidelines for the protection of aquatic life: 9.5 mg/L for early life stages; 6.5 mg/L for other life stages.

Figure 3.1-2

Winter Dissolved Oxygen Concentrations at Marine Sites, Doris Project, 2006 to 2016

ERM



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.

Baseline winter dissolved oxygen concentrations varied widely in the shallow exposure site Little Roberts Lake between 2006 and 2010 (range: < 1 mg/L in May 2007 to 17.6 mg/L in May 2009; Figure 3.1-1b). In 2016, the recorded under-ice dissolved oxygen concentrations of 14.7 and 15.2 mg/L in Little Roberts Lake were relatively high compared to baseline concentrations and above the CCME freshwater cold-water guideline for early life stages of 9.5 mg/L. Thus, no adverse changes to 2016 winter dissolved oxygen concentrations were apparent in Little Roberts Lake. In the shallow reference lake, Reference Lake D, under-ice dissolved oxygen concentrations also varied widely over time. Concentrations measured in April 2016 in Reference Lake D were within the historical range but below the CCME freshwater cold-water guideline for non-early life stages of 6.5 mg/L throughout the water column. Shallow, ice-covered lakes are prone to large fluctuations in dissolved oxygen concentrations, particularly late in the ice-covered season, because of increases in epontic and benthic photosynthesis and the respiratory consumption of organic material in the sediments.

3.1.2 Marine

The 2016 under-ice dissolved oxygen concentrations were similar at both of the marine exposure sites RBW and RBE, averaging 11.9 and 11.4 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). 2016 under-ice concentrations at RBW and RBE were within the range of or greater than baseline concentrations recorded between 2006 and 2010. Under-ice dissolved oxygen concentrations at the reference site (REF-Marine 1) in April 2016 were similar to those observed at the exposure sites (mean: 11.2 mg/L). Thus, there was no evidence of adverse effects on under-ice dissolved oxygen levels in the marine environment as a result of Project activities.

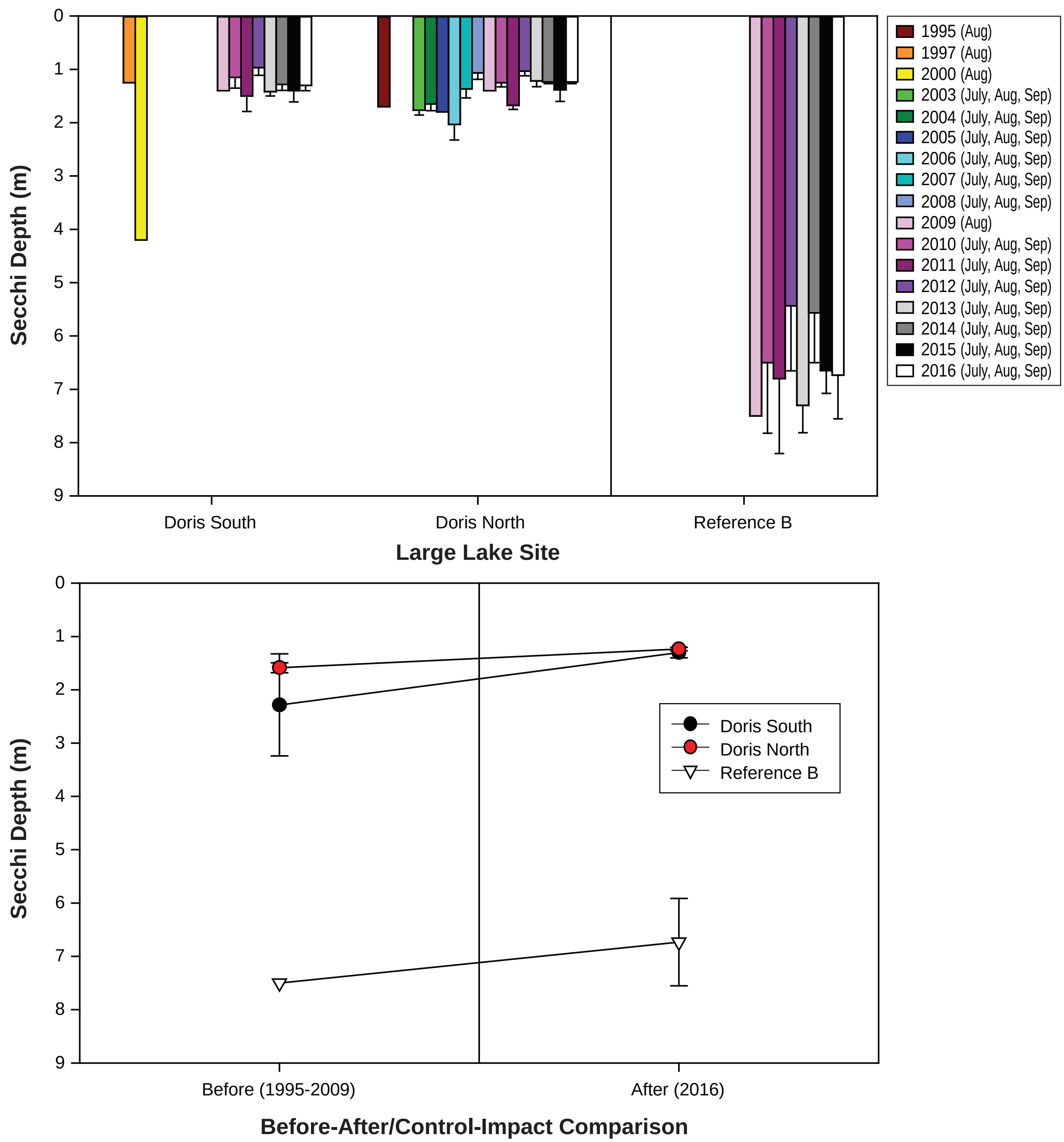
3.2 Secchi Depth

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

The Secchi depth at all marine sites (RBE, RBW, and REF-Marine 1) and small lake sites (Little Roberts Lake and Reference Lake D) extended down to the sea or lake bottom during all open-water season surveys in 2016 (July, August, and September) with one exception (RBW in July; Appendix A). Because the Secchi depth at marine and small lakes sites reached the maximum possible depth for these sites (i.e., Secchi depth cannot be greater than the bottom depth), water clarity as estimated by the Secchi depth was at a maximum and Secchi depth was not evaluated for theses waterbodies. Only large lake sites were evaluated for Secchi depth.

3.2.1 Lakes

Figure 3.2-1 shows the mean annual Secchi depth at large lake sites from 1995 to 2016. In Doris Lake, the mean annual Secchi depth was similar among years and between South and North sites, generally ranging between 1.0 and 2.0 m, although the Secchi depth recorded in August 2000 (4.2 m) at Doris Lake South was greater than other years. In Reference Lake B, Secchi depths were consistently higher than in Doris Lake, ranging from 5.4 to 7.5 m.



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.

Mean 2016 Secchi depths in the exposure lakes were within the range of baseline measurements. The before-after comparison confirmed that the 2016 mean Secchi depth was not distinguishable from the baseline mean Secchi depth for any large lake exposure site (p = 0.68 for Doris Lake South and p = 0.30 for Doris Lake North). Therefore, there was no apparent effect of Project activities on large lake Secchi depth in 2016.

3.3 WATER QUALITY

A specific subset of water quality variables (see Table 2.2-1) was evaluated to determine whether 2016 Project activities resulted in adverse changes to water quality. Baseline data collected from 1995 to 2009 were included in the effects analysis.

Graphical analyses, before-after comparisons, and BACI analyses (where applicable) were 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 2016b) 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

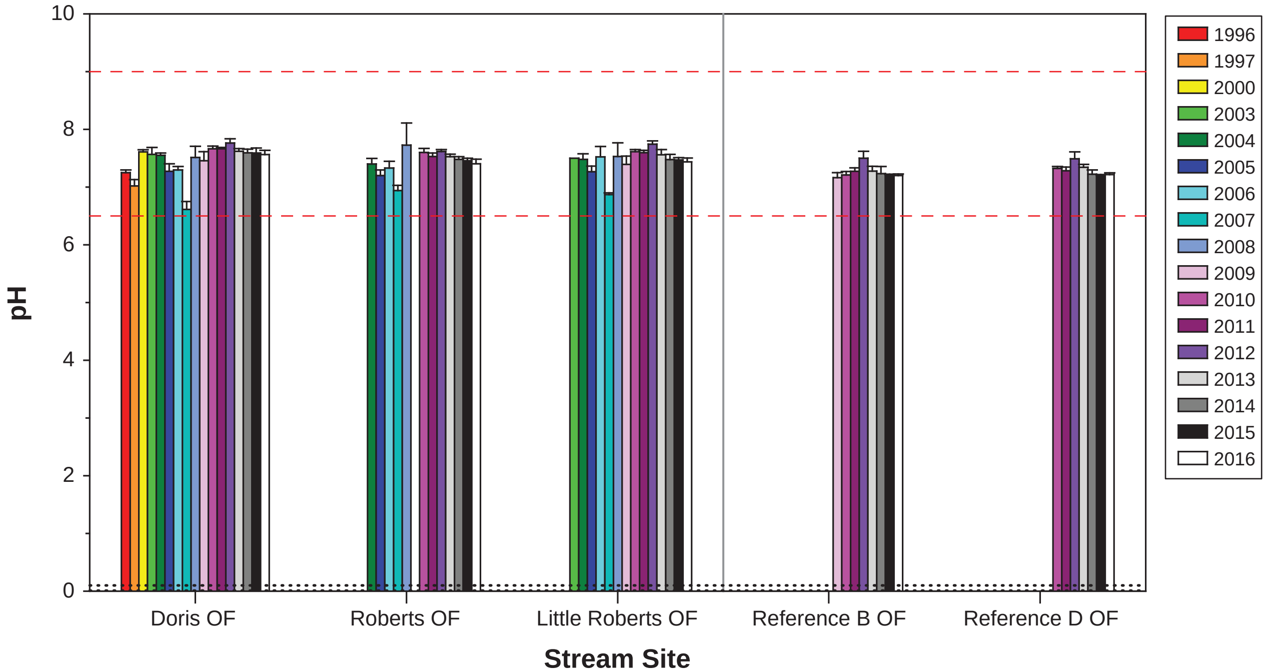
Water quality samples were collected from three exposure streams (Doris Outflow, Roberts Outflow, and Little Roberts Outflow) and two reference streams (Reference B Outflow and Reference D Outflow) in 2016. For the exposure streams, relevant baseline data are available from 1996, 1997, 2000, and 2003 to 2009 (though not all streams were sampled each year). For Reference B Outflow, the only available baseline data are from 2009, and no baseline data are available for Reference D Outflow. Note that water quality data and statistical analysis results for Roberts Outflow are shown in the following figures and in Appendices A and B, but this stream is not discussed in the following sections. Roberts Outflow is not expected to be affected by the Project but rather serves to characterize any influence of a closed silver mine and past neighbouring exploration activity (North Arrow Minerals Inc.) on Roberts Outflow and potentially downstream, and to be able to differentiate this from potential effects of TIA discharge upstream.

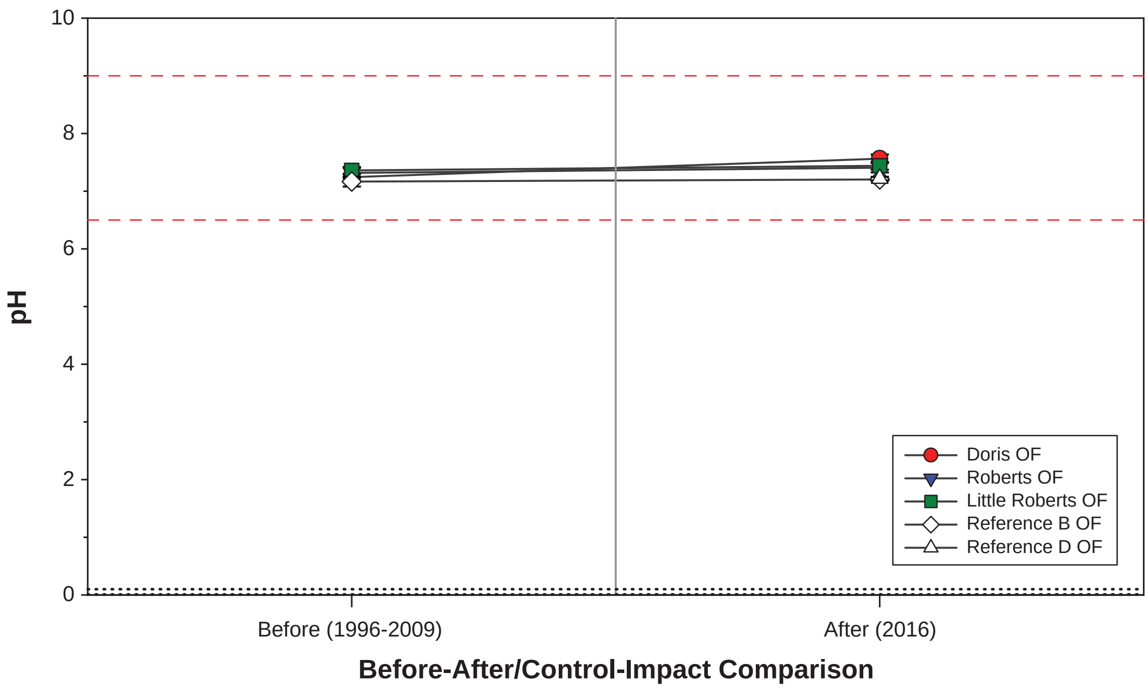
3.3.1.1 pH

pH is a required variable for water quality monitoring as per Schedule 5, s. 7(1)(c) of the MMER. 2016 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 2016 ranged from 7.3 to 7.7, while reference stream pH ranged from 7.1 to 7.3 (Figure 3.3-1). The before-after comparison confirmed that the baseline (1996 to 2009) mean pH was not statistically distinguishable from the 2016 mean pH in either exposure stream (p = 0.47 for Doris Outflow and p = 0.57 for Little Roberts Outflow). Therefore, there were no apparent effects of 2016 Project activities on the pH of exposure streams.

pH in AEMP Stream Sites, Doris Project, 1996 to 2016

ERM





Analytical detection limits:
1996, 1997, 2000: 0.01
2003-2016: 0.1

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 comparison determined that there was no significant difference in alkalinity between the before and after periods for Doris Outflow (p = 0.22). There was a significant change in alkalinity in Little Roberts Outflow between the before and after periods (p = 0.0051); however, the BACI analysis showed that a similar change occurred in the reference streams, as there was no evidence of a differential before-after change between Little Roberts Outflow and the reference streams (p = 0.36). Thus, there was no apparent effect of 2016 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). The before-after comparisons determined that there were no significant differences between the before and after periods for either of the exposure streams (p = 0.22 for Doris Outflow and p = 0.069 for Little Roberts Outflow); therefore, there was no apparent effect of 2016 Project activities on stream hardness.

3.3.1.4 *Total Suspended Solids*

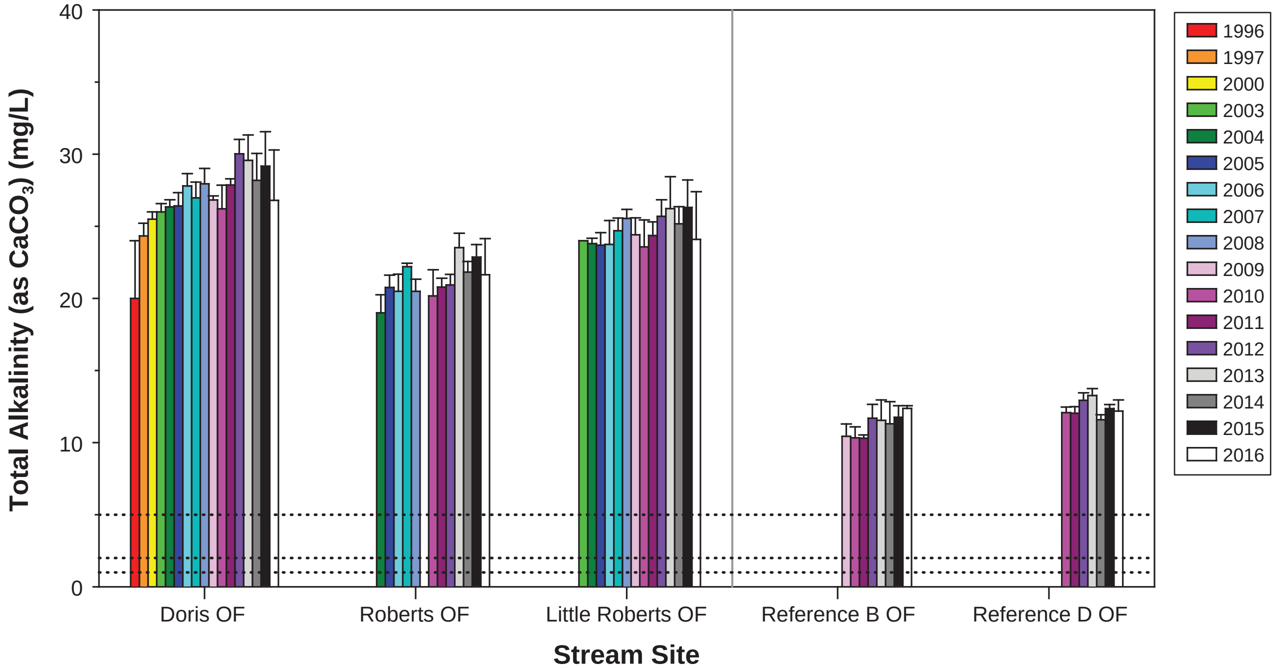
Total suspended solids (TSS) are regulated as deleterious substances in effluents as per Schedule 4 of the MMER. Mean TSS concentrations were variable among streams. Within each stream, there was also relatively high inter-annual and within-year variability (Figure 3.3-4). It is therefore difficult to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

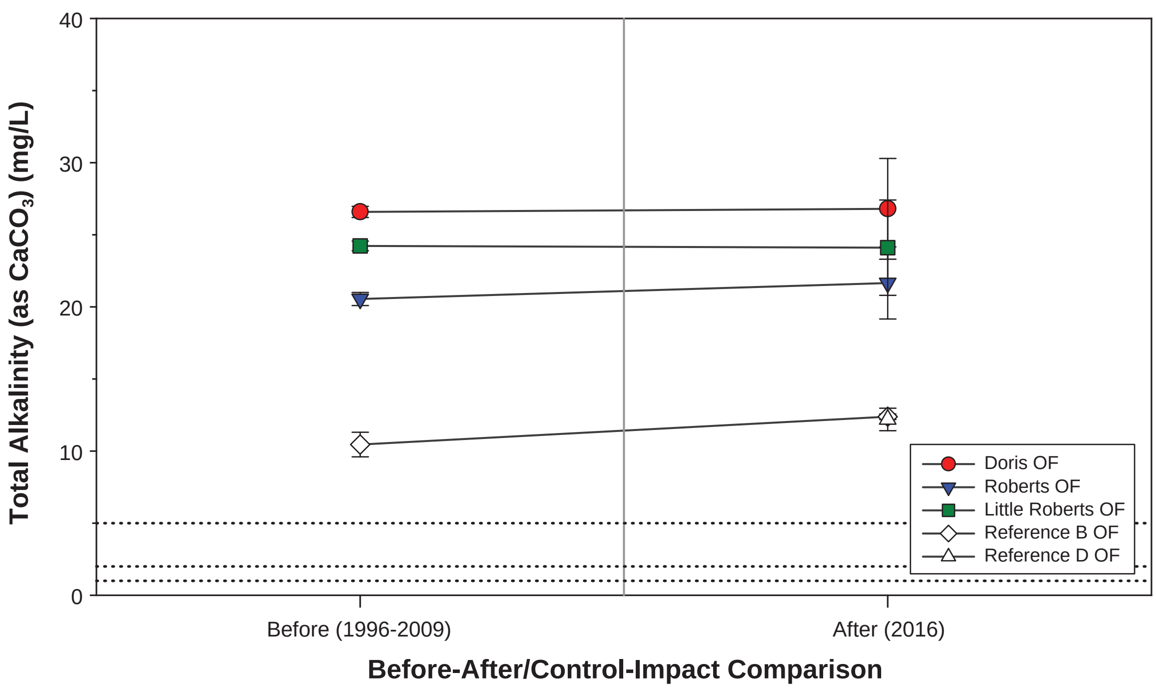
The mean 2016 TSS concentrations in all three exposure streams were within the range of the baseline means (Figure 3.3-4), and the before-after analysis confirmed that there was no significant difference between 2016 and baseline concentrations in either of the exposure streams (p = 0.79 for Doris Outflow and p = 0.48 for Little Roberts Outflow). Therefore, there is no evidence of an effect of 2016 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 2016b). Because there was no significant increase in TSS concentrations from baseline levels in Doris or Little Roberts outflows, 2016 TSS concentrations in these streams were below the CCME guideline.

Figure 3.3-2

Total Alkalinity in AEMP Stream Sites, Doris Project, 1996 to 2016

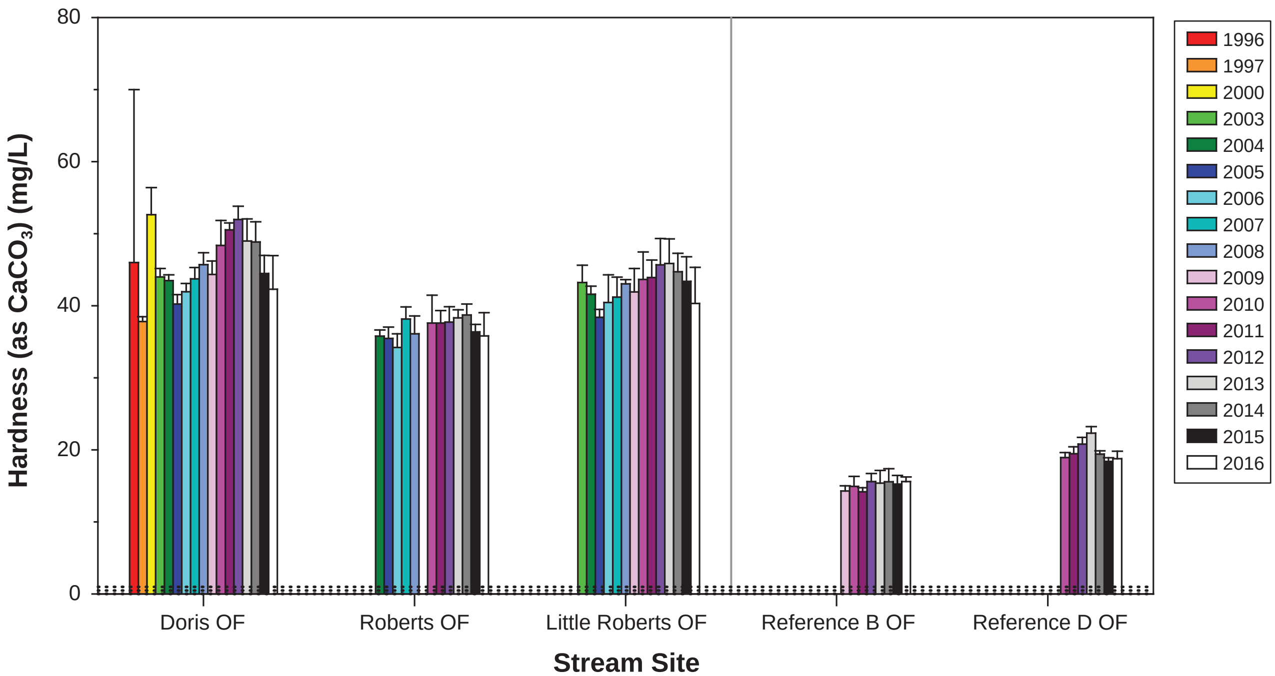


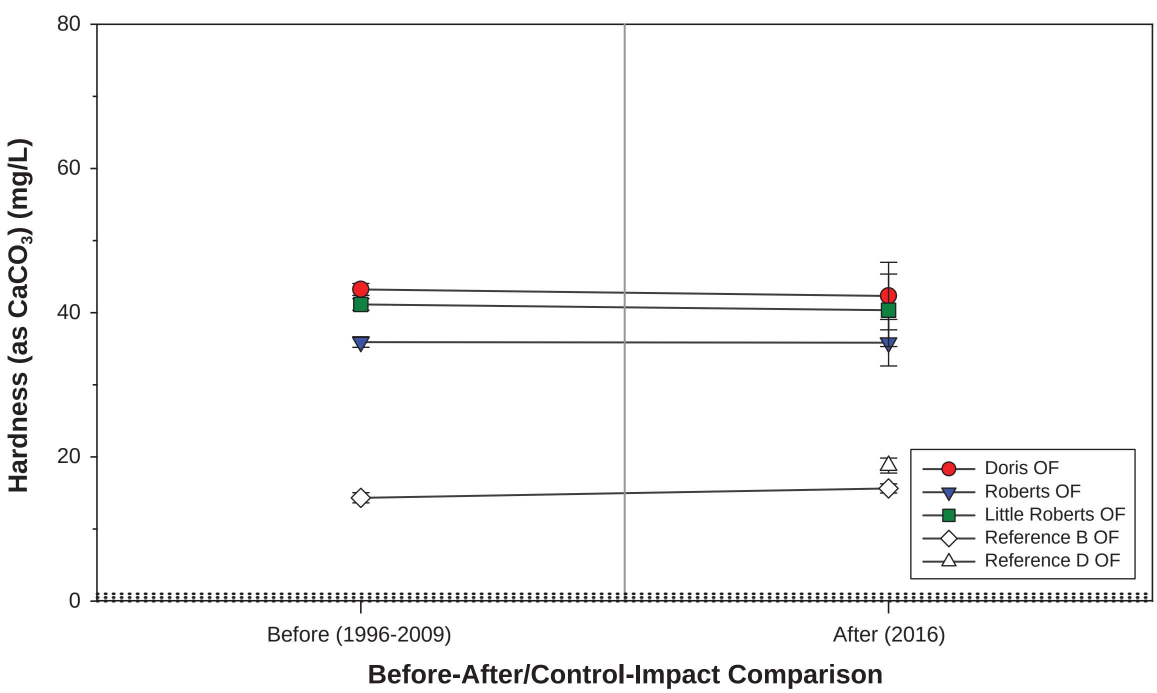


Analytical detection limits:
1996, 1997, 2000, 2003, 2005-2008, 2013-2016: 1 mg/L
2009-2012: 2 mg/L
2004: 5 mg/L

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.

Hardness in AEMP Stream Sites, Doris Project, 1996 to 2016



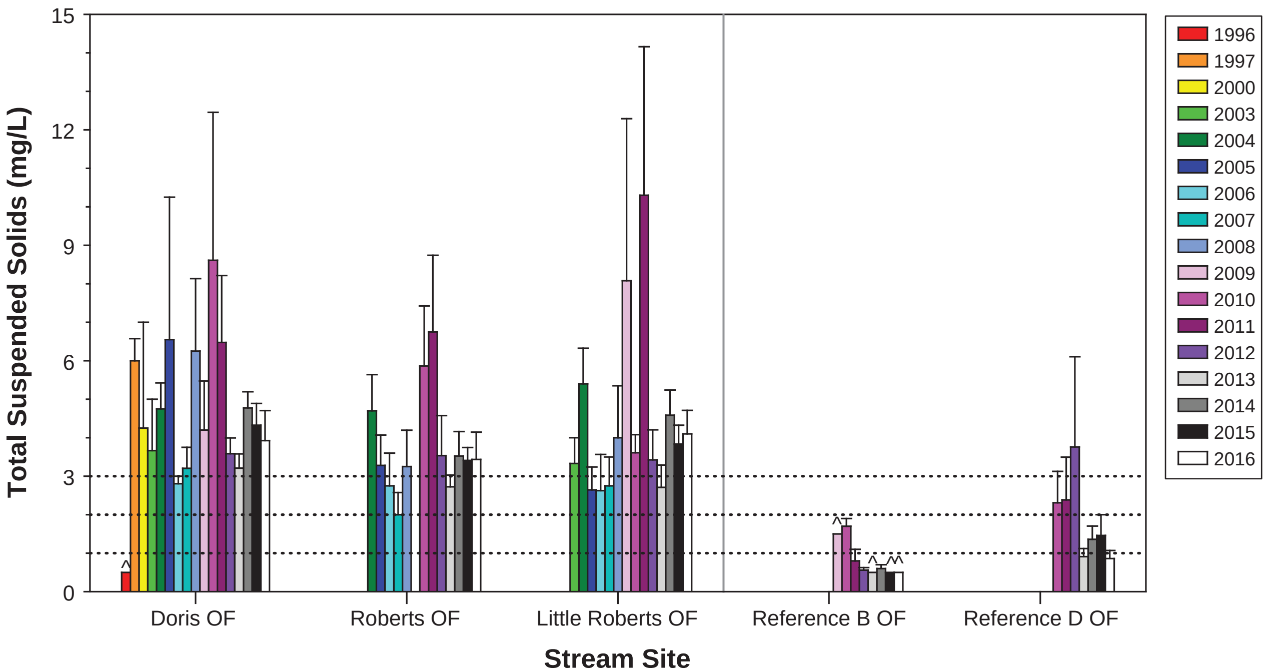


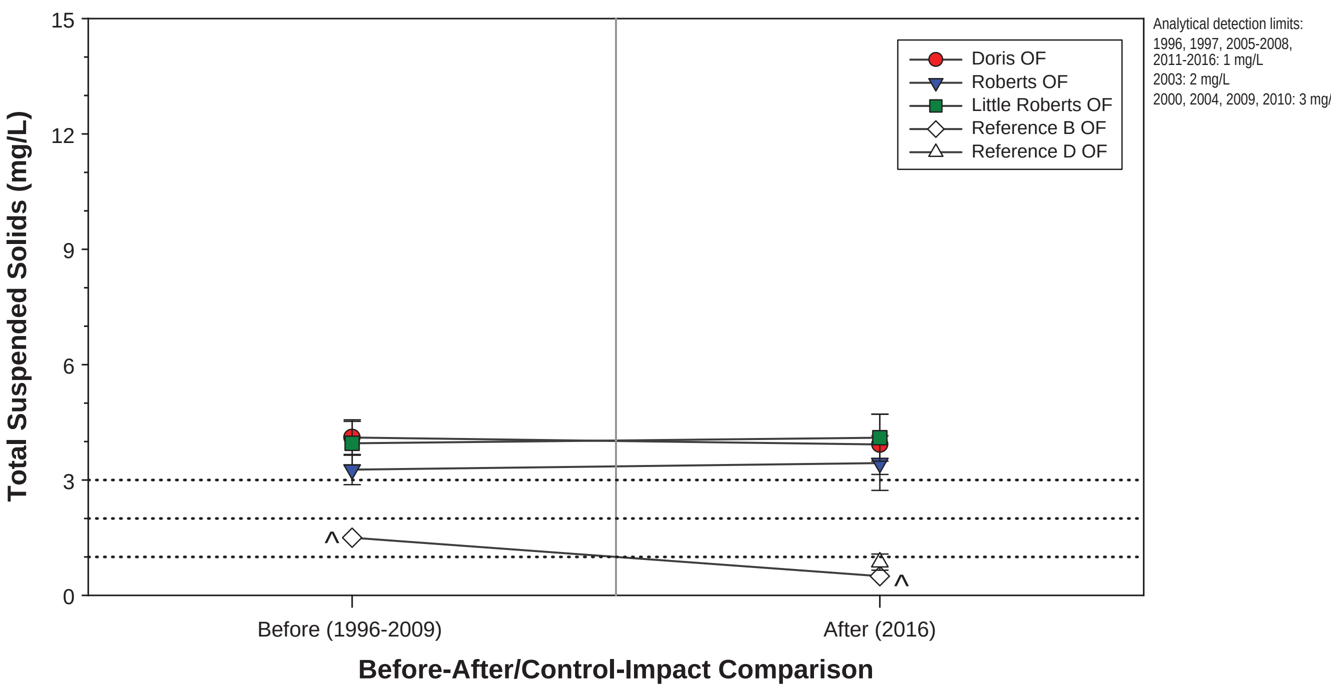
Analytical detection limits:
2005-2008: 0.01 mg/L
1996, 1997: 0.05 mg/L
2000, 2009-2016: 0.5 mg/L
2004: 1 mg/L
2003 - not reported

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 in AEMP Stream Sites, Doris Project, 1996 to 2016





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 2016 concentrations of total ammonia in exposure and reference streams were well below the pH- and temperature-dependent CCME guideline (Figure 3.3-5). The before-after analysis showed that there was no significant difference between 2016 and baseline means in either exposure stream (p = 0.52 for Doris Outflow and p = 0.23 for Little Roberts Outflow), suggesting that there was no effect of 2016 Project activities on ammonia concentrations in these waterbodies (Figure 3.3-5).

3.3.1.6 Nitrate

Nitrate is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. All 2016 nitrate concentrations in Doris and Little Roberts outflows were below the analytical detection limit of 0.005 mg nitrate-N/L and well below the CCME guideline of 3.0 mg nitrate-N/L (Figure 3.3-6). Therefore, there was no evidence of an effect of 2016 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 2016 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 2016 Project activities on total cyanide concentrations in the exposure streams.

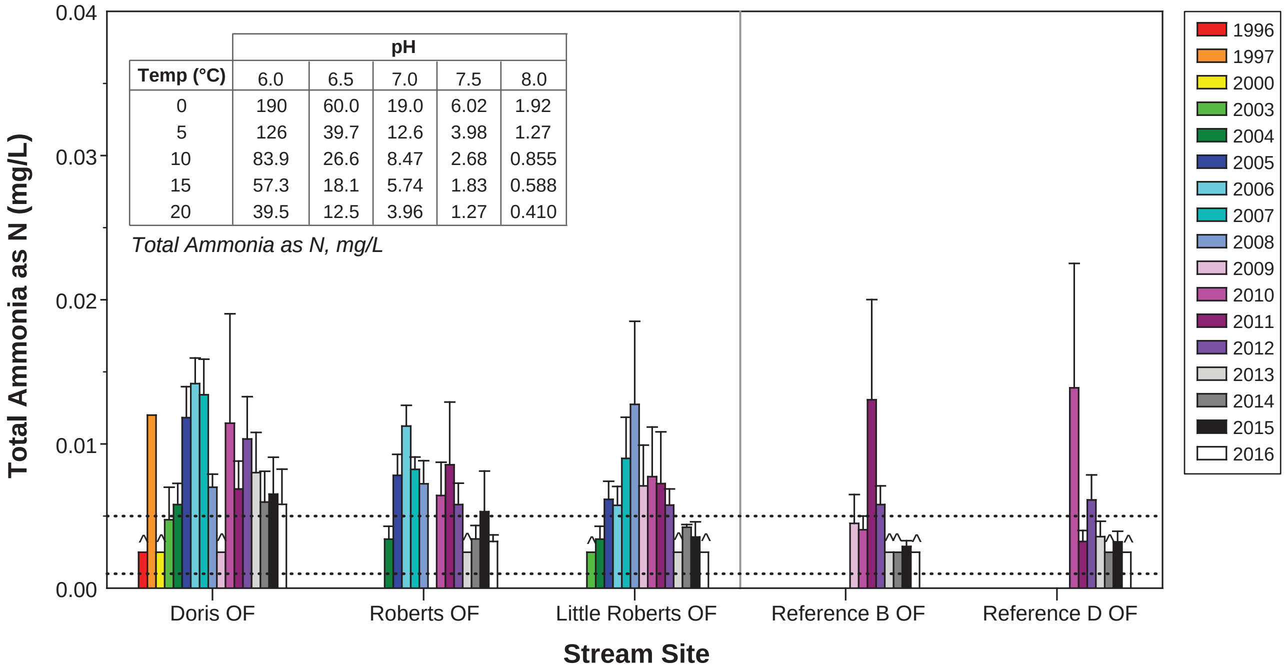
Free cyanide concentrations (cyanide existing in the form of HCN and CN^-) in stream samples were also measured in 2016 to allow for direct comparisons with the CCME guideline (0.005 mg/L as free cyanide). The free cyanide concentrations in 2016 stream samples were always below the detection limit of 0.001 mg/L and the CCME guideline for free cyanide (Appendix A). There was no apparent effect of 2016 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 2016 radium-226 concentrations in exposure and reference streams were below the analytical detection limit of 0.01 Bq/L (Figure 3.3-8). Thus, there was no evidence of an effect of 2016 Project activities on radium-226 concentrations in any exposure stream.

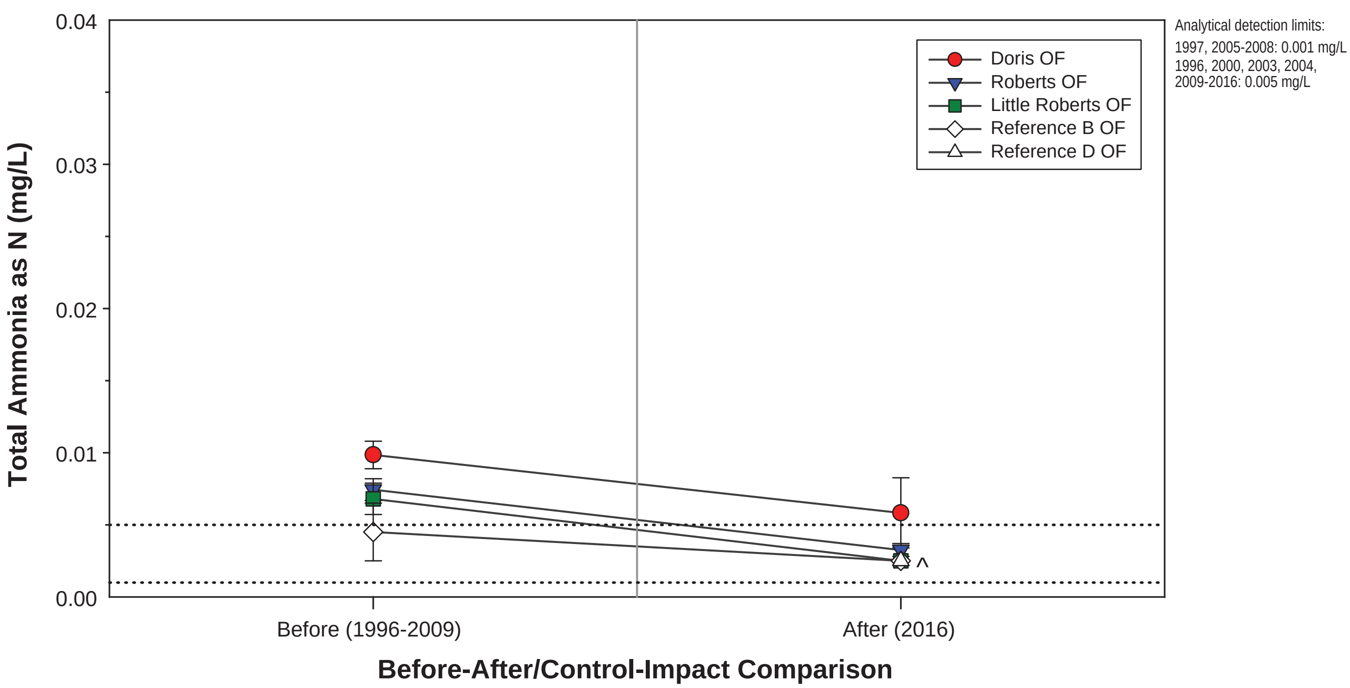
Figure 3.3-5

Total Ammonia Concentration in AEMP Stream Sites, Doris Project, 1996 to 2016



	pH				
Temp (°C)	6.0	6.5	7.0	7.5	8.0
0	190	60.0	19.0	6.02	1.92
5	126	39.7	12.6	3.98	1.27
10	83.9	26.6	8.47	2.68	0.855
15	57.3	18.1	5.74	1.83	0.588
20	39.5	12.5	3.96	1.27	0.410

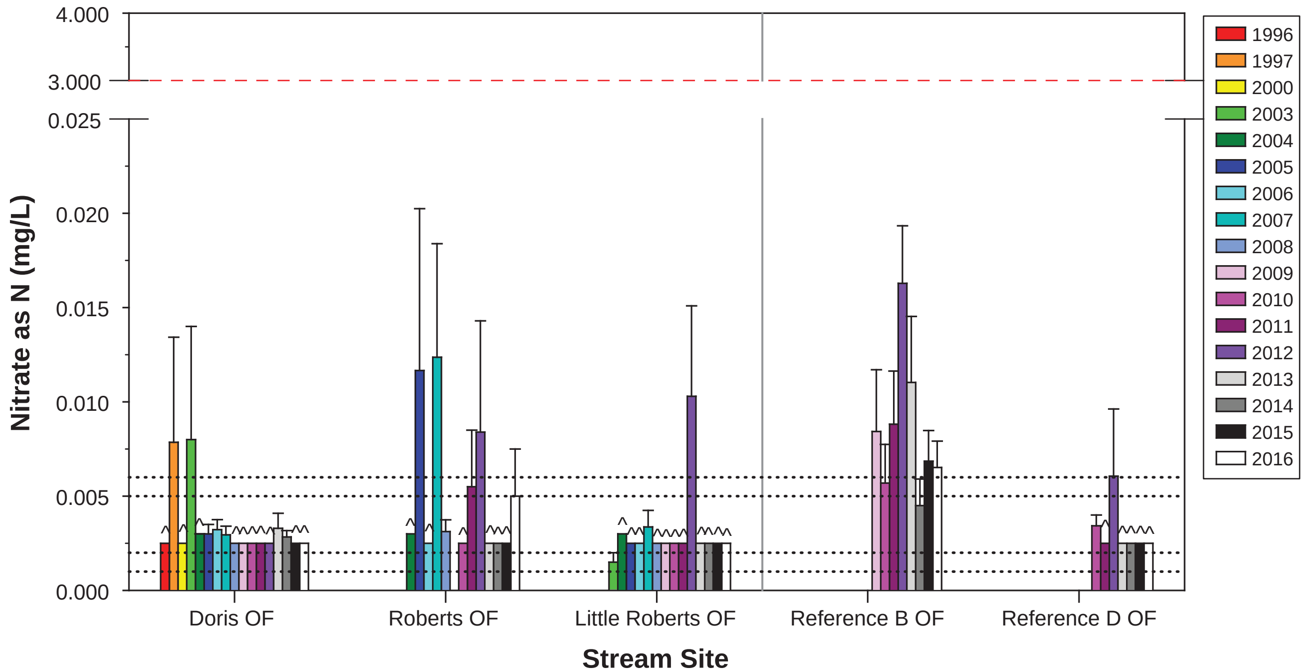
Total Ammonia as N, mg/L

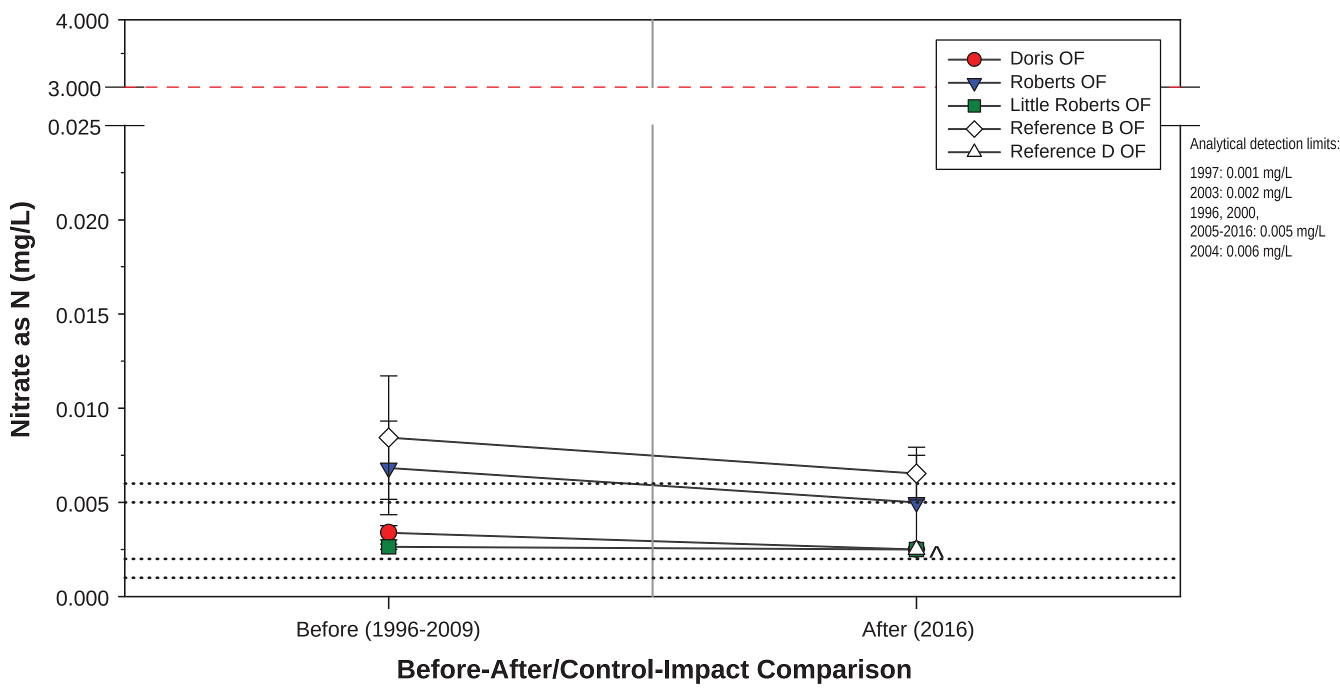


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Inset table shows the 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.
See Appendix B.2.2 for a list of outliers excluded from plots and analyses.

Figure 3.3-6

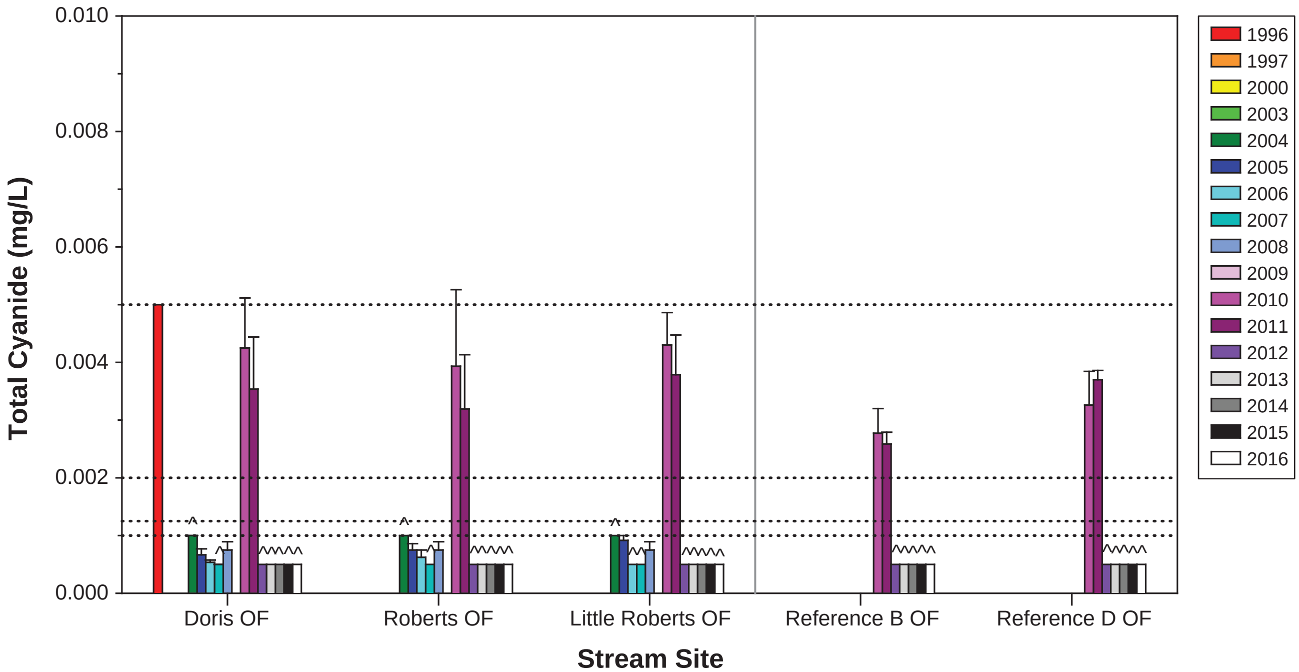
Nitrate Concentrations in AEMP Stream Sites, Doris Project, 1996 to 2016

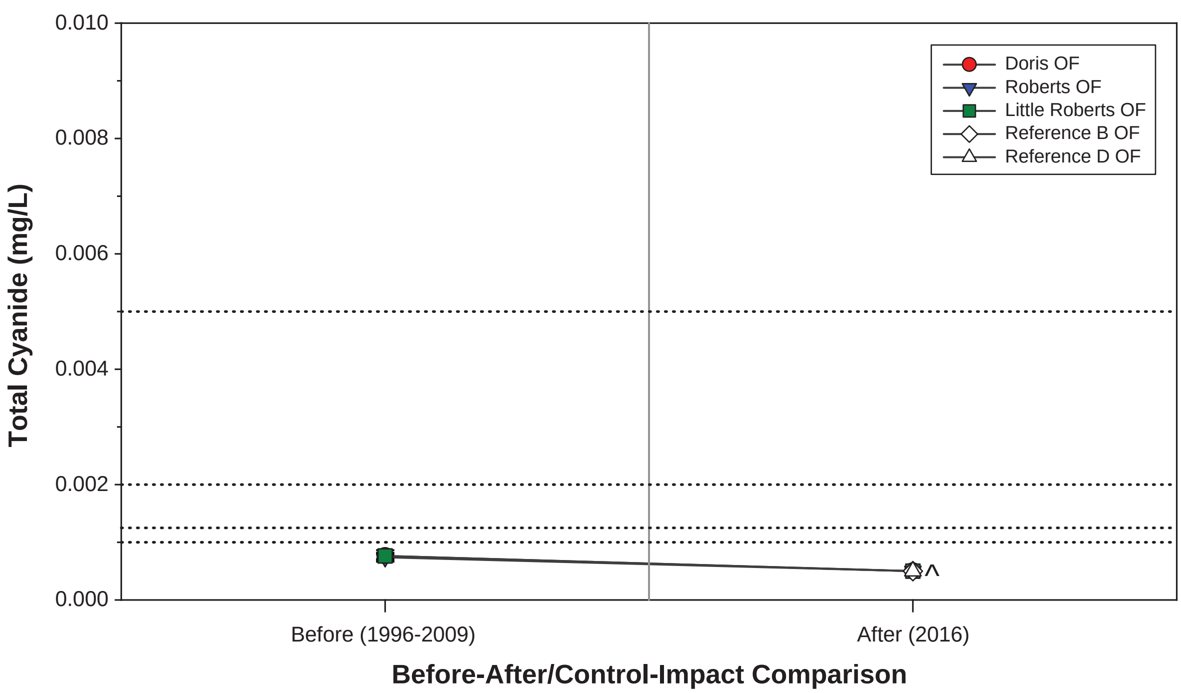




Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed line represents 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 in AEMP Stream Sites, Doris Project, 1996 to 2016





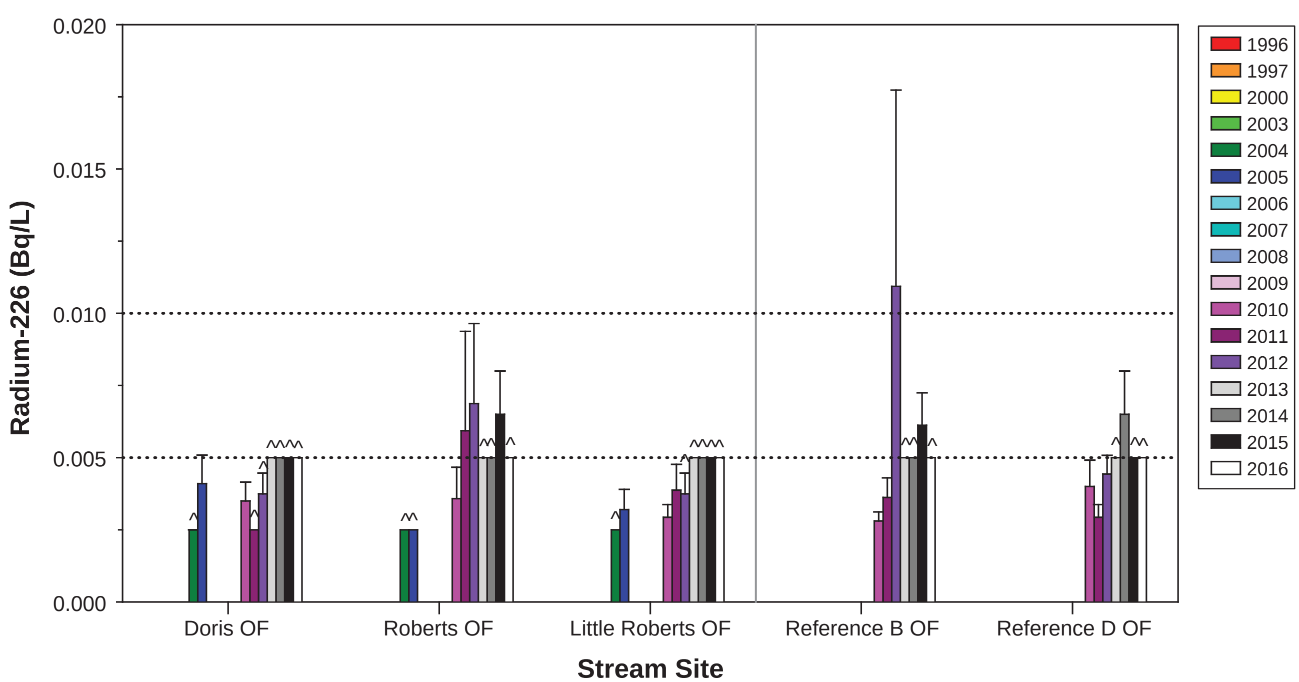
Analytical detection limits:

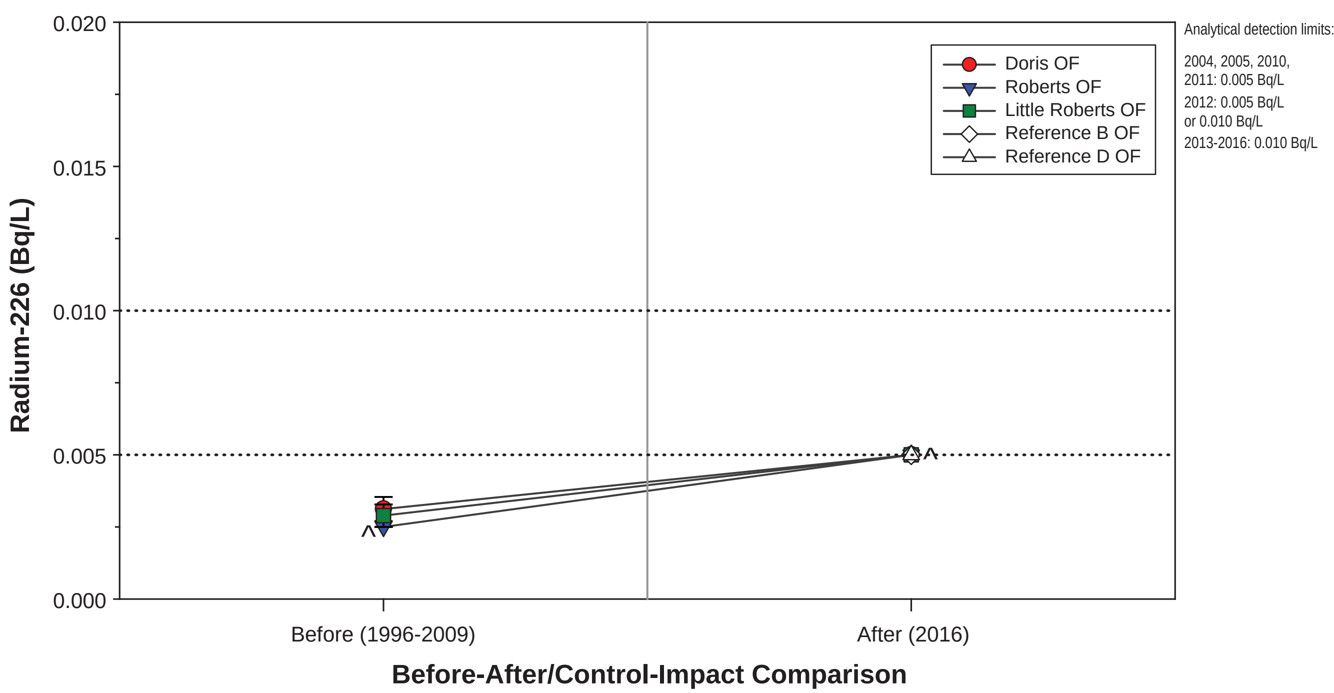
2005-2008, 2010,
2012-2016: 0.001 mg/L
2011: 0.001 to 0.00125 mg/L
2004: 0.002 mg/L
1996: 0.005 mg/L

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 in AEMP Stream Sites, Doris Project, 1996 to 2016





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. Within each stream, there was relatively high inter-annual and seasonal variability in total aluminum concentrations (Figure 3.3-9). The mean 2016 total aluminum concentration in Little Roberts Outflow was above the pH-dependent CCME guideline of 0.1 mg/L, and the mean 2016 total aluminum concentration in Doris Outflow was below the guideline level. However, the guideline has been frequently exceeded in all exposure streams during baseline years, particularly in Little Roberts Outflow where nearly all mean baseline concentrations exceeded the guideline. The total aluminum guideline was also frequently exceeded in Reference D Outflow (Figure 3.3-9).

In both Doris and Little Roberts outflows, mean 2016 total aluminum concentrations were within the range of baseline concentrations (Figure 3.3-9). The before-after analysis showed that for each exposure stream, the mean 2016 total aluminum concentration was not significantly different from baseline mean (p = 0.78 for Doris Outflow and p = 0.052 for Little Roberts Outflow). Therefore, there was no indication that 2016 Project activities adversely affected 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 2016 total arsenic concentrations in the exposure streams were well below the CCME guideline of 0.005 mg/L, and were generally similar to or slightly lower than mean baseline concentrations (Figure 3.3-10).

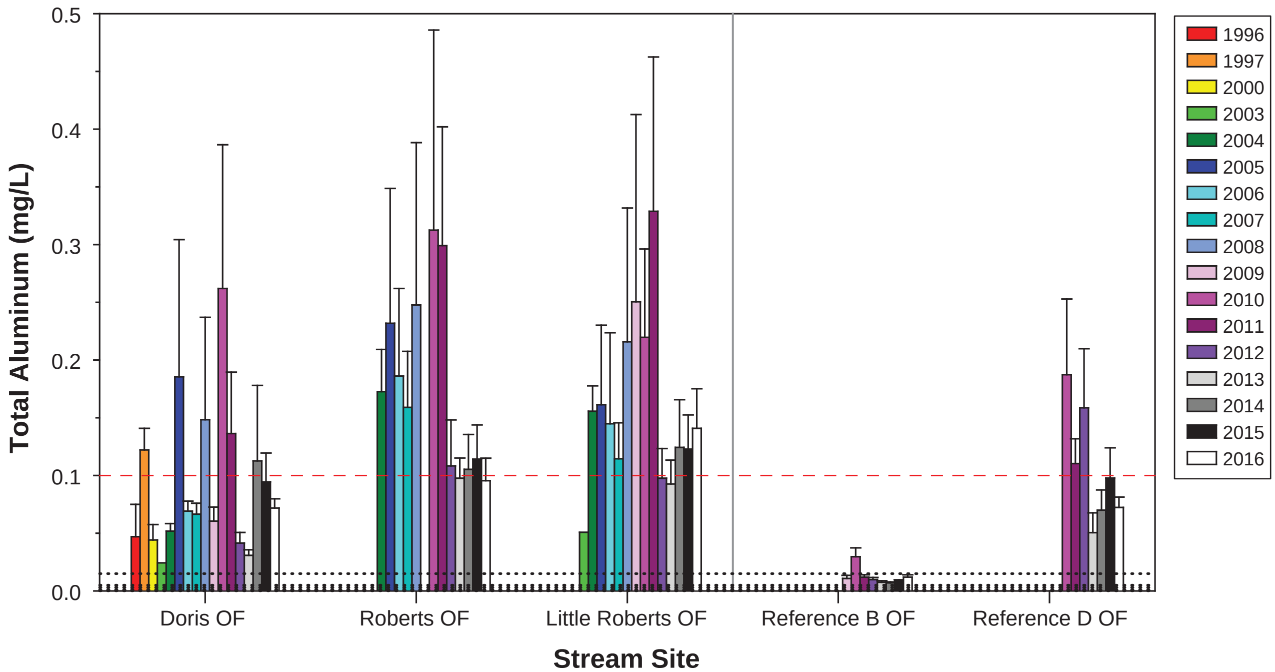
The before-after comparison indicated that 2016 mean total arsenic concentrations were not significantly different from baseline mean total arsenic concentrations for Doris Outflow (p = 0.25) and Little Roberts Outflow (p = 0.14). Therefore, there were no apparent adverse effects of Project activities on total arsenic concentrations in exposure streams in 2016.

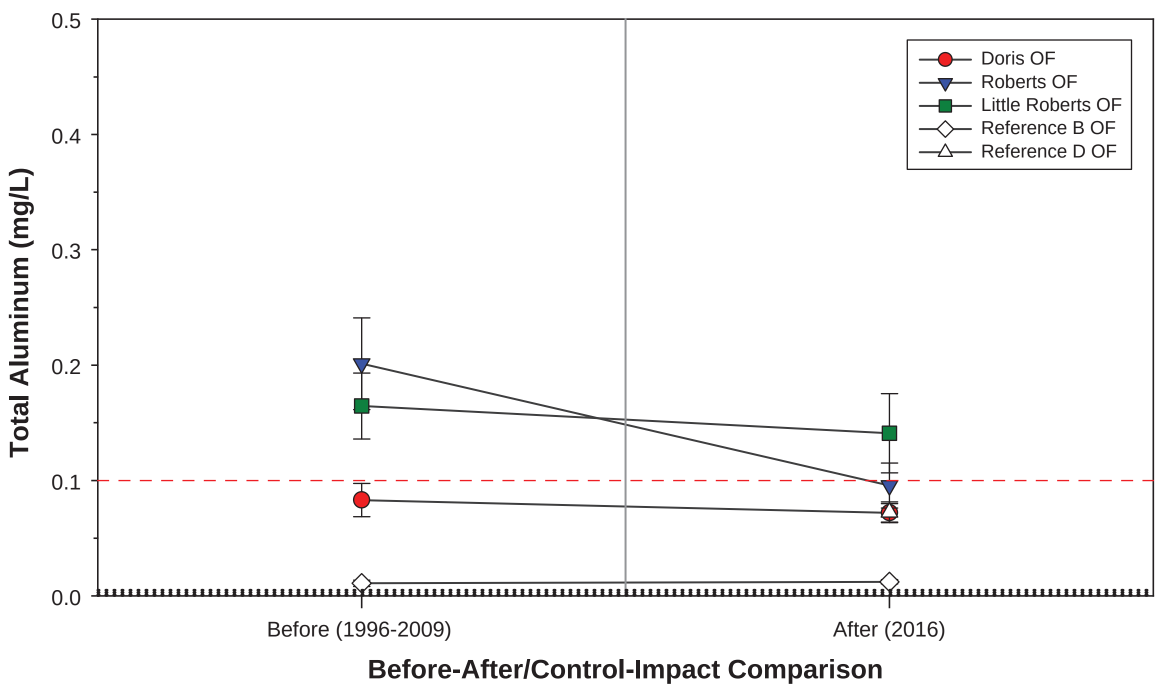
3.3.1.11 Total Cadmium

Total cadmium is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. All total cadmium concentrations measured in exposure and reference streams in 2016 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 2016 Project activities on total cadmium concentrations in any of the exposure streams. All total cadmium concentrations measured in streams in 2016 were well below the CCME hardness-dependent cadmium guideline (Figure 3.3-11).

Figure 3.3-9

Total Aluminum Concentration in AEMP Stream Sites, Doris Project, 1996 to 2016



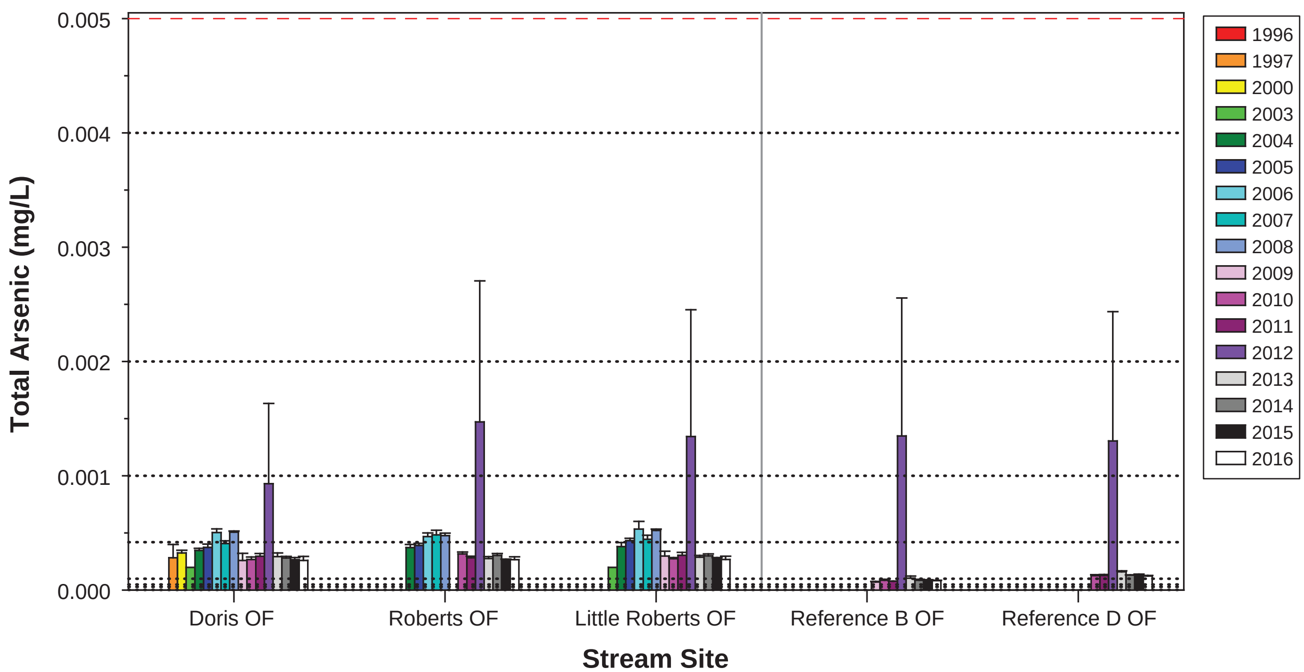


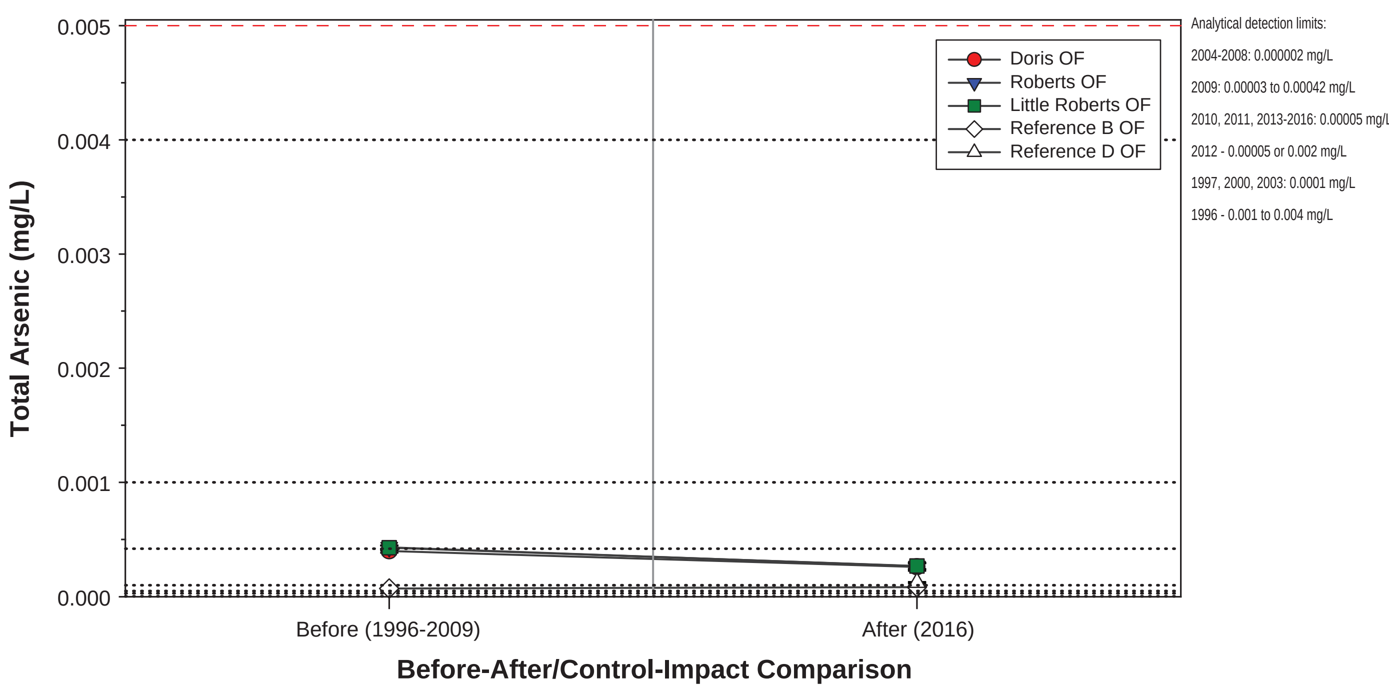
Analytical detection limits:
2003: 0.0003 mg/L
2004-2008: 0.0005 mg/L
1996, 2000, 2009 - 0.001 mg/L
2010, 2013-2016: 0.003 mg/L
2011: 0.003 to 0.015 mg/L
2012: 0.003 to 0.021 mg/L
1997: 0.005 mg/L

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 in AEMP Stream Sites, Doris Project, 1996 to 2016

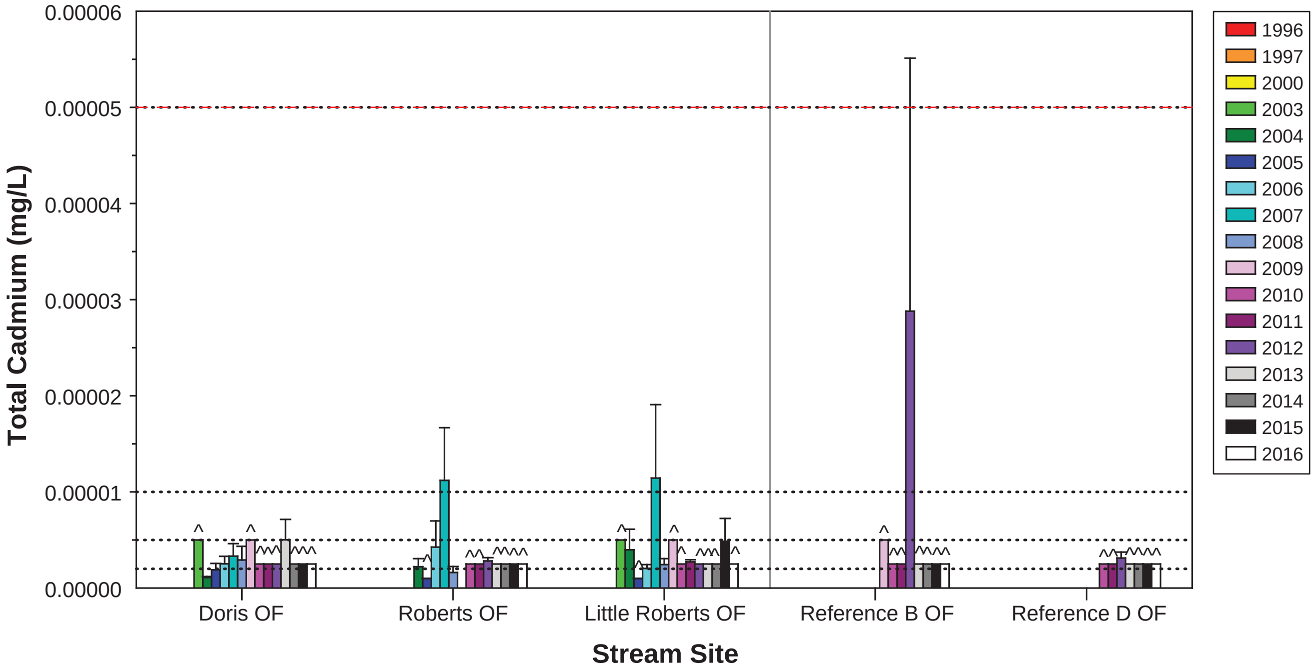


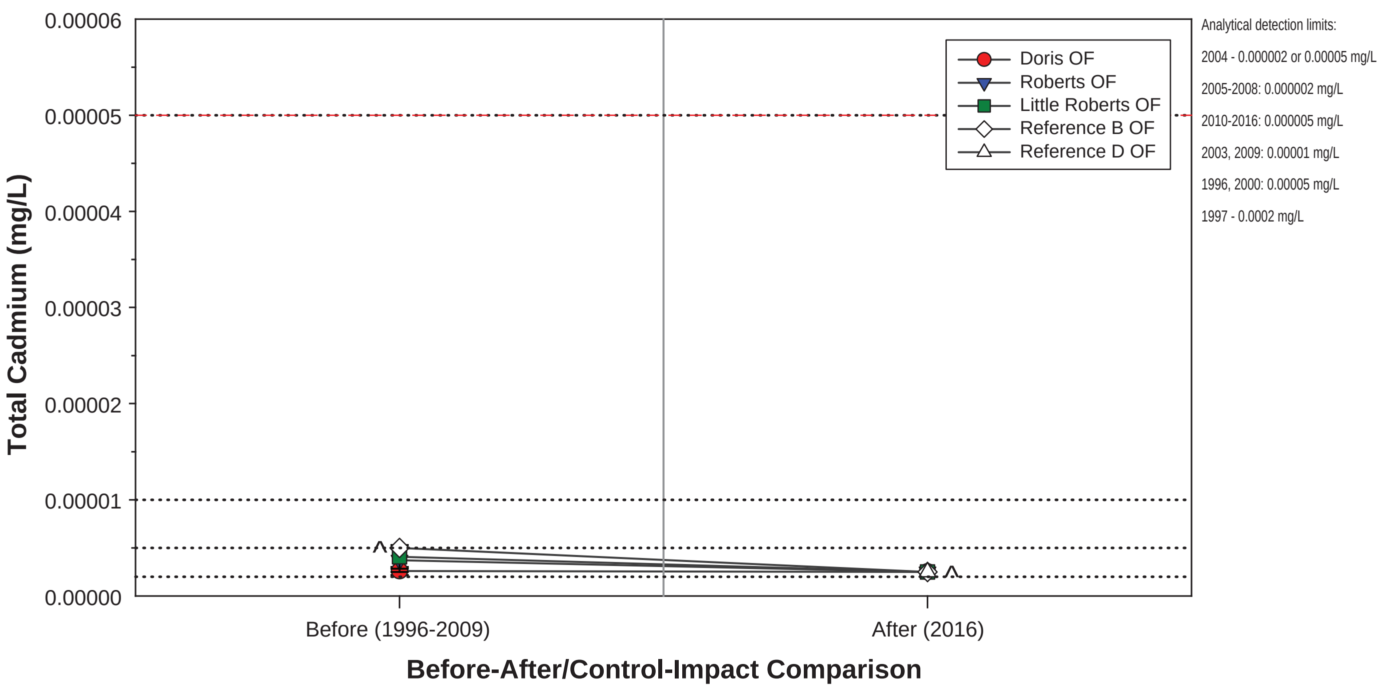


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Red dashed lines represent the CCME freshwater guideline for arsenic (0.005 mg/L).
Total arsenic is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.
See Appendix B.2.2 for a list of outliers excluded from plots and analyses.

Figure 3.3-11

Total Cadmium Concentration in AEMP Stream Sites, Doris Project, 1996 to 2016





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 2016 (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.
See Appendix B.2.2 for a list of outliers excluded from plots and analyses.

3.3.1.12 Total Copper

Total copper is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. In exposure streams, mean 2016 total copper concentrations were below the hardness-dependent CCME guideline (Figure 3.3-12); however, total copper concentrations measured in September 2016 at all exposure streams were greater than the CCME guideline level (Appendix A). The before-after analysis indicated that there was no significant difference in the mean total copper concentration between baseline years and 2016 in either Doris Outflow (p = 0.59) or Little Roberts Outflow (p = 0.73). Therefore, there was no indication of an adverse effect of 2016 Project activities on total copper concentrations in exposure streams.

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 2016 total iron concentrations in exposure streams were below the CCME guideline concentration of 0.3 mg/L and within the range of baseline concentrations (Figure 3.3-13). The before-after analysis confirmed that there was no significant difference between baseline and 2016 means for any exposure stream (p = 0.85 for Doris Outflow and p = 0.62 for Little Roberts Outflow), suggesting that 2016 Project activities did not affect total iron concentrations in 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 2016 total lead concentrations in the exposure streams were lower than mean baseline concentrations (Figure 3.3-14); however, the before-after comparison indicated that 2016 mean total lead concentrations were not significantly different from baseline means for the exposure streams (p = 0.27 for Doris 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 2016.

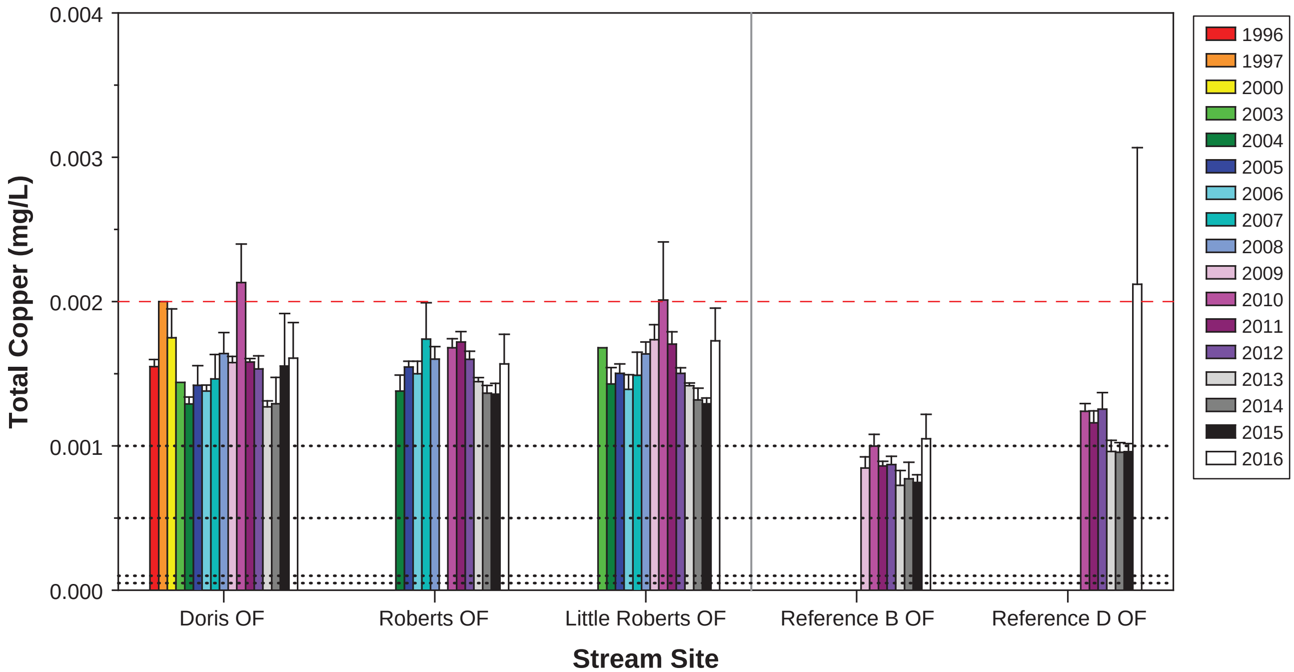
3.3.1.15 Total Mercury

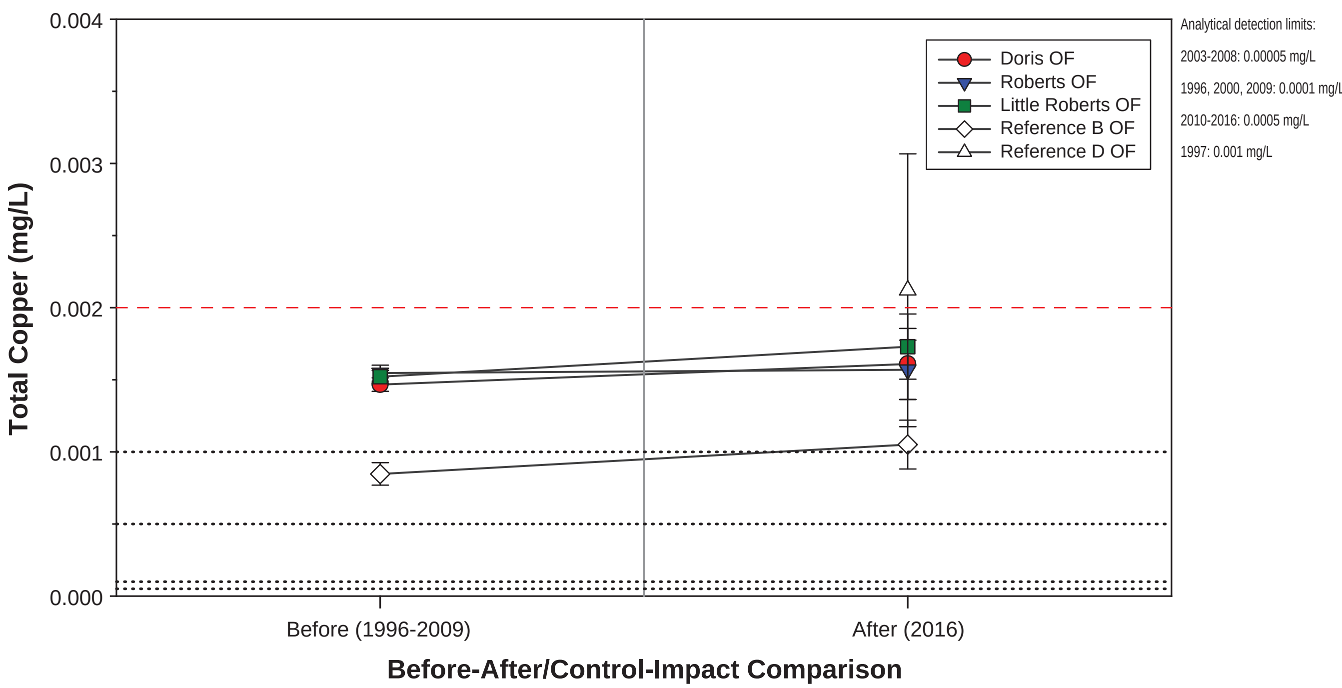
Total mercury is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. The analysis of mercury concentrations in streams is complicated by the high proportion of censored values (i.e., concentrations that are below detection limits) in the combined baseline and 2016 datasets for the exposure streams (75% for Doris Outflow and 71% for Little Roberts Outflow). However, the majority of 2016 mercury concentrations in exposure streams were above detection limits because of the use of ultra-low level mercury analysis for 2016 samples.

The mean 2016 total mercury concentrations in Doris and Little Roberts outflows were well below the CCME guideline of 0.000026 mg/L, and similar to detectable baseline concentrations (Figure 3.3-15). The before-after analysis confirmed that the baseline and 2016 means for total mercury were not significantly different for either exposure stream (p = 0.77 for Doris Outflow and p = 0.75 for Little Roberts Outflow), suggesting that there was no effect of 2016 Project activities on total mercury concentrations in exposure streams (Figure 3.3-15).

Figure 3.3-12

Total Copper Concentration in AEMP Stream Sites, Doris Project, 1996 to 2016

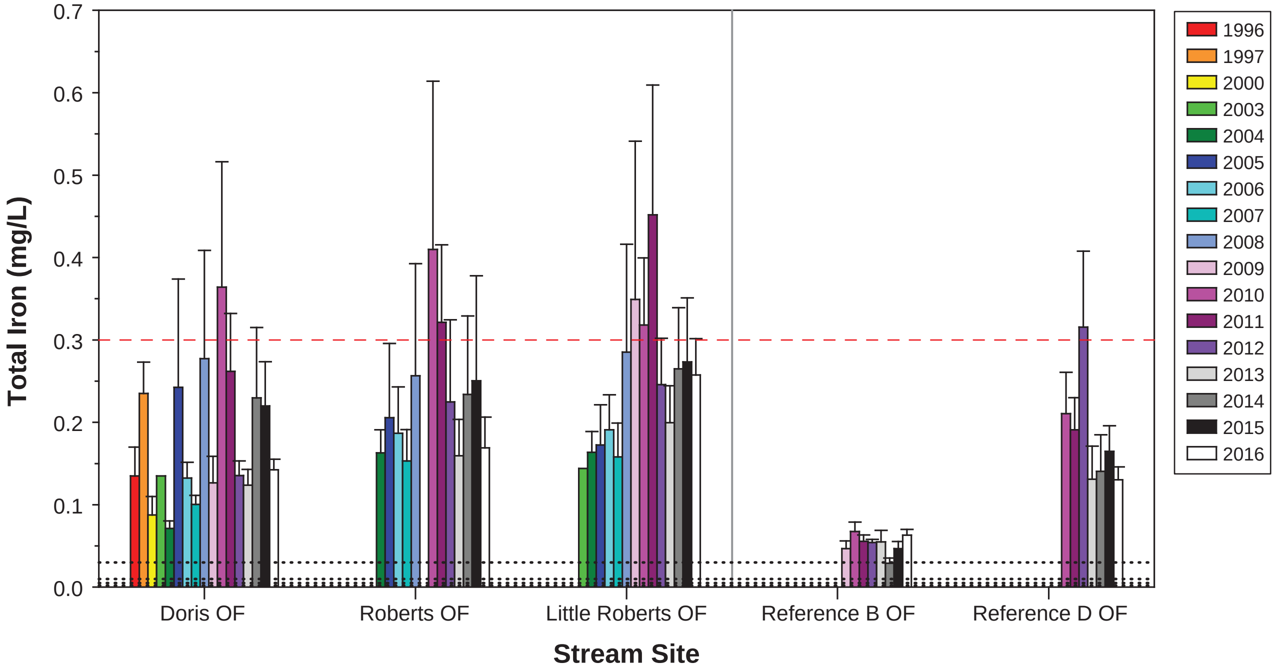


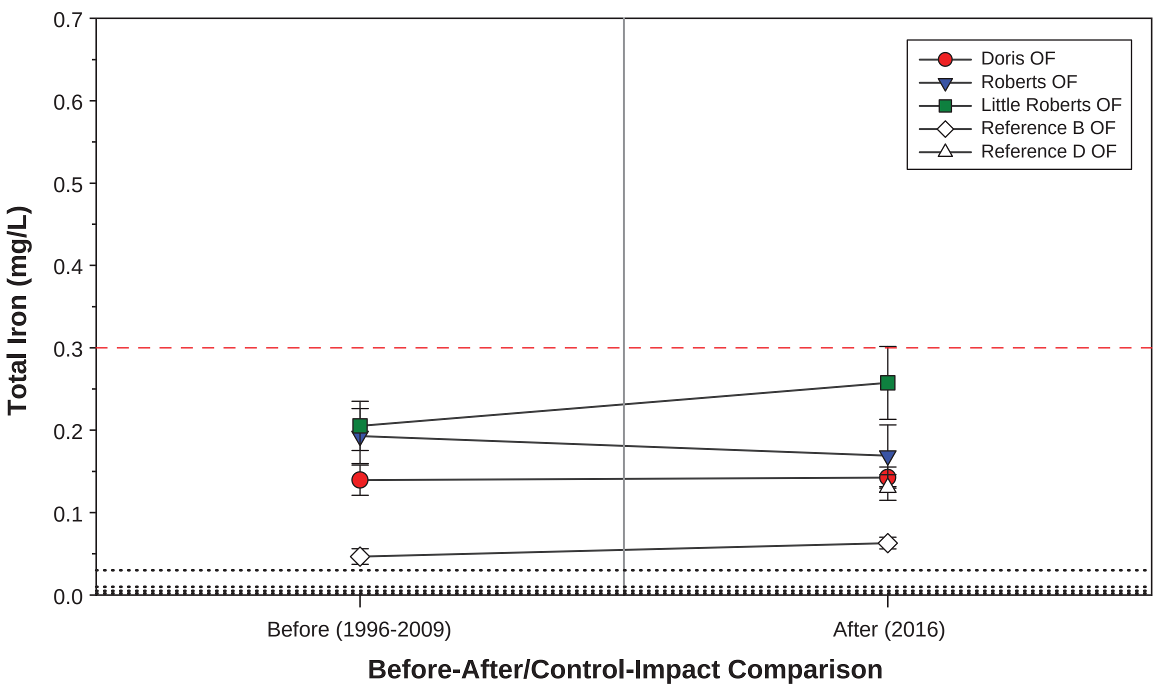


Notes: *Error bars represent the standard error of the mean.*
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
The CCME freshwater guideline for copper is hardness dependent.
Red dashed lines represent the minimum 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 3.3-13

Total Iron Concentration in AEMP Stream Sites, Doris Project, 1996 to 2016



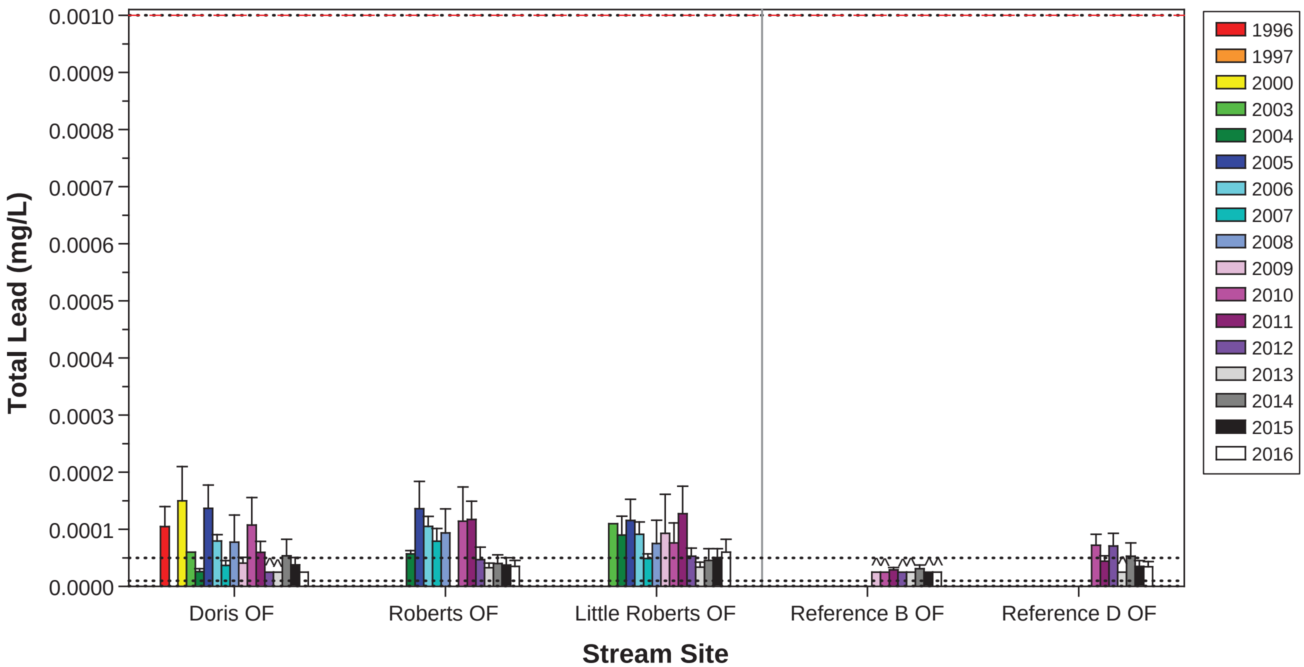


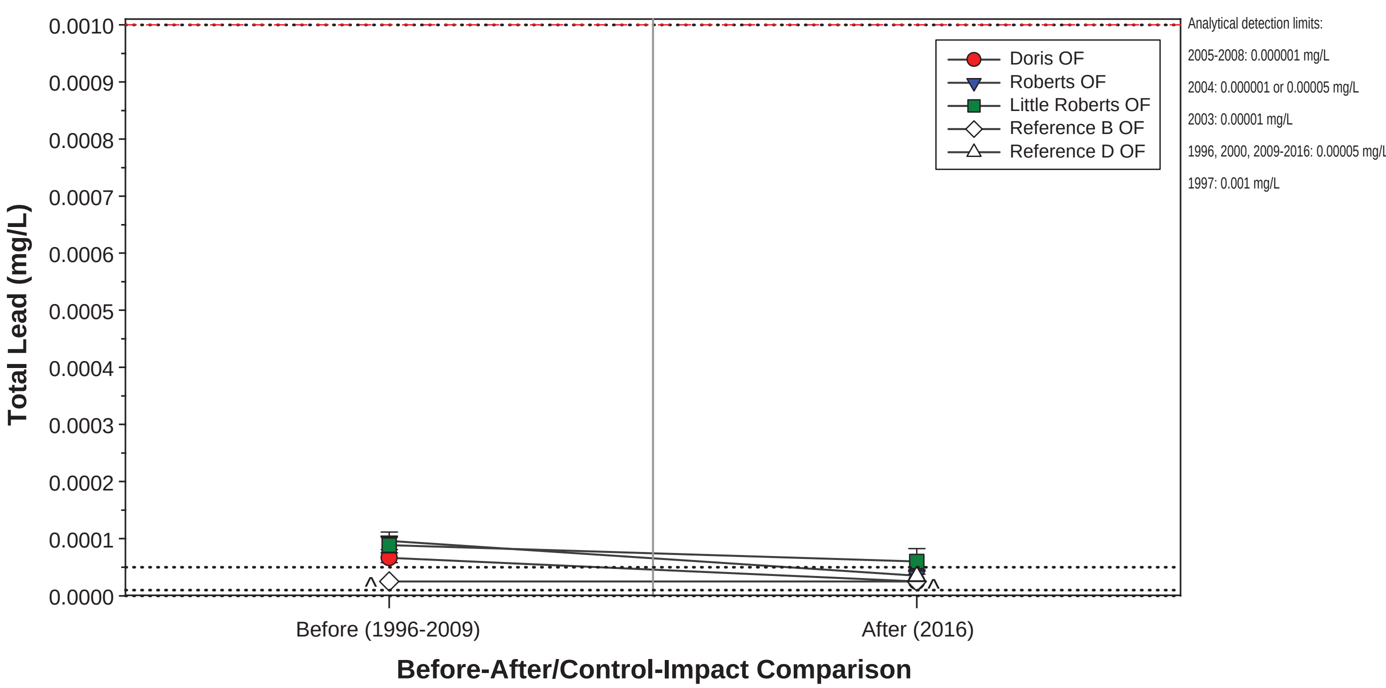
Analytical detection limits:
2004-2008: 0.002 mg/L
2003: 0.005 mg/L
1996, 1997, 2009: 0.01 mg/L
2000, 2010-2016: 0.03 mg/L

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 in AEMP Stream Sites, Doris Project, 1996 to 2016

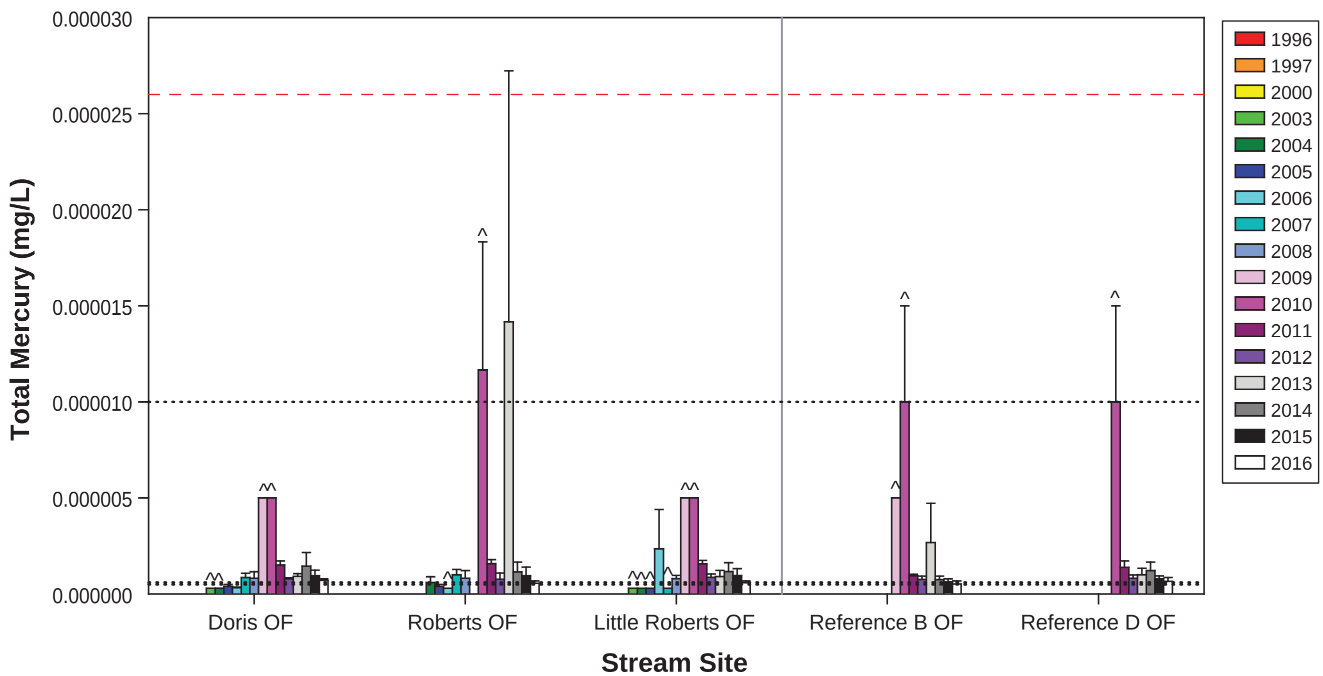


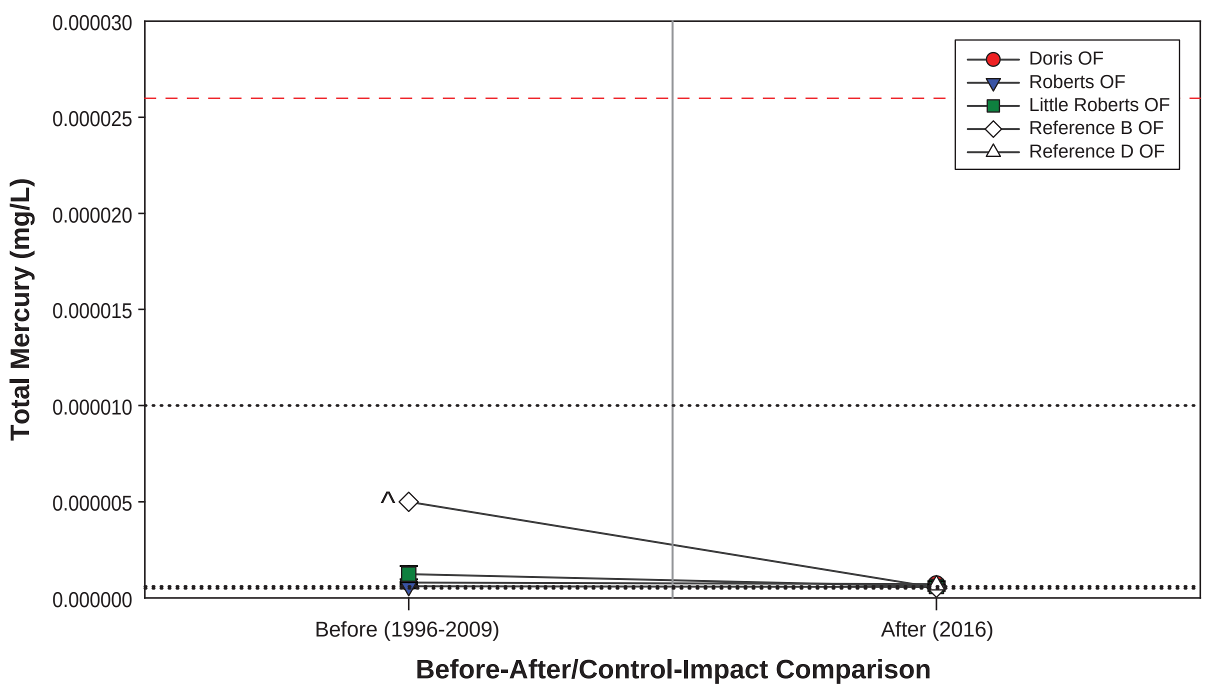


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
The CCME freshwater guideline 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.
See Appendix B.2.2 for a list of outliers excluded from plots and analyses.

Figure 3.3-15

Total Mercury Concentration in AEMP Stream Sites, Doris Project, 1996 to 2016





Analytical detection limits:
2011-2016: 0.0000005 mg/L
2003: 0.0000006 or 0.00005 mg/L
2004-2008: 0.0000006 mg/L
2009: 0.00001 mg/L
2010: 0.00001 or 0.00005 mg/L
1997, 2000: 0.00005 mg/L

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.
See Appendix B.2.2 for a list of outliers excluded from plots and analyses.

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. Total molybdenum concentrations in all 2016 samples were well below the interim CCME guideline of 0.073 mg/L (Figure 3.3-16). Mean total molybdenum concentrations within each exposure stream were relatively consistent over time (Figure 3.3-16). The before-after comparison showed that there was no significant difference between before and after periods for total molybdenum concentrations for Doris Outflow (p = 0.26) and Little Roberts Outflow (p = 0.87). There was no evidence of a change in total molybdenum concentrations in exposure streams due to 2016 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 2016 nickel concentrations in all streams were well below the hardness-dependent CCME guideline (Figure 3.3-17). In both Doris and Little Roberts outflows, total nickel concentrations in 2016 were within the range of baseline concentrations (Figure 3.3-17), and the before-after analysis confirmed that there was no significant difference between mean baseline and mean 2016 total nickel concentrations for either exposure stream (p = 0.97 for Doris Outflow and p = 0.51 for Little Roberts Outflow). Therefore, there was no apparent effect of 2016 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. All 2016 total zinc concentrations in exposure and reference streams were below the detection limit of 0.003 mg/L, and well below the CCME guideline of 0.03 mg/L (Figure 3.3-18). Therefore, there was no evidence of an effect of 2016 Project activities on total zinc concentrations in exposure streams.

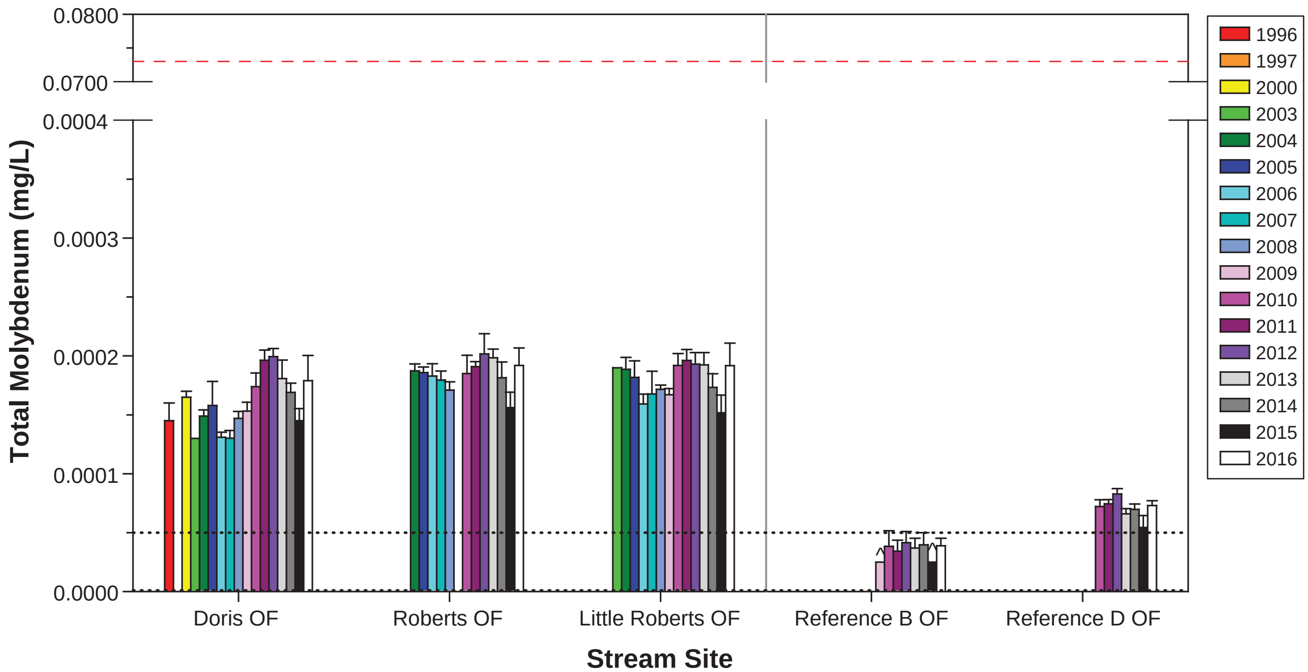
3.3.2 Lakes

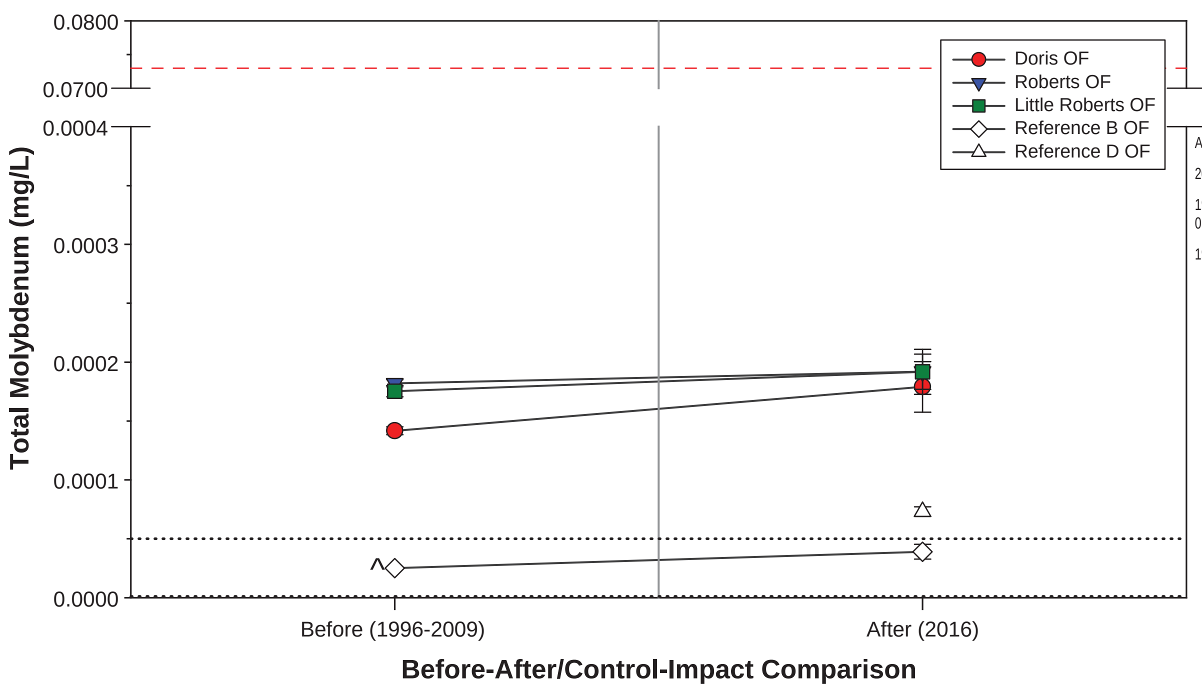
Water quality samples from lakes were collected from three exposure lake sites (Doris Lake South, Doris Lake North, and Little Roberts Lake) and two reference lakes (Reference Lake B and Reference Lake D) in 2016. For the exposure lakes, relevant baseline data are available from 1995 to 1998, 2000, and 2003 to 2009 (though all lake sites were not sampled each year). The only available baseline data for Reference Lake B are from 2009, and no baseline data are available for Reference Lake D.

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.

Figure 3.3-16

Total Molybdenum Concentration in AEMP Stream Sites, Doris Project, 1996 to 2016





Analytical detection limits:

2004-2008: 0.000001 mg/L

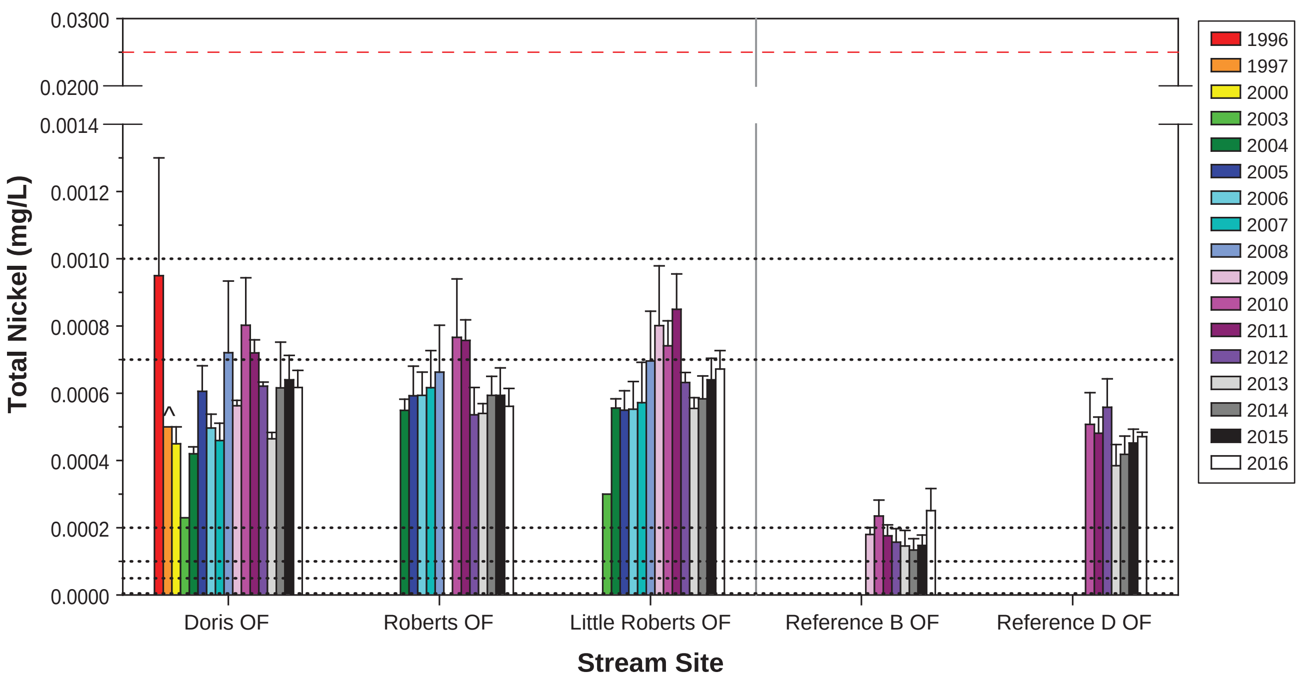
1996, 2000, 2003, 2009-2016: 0.00005 mg/L

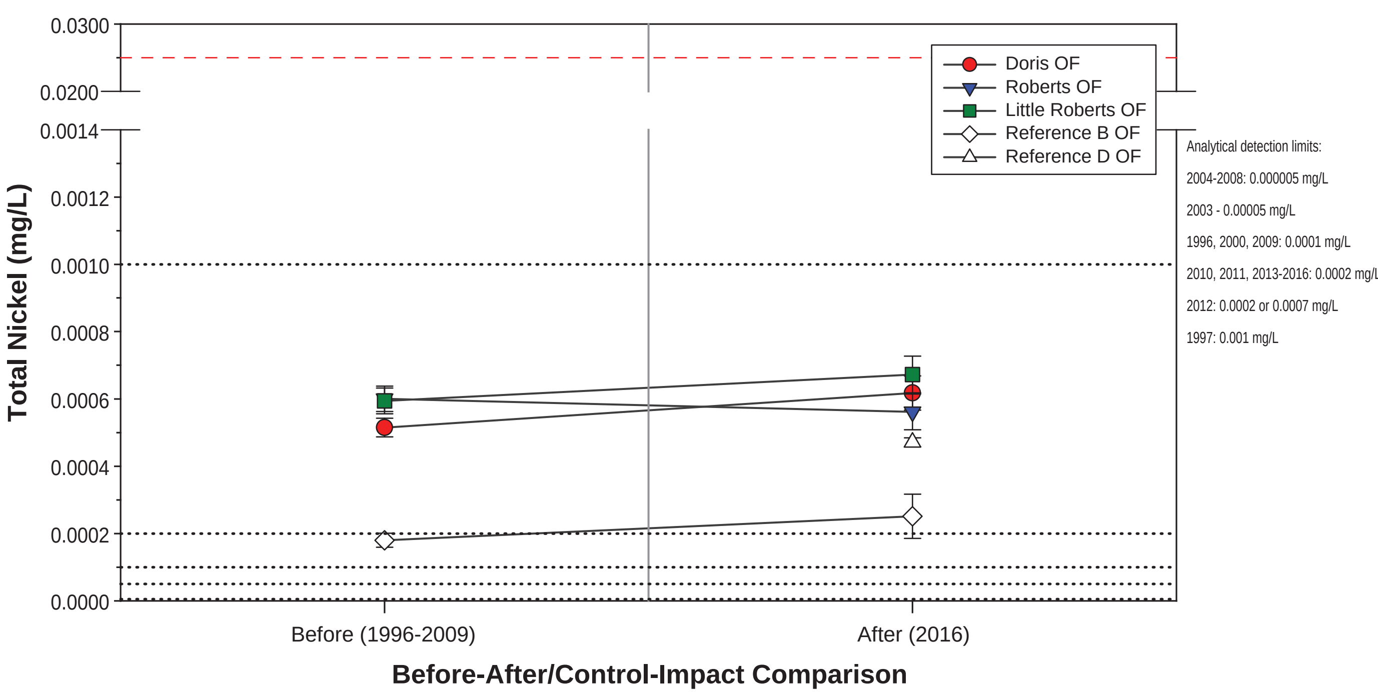
1997: 0.001 mg/L

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.
See Appendix B.2.2 for a list of outliers excluded from plots and analyses.

Figure 3.3-17

Total Nickel Concentration in AEMP Stream Sites, Doris Project, 1996 to 2016

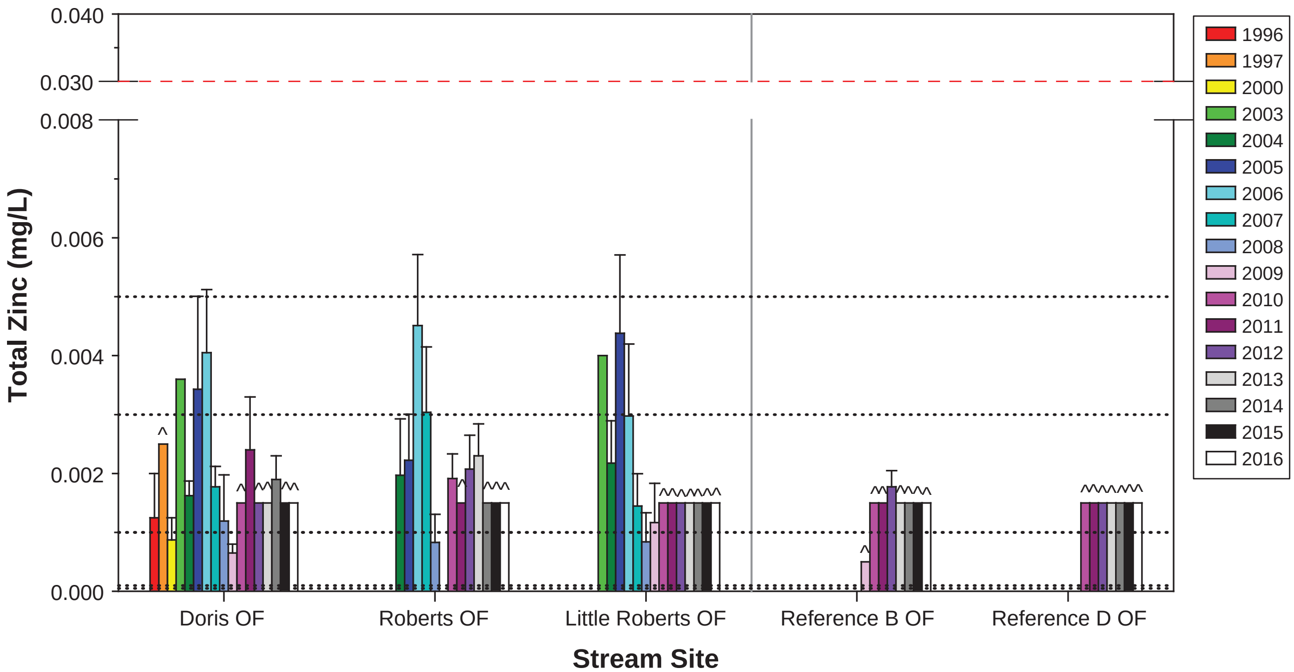


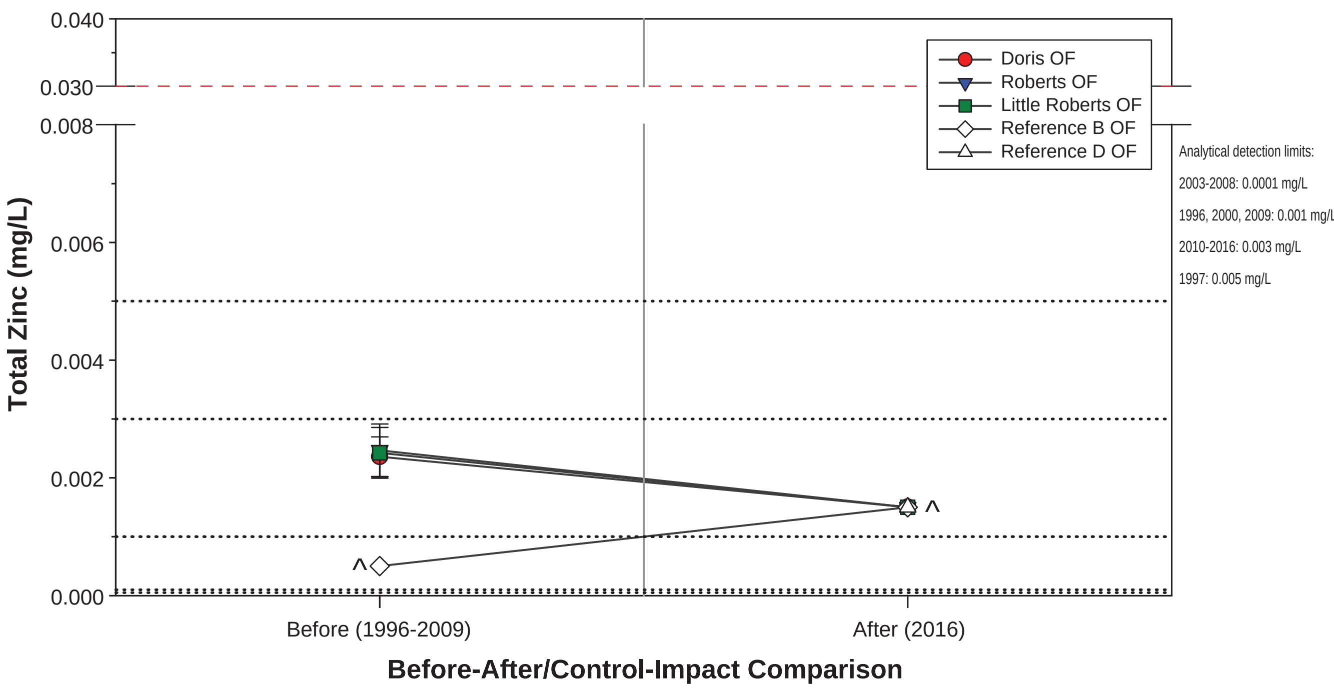


Notes: *Error bars represent the standard error of the mean.*
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
The CCME freshwater 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 in AEMP Stream Sites, Doris Project, 1996 to 2016





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.

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 2016 in exposure lakes were 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 showed that the mean baseline pH was not statistically distinguishable from the mean 2016 pH for Doris Lake South (p = 0.41) and Doris Lake North (p = 0.28). However, in Little Roberts Lake, there was a significant increase in pH from baseline years (mean pH of 7.22) to 2016 (mean pH of 7.53; p = 0.032). The mean 2016 pH in Little Roberts Lake of 7.53 remained within the optimal pH range for freshwater aquatic life (CCME 2016b), and was identical to mean pH levels recorded during individual baseline years (7.5 in 1996 and 7.53 in 2003). A BACI analysis was not possible to determine if a parallel change occurred in Reference Lake D since there were no baseline data available for this reference lake. Given that there was no discharge from the TIA in 2016, there were no pH changes in waterbodies upstream of Little Roberts Lake, and similar pH levels were recorded during some baseline years, it is unlikely that Project activities had an effect on pH in Little Roberts Lake.

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 the Doris Lake exposure sites in 2016 were slightly higher than baseline alkalinity levels (Figure 3.3-20); however, the before-after analysis confirmed that the increase was not statistically significant for either site (p = 0.15 for Doris Lake South and p = 0.21 for Doris Lake North). In Little Roberts Lake, mean 2016 total alkalinity was within the range of baseline levels, and the before-after analysis showed that there was no significant difference between the baseline and 2016 means (p = 0.95). Thus, there was no evidence that 2016 Project activities affected total alkalinity in exposure lakes.

3.3.2.3 Hardness

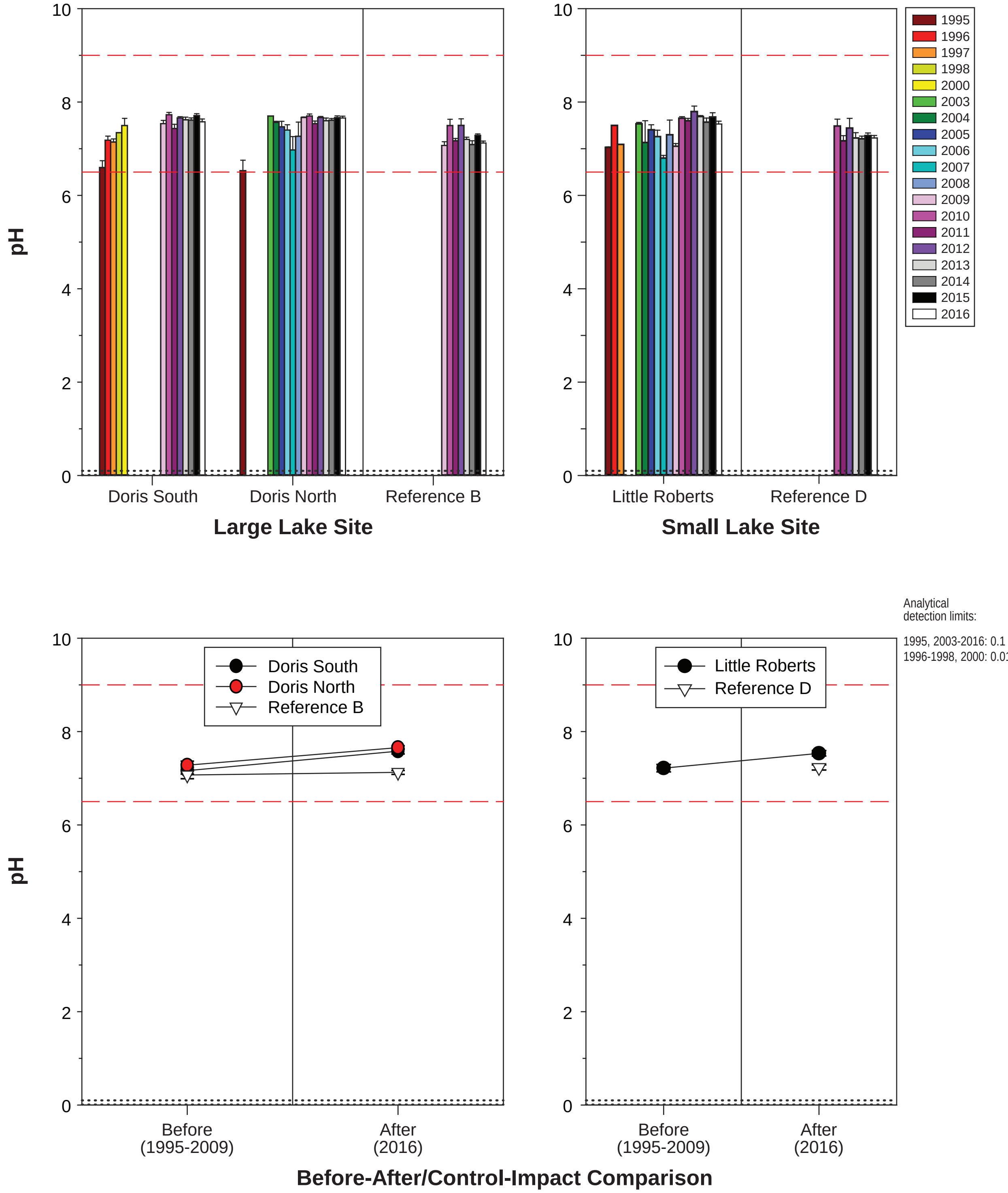
Hardness is a required variable for effluent characterization and water quality monitoring as per Schedule 5, s. 4(1) and s. 7(1)(c) of the MMER. Mean 2016 hardness levels were slightly higher than baseline means in the exposure lakes (Figure 3.3-21). However, the before-after analysis indicated that this increase was not statistically significant for any exposure lake site (p = 0.052 for Doris Lake South, p = 0.21 for Doris Lake North, and p = 0.87 for Little Roberts Lake). There was no evidence that 2016 Project activities had an effect on lake water hardness.

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 2016 TSS concentrations measured in the exposure lakes were within the range of baseline concentrations, and the before-after analysis showed that 2016 means were not statistically different from baseline means in any of the exposure lake sites (p = 0.83 for Doris Lake South, p = 0.75 for Doris Lake North, and p = 0.45 for Little Roberts Lake). Therefore, there was no apparent effect of 2016 activities on TSS levels in these lakes.

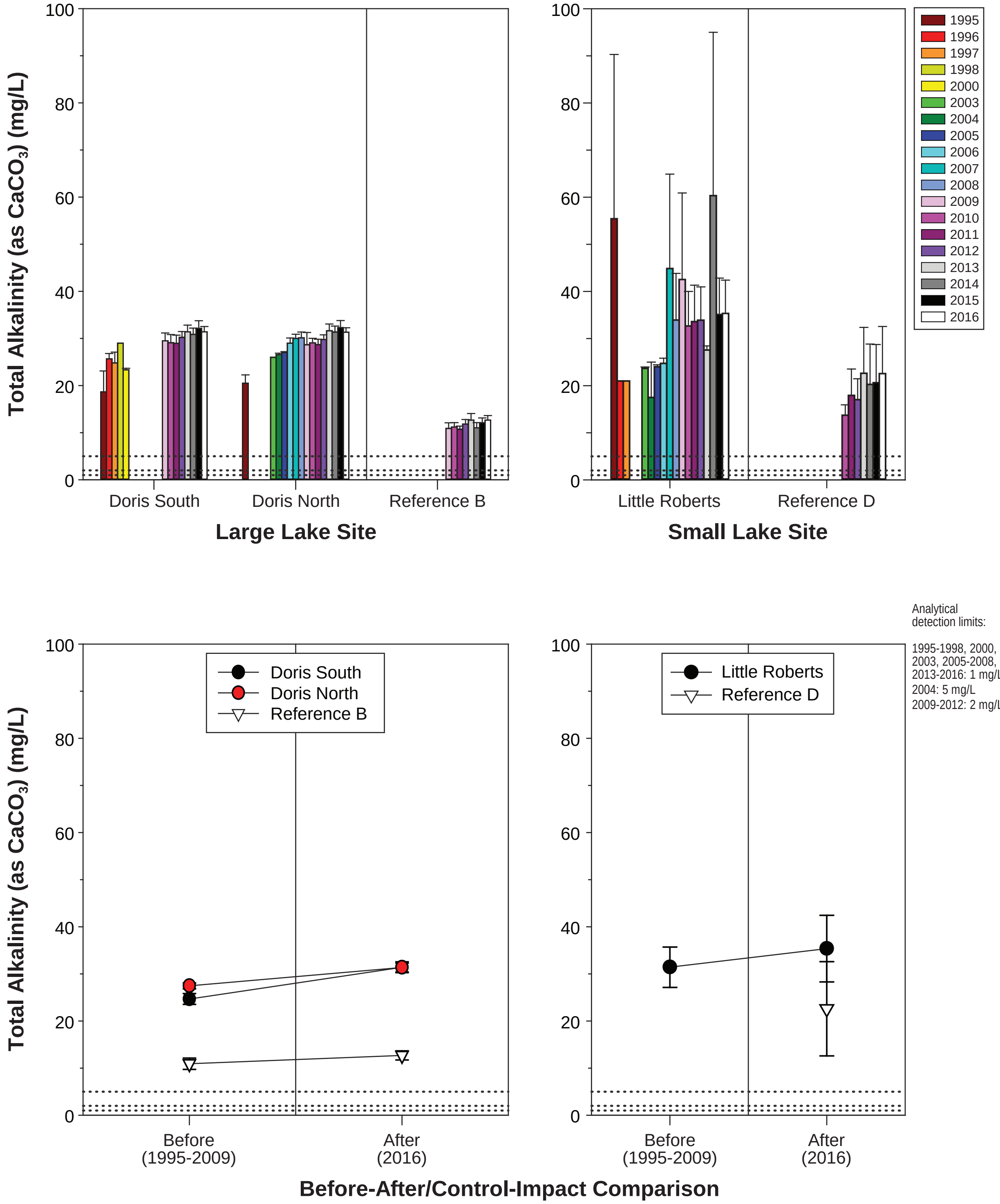
Figure 3.3-19

pH in AEMP Lake Sites, Doris Project, 1995 to 2016



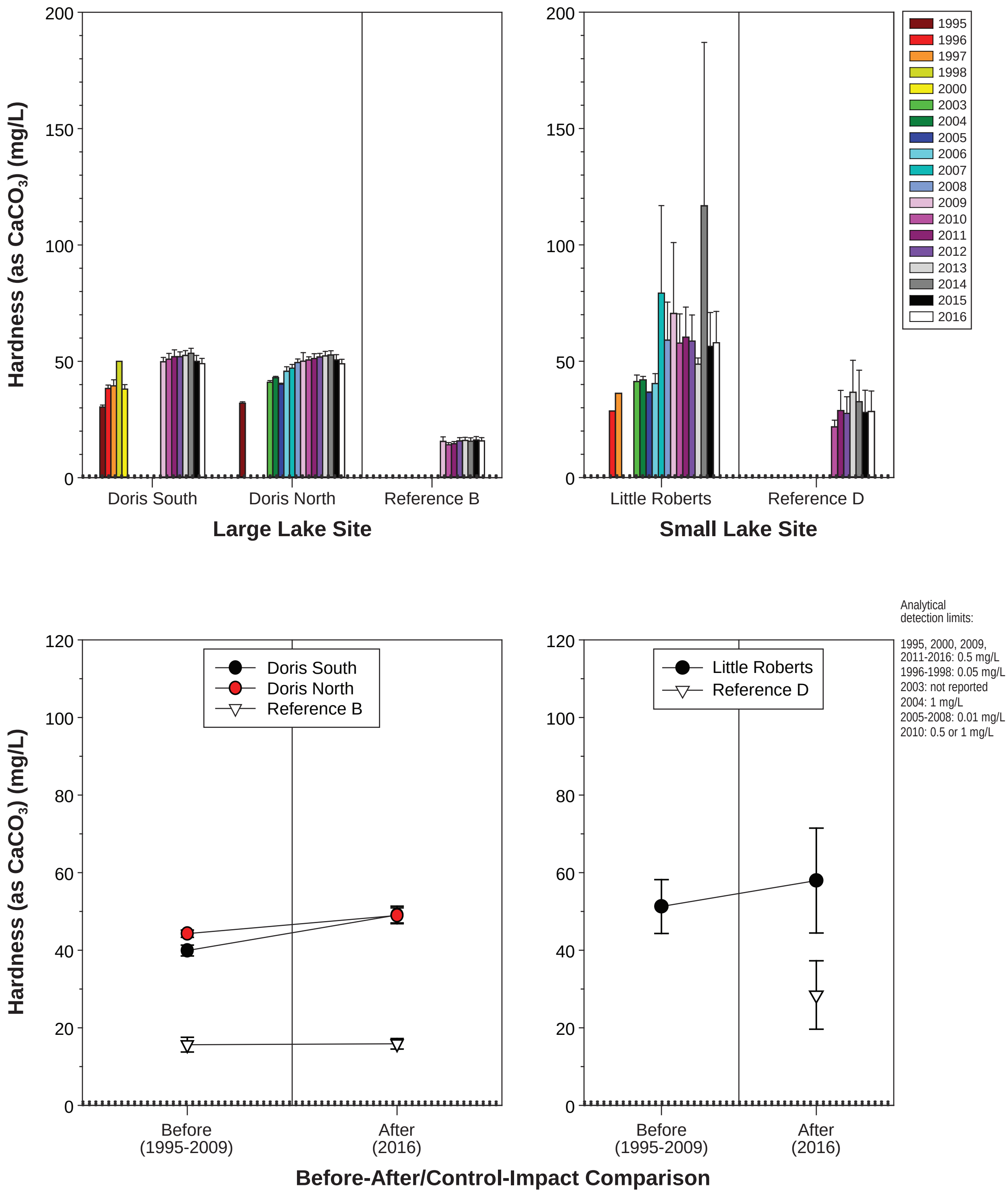
Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits.
Red dashed lines represent the CCME freshwater guideline pH range (6.5–9.0).
pH is a required parameter for water quality monitoring as per Schedule 5, s. 7(1)(c) of the MMER.

Total Alkalinity in AEMP Lake Sites, Doris Project, 1995 to 2016



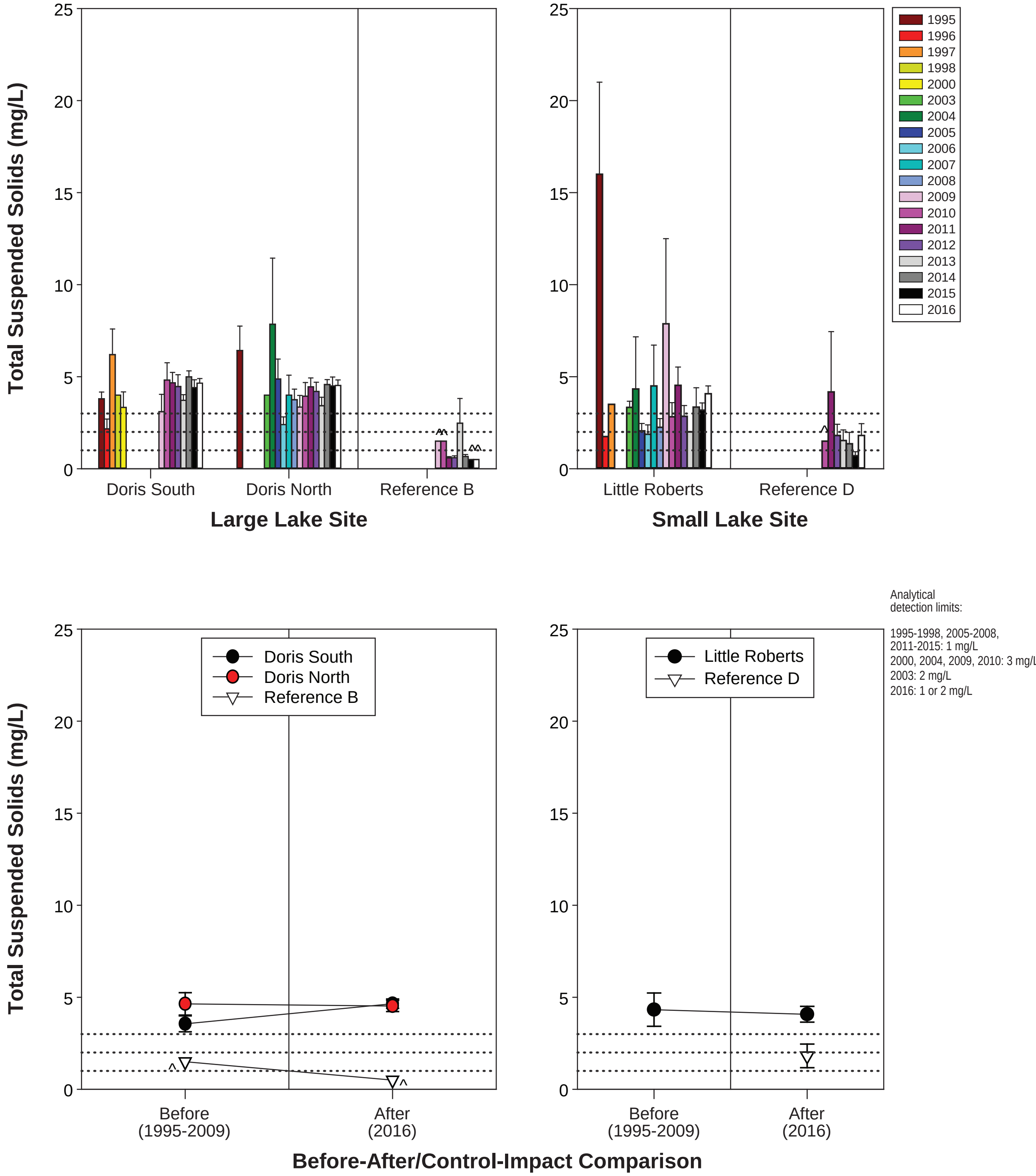
Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Total alkalinity is a required parameter for effluent characterization and water quality monitoring as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

Figure 3.3-21
Hardness in AEMP Lake Sites, Doris Project, 1995 to 2016



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.

Total Suspended Solids Concentration in AEMP Lake Sites, Doris Project, 1995 to 2016



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.

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 2016b). Because there was no evidence of an increase in TSS concentrations from background levels, 2016 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 2016 concentrations of total ammonia in exposure and reference lakes were well below the pH- and temperature-dependent CCME guideline (Figure 3.3-23). Although mean 2016 total ammonia concentrations in the exposure lakes were lower than baseline means, the before-after analysis determined that there was no significant difference between baseline and 2016 means for any exposure lake site ($p = 0.12$ for Doris Lake South, $p = 0.067$ for Doris Lake North, and $p = 0.14$ for Little Roberts Lake). Therefore, there was no evidence of an adverse effect of 2016 Project activities on ammonia concentrations in exposure lakes.

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). All 2016 nitrate concentrations measured in exposure lake sites were below the analytical detection limit of 0.005 mg/L, and well below the long-term CCME guideline of 3.0 mg nitrate-N/L (Figure 3.3-24). Therefore, there was no evidence of an adverse effect of 2016 Project activities on nitrate concentrations in exposure lakes.

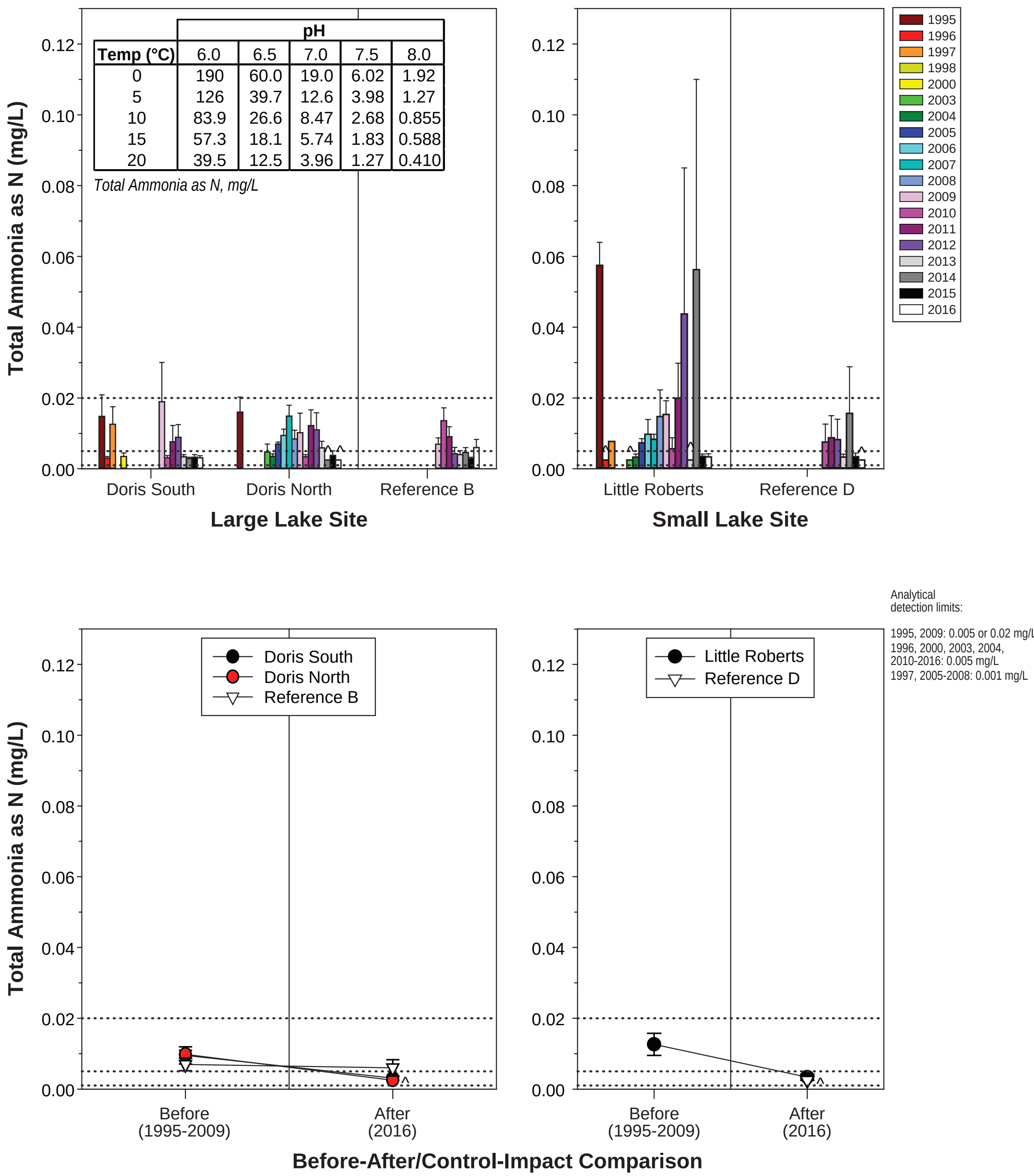
3.3.2.7 Total Cyanide

Total cyanide is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. Because of the high proportion of non-detectable total cyanide concentrations (> 80%) in the combined baseline and 2016 datasets for the exposure lake sites, statistical analysis results are not discussed. Nearly all total cyanide concentrations measured in exposure lakes in 2016 were below the analytical detection limit of 0.001 mg/L (Figure 3.3-25). The only exception was one of two replicate samples collected from Doris Lake North in April 2016, which had a total cyanide concentration of 0.0011 mg/L (just over the detection limit; Appendix A). There was no evidence of an increase in total cyanide concentrations from baseline levels due to 2016 Project activities. No cyanide was stored or used on site prior to August 2016.

Free cyanide concentrations (cyanide existing in the form of HCN and CN^-) in lake samples were measured in 2016 to allow for direct comparisons with the CCME guideline for cyanide (0.005 mg/L as free cyanide). Concentrations of free cyanide in all lakes samples were below the detection limit of 0.001 mg/L (Appendix A). Therefore, all free cyanide concentrations measured in lakes in 2016 were well below the CCME guideline and would not be expected to pose a threat to freshwater aquatic life.

Figure 3.3-23

Total Ammonia Concentration in AEMP Lake Sites, Doris Project, 1995 to 2016



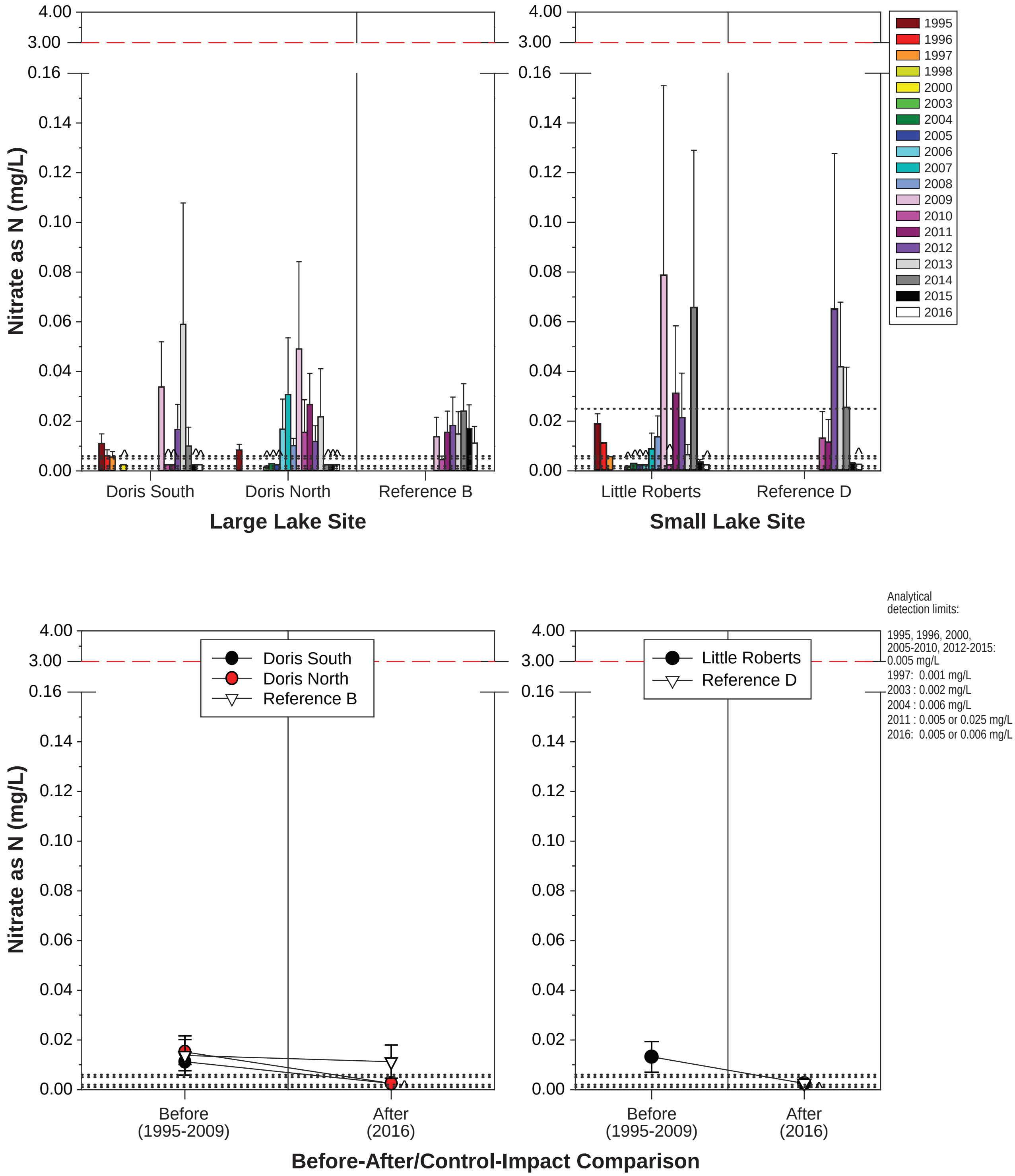
	pH				
Temp (°C)	6.0	6.5	7.0	7.5	8.0
0	190	60.0	19.0	6.02	1.92
5	126	39.7	12.6	3.98	1.27
10	83.9	26.6	8.47	2.68	0.855
15	57.3	18.1	5.74	1.83	0.588
20	39.5	12.5	3.96	1.27	0.410

Total Ammonia as N, mg/L

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.
See Appendix B.2.2 for a list of outliers excluded from plots and analyses.
Total ammonia is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of the MMER.

Figure 3.3-24

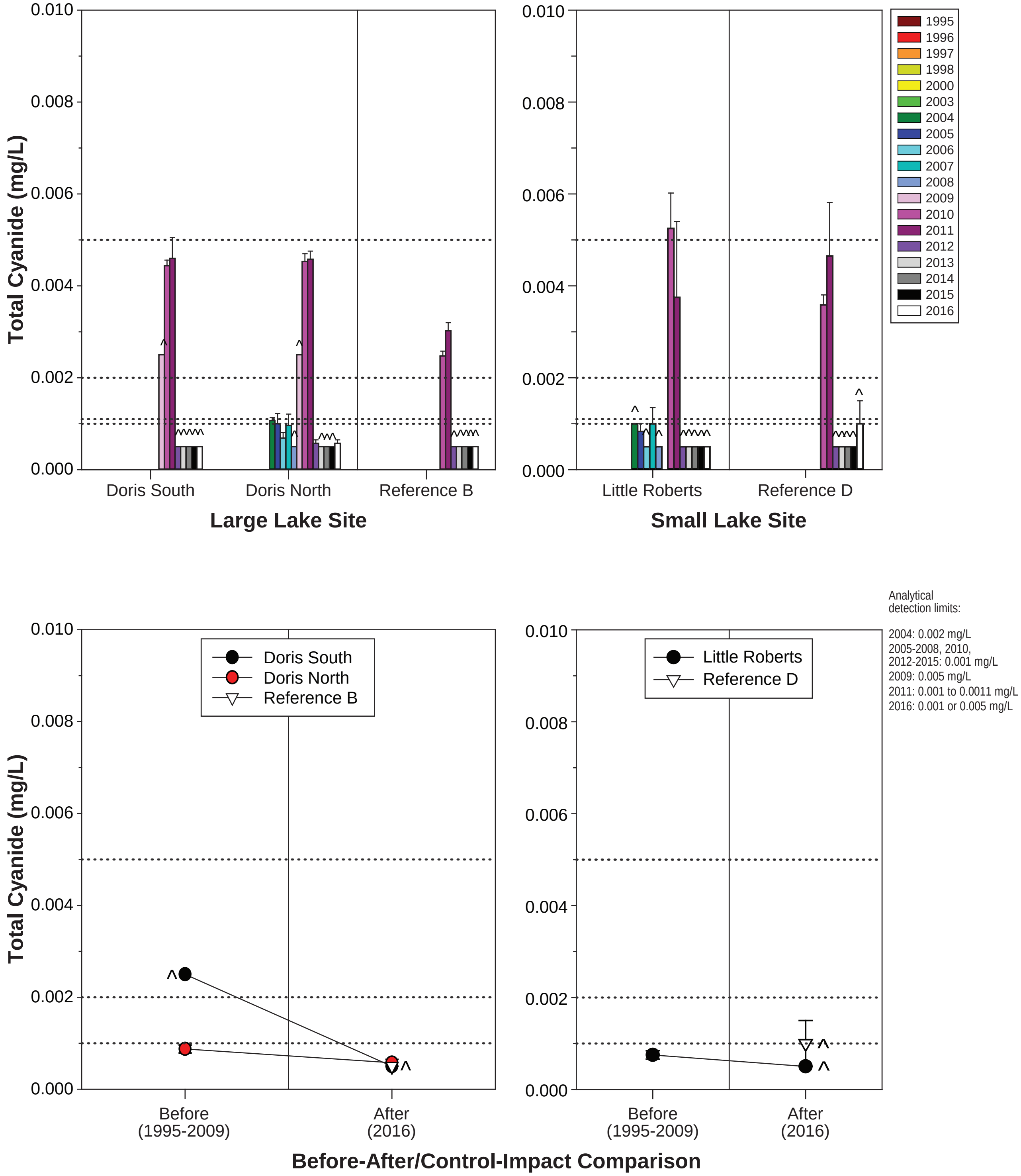
Nitrate Concentration in AEMP Lake Sites, Doris Project, 1995 to 2016



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).
See Appendix B.2.2 for a list of outliers excluded from plots and analyses.
Nitrate is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of the MMER.

Figure 3.3-25

Total Cyanide Concentration in AEMP Lake Sites, Doris Project, 1995 to 2016



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.

3.3.2.8 Radium-226

Radium-226 is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. Because of the high proportion of non-detectable radium-226 concentrations (> 85%) in the combined baseline and 2016 datasets for the exposure lake sites, statistical analysis results are not discussed. Radium-226 concentrations at the exposure sites were near or below the analytical detection limit, and were similar to baseline concentrations (Figure 3.3-26). Therefore, there was no evidence of an increase in radium-226 concentrations due to 2016 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 2016 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 2016 total aluminum concentration was not distinguishable from the baseline mean for any exposure lake site (p = 0.78 for Doris Lake South, p = 0.74 for Doris Lake North, and p = 0.45 for Little Roberts Lake). Therefore, there was no apparent effect of 2016 Project activities on total aluminum concentrations in the exposure lakes.

3.3.2.10 Total Arsenic

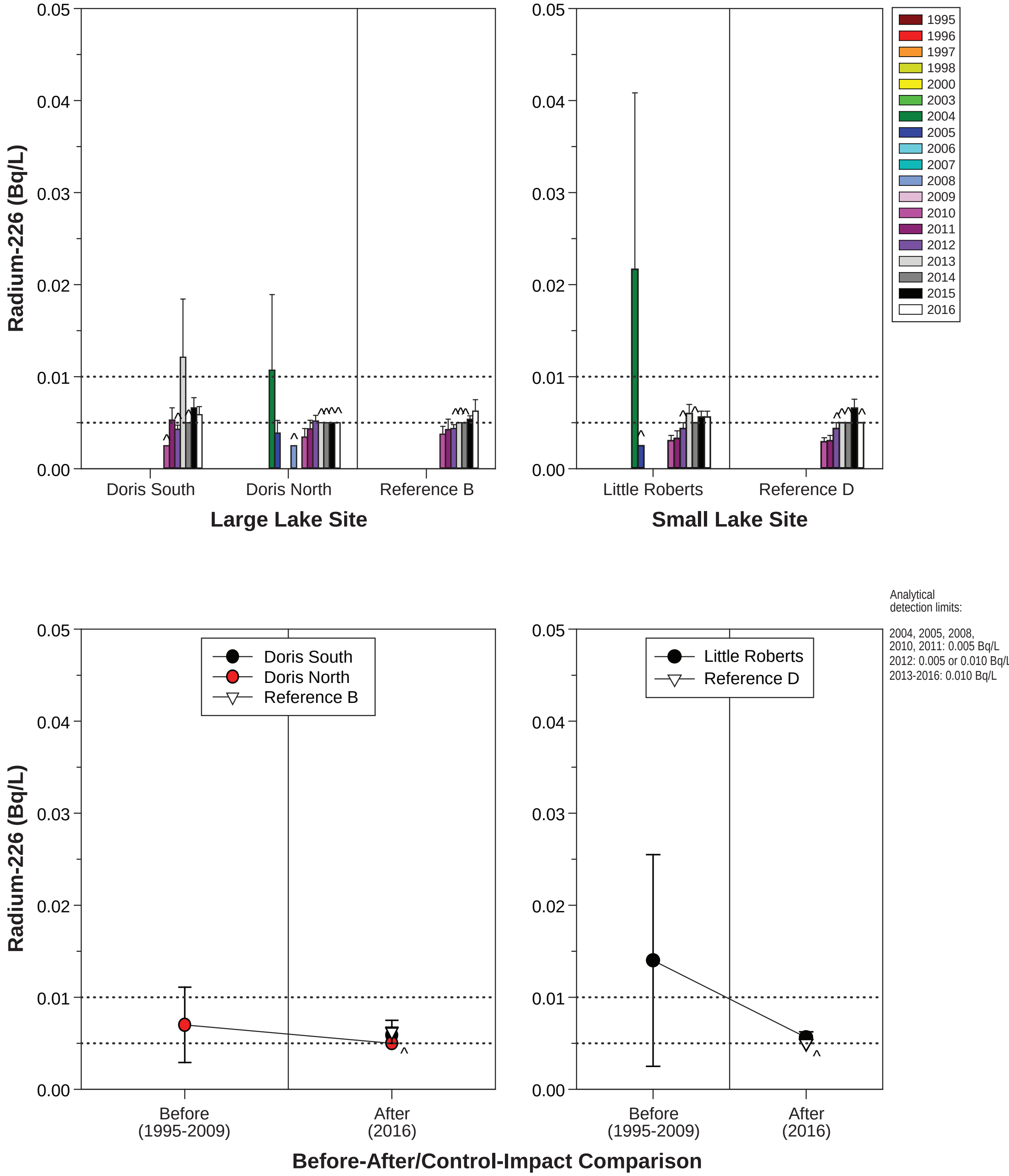
Total arsenic is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. Mean 2016 total arsenic concentrations in exposure lakes were well below the CCME guideline of 0.005 mg/L, and were similar to or less than baseline means (Figure 3.3-28). The before-after comparison indicated that there was no difference between the 2016 mean total arsenic concentration and the baseline mean at Doris Lake South (p = 0.47) and Little Roberts Lake (p = 0.45). The mean 2016 total arsenic concentration at Doris Lake North was significantly lower than the baseline mean (p = 0.0016); however, this was an artifact 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 = 0.13). Regardless, since the change was a decrease, there was no adverse effect of 2016 Project activities on total arsenic concentrations in the exposure lakes.

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 2016, all total cadmium concentrations in exposure lake sites were below the analytical detection limit of 0.000005 mg/L, and well below the CCME hardness-dependent cadmium guideline (Figure 3.3-29). Thus, there was no evidence of an effect of 2016 Project activities on total cadmium concentrations in exposure lakes.

Figure 3.3-26

Radium-226 Concentration in AEMP Lake Sites, Doris Project, 1995 to 2016

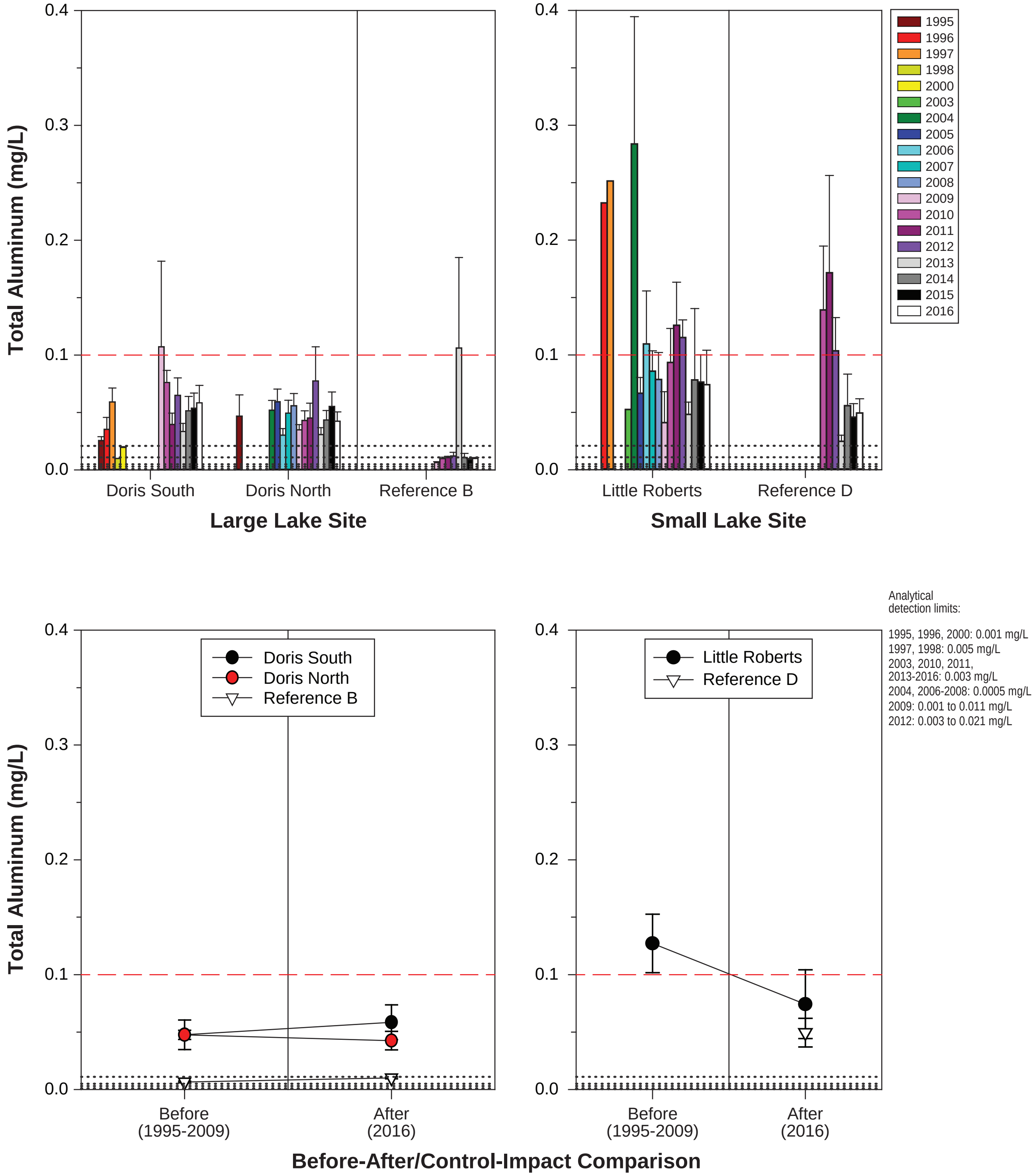


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Radium-226 is regulated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

Figure 3.3-27

Total Aluminum Concentration in AEMP Lake Sites, Doris Project, 1995 to 2016

ERM

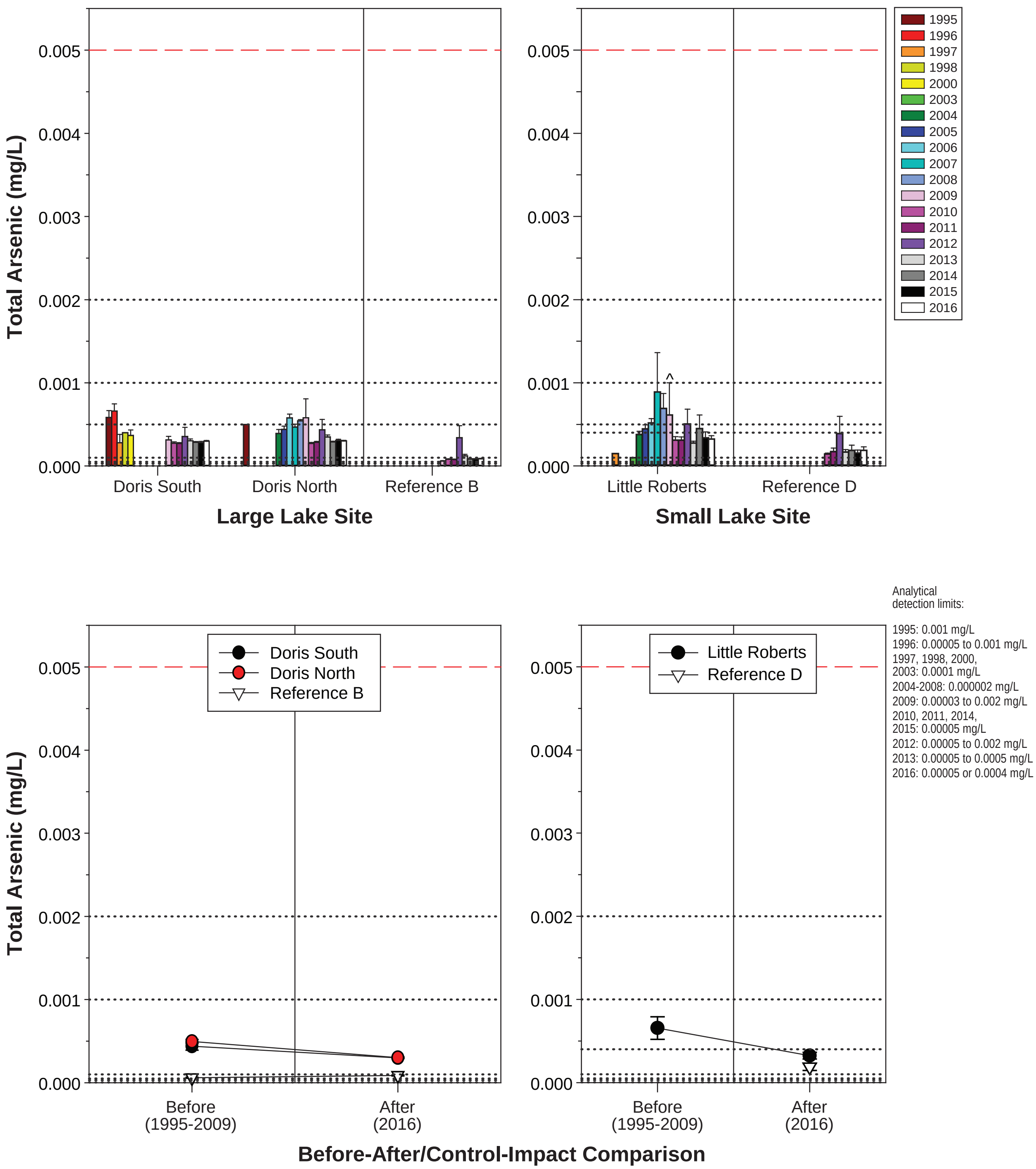


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Red dashed lines represent the pH-dependent CCME freshwater guideline for aluminum (0.005 mg/L at pH < 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 in AEMP Lake Sites, Doris Project, 1995 to 2016

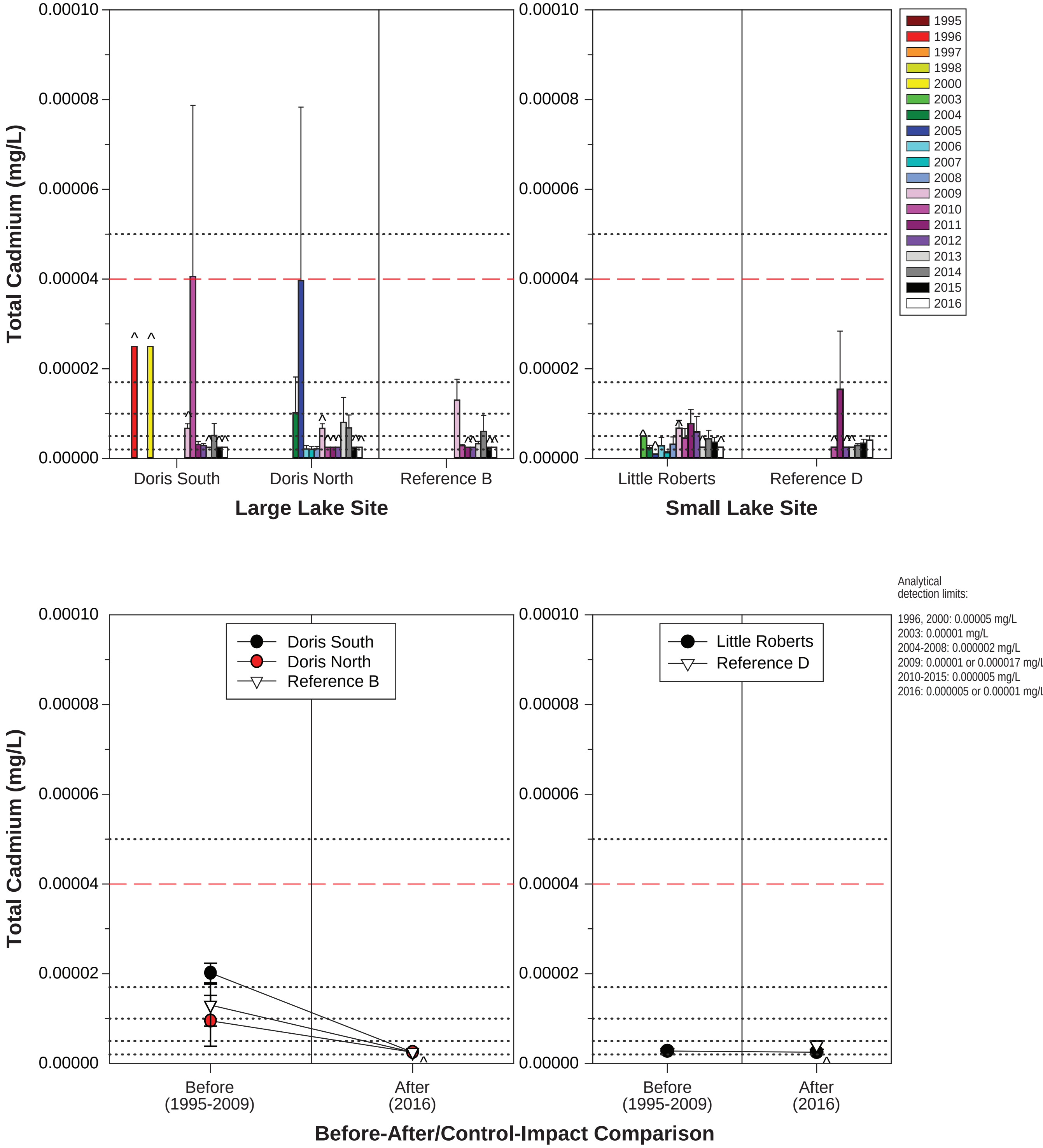
ERM



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 arsenic (0.005 mg/L).
See Appendix B.2.2 for a list of outliers excluded from plots and analyses.
Total arsenic is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.

Figure 3.3-29

Total Cadmium Concentration in AEMP Lake Sites, Doris Project, 1995 to 2016



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 2016 (hardness: 14.3 mg/L; CCME guideline: 0.00004 mg/L).
See Appendix B.2.2 for a list of outliers excluded from plots and analyses.
Total cadmium is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of the MMER.

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 2016 total copper concentrations were within the range of baseline means (Figure 3.3-30). The before-after analysis found that 2016 mean total copper concentrations were not distinguishable from baseline means at the exposure lake sites (p = 0.59 for Doris Lake South, p = 0.70 for Doris Lake North, and p = 0.79 for Little Roberts Lake). The mean 2016 total copper concentrations at Doris Lake South and North were below the minimum CCME guideline of 0.002 mg/L, while the mean 2016 total copper concentration at Little Roberts Lake was slightly above the guideline (Figure 3.3-30). However, the baseline mean total copper concentration at Little Roberts Lake was also above the CCME guideline, suggesting that total copper concentrations are naturally elevated in this lake. Therefore, there was no apparent effect of 2016 Project activities on total copper concentrations in any exposure lake.

3.3.2.13 *Total Iron*

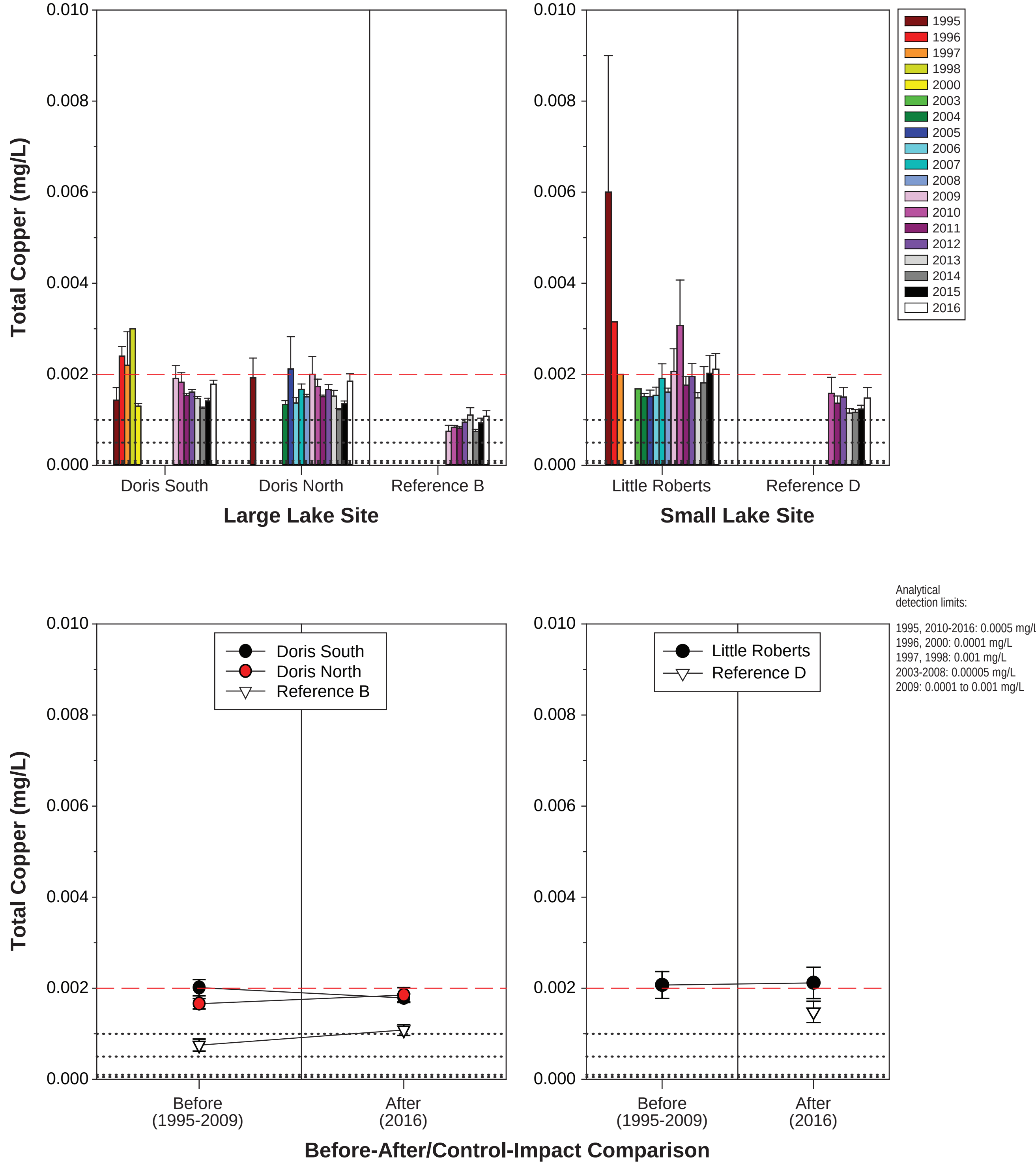
Total iron is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. Mean total iron concentrations at the exposure lake sites in 2016 were within the range of baseline concentrations and below the CCME guideline of 0.3 mg/L (Figure 3.3-31). For all exposure sites, the before-after analysis showed that mean 2016 total iron concentrations were not distinguishable from mean baseline concentrations (p = 0.69 for Doris Lake South, p = 0.47 for Doris Lake North, and p = 0.11 for Little Roberts Lake), suggesting that 2016 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. For all exposure lake sites, mean 2016 total lead concentrations were within the range or lower than baseline means and below the hardness-dependent CCME guideline (Figure 3.3-32), suggesting that there was no adverse effect of Project activities on total lead concentrations in exposure lakes. The before-after analysis confirmed that there was no significant difference between the 2016 and baseline mean concentrations for any exposure lake site (p = 0.31 for Doris Lake South, p = 0.44 for Doris Lake North, and p = 0.52 for Little Roberts Lake).

Figure 3.3-30

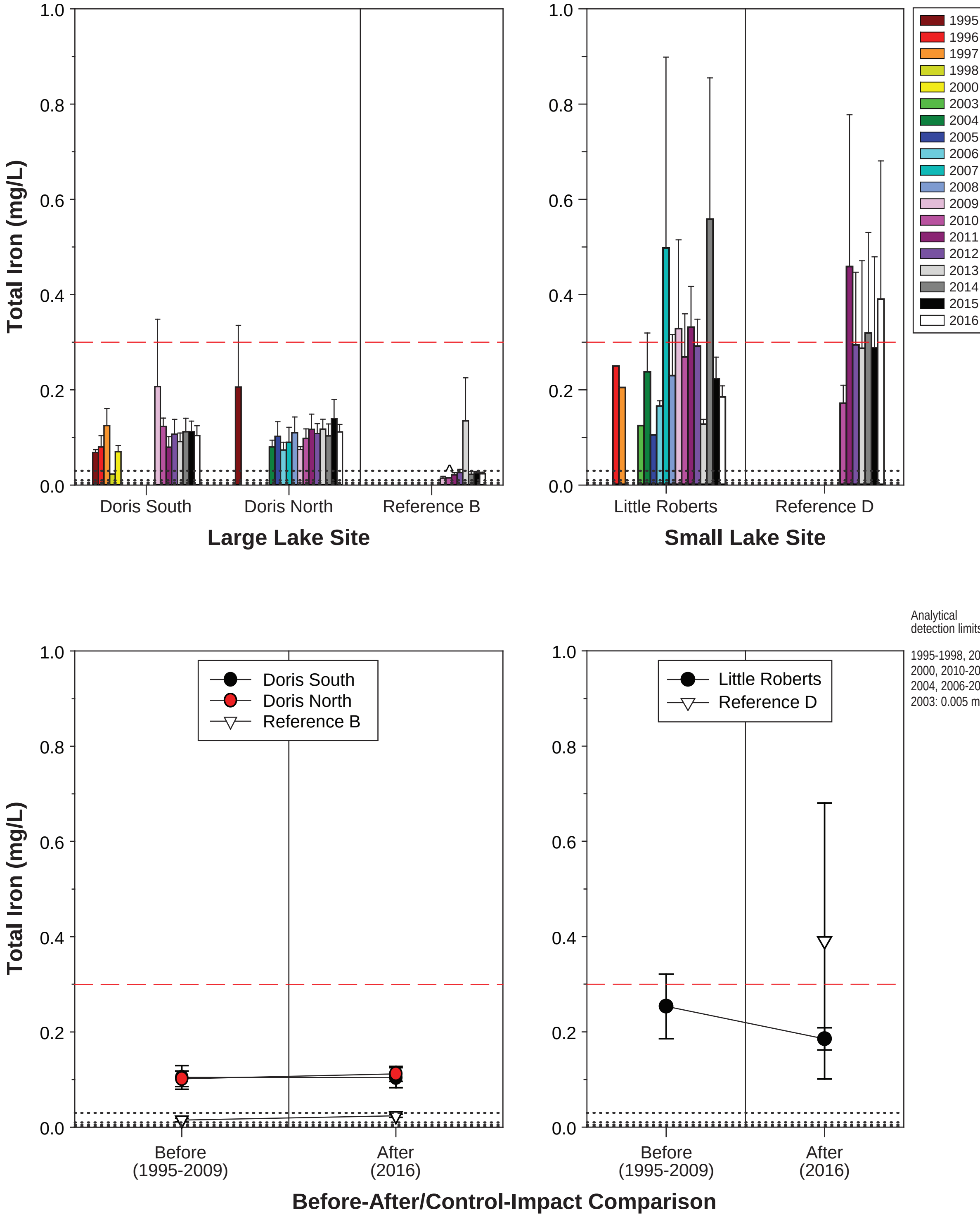
Total Copper Concentration in AEMP Lake Sites, Doris Project, 1995 to 2016



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 in AEMP Lake Sites, Doris Project, 1995 to 2016



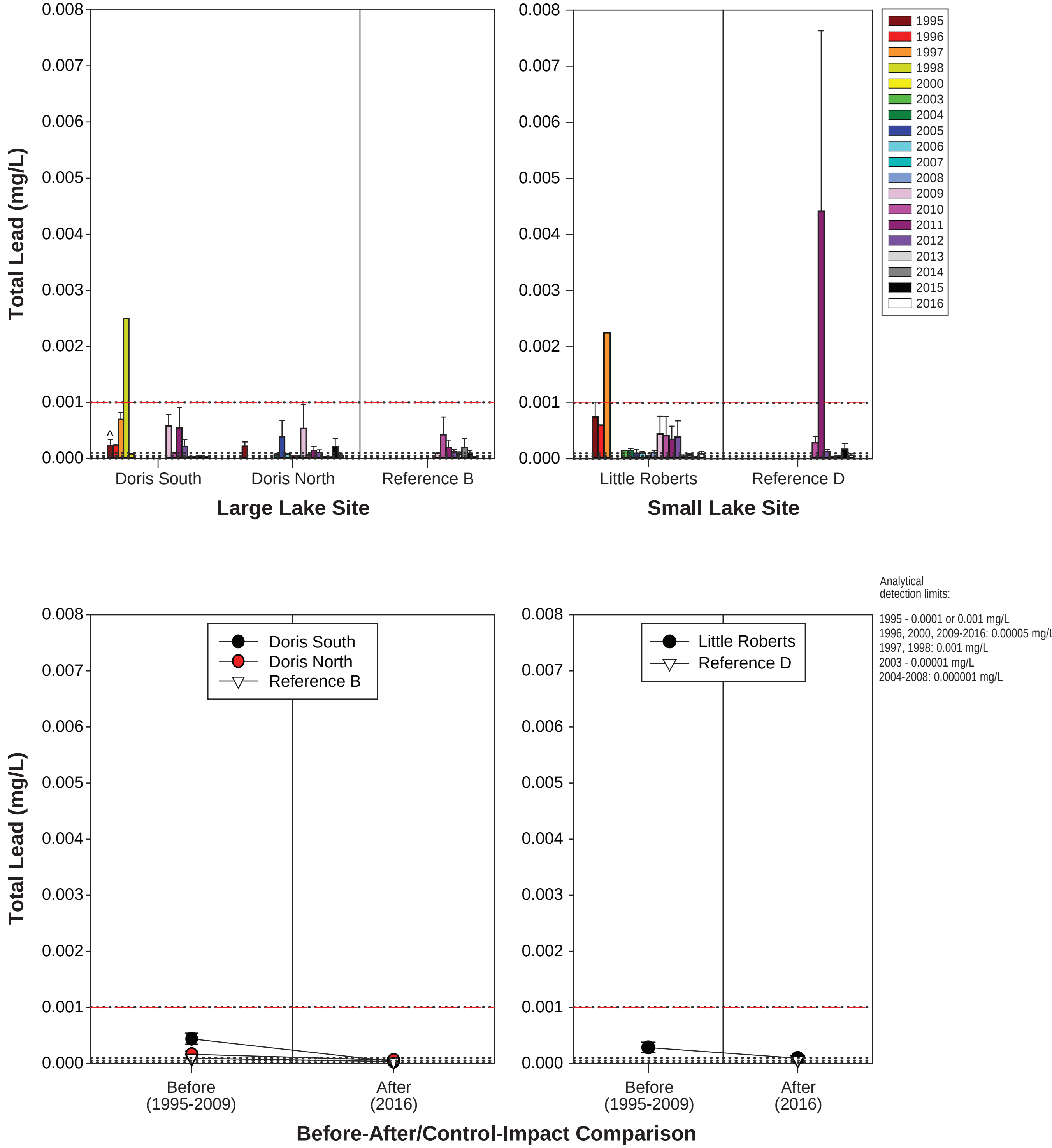
Analytical detection limits:

1995-1998, 2009: 0.01 mg/L
2000, 2010-2016: 0.03 mg/L
2004, 2006-2008: 0.002 mg/L
2003: 0.005 mg/L

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.

Figure 3.3-32

Total Lead Concentration in AEMP Lake Sites, Doris Project, 1995 to 2016



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).
See Appendix B.2.2 for a list of outliers excluded from plots and analyses.
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. Total mercury concentrations in exposure lake sites in 2016 were similar to concentrations in reference lake sites 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 lake sites in 2016 were within or below the range of detectable baseline concentrations. The before-after analysis indicated that there was no difference between the baseline and 2016 mean for either Doris Lake North (p = 0.30) or Little Roberts Lake (p = 0.30). At Doris Lake South, all baseline data were below detection limits that were relatively high compared to the detection limits achieved by the ultra-low mercury analysis used for 2016 samples, making comparisons to baseline data difficult. In the combined baseline and 2016 total mercury dataset for Doris Lake South, 87% of concentrations were below analytical detection; therefore, the before-after results for Doris Lake South are considered unreliable and are not discussed. However, total mercury concentrations in Doris Lake South in 2016 were similar to concentrations measured in Reference Lake B, and lower than detectable baseline concentrations measured in the northern end of Doris Lake. Thus, there was no evidence of Project-related effects on total mercury at Doris Lake South or any other exposure lake site in 2016.

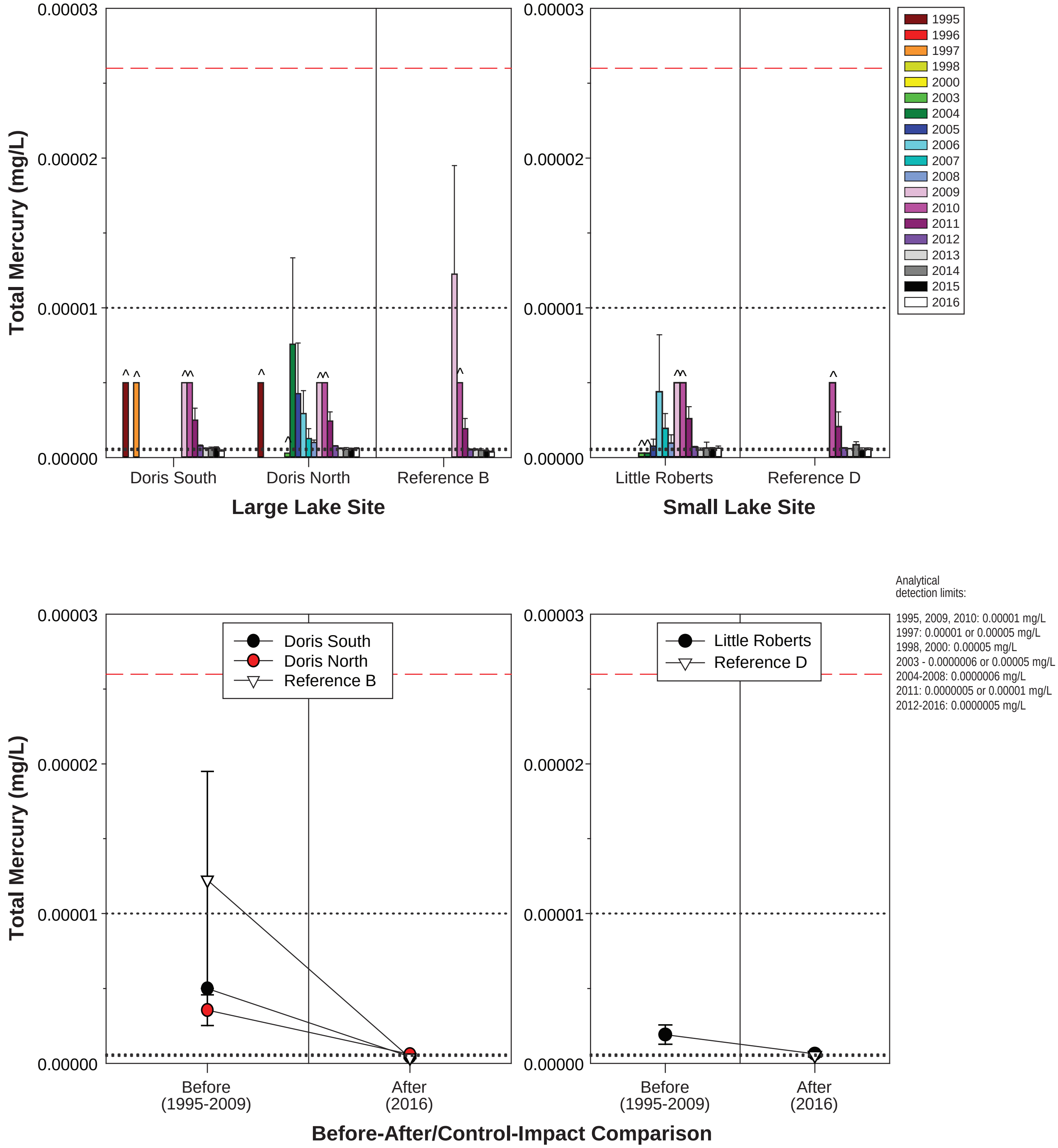
3.3.2.16 Total Molybdenum

Total molybdenum is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. Mean 2016 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 all three exposure lake sites, mean 2016 total molybdenum concentrations were slightly higher than baseline means (Figure 3.3-34). The before-after analysis showed that this apparent increase was statistically significant for Doris Lake North (p = 0.0015) and Little Roberts Lake (p = 0.026) but not for Doris Lake South (p = 0.98). For Doris Lake North, the BACI analysis further revealed that a parallel increase in total molybdenum occurred in Reference Lake B (p = 0.27); therefore, there was no indication that total molybdenum concentrations increased as a result of Project activities. A BACI analysis could not be conducted for Little Roberts Lake because there is no baseline data available for Reference Lake D. The observed increase in total molybdenum in Little Roberts Lake was slight (mean baseline concentration of 0.00019 mg/L compared to mean 2016 concentration of 0.00022 mg/L) and is not considered environmentally or biologically important since 2016 concentrations remained well below the CCME guideline of 0.073 mg/L. Given that there was no discharge from the TIA in 2016 and there was an apparent increase in the mean molybdenum concentration in Reference Lake B in 2016 (Figure 3.3-34), the observed increase in total molybdenum in Little Roberts Lake was likely due to natural inter-annual variability rather than Project effects.

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 2016 were well below the hardness-dependent CCME guideline for total nickel and within the range of baseline concentrations (Figure 3.3-35). This suggests that 2016 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 2016 compared to baseline years (p = 0.97 for Doris Lake South, p = 0.89 for Doris Lake North, and p = 0.82 for Little Roberts Lake).

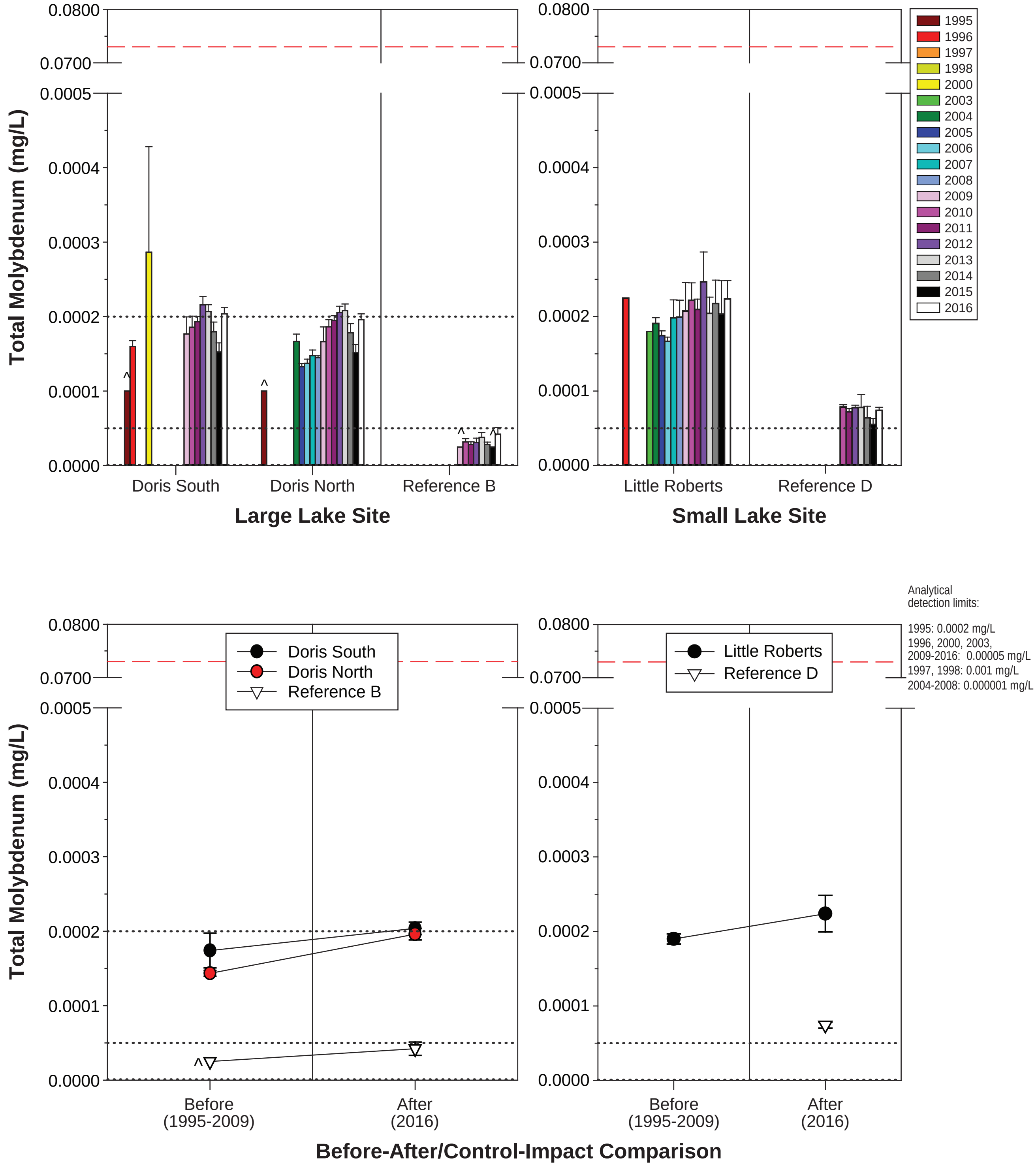
Total Mercury Concentration in AEMP Lake Sites, Doris Project, 1995 to 2016



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).
See Appendix B.2.2 for a list of outliers excluded from plots and analyses.
Total mercury is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of the MMER.

Figure 3.3-34

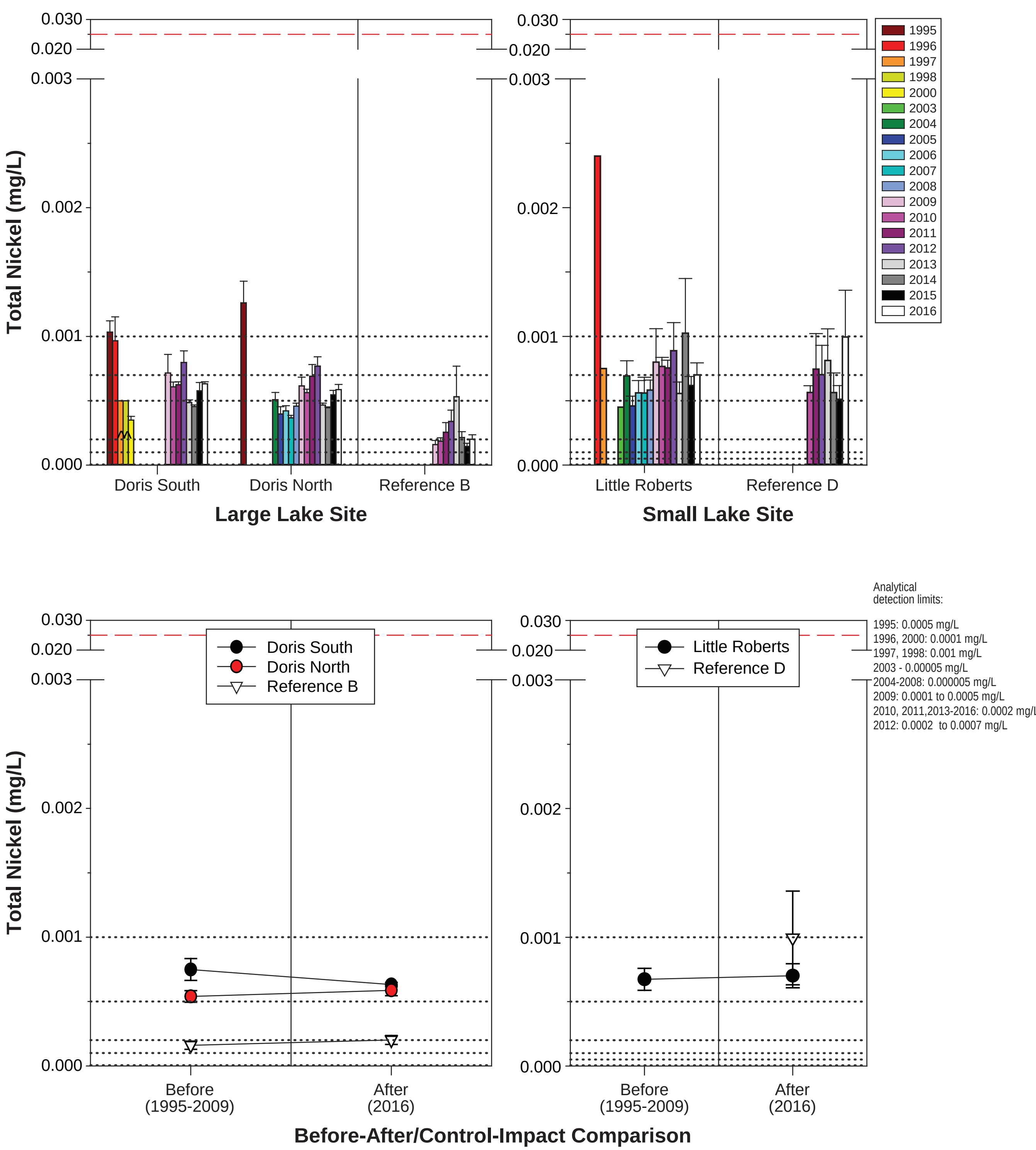
Total Molybdenum Concentration in AEMP Lake Sites, Doris Project, 1995 to 2016



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).
See Appendix B.2.2 for a list of outliers excluded from plots and analyses.
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 in AEMP Lake Sites, Doris Project, 1995 to 2016



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).
See Appendix B.2.2 for a list of outliers excluded from plots and analyses.
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 2016, nearly all total zinc concentrations measured in exposure lakes were below the analytical detection limit of 0.003 mg/L; the only exception was the concentration of 0.0033 mg/L (just over the detection limit) measured at Doris Lake North in April. All total zinc concentrations measured in lake sites in 2016 were well below the CCME guideline of 0.03 mg/L (Appendix A; Figure 3.3-36). Mean 2016 total zinc concentrations in the exposure lakes were always lower than baseline means. Therefore, there was no evidence of an increase in total zinc in exposure lakes as a result of 2016 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 2016. Baseline data from 2009 are available for all sites, and additional baseline data from 1996 and 2004 to 2008 are available for site RBE. All 2016 samples were collected at the surface (0 to 1 m depth), therefore any baseline data collected from near the water-sediment interface were excluded from the baseline dataset used for the effects analyses.

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 2016 pH levels in marine exposure and reference sites were 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 2016 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 showed that there was no change in marine pH in 2016 compared to baseline years at the marine exposure sites (p = 0.60 for RBW and p = 0.92 for RBE). Therefore, there was no effect of 2016 Project activities on marine pH at the exposure sites.

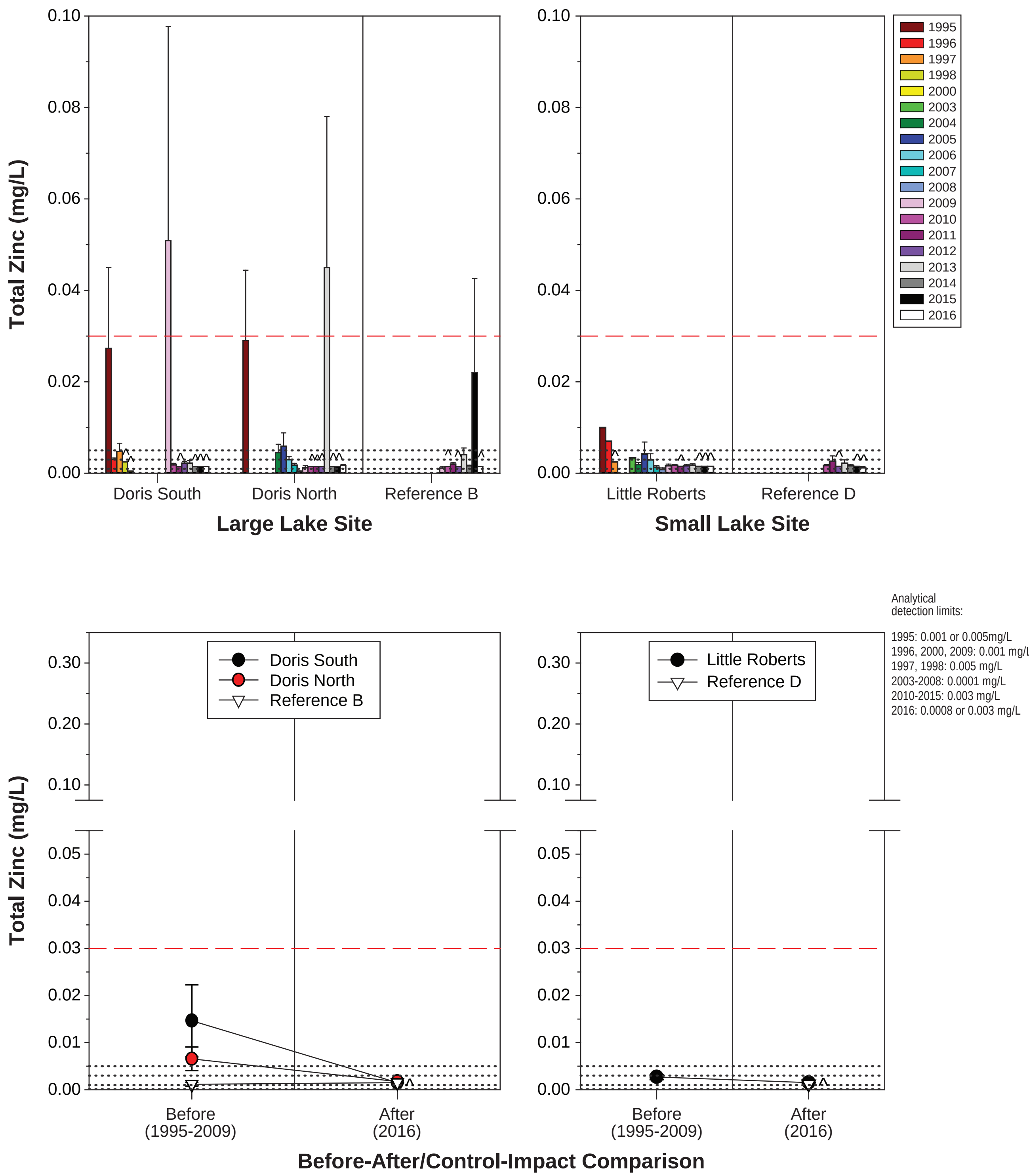
3.3.3.2 Total Alkalinity

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 are available. At this site, the mean 2016 total alkalinity was similar to the baseline mean (Figure 3.3-38), and the before-after comparison indicated that there was no statistically significant change in total alkalinity in 2016 at RBE compared to baseline levels (p = 0.87). Although no statistical analysis was possible for site RBW, mean 2016 total alkalinity was within the range of total alkalinity levels measured at this site between 2010 and 2015 as well as reference site total alkalinity levels (Figure 3.3-38). Thus, there was no evidence that 2016 Project activities affected total alkalinity at the exposure sites.

Figure 3.3-36

Total Zinc Concentration in AEMP Lake Sites, Doris Project, 1995 to 2016

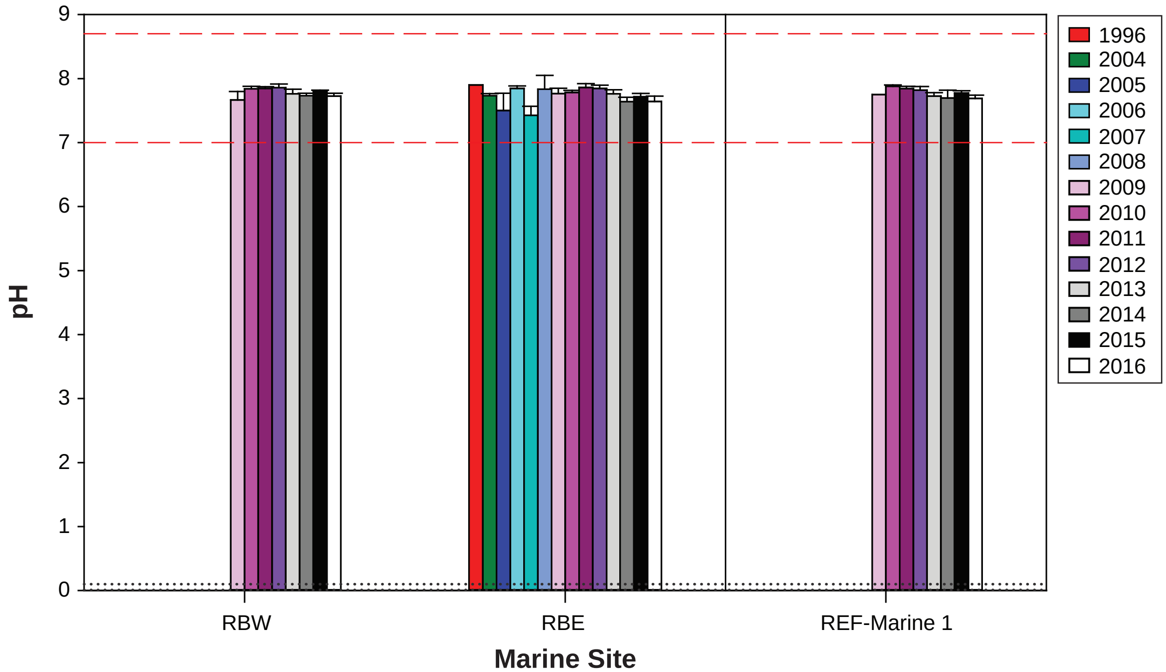
ERM

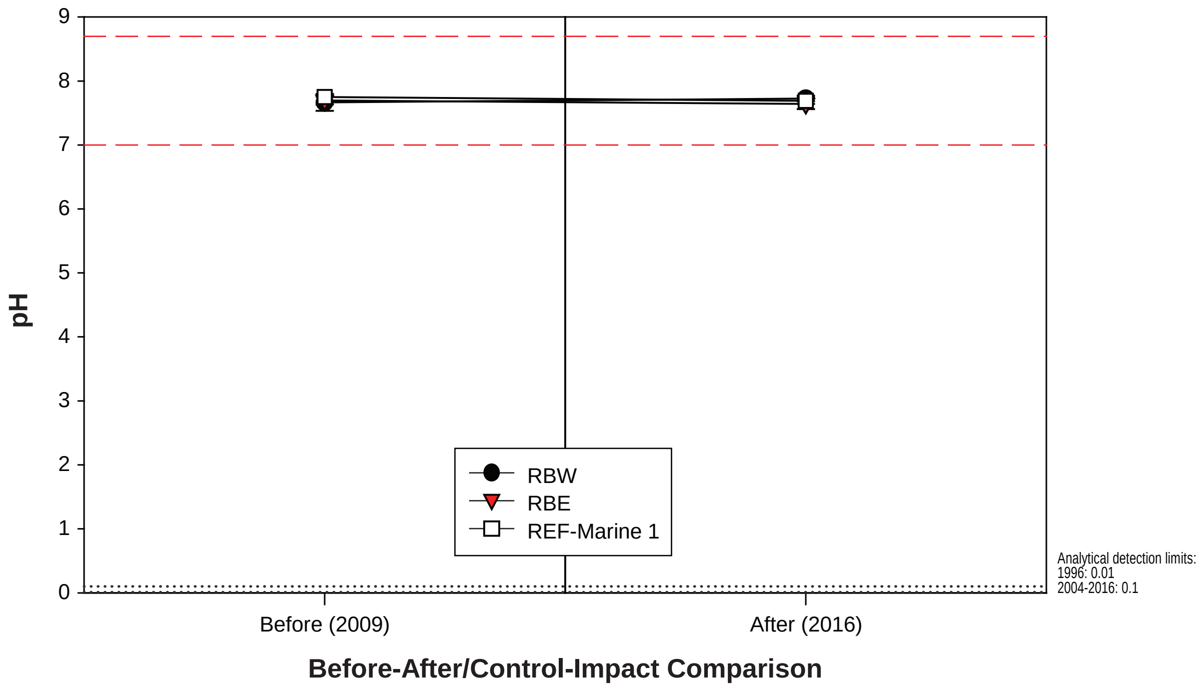


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed lines represent the CCME freshwater guideline for zinc (0.03 mg/L).
See Appendix B.2.2 for a list of outliers excluded from plots and analyses.
Total zinc is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.

Figure 3.3-37

pH in AEMP Marine Sites, Doris Project, 1996 to 2016

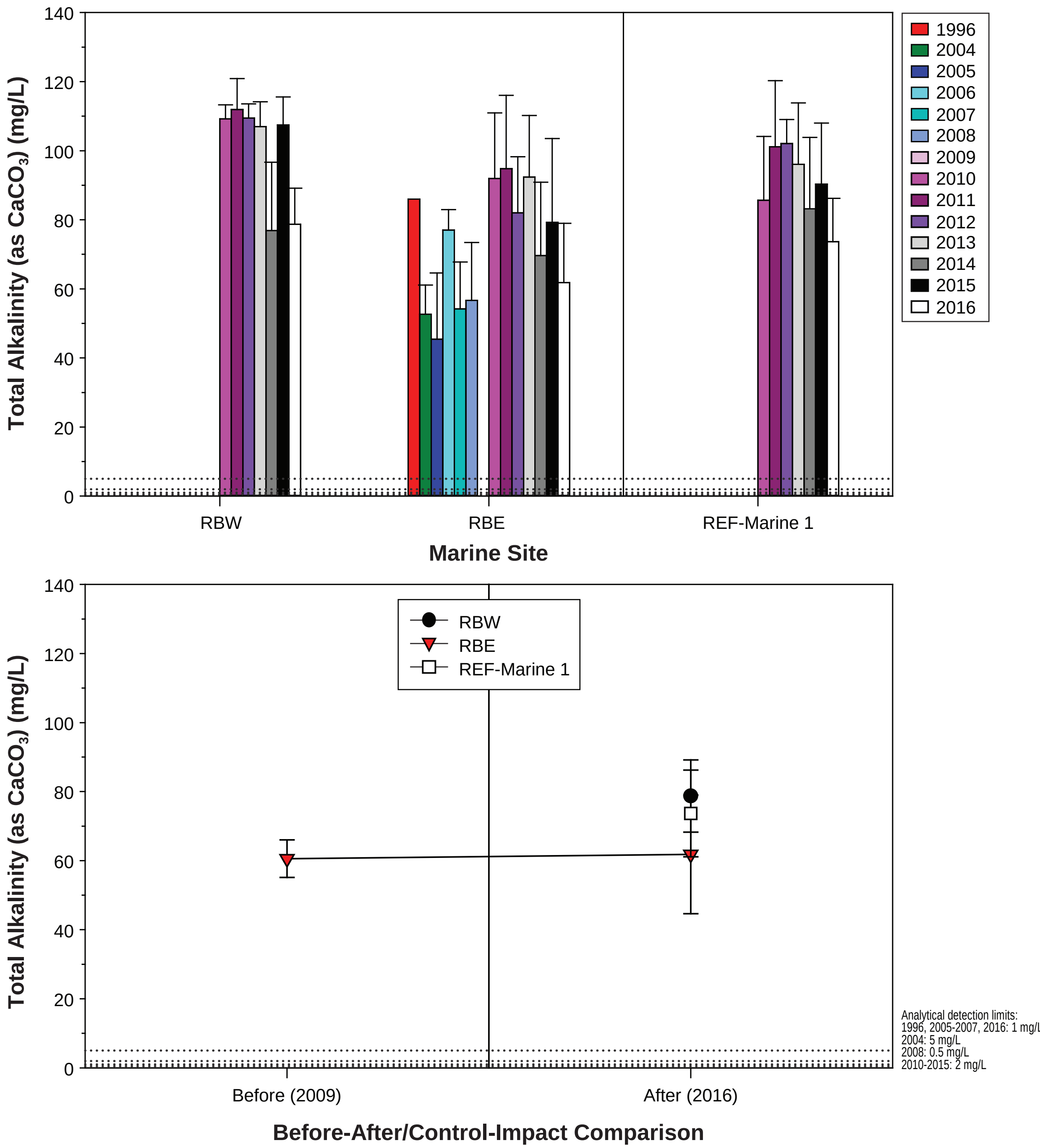




Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits.
Red dashed lines represent the CCME marine and estuarine guideline pH range (7.0–8.7).
pH is a required parameter for water quality monitoring as per Schedule 5, s. 7(1)(c) of the MMER.

Figure 3.3-38

Total Alkalinity in AEMP Marine Sites, Doris Project, 1996 to 2016



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.

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 2016 in Roberts Bay sites were within or below 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 2016 hardness levels at RBW and RBE were not distinguishable from baseline levels (p = 0.89 for RBW and p = 0.90 for RBE), suggesting that there was no effect of 2016 Project activities on the hardness of marine waters at exposure sites.

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; Appendix A). Mean 2016 TSS concentrations at RBW and RBE were within or lower than the range of baseline concentrations (Figure 3.3-40). The before-after comparison showed that the mean 2016 TSS concentration at RBE was not statistically distinguishable from the baseline mean (p = 0.34), but the mean 2016 TSS concentration at RBW was significantly lower than the baseline mean (p = 0.0081). A decrease in TSS is not of environmental concern as it is not considered to be an adverse effect. Therefore, there were no apparent adverse effects of 2016 Project activities on TSS concentrations at the marine exposure sites.

The marine CCME guideline for TSS is dependent upon background (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 2016b). Because there was no increase in TSS concentrations from background levels at either RBW or RBE, 2016 TSS concentrations in marine exposure sites continued to remain below the CCME guideline.

3.3.3.5 *Total Ammonia*

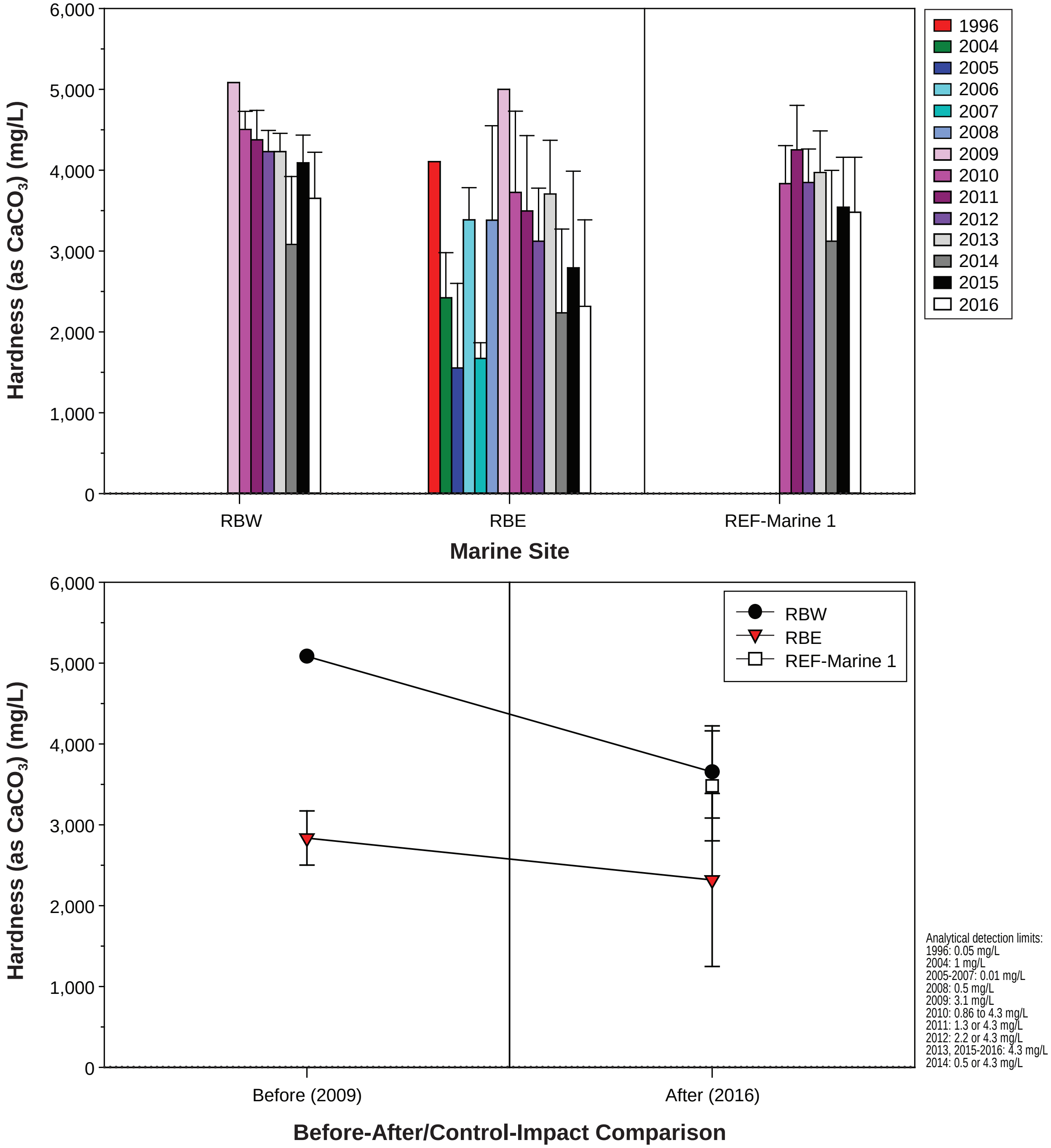
Total ammonia is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. Total ammonia concentrations in all 2016 marine water samples were below the analytical detection limit of 0.005 mg ammonia-N/L (Figure 3.3-41). Thus there was no evidence of an effect of 2016 Project 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 2016 nitrate concentrations measured in marine exposure sites were within the range of baseline concentrations, and well below the marine CCME guideline of 45 mg nitrate-N/L (Figure 3.3-42). Because of the high proportion of censored nitrate concentrations in the combined baseline and 2016 dataset for RBE (82%), statistical analysis results are not presented for this site. However, the mean 2016 concentration was similar to the mean baseline concentration at RBE (Figure 3.3-42), and there was no evidence of an adverse effect of Project activities on nitrate concentrations at this site. For site RBW, the before-after analysis showed that the mean nitrate concentration differed significantly between baseline years and 2016 (p < 0.0001); however, the observed change was a decrease, which is not of environmental concern. Thus, there was no apparent adverse effect of 2016 Project activities on nitrate concentrations in the marine exposure sites.

Figure 3.3-39

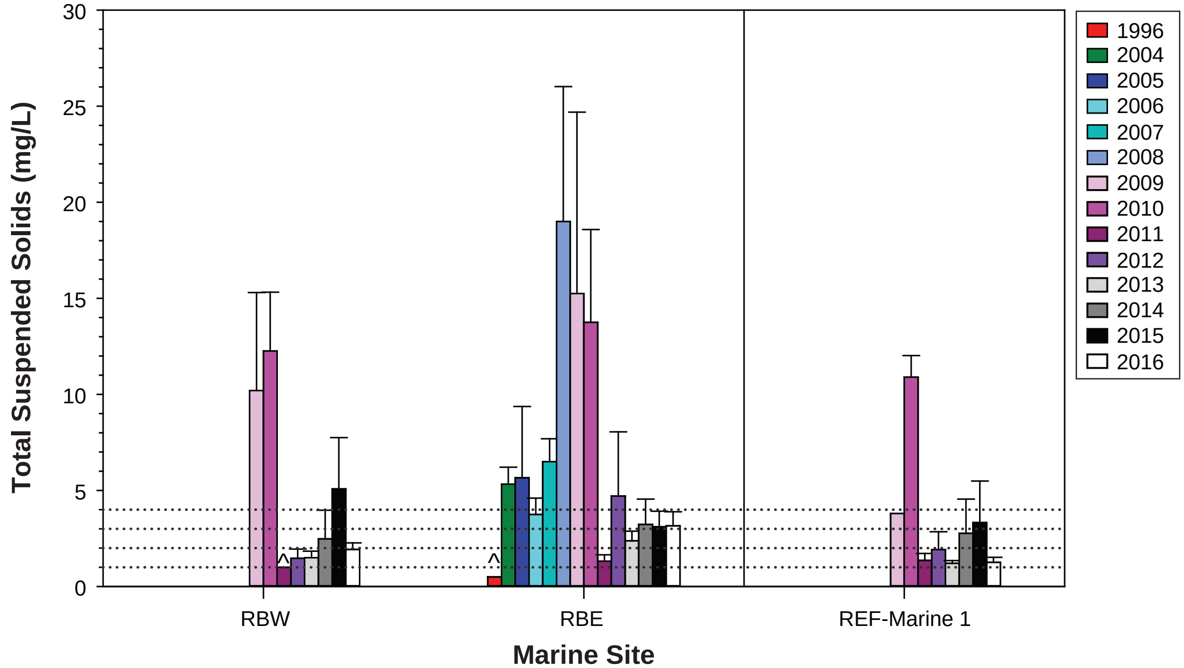
Hardness in AEMP Marine Sites, Doris Project, 1996 to 2016

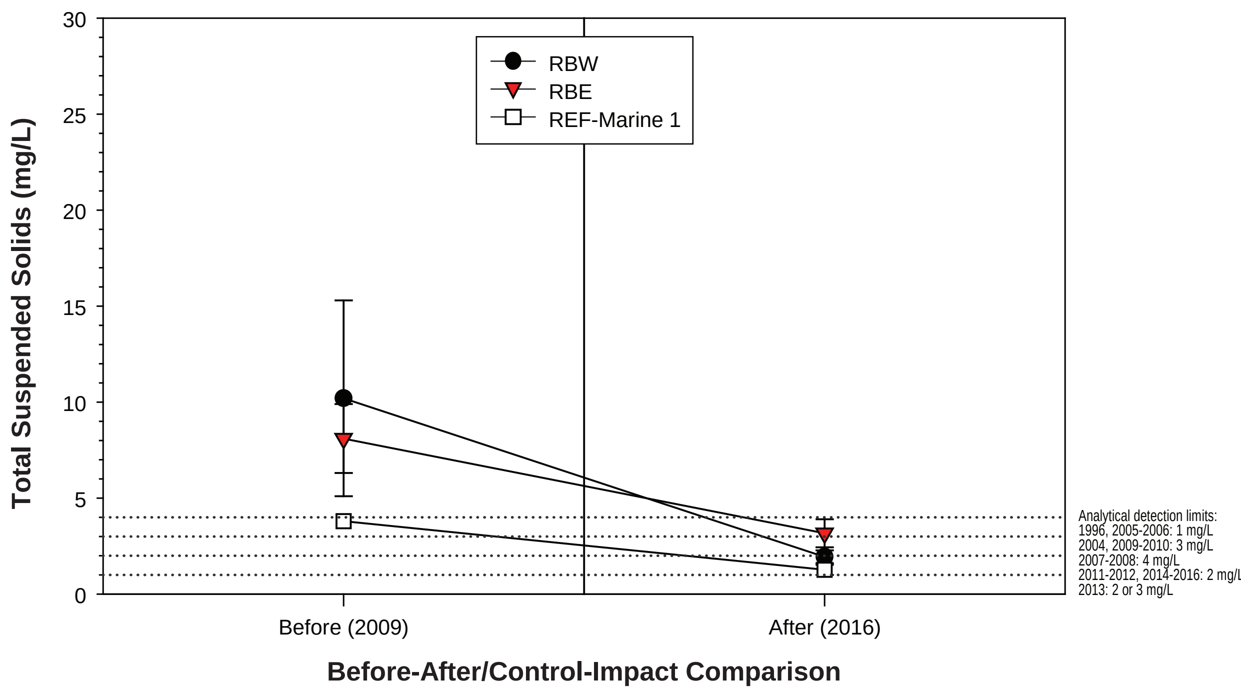


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits.
Hardness is a required parameter for effluent characterization and water quality monitoring as per Schedule 5, s. 4(1) and s. 7(1)(c) of the MMER.

Figure 3.3-40

Total Suspended Solids Concentration in AEMP Marine Sites, Doris Project, 1996 to 2016

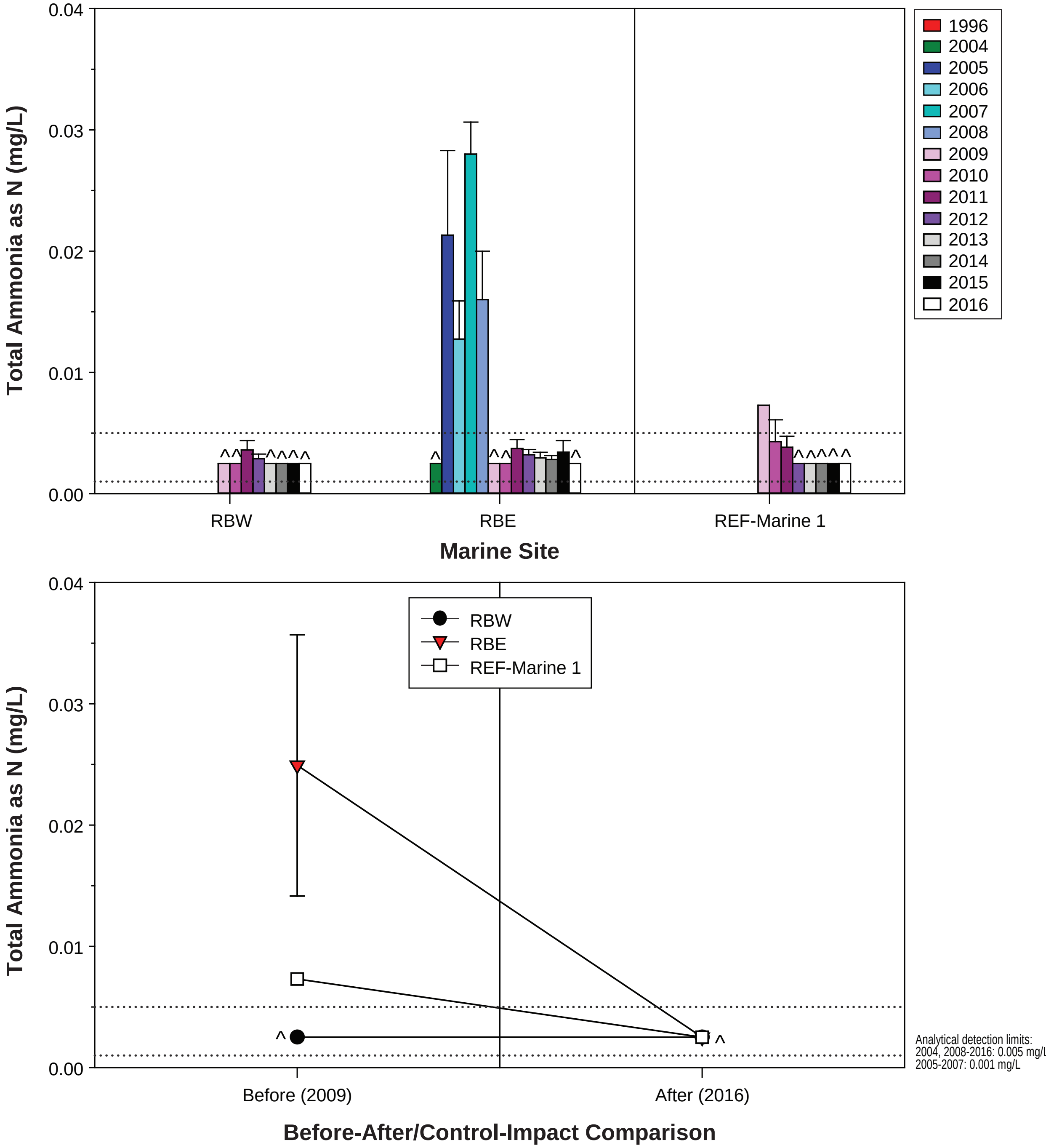




Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
The CCME marine guideline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

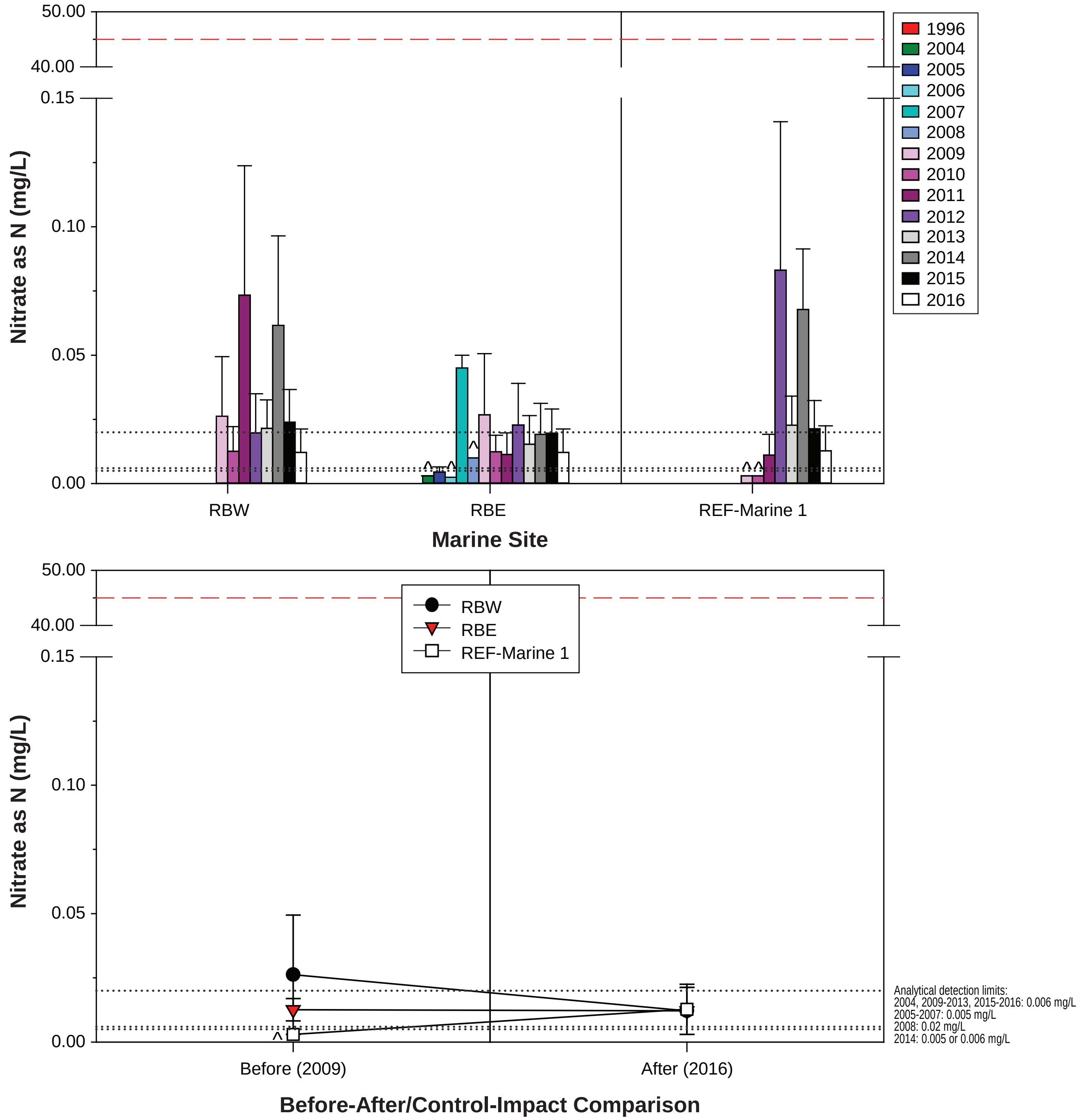
Total Ammonia Concentration in AEMP Marine Sites, Doris Project, 1996 to 2016



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 ammonia is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of the MMER.
See Appendix B.2.2 for a list of outliers excluded from plots and analyses.

Figure 3.3-42

Nitrate Concentration in AEMP Marine Sites, Doris Project, 1996 to 2016



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 marine guideline for nitrate as N (45 mg/L; long-term concentration).
Nitrate is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of the MMER.
See Appendix B.2.2 for a list of outliers excluded from plots and analyses.

3.3.3.7 Total Cyanide

Total cyanide is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. Nearly all 2016 total cyanide concentrations in marine samples were below the analytical detection limit (which ranged from 0.001 to 0.005 mg/L; Figure 3.3-43; Appendix A). The only exception was a detectable concentration of 0.001 mg/L (equal to the lowest detection limit) in one of two replicates collected from RBE in July 2016. Free cyanide concentrations were also measured at marine sites in 2016, and all concentrations were below analytical detection limits (Appendix A). Therefore, there was no evidence that 2016 Project activities adversely affected cyanide concentrations at marine exposure sites.

3.3.3.8 Radium-226

Radium-226 is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. All radium-226 concentrations measured at the marine exposure sites in 2016 were below the analytical detection limit of 0.01 Bq/L (Figure 3.3-44). Therefore, there was no evidence of an effect of 2016 Project activities on radium-226 concentrations at the marine exposure sites.

3.3.3.9 Total Aluminum

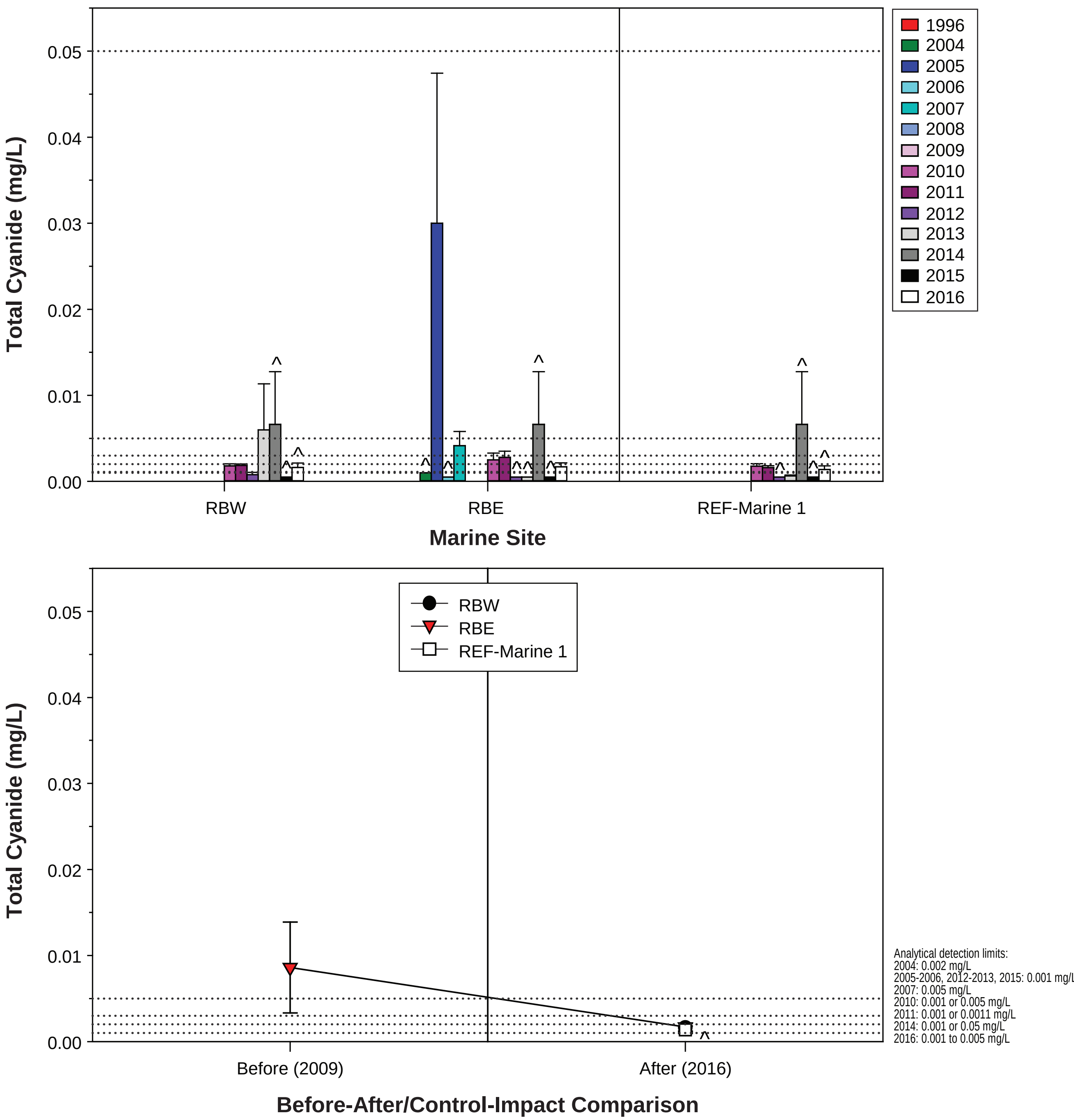
Total aluminum is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. At site RBE, the mean 2016 total aluminum concentration was within the range of baseline concentrations (Figure 3.3-45). At site RBW, the 2016 mean was higher than the 2009 mean (Figure 3.3-45). However, the before-after comparison for both marine exposure sites indicated that the 2016 means were not statistically different from the baseline means (p = 0.56 for RBW and p = 0.78 for RBE). This suggests that there was no effect of 2016 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 4 of the MMER. All total arsenic concentrations measured at marine exposure and reference sites in 2016 were well below the marine CCME guideline of 0.0125 mg/L (Figure 3.3-46). The mean 2016 total arsenic concentrations at RBW and RBE were similar to baseline concentrations (Figure 3.3-46), and the before-after comparisons confirmed that the 2016 mean total arsenic concentrations at RBW and RBE were not distinguishable from the baseline means (p = 0.33 for RBW and p = 0.92 for RBE). Therefore, there was no apparent effect of 2016 Project activities on total arsenic concentrations at the marine exposure sites.

Figure 3.3-43

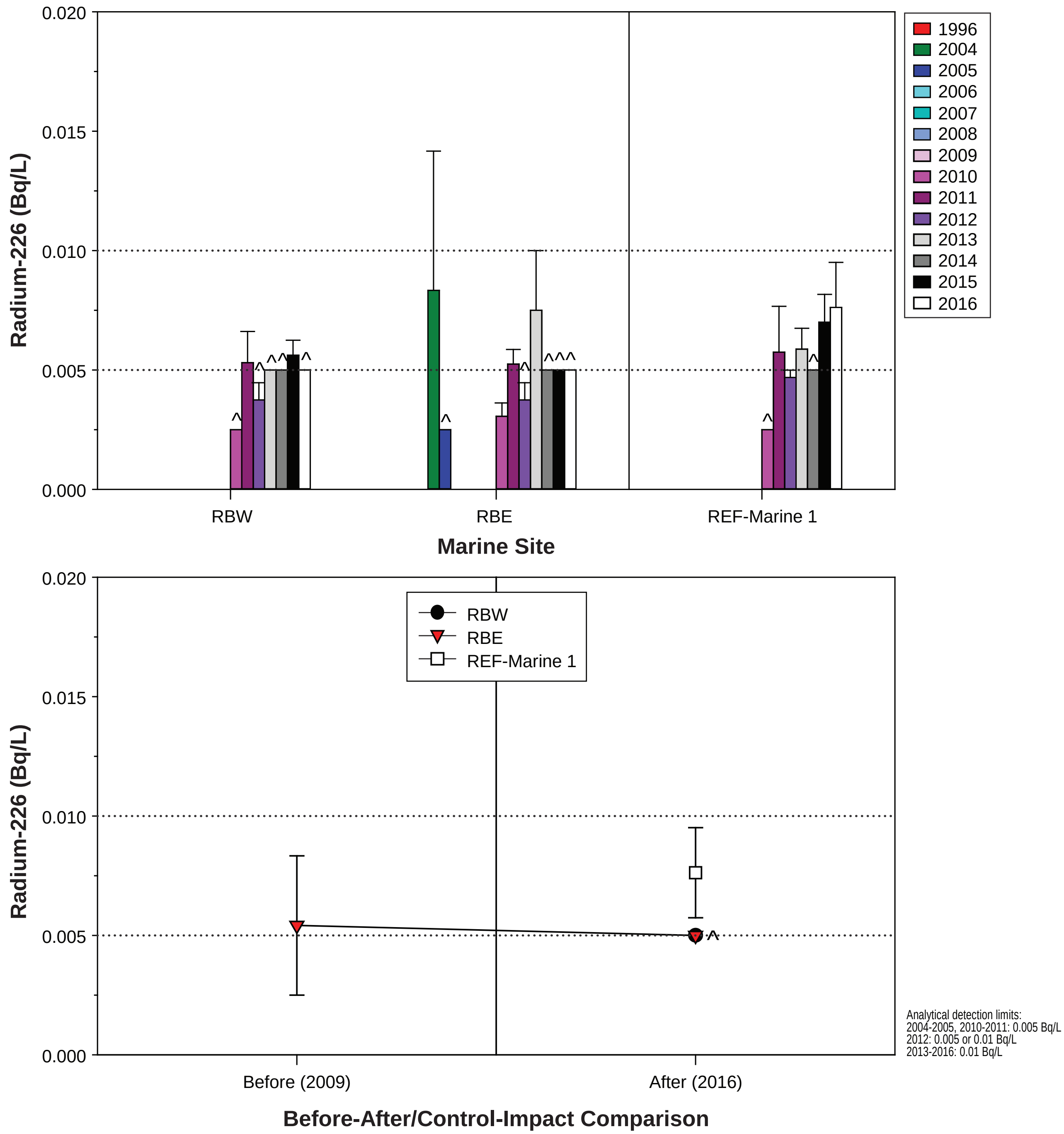
Total Cyanide Concentration in AEMP Marine Sites, Doris Project, 1996 to 2016



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.
See Appendix B.2.2 for a list of outliers excluded from plots and analyses.

Figure 3.3-44

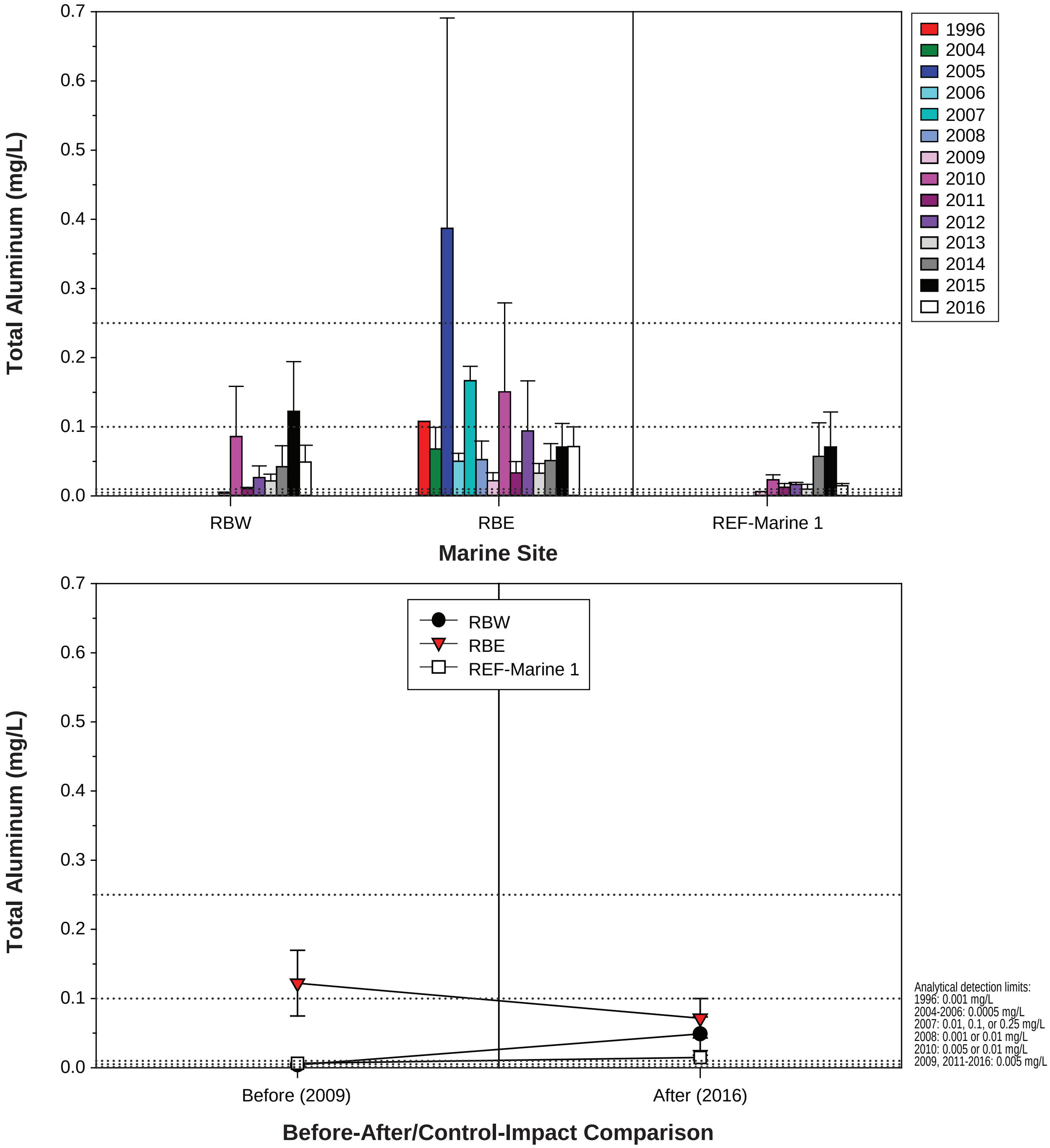
Radium-226 Concentration in AEMP Marine Sites, Doris Project, 1996 to 2016



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.
Radium-226 is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.

Figure 3.3-45

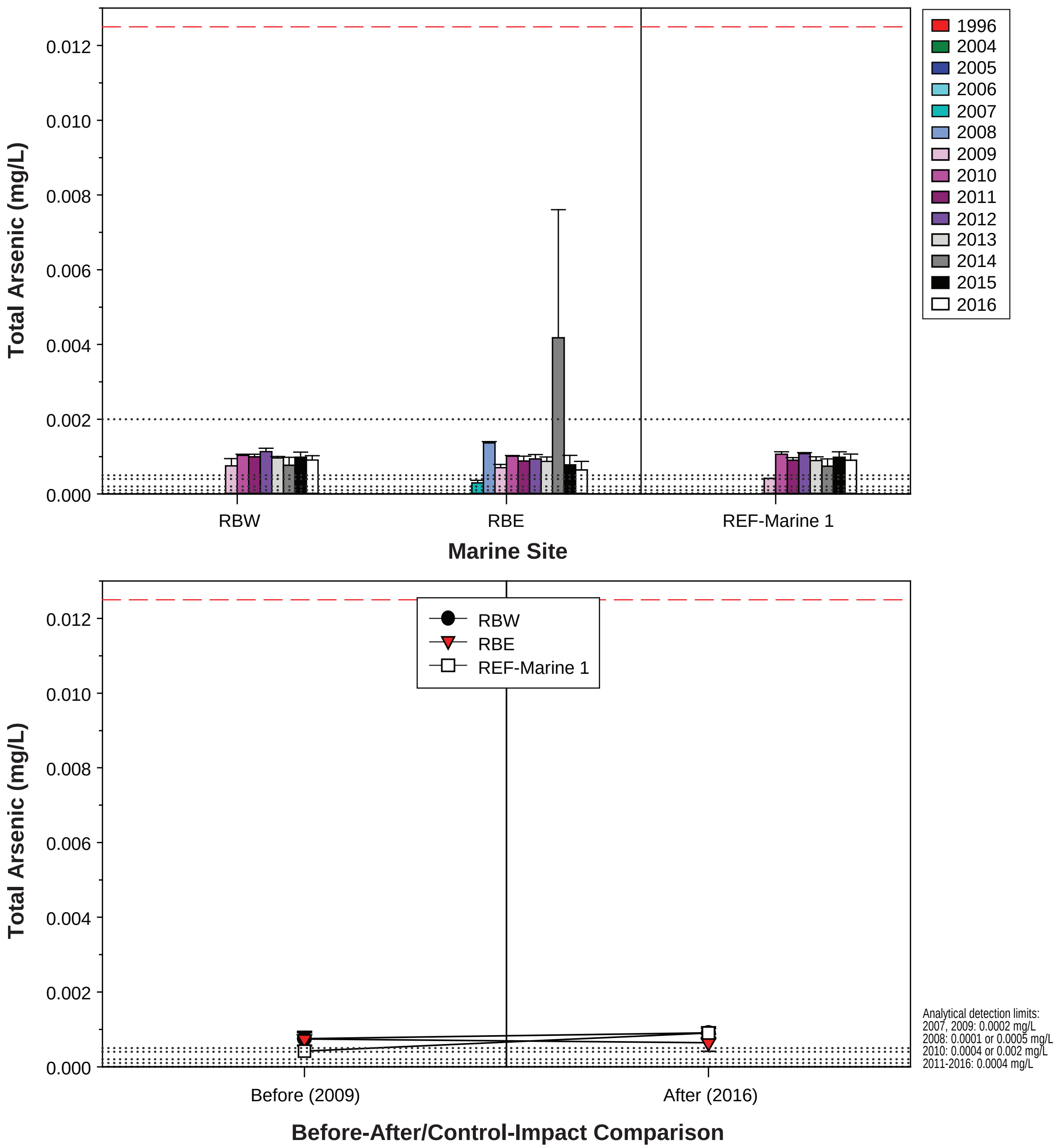
Total Aluminum Concentration in AEMP Marine Sites, Doris Project, 1996 to 2016



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 in AEMP Marine Sites, Doris Project, 1996 to 2016



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.
See Appendix B.2.2 for a list of outliers excluded from plots and analyses.

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 2016, 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, 2016 total cadmium concentrations were within the range of baseline concentrations (Figure 3.3-47), and before-after statistical comparisons confirmed that the 2016 and baseline means were not statistically distinguishable for either marine exposure site (p = 0.66 for RBW and p = 0.77 for RBE). Therefore, there was no apparent effect of 2016 Project activities on total cadmium concentrations at the marine exposure sites.

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 2016 mean concentration at RBE was within the range of baseline concentrations (Figure 3.3-48). At RBW and REF-Marine 1, 2016 total copper concentrations were similar to 2009 concentrations (Figure 3.3-48). The before-after comparison showed that for both RBW and RBE, there was no significant difference between baseline and 2016 mean total copper concentrations (p = 0.58 for RBW and p = 0.63 for RBE). Therefore, there was no apparent effect of 2016 Project activities on total copper concentrations at the marine exposure sites.

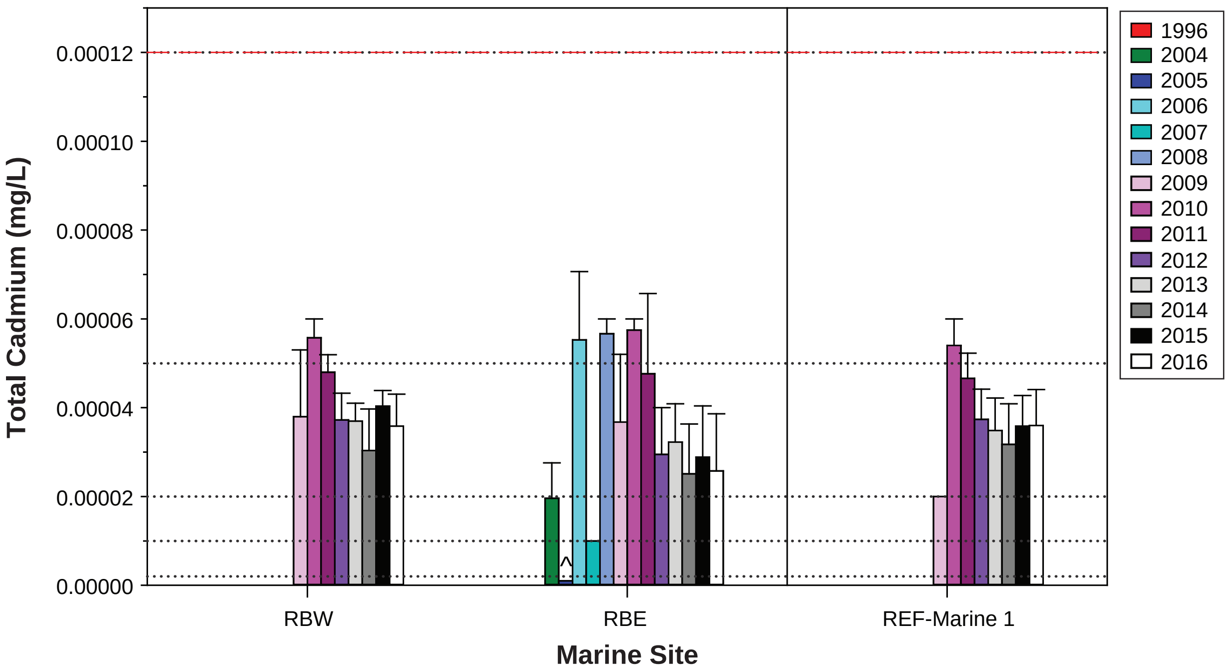
3.3.3.13 *Total Iron*

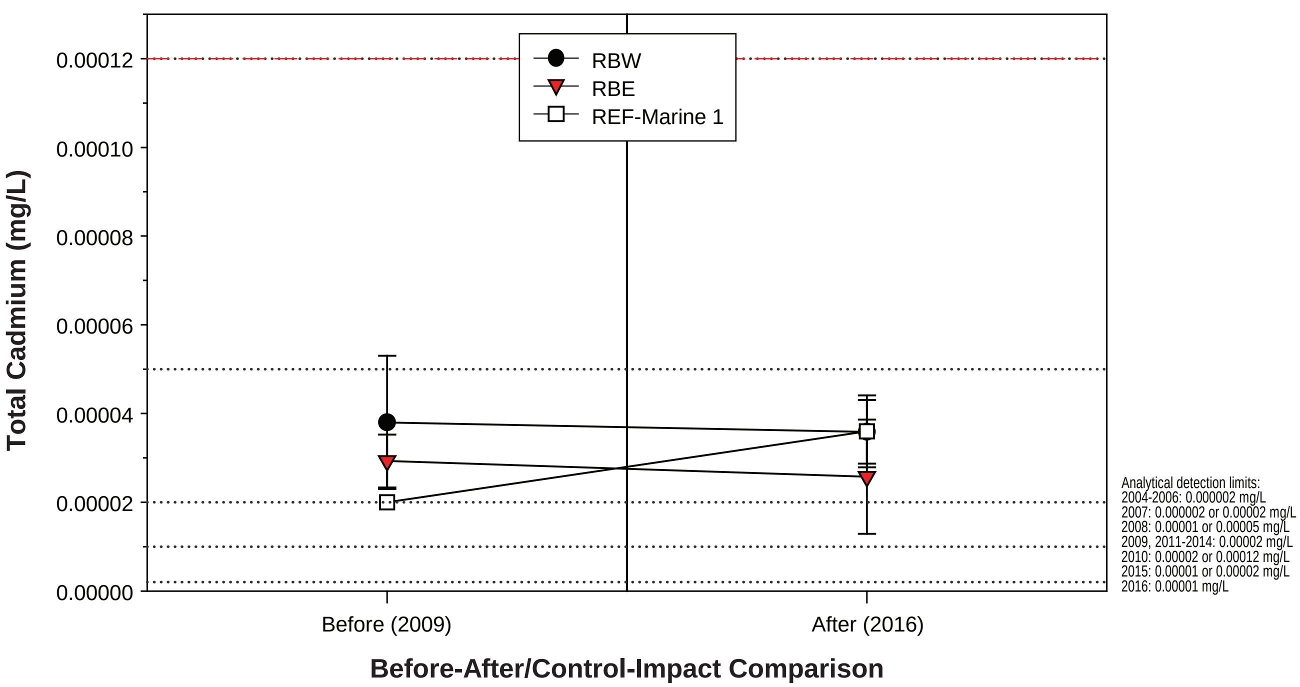
Total iron is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. At site RBE, the mean 2016 total iron concentration was within the range of the widely varying baseline concentrations (Figure 3.3-49). At sites RBW and REF-Marine 1, mean 2016 total iron concentrations were slightly higher than baseline (2009) concentrations (Figure 3.3-49). The before-after analysis showed that 2016 means were not distinguishable from baseline means at the exposure sites (p = 0.64 for RBW and p = 0.71 for RBE), indicating that there was no effect of 2016 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. At site RBW, 73% of the total lead concentrations in the combined baseline (2009) and 2016 dataset were below detection limits; therefore, statistical analysis results are not considered reliable. However, the mean 2016 total lead concentration at site RBW was lower than the 2009 baseline concentration (Figure 3.3-50). At site RBE, the mean 2016 total lead concentration was lower than the baseline mean (Figure 3.3-50), but the before-after analysis showed that the baseline and 2016 means were not significantly different (p = 0.68). Thus, there was no apparent adverse effect of 2016 Project activities on total lead concentrations at marine exposure sites.

Total Cadmium Concentration in AEMP Marine Sites, Doris Project, 1996 to 2016

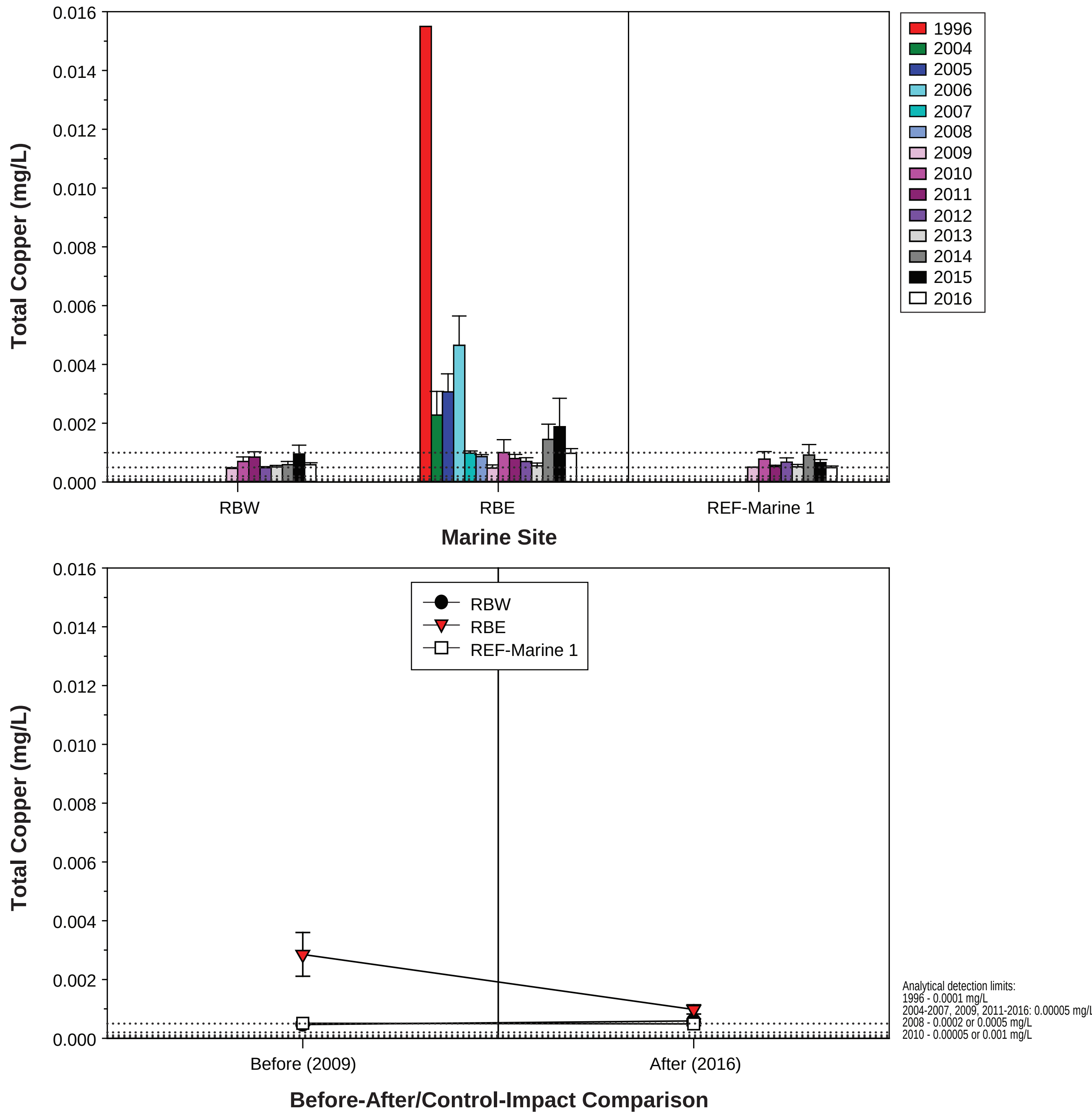




Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed lines represent the CCME marine guideline for cadmium (0.00012 mg/L).
Total cadmium is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of the MMER.
See Appendix B.2.2 for a list of outliers excluded from plots and analyses.

Figure 3.3-48

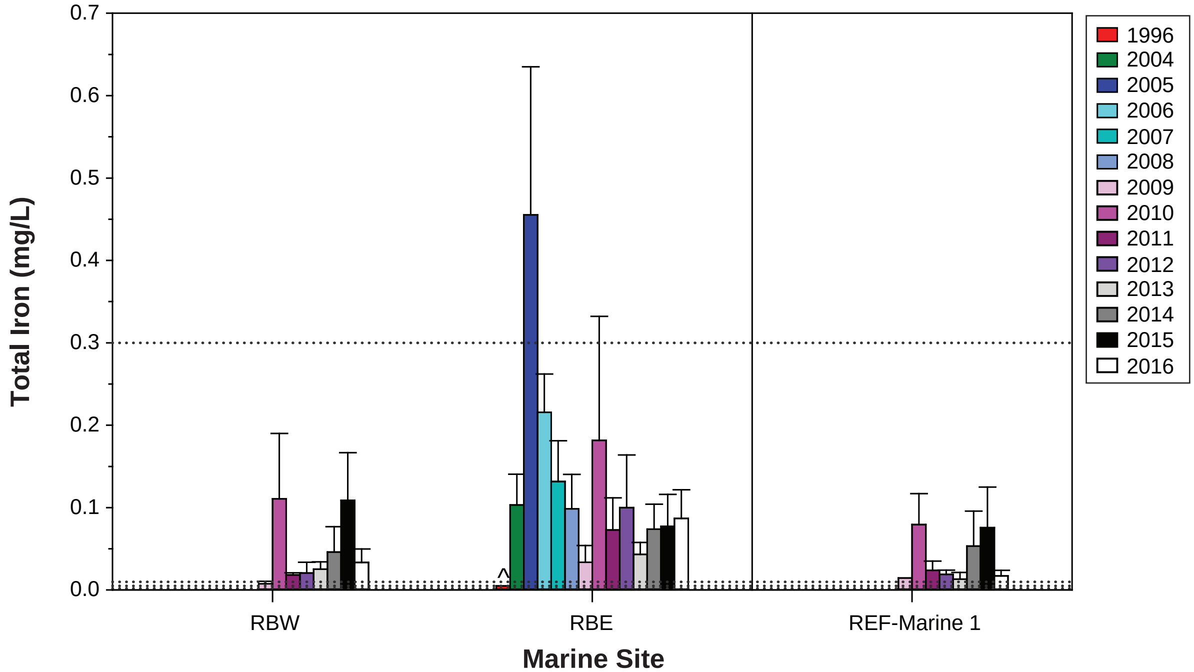
Total Copper Concentration in AEMP Marine Sites, Doris Project, 1996 to 2016

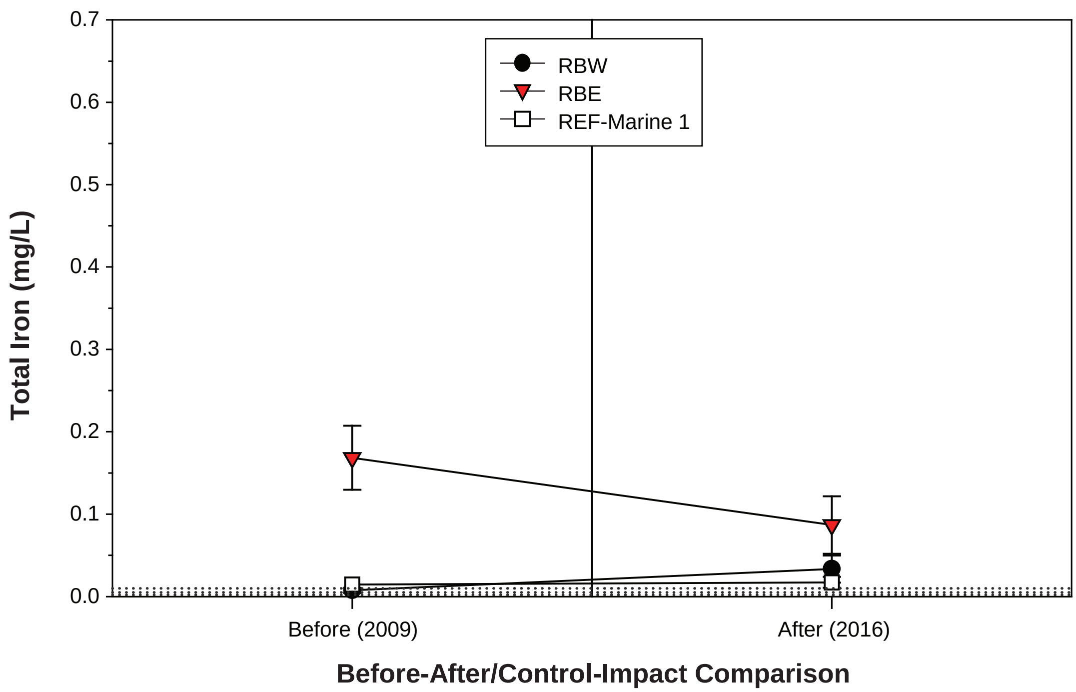


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Total copper is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.

Figure 3.3-49

Total Iron Concentration in AEMP Marine Sites, Doris Project, 1996 to 2016



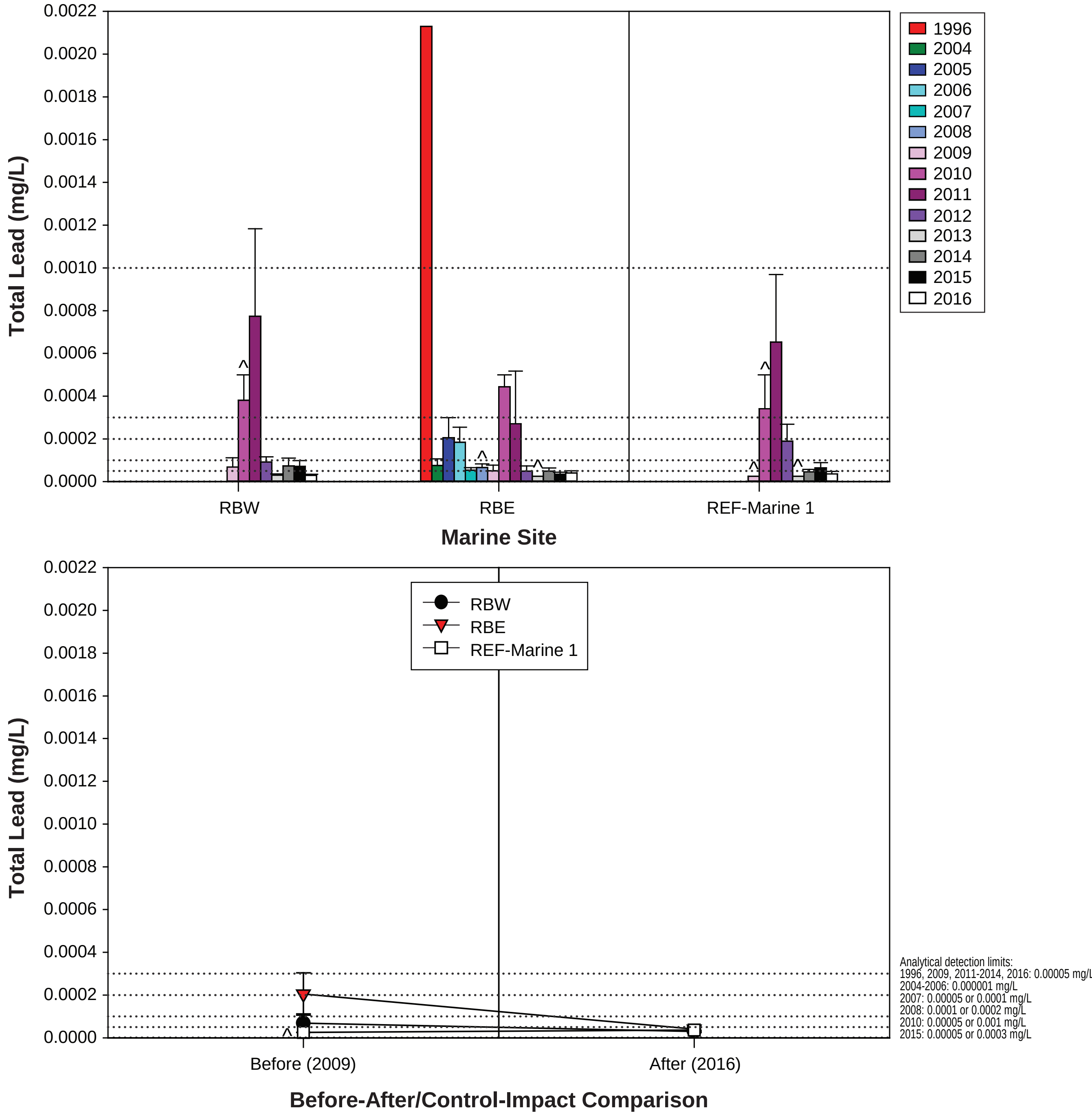


Analytical detection limits:
1996, 2011-2016: 0.01 mg/L
2004-2006:0.002 mg/L
2007: 0.002 or 0.01 mg/L
2008: 0.002 or 0.005 mg/L
2009: 0.005 mg/L
2010: 0.01 to 0.3 mg/L

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 in AEMP Marine Sites, Doris Project, 1996 to 2016



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.

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 2016, the total mercury concentrations measured in April, August, and September at marine exposure and reference sites were all below the ultra-low detection limit of 0.0000005 mg/L (Figure 3.3-51; Appendix A). Concentrations measured in July were slightly higher than this detection limit, but well below the interim CCME guideline for inorganic mercury of 0.000016 mg/L (Figure 3.3-51; Appendix A). Given the high proportion of censored values (≥ 70%) in the combined baseline and 2016 total mercury datasets for the exposure sites (Appendix B.2.2), the results of the before-after and BACI analyses are not considered reliable. However, Figure 3.3-51 shows no evidence of an increase in total mercury concentrations over time at the marine exposure sites; therefore, there was no apparent adverse effect of 2016 Project activities on total mercury concentrations in the Roberts Bay monitoring sites.

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. 2016 total molybdenum concentrations at the two marine exposure sites were similar to baseline concentrations (Figure 3.3-52). The before-after comparison confirmed that there was no difference between 2016 mean concentrations and baseline means for the Roberts Bay sites ($p = 0.79$ for RBW and $p = 0.97$ for RBE). Therefore, 2016 Project activities had no apparent effect on total molybdenum concentrations at the marine exposure sites.

3.3.3.17 Total Nickel

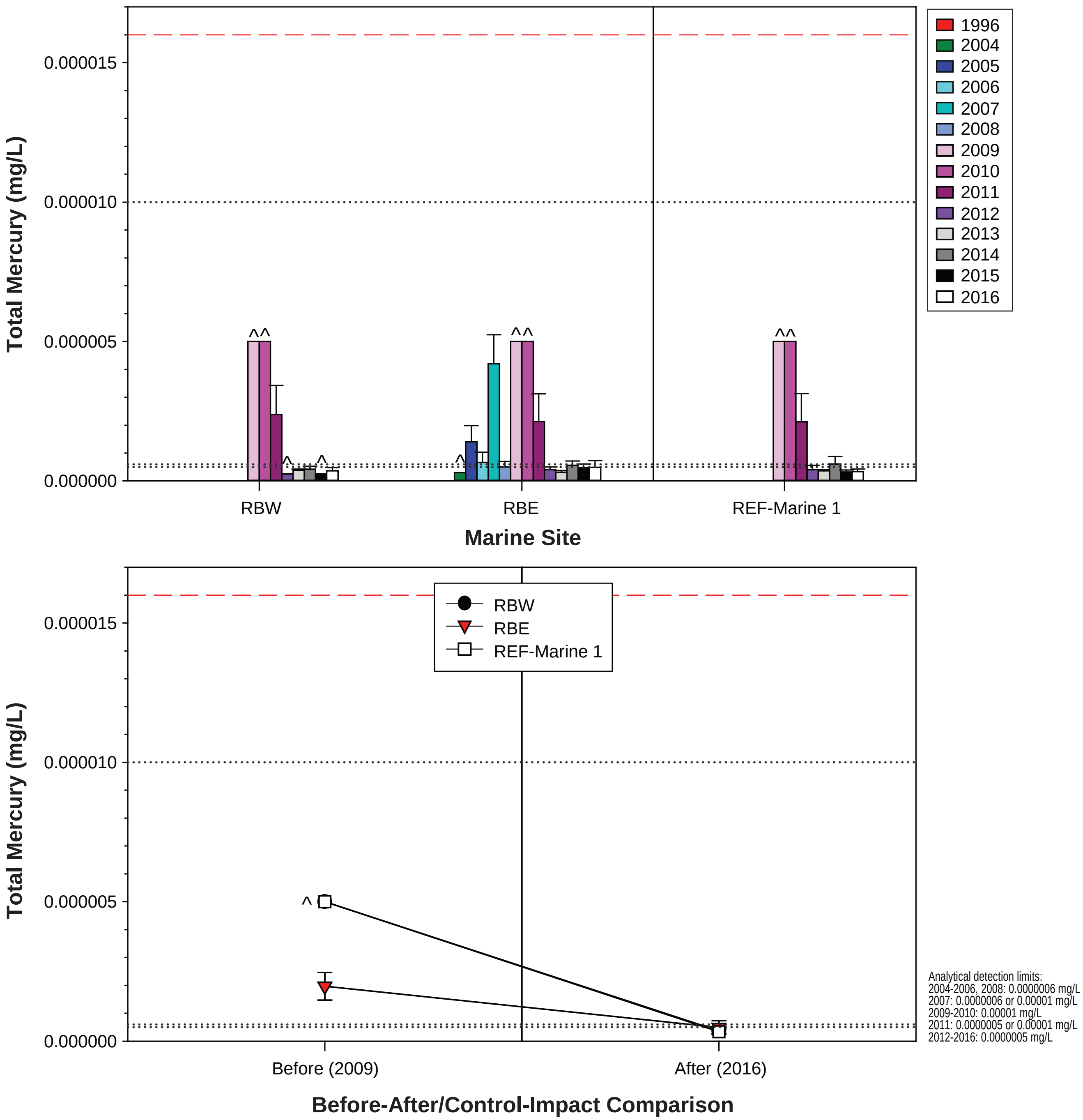
Total nickel is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. The mean 2016 total nickel concentration at site RBW was similar to the mean 2009 concentration, while the mean 2016 total nickel concentration at RBE was lower than the baseline mean (Figure 3.3-53). The before-after analysis showed that the baseline and 2016 means were not statistically distinguishable for either marine exposure site ($p = 0.86$ for RBW and $p = 0.79$ for RBE). Therefore, there was no indication that 2016 Project activities had an effect 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, mean total zinc concentrations were similar in 2009 and 2016 (Figure 3.3-54). At site RBE, the 2016 mean was lower than the baseline mean (Figure 3.3-54). The before-after comparison showed that there was no significant difference between baseline and 2016 mean zinc concentrations for either of the Roberts Bay sites ($p = 0.51$ for RBW and $p = 0.46$ for RBE), indicating that 2016 Project activities did not affect total zinc concentrations at the marine exposure sites.

Figure 3.3-51

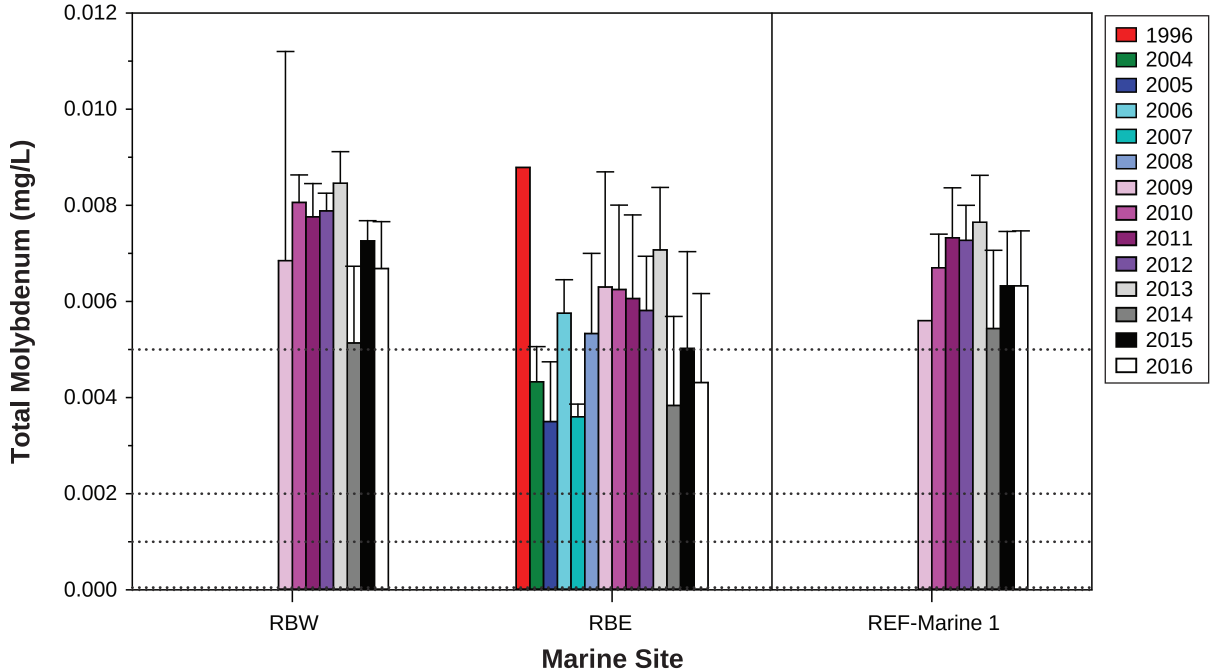
Total Mercury Concentration in AEMP Marine Sites, Doris Project, 1996 to 2016

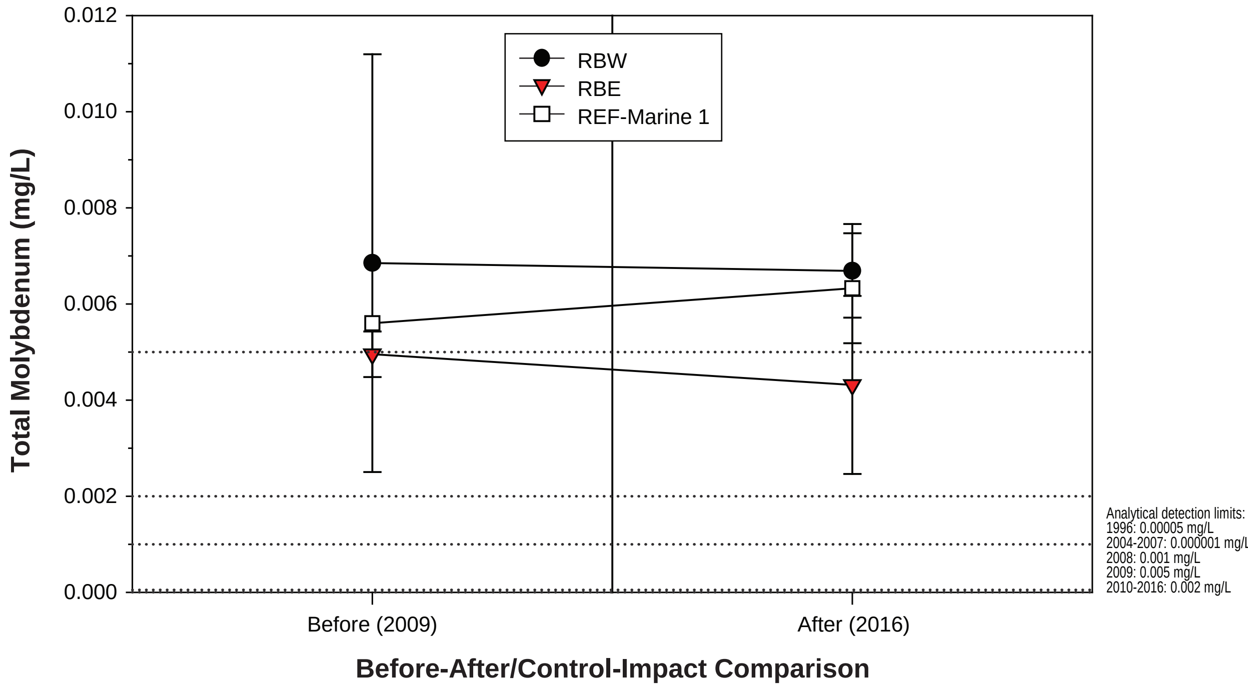


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed lines represent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

Figure 3.3-52

Total Molybdenum Concentration in AEMP Marine Sites, Doris Project, 1996 to 2016

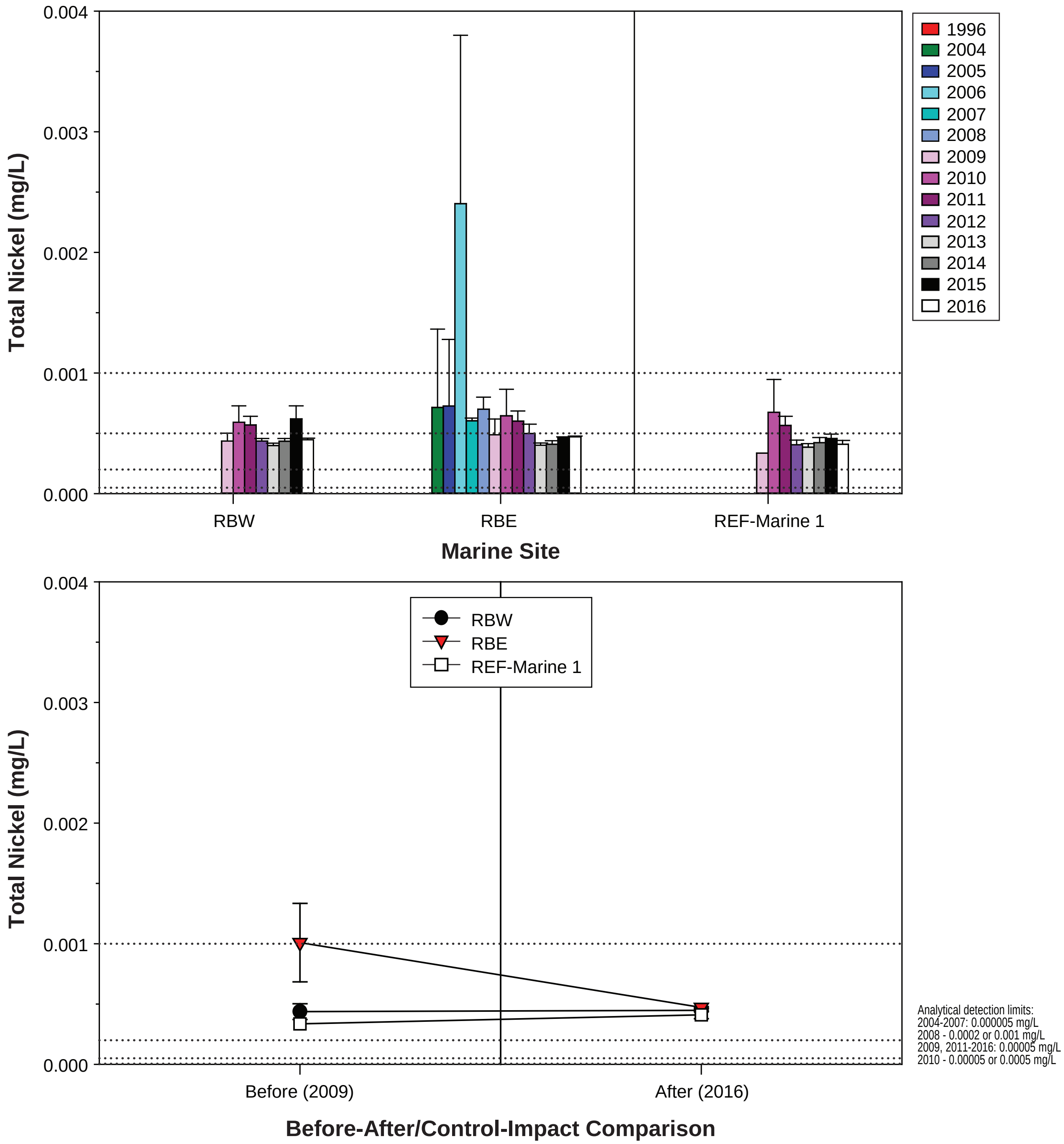




Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Total molybdenum is a required parameter for effluent characterization as per Schedule 5, s. 4(1) of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

Figure 3.3-53

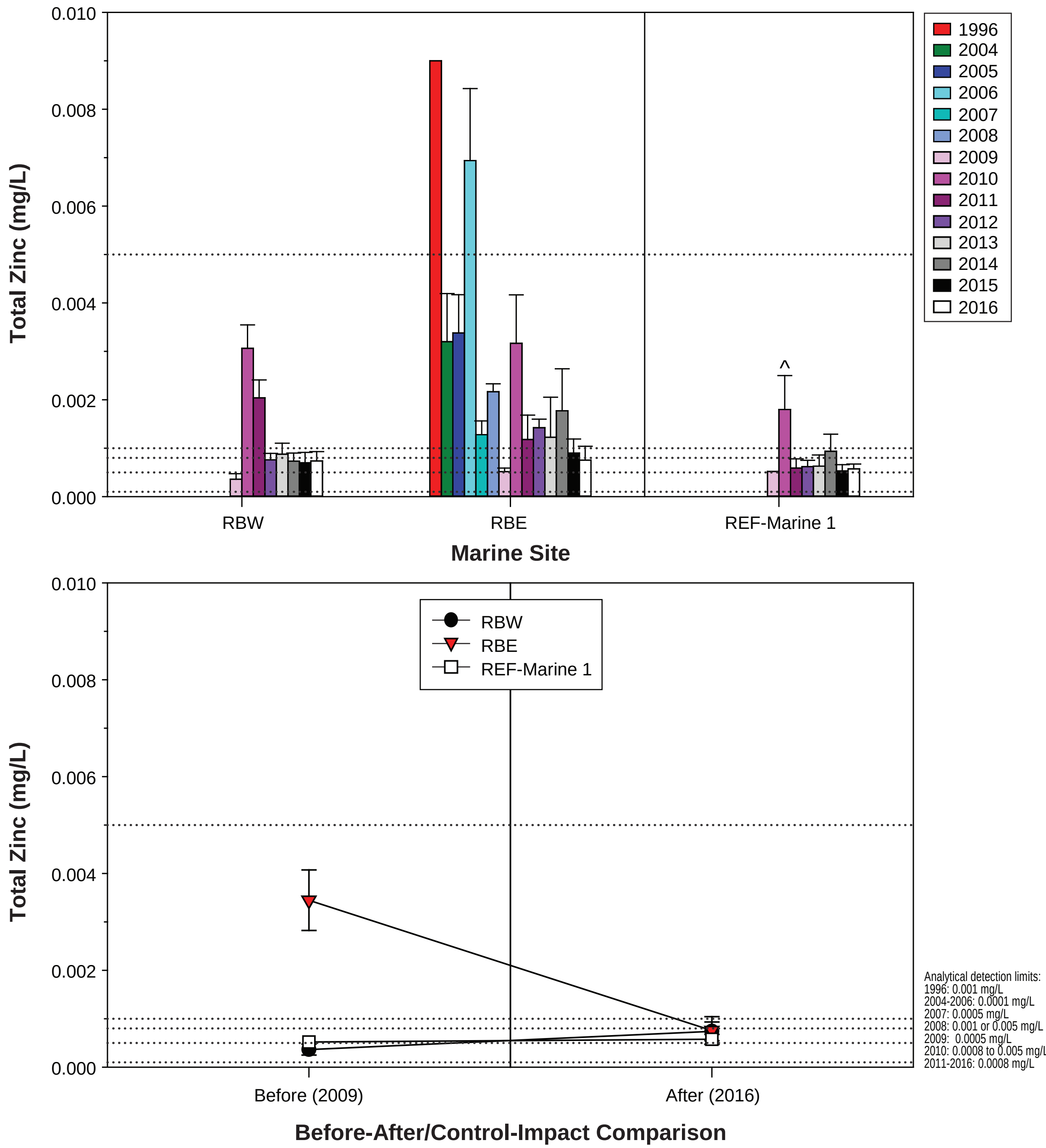
Total Nickel Concentration in AEMP Marine Sites, Doris Project, 1996 to 2016



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 nickel is regulated as a deleterious substance in effluentsTas per Schedule 4 of the MMER.
See Appendix B.2.2 for a list of outliers excluded from plots and analyses.

Figure 3.3-54

Total Zinc Concentration in AEMP Marine Sites, Doris Project, 1996 to 2016



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.

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 2016 are compared against available baseline information as well as reference sites to evaluate whether 2016 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 2016a) 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 2016a). 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.

For both graphical and statistical analyses, a value equal to half the detection limit was substituted for sediment quality concentrations that were below analytical detection limits. 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 2016 were compared to 2009 data 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. Note that sediment quality data and statistical analysis results for Roberts Outflow are shown in the following figures and in Appendices A and B, but this stream is not discussed in the following sections. Roberts Outflow is not expected to be affected by the Project but rather serves to characterize any influence of a closed silver mine and past neighbouring exploration activity (North Arrow Minerals Inc.) on Roberts Outflow and potentially downstream, and to be able to differentiate this from potential effects of TIA discharge upstream.

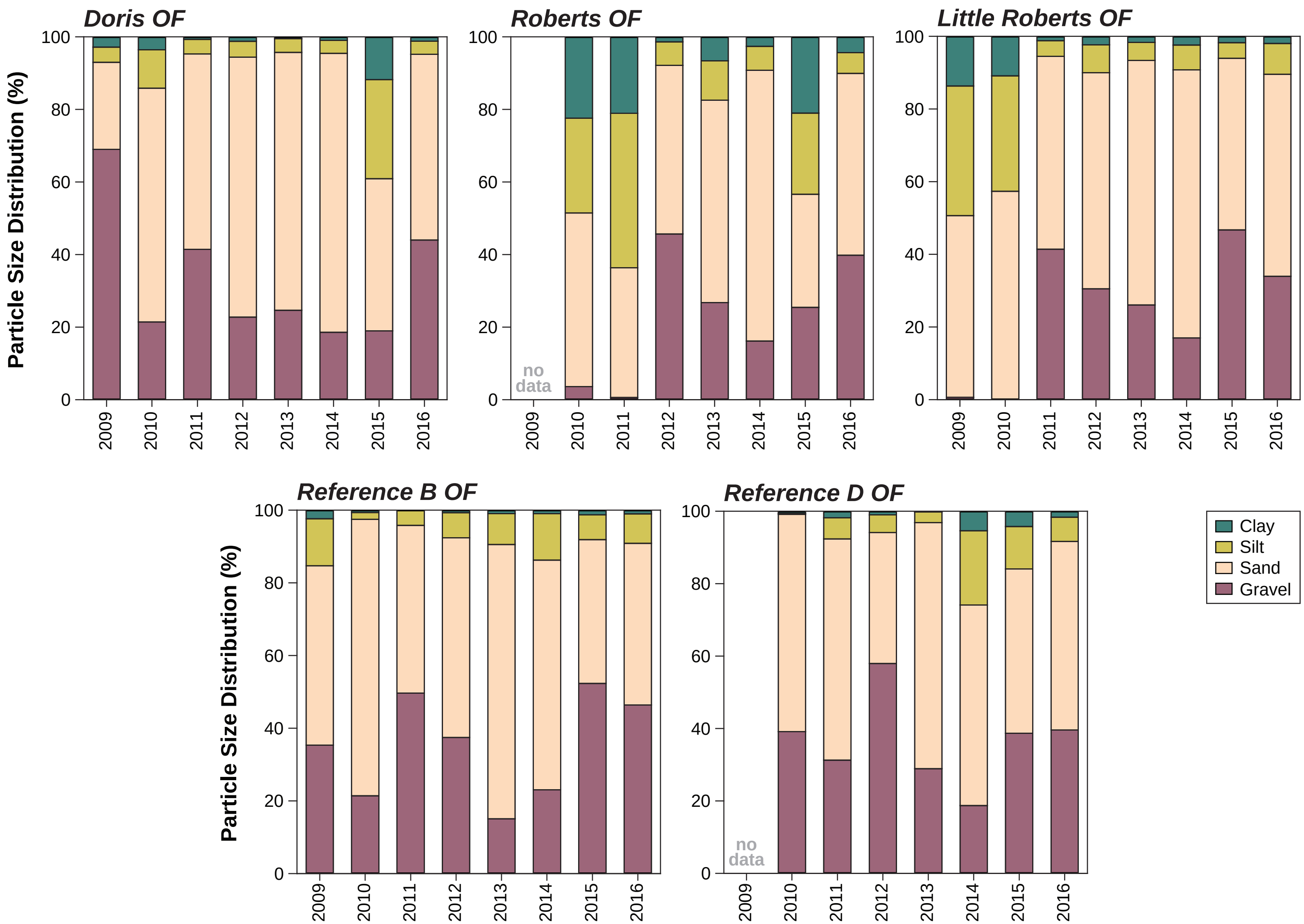
3.4.1.1 Particle Size

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 important differences in the particle size composition of stream sediments in 2016 compared to 2009 (Figure 3.4-1). This most likely resulted from natural spatial heterogeneity in sediment particle size composition.

Figure 3.4-1

Particle Size Distribution in AEMP Stream Sediments, Doris Project, 2009 to 2016

ERM



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.

In Doris Outflow, 2016 sediments contained a higher proportion of sand and a lower proportion of gravel compared to 2009. Proportions of silt and clay were similar between 2009 and 2016. The before-after analysis showed that the observed changes in particle size in Doris Outflow sediments were statistically significant for sand (p = 0.0008) and gravel (p = 0.020), but not for the other size classes (p = 0.87 for silt and p = 0.49 for clay). The BACI analysis showed that there was evidence of significant non-parallelism for sand content in Doris Outflow compared to the reference streams (p = 0.039); however, there was no differential change in gravel content relative to the reference streams (p = 0.14). Figure 3.4-1 shows that Doris Outflow sediments sampled in 2009 contained substantially less sand (24%) than sediment samples collected annually from 2010 to 2016 (42 to 77% sand).

In Little Roberts Outflow, the gravel content of sediments was higher and the clay and silt content was lower in 2016 than in 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 (p = 0.021), silt (p = 0.0004), and clay (p < 0.0001), but that sand content was not significantly different between 2009 and 2016 (p = 0.52). The BACI analysis showed that there was evidence of non-parallelism for the decrease in clay (p = 0.0006), but not for the changes in silt (p = 0.059) and gravel (p = 0.36) relative to the reference streams.

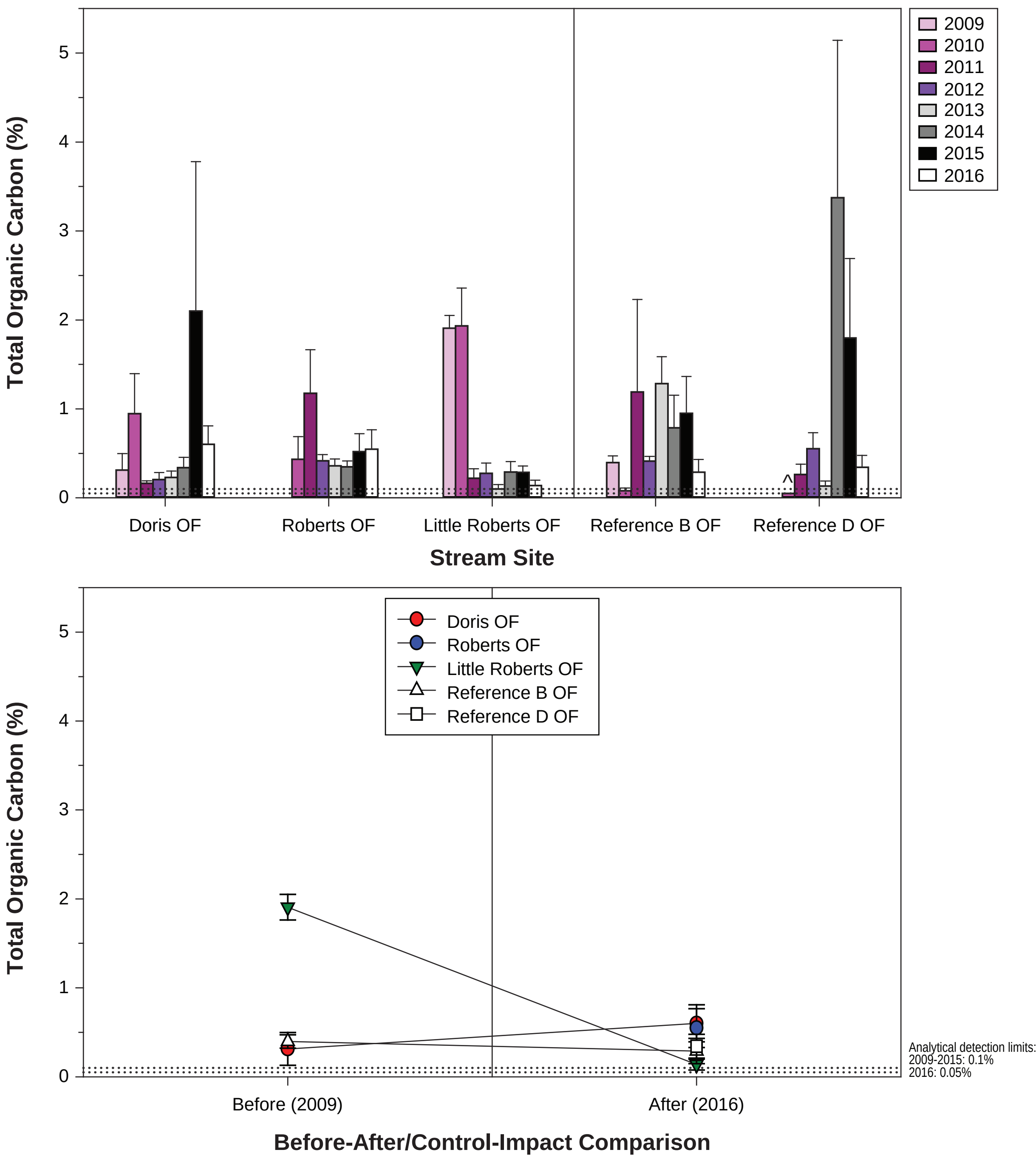
It is unlikely that variation in sediment particle size composition is related to 2016 Project activities, particularly given that no water was discharged from the TIA in 2016. Rather, variation in particle size composition probably reflects natural spatial heterogeneity in stream sediments since corresponding Project-related changes in water quality have not been observed (e.g., increases in TSS). The variability in sediment particle size between 2009 and 2016 in Doris and Little Roberts outflows confounds the comparison of sediment chemistry variables between 2009 and 2016, since metal and TOC concentrations are closely related to sediment particle size and tend to be greater in finer sediments (e.g., Lakhan, Cabana, and LaValle 2003; Secrieri and Oaie 2009; Yao et al. 2015). Relative to 2009 samples, Doris Outflow sediments were finer in 2016, while Little Roberts sediments were coarser in 2016. Based on particle size alone, the expectation based on well-established trends would be that metal and TOC concentrations in Doris Outflow sediments would be higher in 2016 than 2009, and conversely, that metal and TOC concentrations in Little Roberts Outflow sediments would be lower in 2016 than 2009, though this would be unrelated to Project activities. As discussed below, this expectation was partially met as concentrations of nearly all the variables subjected to evaluation decreased in Little Roberts Outflow between 2009 and 2016. Metal concentrations tend to be highest in the fine sediment fractions (silt and clay; Yao et al. 2015) and the proportions of silt and clay did not change in Doris Outflow between 2009 and 2016 samples; instead, there was a redistribution within the coarse fractions (sand and gravel). This may explain why sediment metal concentrations did not change significantly from 2009 to 2016 in Doris Outflow despite the variability in particle size composition of sediments.

3.4.1.2 Total Organic Carbon

TOC content is a required sediment variable that supports benthic invertebrate surveys as per Schedule 5, s. 16(a) (iii) of the MMER. In both exposure and reference stream sediments, the TOC content was highly variable both inter-annually and among replicates collected from each stream within a year (Figure 3.4-2). Although the mean TOC content of Doris Outflow sediments was higher in 2016 than in 2009, the before-after comparison showed that the 2016 mean was not distinguishable from the 2009 mean (p = 0.36).

Figure 3.4-2

Total Organic Carbon Concentrations in AEMP Stream Sediments, Doris Project, 2009 to 2016



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.

For Little Roberts Outflow, the before-after comparison showed that the TOC content of sediments decreased significantly in 2016 compared to 2009 (p = 0.0003), and the BACI analysis indicated that there was no parallel decrease observed at the reference streams (p = 0.0001). This differential decrease in TOC at Little Roberts Outflow was likely related to the lower proportion of fine sediments in 2016 samples compared to 2009, since TOC concentrations tend to be higher in finer sediments (e.g., Secrieri and Oaie 2009). Indeed, the highest TOC levels in Little Roberts Outflow sediments were measured in 2009 and 2010 (Figure 3.4-2), corresponding to the years that sediments in this stream were markedly finer than other years (Figure 3.4-1). There was no discharge of TIA water in 2016 and no reason to suspect that 2016 Project activities caused a decrease in the sediment TOC content of Little Roberts Outflow. Variation in particle size composition and TOC levels was likely due to natural environmental heterogeneity or inter-annual variability.

3.4.1.3 Total Arsenic

Mean arsenic concentrations in exposure stream sediments in 2016 were below the CCME ISQG of 5.9 mg/kg and the PEL of 17 mg/kg (Figure 3.4-3). In both Doris Outflow and Little Roberts Outflow, mean 2016 sediment arsenic concentrations were lower than 2009 baseline concentrations (Figure 3.4-3). However, the before-after comparison showed that there were no significant differences between 2009 and 2016 mean arsenic concentrations at Doris Outflow (p = 0.49) or Little Roberts Outflow (p = 0.052). There was no indication that 2016 Project activities adversely affected arsenic concentrations in exposure stream sediments.

3.4.1.4 Total Cadmium

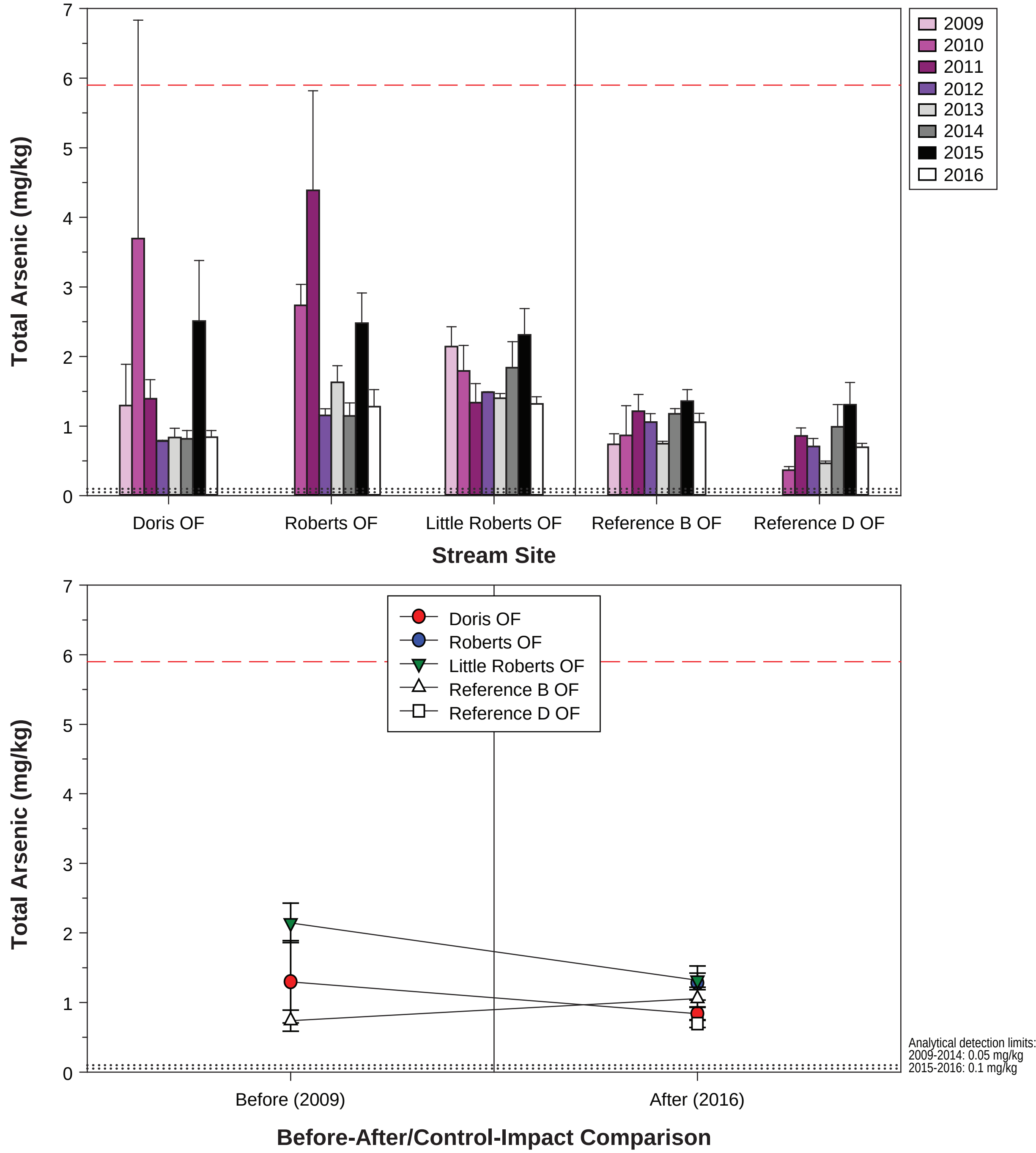
In the exposure streams, concentrations of cadmium in sediments were always below the detection limit of 0.05 mg/kg in 2016, and well below the CCME ISQG of 0.6 mg/kg and the PEL of 3.5 mg/kg (Figure 3.4-4). Therefore, there was no apparent effect of 2016 Project activities on sediment cadmium concentrations in the exposure streams.

3.4.1.5 Total Chromium

Mean 2016 chromium concentrations in exposure stream sediments were below the CCME ISQG of 37.3 mg/kg and the CCME PEL of 90 mg/kg (Figure 3.4-5). In both Doris Outflow and Little Roberts Outflow, mean sediment chromium concentrations were slightly lower in 2016 than in 2009. The before-after analysis showed that mean 2009 and 2016 sediment chromium concentrations were not significantly different in Doris Outflow (p = 0.26), but were significantly different in Little Roberts Outflow (p = 0.003). Since a decrease in the sediment chromium concentration in Little Roberts Outflow is not of environmental concern, there was no apparent adverse effect of 2016 Project activities on sediment chromium concentrations in exposure streams.

Figure 3.4-3

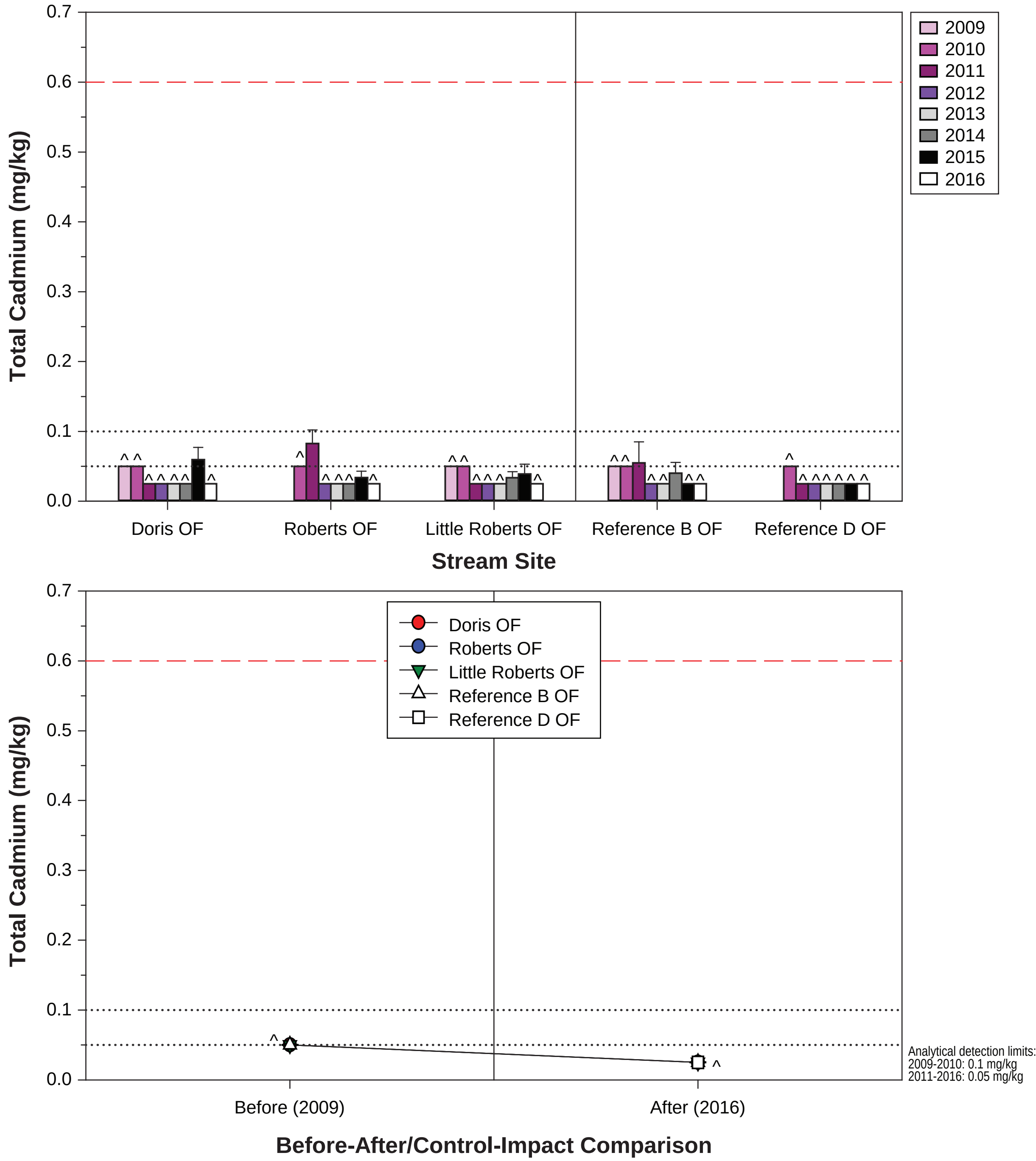
Total Arsenic Concentrations in AEMP Stream Sediments, Doris Project, 2009 to 2016



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

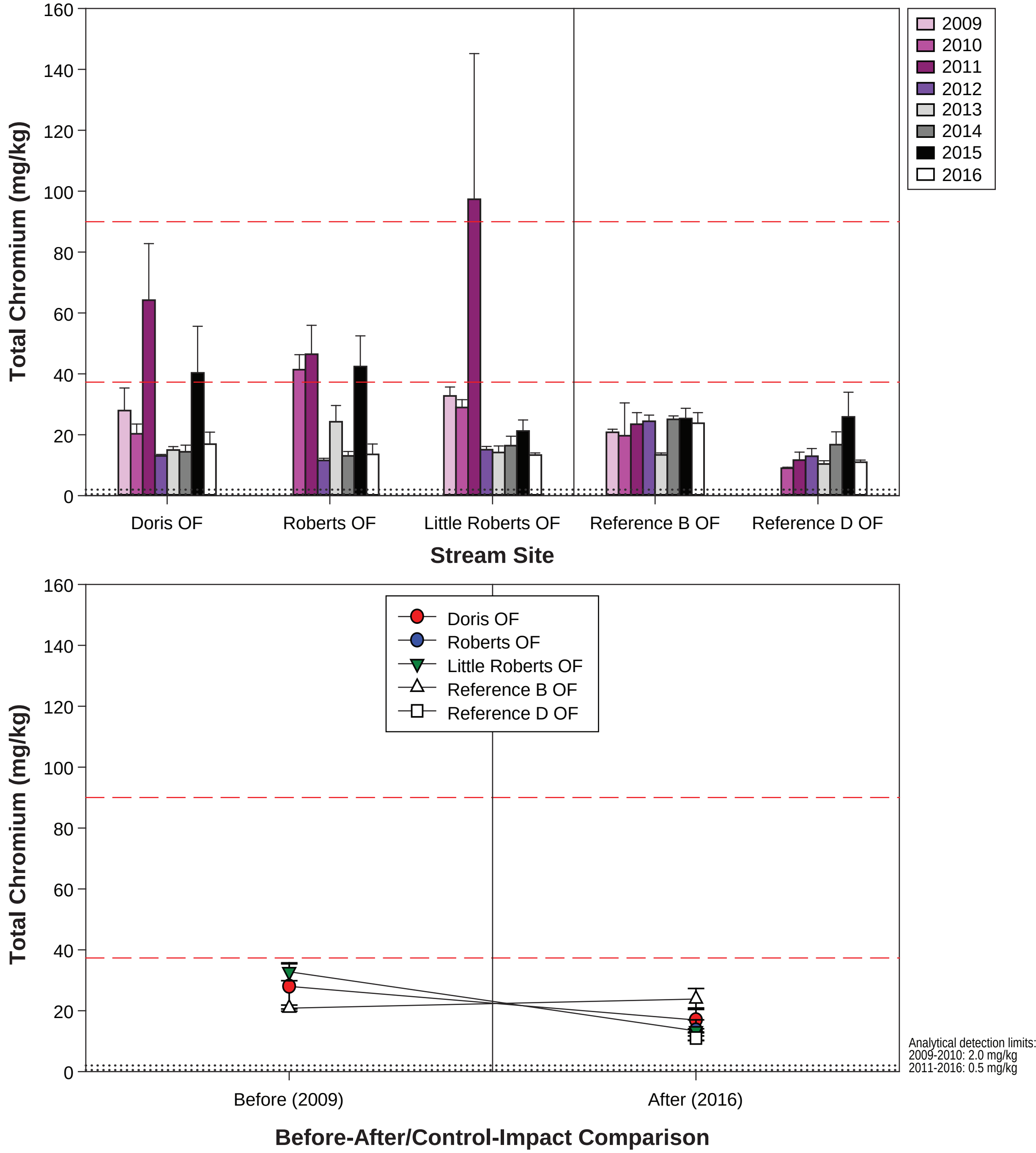
Total Cadmium Concentrations in AEMP Stream Sediments, Doris Project, 2009 to 2016



Notes: Error bars represent the standard error of the mean.
Black 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 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 3.4-5

Total Chromium Concentrations in AEMP Stream Sediments, Doris Project, 2009 to 2016



Notes: Error bars represent the standard error of the mean.
Black 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 freshwater interim sediment quality guideline (ISQG) for chromium (37.3 mg/kg) and the probable effects level (PEL) for chromium (90 mg/kg).

3.4.1.6 Total Copper

Mean 2016 sediment copper concentrations in exposure streams were below the CCME ISQG of 35.7 mg/kg and the PEL of 197 mg/kg (Figure 3.4-6). In Doris Outflow sediments, the 2016 mean copper concentration was lower than the 2009 mean, but the before-after analysis showed that the 2009 and 2016 means were not distinguishable (p = 0.39). In Little Roberts Outflow, the before-after analysis showed that there was a statistically significant decrease in the mean copper concentration in 2016 compared to 2009 (p = 0.018). This decrease in sediment copper concentration is not of environmental concern, and is likely related to the coarser nature of the sediments collected in 2016 compared to the finer sediments collected in 2009. Therefore, 2016 Project activities had no apparent adverse effect on sediment copper concentrations in the exposure streams.

3.4.1.7 Total Lead

2016 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 Little Roberts Outflow, the mean lead concentration in sediments was lower in 2016 than in 2009 (Figure 3.4-7), and the before-after analysis showed that this decrease was statistically significant (p = 0.0009). This decrease in lead concentration is not of environmental concern, and is likely related to the coarser nature of the sediments collected in 2016 compared to the finer sediments collected in 2009. For Doris Outflow, although the mean total lead concentration in the sediments was lower in 2016 than in 2009 (Figure 3.4-7), the before-after analysis showed that 2009 and 2016 means were not distinguishable (p = 0.49). Thus, there was no apparent adverse effect of 2016 Project activities on lead in exposure stream sediments.

3.4.1.8 Total Mercury

Total mercury concentrations measured in the sediments of Doris and Little Roberts outflows in 2016 were always below the detection limit of 0.005 mg/kg, and well below the CCME ISQG of 0.17 mg/kg and the PEL of 0.486 mg/kg (Figure 3.4-8). Therefore, there was no apparent effect of 2016 Project activities on mercury concentrations in the sediments of exposure streams.

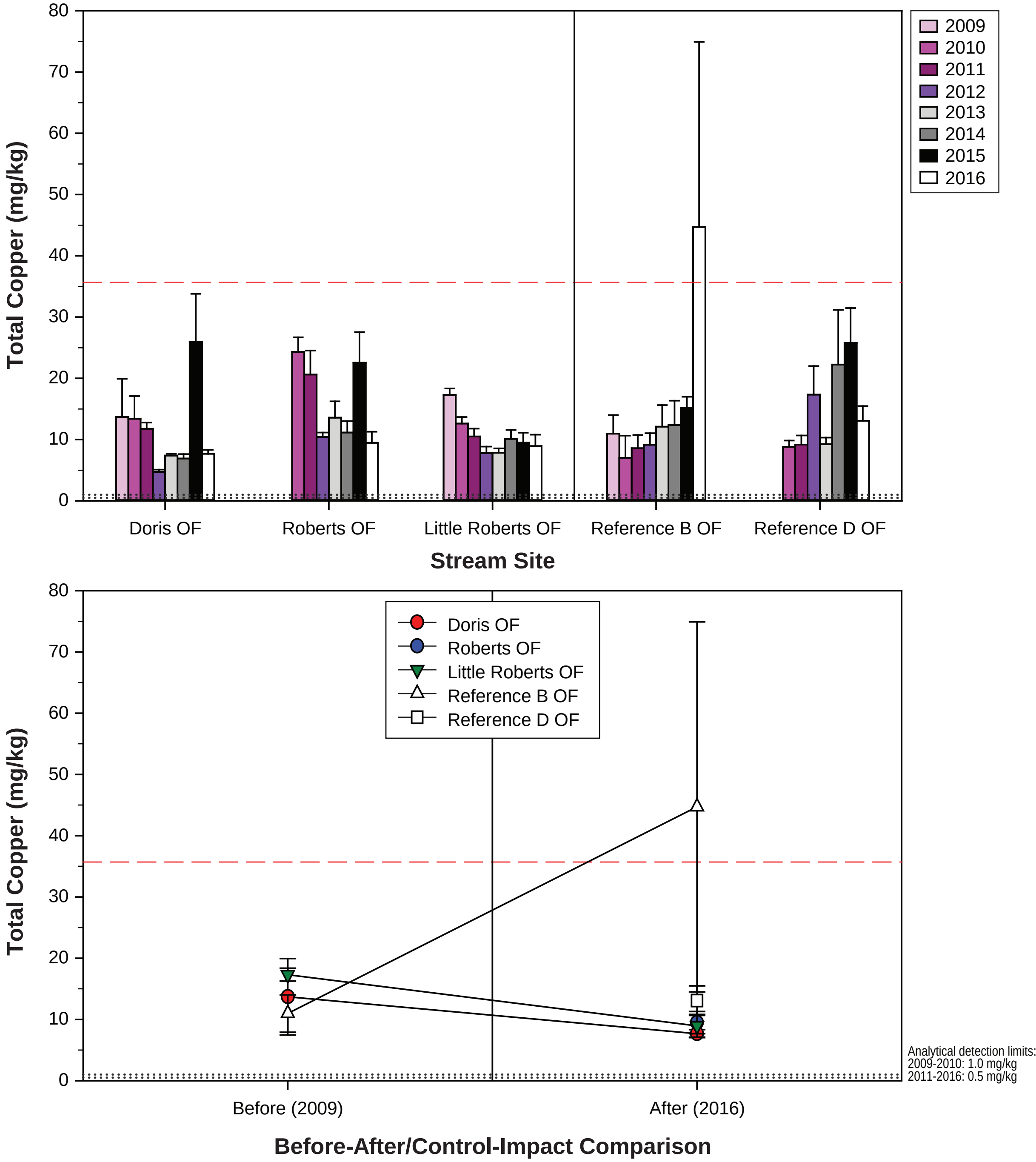
3.4.1.9 Total Zinc

2016 zinc concentrations in exposure stream sediments were well below the CCME ISQG of 123 mg/kg and the PEL of 315 mg/kg (Figure 3.4-9). Although the zinc concentration in sediments of both Doris and Little Roberts outflows were lower in 2016 than in 2009, the before-after analysis showed that this apparent decrease was statistically significant for Little Roberts Outflow (p = 0.0023) but not for Doris Outflow (p = 0.33). Given that sediment zinc concentrations in 2016 were lower than baseline concentrations, there was no indication that 2016 Project activities adversely affected zinc concentrations in exposure stream sediments.

Figure 3.4-6

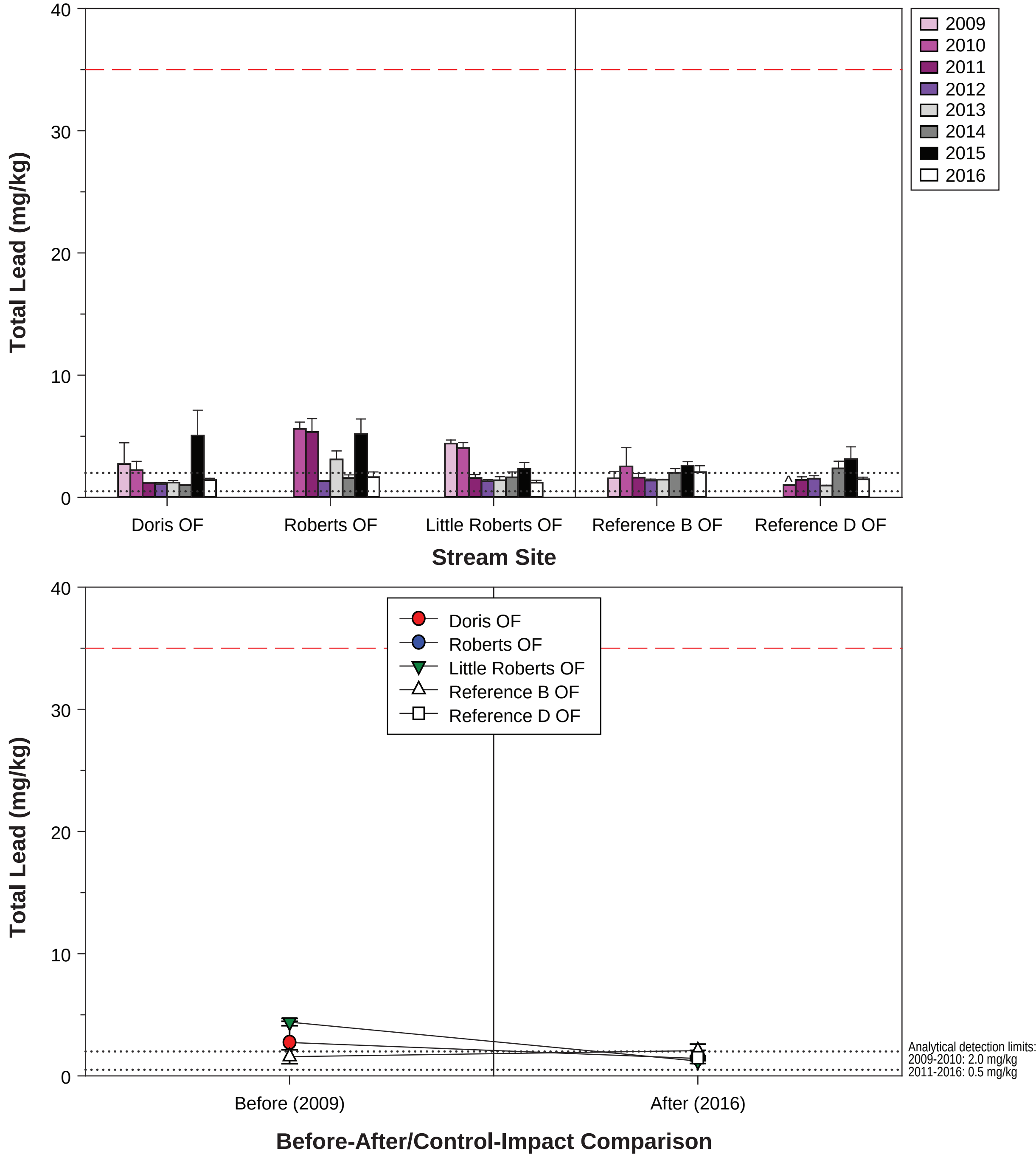
Total Copper Concentrations in AEMP Stream Sediments, Doris Project, 2009 to 2016

ERM



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

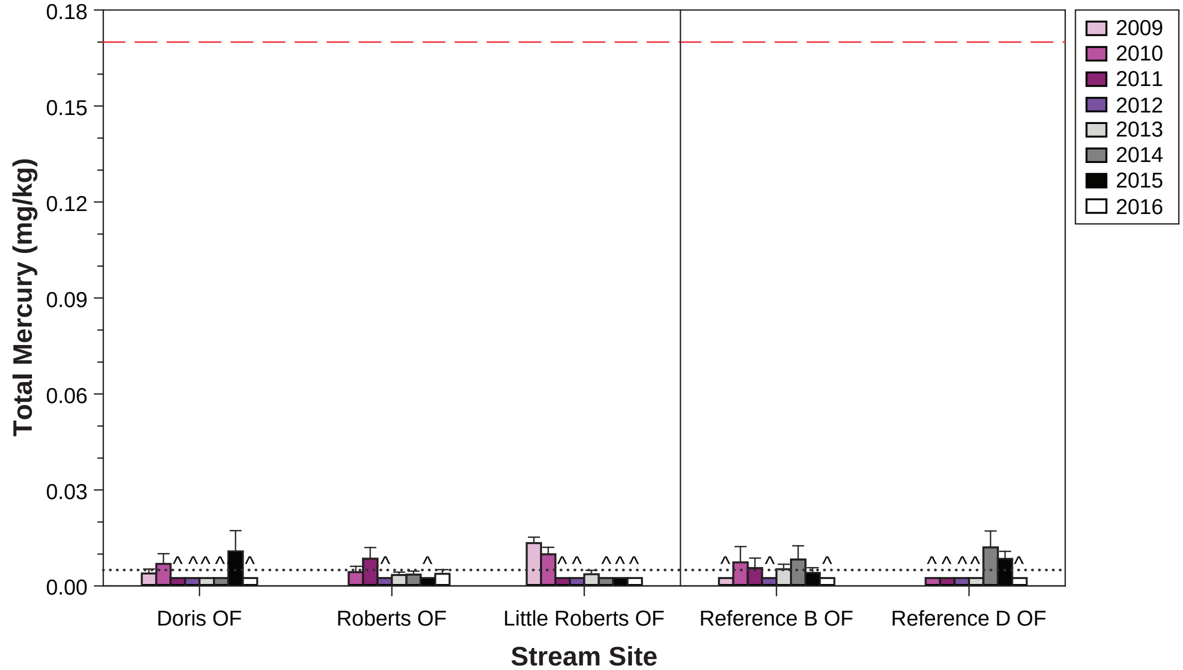
Figure 3.4-7
Total Lead Concentrations in AEMP Stream Sediments, Doris Project, 2009 to 2016

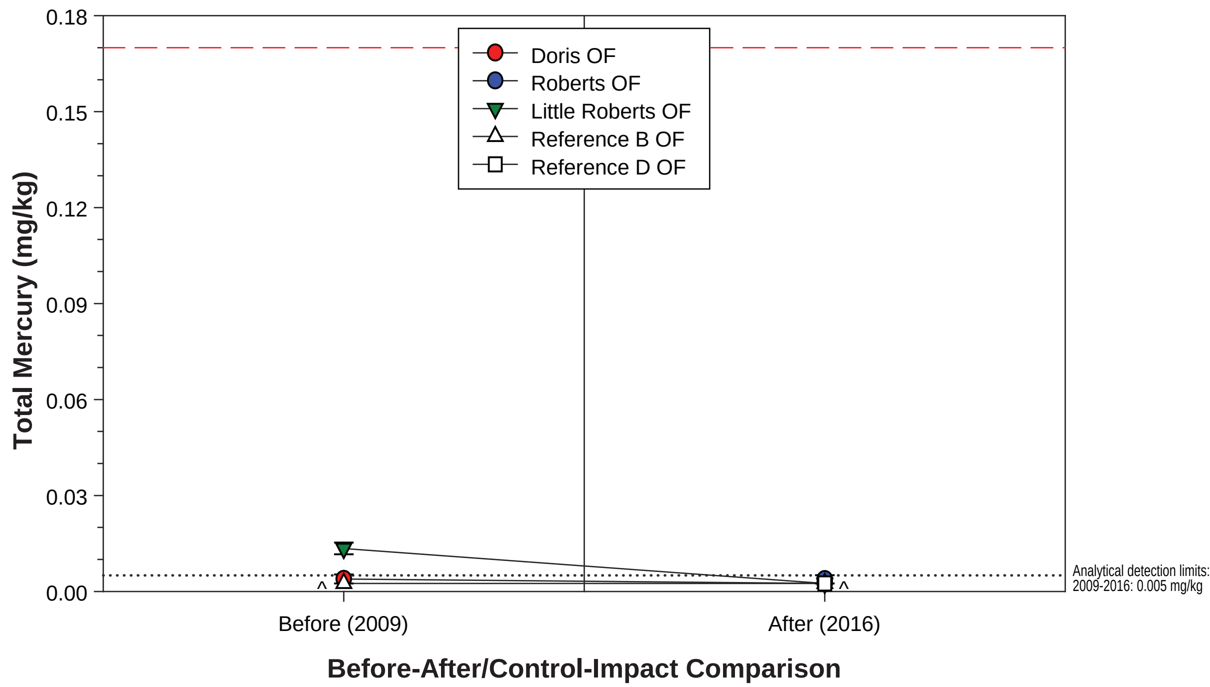


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below the detection limit are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed lines represent the CCME 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 3.4-8

Total Mercury Concentrations in AEMP Stream Sediments, Doris Project, 2009 to 2016

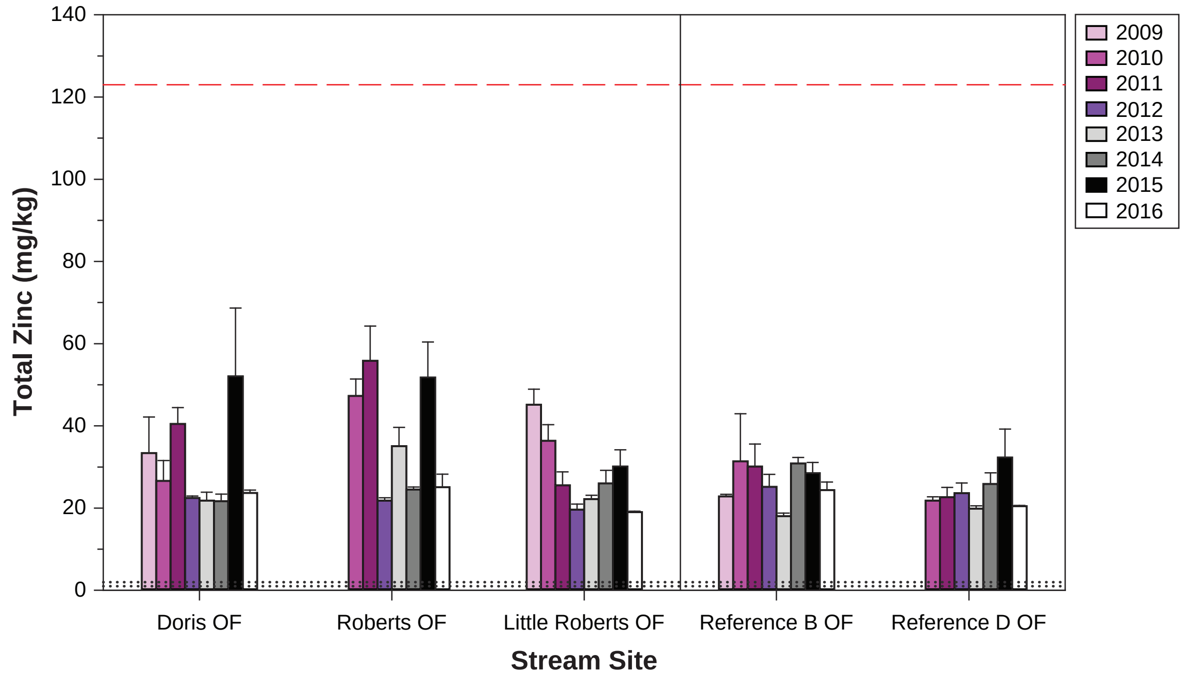


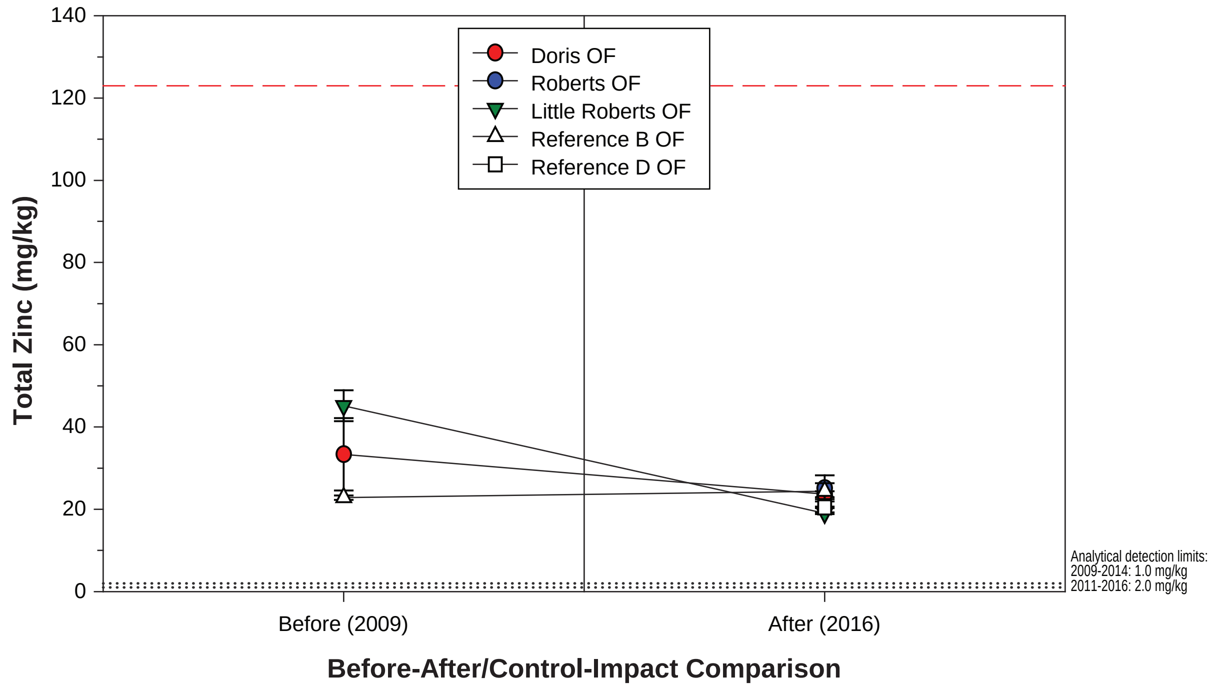


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent the analytical detection limit; values below the detection limit are plotted at half the detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed lines represent 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 in AEMP Stream Sediments, Doris Project, 2009 to 2016





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 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 2016. Sediment samples have been collected in the Doris area since 1996. However, most of the historical data were not directly comparable to 2016 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 2016 sediment sampling was conducted in August. No baseline sediment quality data are available for the reference lakes; therefore, no before-after or 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.

3.4.2.1 Particle Size

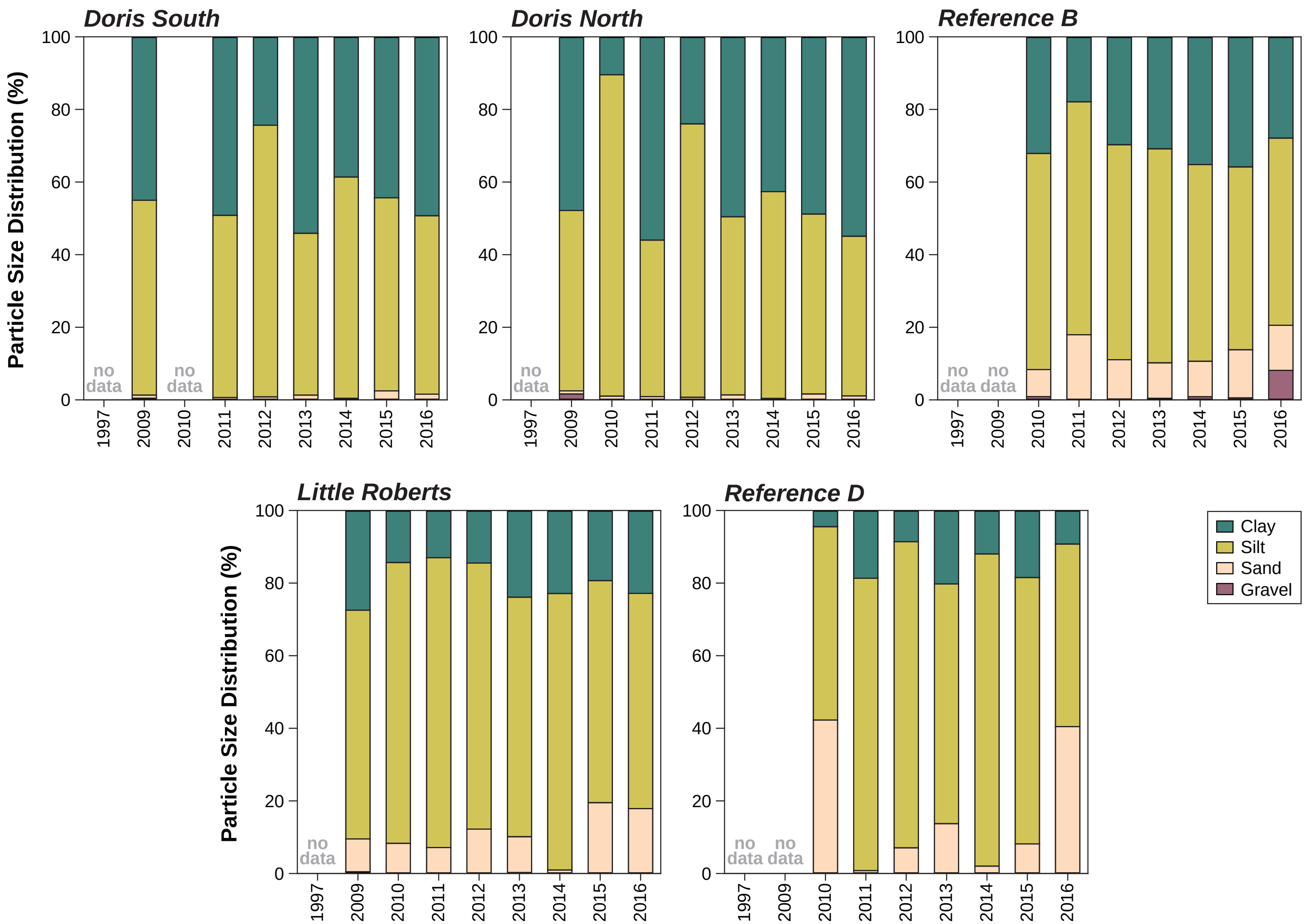
Consistent with previous years, exposure and reference lakes were dominated by fine sediments (silt and clay) in 2016 (Figure 3.4-10). In the three exposure lake sites, the particle size composition was generally similar between 2009 and 2016 (Figure 3.4-10). This was confirmed by the results of the before-after analysis, which found that there were no significant differences in the particle size composition of any exposure lake site between 2009 and 2016 (Doris Lake South: $p = 0.080$ for sand, $p = 0.11$ for silt, and $p = 0.21$ for clay; Doris Lake North: $p = 0.23$ for sand, $p = 0.083$ for silt, and $p = 0.065$ for clay; Little Roberts Lake: $p = 0.38$ for sand, $p = 0.40$ for silt, and $p = 0.35$ for clay; gravel content was highly censored at all exposure sites (> 96% censored), so statistical results are not discussed). Overall, the sediment particle size composition was largely similar between 2009 and 2016 in all the exposure lake sites, which simplifies the comparison of metal and TOC content of sediments between 2009 and 2016.

3.4.2.2 Total Organic Carbon

The mean sediment TOC content decreased marginally but significantly from baseline years to 2016 in both Doris Lake South ($p < 0.0001$) and Doris Lake North ($p = 0.0188$; Figure 3.4-11). There was also a decrease in TOC in sediments from Little Roberts Lake, but the before-after analysis determined that this decrease was not significant ($p = 0.21$). No BACI analysis could be performed because no baseline data exist for the reference lakes. Data from the reference sites show that 2016 TOC levels in sediments were relatively low compared to other years, and also demonstrate that TOC can be naturally variable over time (Figure 3.4-11). The apparent decreases in sediment TOC in Doris Lake South and North and South are well within the range of expected natural variability observed at the reference sites. As well, there was no discharge of TIA water in 2016. Therefore, the observed decreases in TOC content in sediments from the Doris Lake exposure sites were likely due to natural inter-annual variability rather than Project effects.

Figure 3.4-10

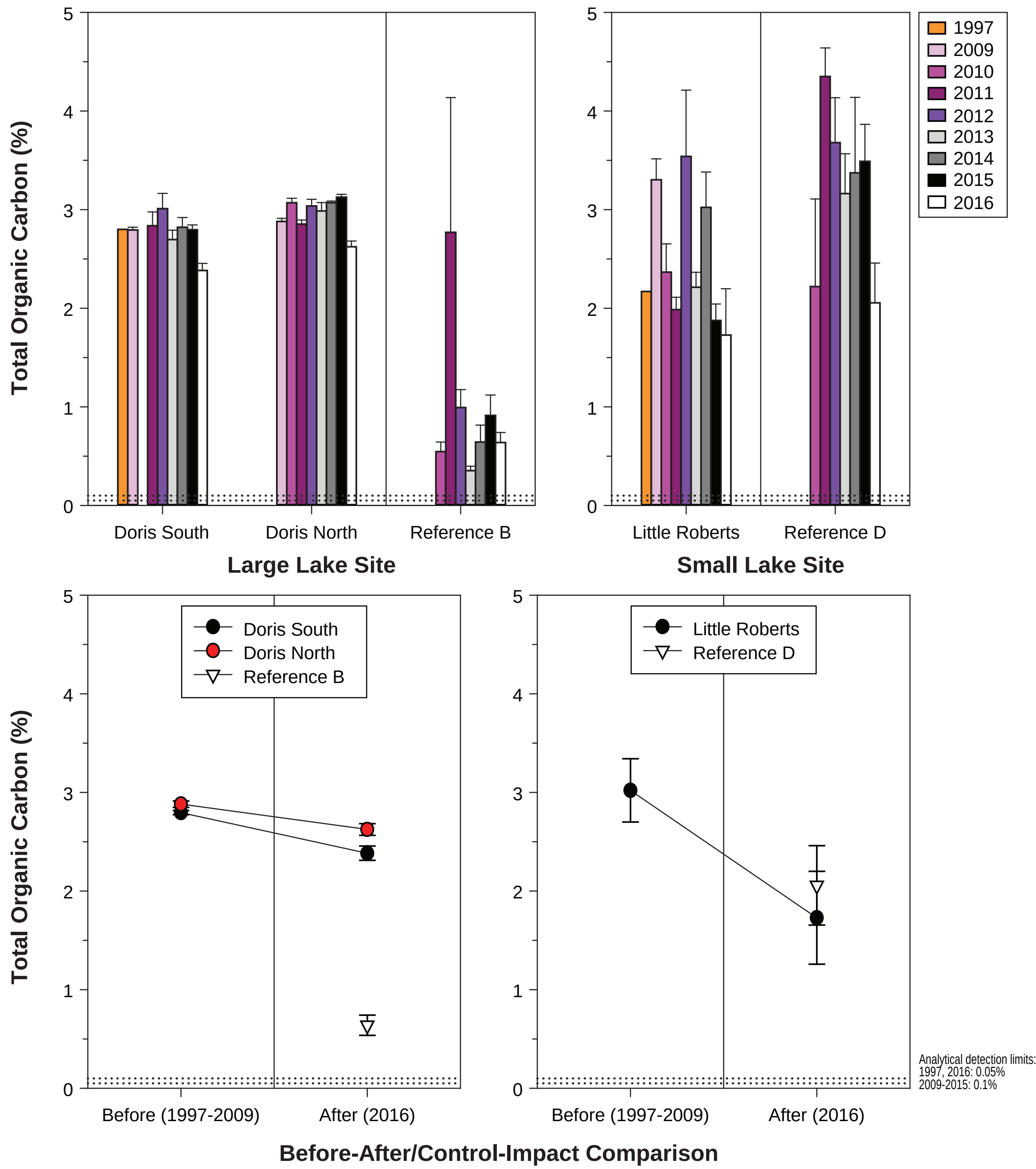
Particle Size Distribution in AEMP Lake Sediments, Doris Project, 1997 to 2016



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 Concentrations in AEMP Lake Sediments, Doris Project, 1997 to 2016



Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below the detection limit are plotted at half the applicable 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.

3.4.2.3 Total Arsenic

As observed in baseline years, the mean 2016 arsenic concentration in Doris Lake South sediments was higher than the CCME ISQG of 5.9 mg/kg and approached the PEL of 17 mg/kg (Figure 3.4-12). The before-after analysis showed that there was no significant difference between the baseline and 2016 mean sediment arsenic concentration at this site (p = 0.91). The mean arsenic concentration in Doris Lake North sediments in 2016 was slightly below the CCME ISQG, and was lower than the baseline mean, though the before-after analysis showed that the baseline and 2016 means were not significantly different (p = 0.088). Arsenic concentrations were generally lower in Little Roberts Lake, where mean annual arsenic concentrations have always remained below the CCME ISQG and PEL guidelines (Figure 3.4-12). The before-after analysis showed that the 2016 mean arsenic concentration in Little Roberts Lake sediments was indistinguishable from the baseline mean (p = 0.068). Therefore, there was no evidence of an adverse effect of Project activities on arsenic levels in exposure lake sediments in 2016.

3.4.2.4 Total Cadmium

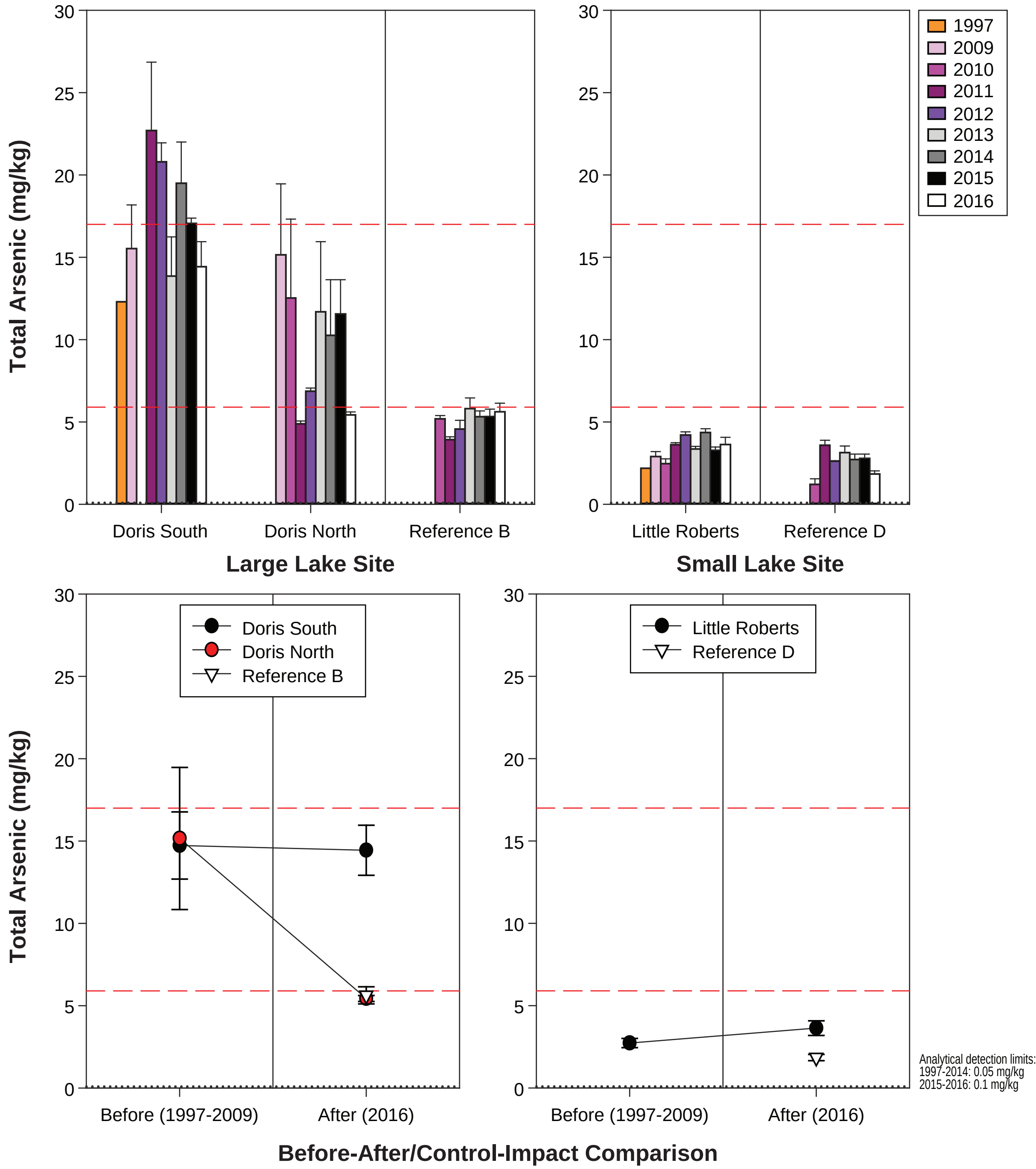
Mean 2016 cadmium concentrations in Doris Lake South and Little Roberts Lake sediments were within the range of baseline means, while the mean 2016 cadmium concentration in Doris Lake North sediments was lower than the 2009 mean (Figure 3.4-13). The 2016 mean cadmium concentrations in exposure and reference 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 2016 for Doris Lake South (p = 0.86) and Little Roberts Lake (p = 0.68). There was a significant decrease in the mean sediment cadmium concentration between 2009 and 2016 in Doris Lake North (p = 0.0090); however, a decline in cadmium levels is not of concern. Thus, 2016 Project activities had no apparent adverse effect on cadmium concentrations in the exposure lake sediments.

3.4.2.5 Total Chromium

Sediment chromium concentrations were naturally high in the exposure lake sediments and in Reference Lake B sediments, as all baseline and 2016 concentrations were above the CCME ISQG of 37.3 mg/kg (Figure 3.4-14). Mean sediment chromium concentrations generally remained below the CCME PEL of 90 mg/kg, with the exception of the 1997 mean for Doris Lake South of 92 mg/kg, which was slightly higher than the PEL (Figure 3.4-14). The before-after analysis showed that mean 2016 sediment chromium concentrations did not differ significantly from baseline means for any exposure lake site (p = 0.53 for Doris Lake South, p = 0.14 for Doris Lake North, and p = 0.069 for Little Roberts Lake). Therefore, there was no evidence of an effect of 2016 Project activities on total chromium concentrations in exposure lake sediments.

Figure 3.4-12

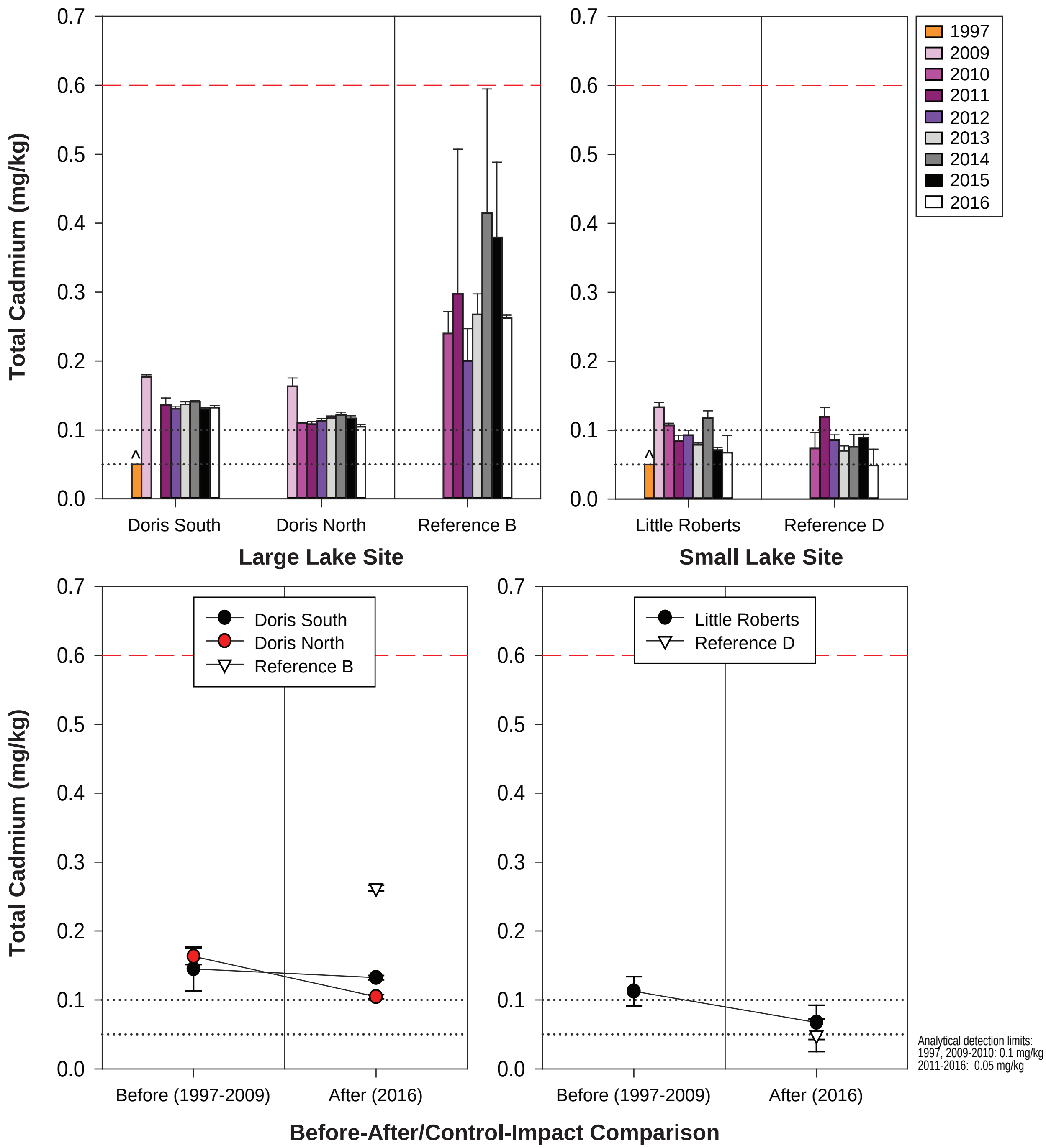
Total Arsenic Concentrations in AEMP Lake Sediments, Doris Project, 1997 to 2016



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) and the probable effects level (PEL) for arsenic (17 mg/kg).

Figure 3.4-13

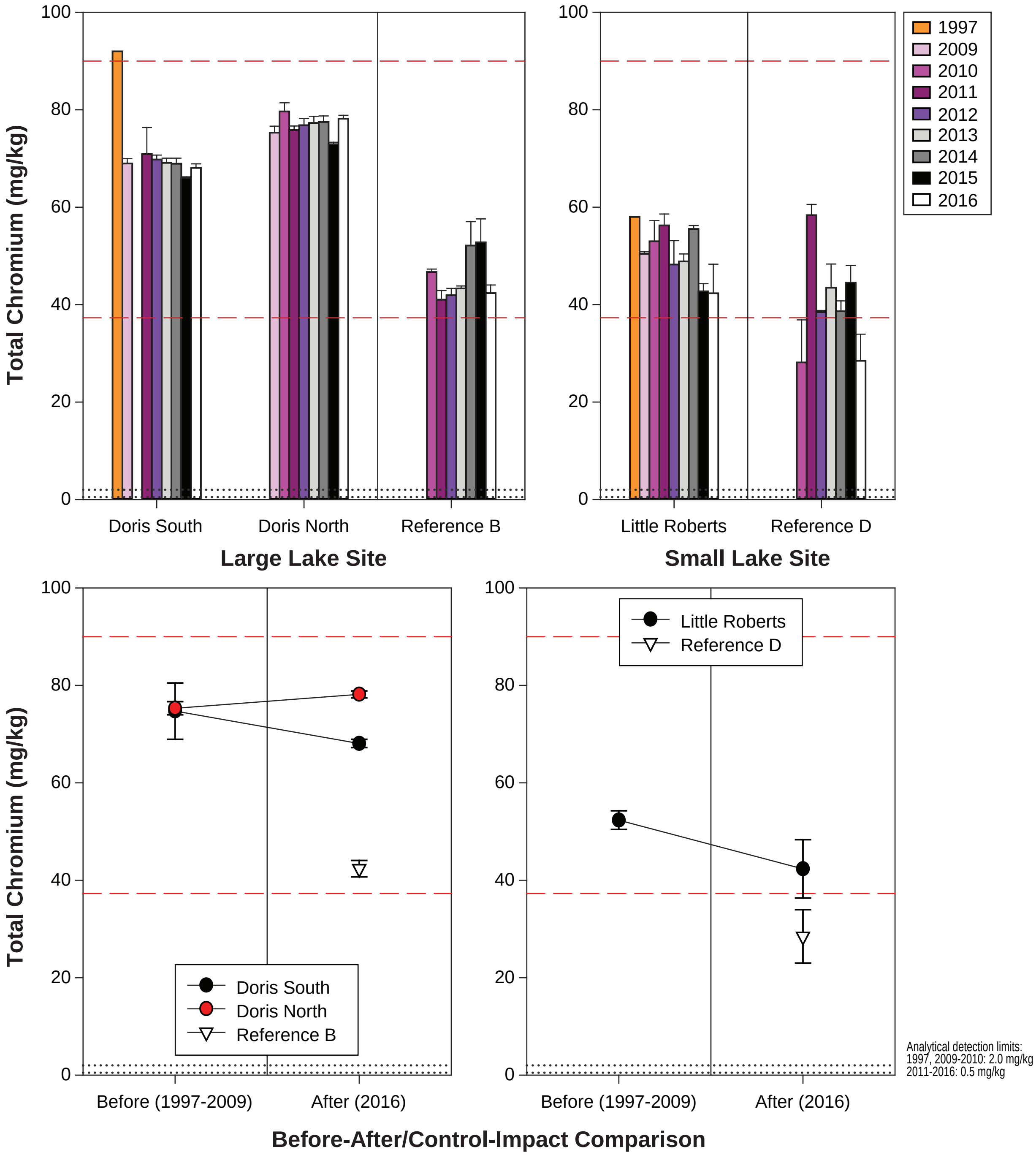
Total Cadmium Concentrations in AEMP Lake Sediments, Doris Project, 1997 to 2016



Notes: Error bars represent the standard error of the mean.
Black 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 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 in AEMP Lake Sediments, Doris Project, 1997 to 2016



Notes: Error bars represent the standard error of the mean.
Black 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 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*

In all three exposure lake sites, mean copper concentrations in sediment decreased between baseline years and 2016 (Figure 3.4-15). Sediments in both exposure sites within Doris Lake were naturally high in copper, as baseline and 2016 mean concentrations were higher than the CCME ISQG of 35.7 mg/kg, but well below the PEL of 197 mg/kg (Figure 3.4-15). In Little Roberts Lake, mean baseline and 2016 concentrations remained below both the ISQG and PEL guidelines (Figure 3.4-15).

The before-after analysis showed that the decrease in copper concentrations between baseline years and 2016 was statistically significant for Doris Lake South (p < 0.0001) and Doris Lake North sediments (p = 0.0015), but not for Little Roberts Lake sediments (p = 0.29). A decrease in copper concentrations in Doris Lake South and North sediments is not of concern; therefore, 2016 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 2016 were lower than the baseline range for all exposure lake sites, 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 2016 sediment lead concentrations were significantly lower than the baseline means for all the exposure lakes (p = 0.024 for Doris Lake South, p = 0.0019 for Doris Lake North, and p < 0.0001 for Little Roberts Lake). A decrease in sediment lead concentrations over time is of no concern; therefore, there was no apparent adverse effect of 2016 Project activities on lead concentrations in the sediments of exposure lakes.

3.4.2.8 *Total Mercury*

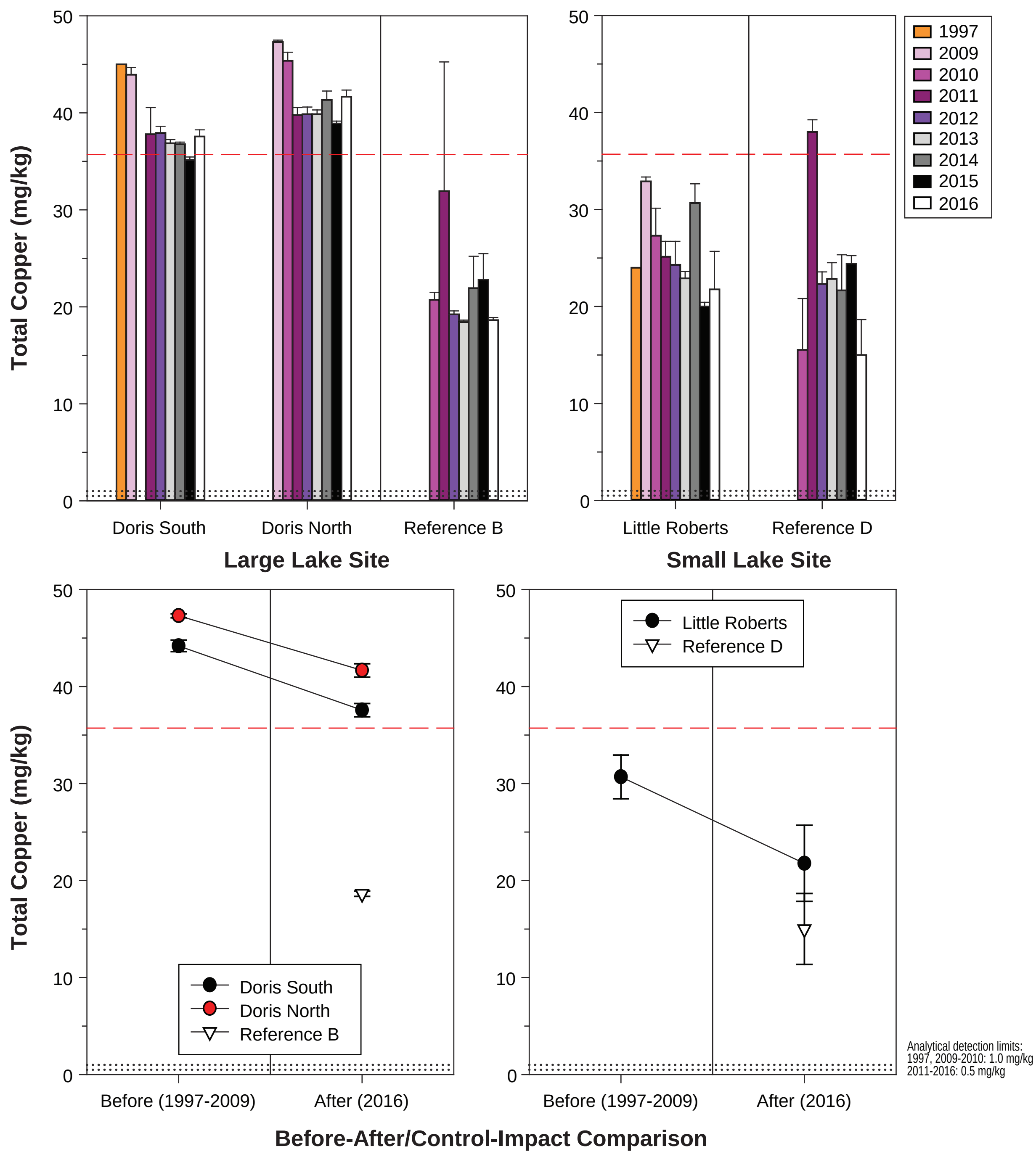
Baseline and 2016 concentrations of mercury in exposure and reference lake sediments were well below the CCME ISQG of 0.17 mg/kg and the PEL of 0.486 mg/kg (Figure 3.4-17). In all exposure sites, 2016 mean concentrations of mercury in sediments were similar to baseline levels, and the before-after analysis confirmed that there were no significant differences between baseline and 2016 means for total mercury in Doris Lake South (p = 0.80), Doris Lake North (p = 0.071), and Little Roberts Lake (p = 0.73). Thus, there was no indication that 2016 Project activities affected sediment mercury concentrations in exposure lakes.

3.4.2.9 *Total Zinc*

2016 zinc concentrations in the exposure and reference lake sediments were below the CCME ISQG of 123 mg/kg and the PEL of 315 mg/kg (Figure 3.4-18). Compared to baseline years, concentrations of zinc in sediments decreased in 2016 in all the exposure lake sites. The before-after analysis showed that this decrease was statistically significant for Doris Lake North (p = 0.015) and Little Roberts Lake (p = 0.033), but not for Doris Lake South (p = 0.37). A decrease in sediment zinc concentrations is not a concern, thus there were no apparent adverse effects of Project activities on sediment zinc concentrations in lake exposure sites.

Figure 3.4-15

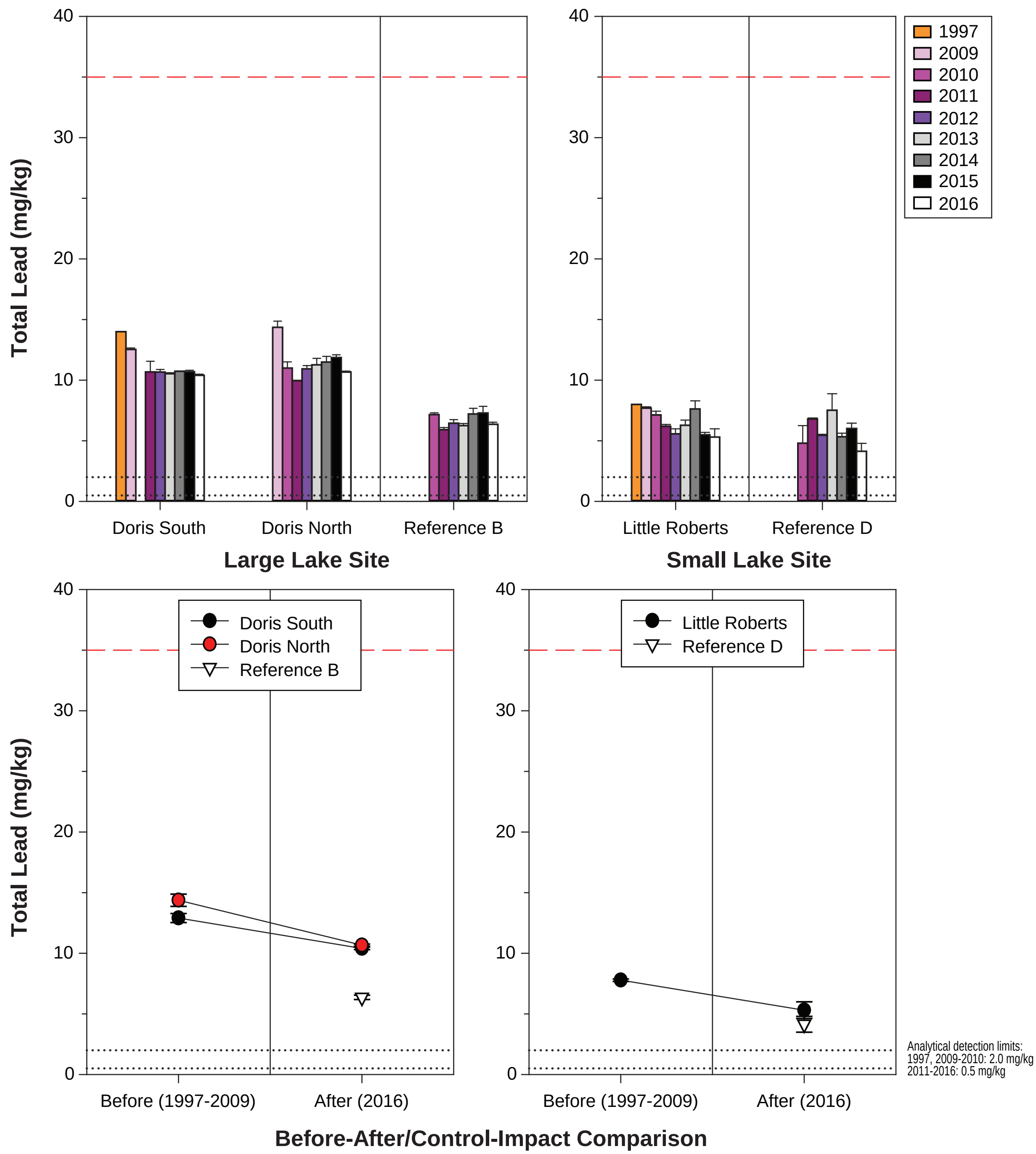
Total Copper Concentrations in AEMP Lake Sediments, Doris Project, 1997 to 2016



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

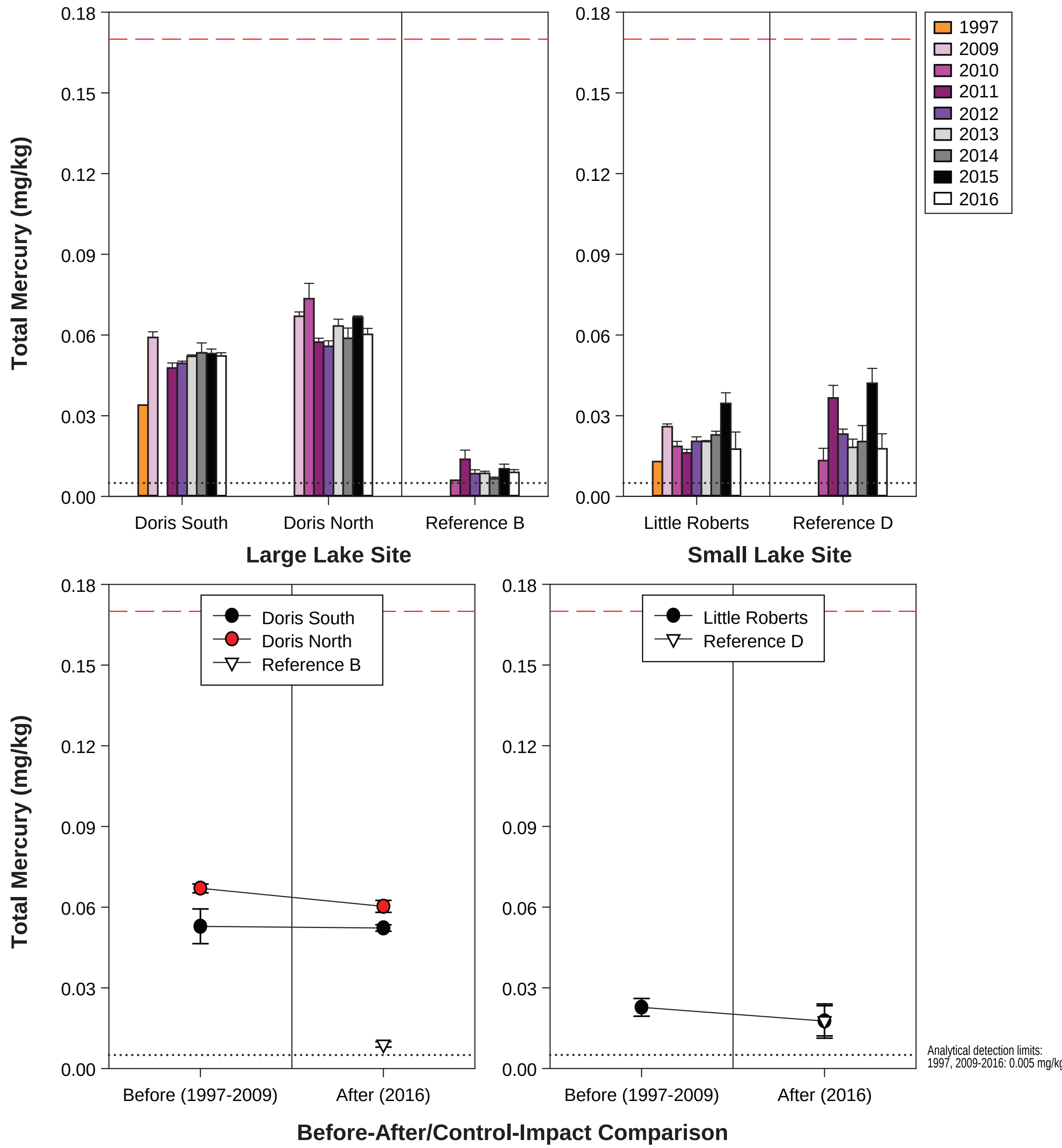
Total Lead Concentrations in AEMP Lake Sediments, Doris Project, 1997 to 2016



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

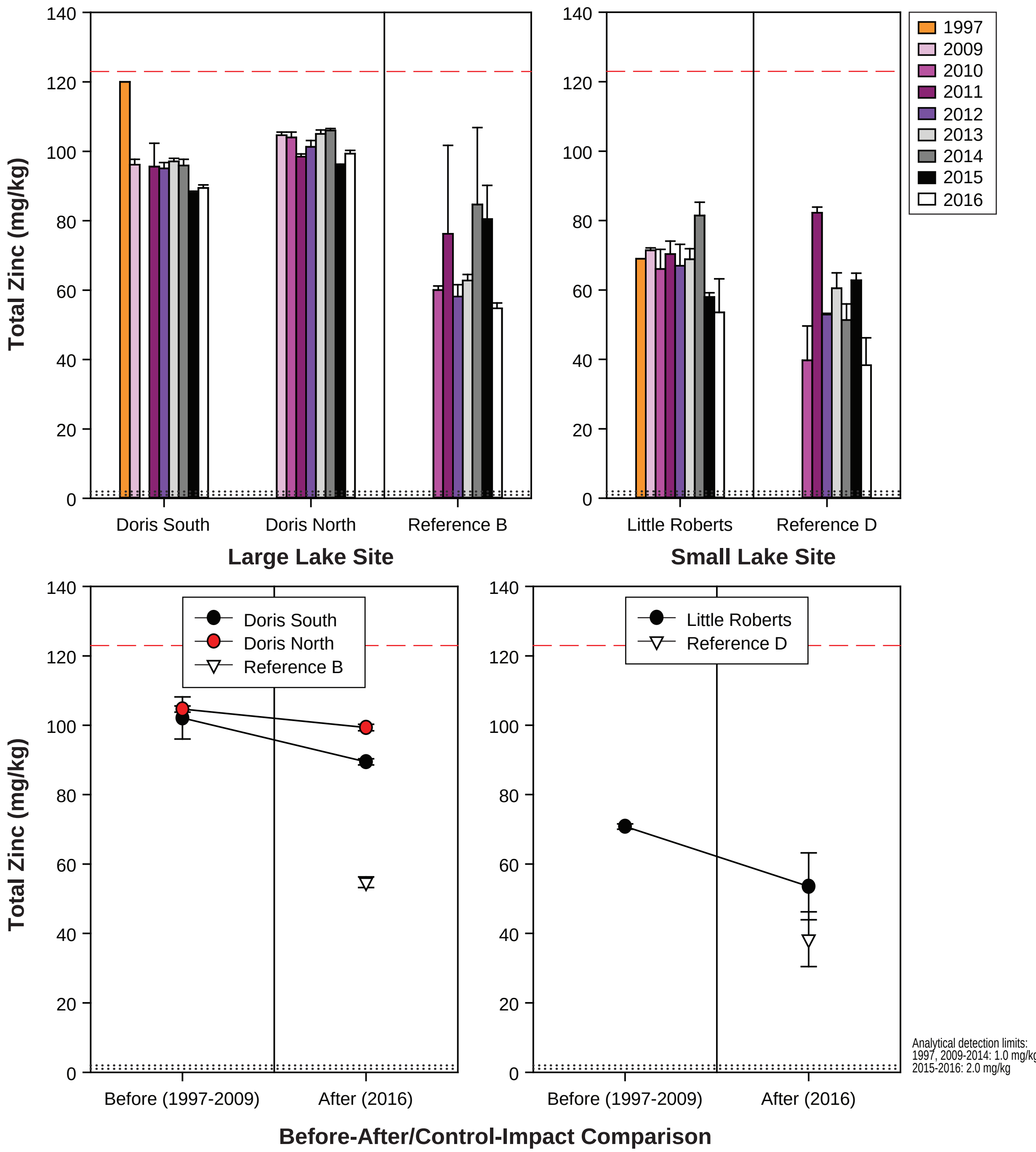
Total Mercury Concentrations in AEMP Lake Sediments, Doris Project, 1997 to 2016



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 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 in AEMP Lake Sediments, Doris Project, 1997 to 2016



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.

3.4.3 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 2016 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 2016 samples (Appendix B). There were no suitable baseline data available for RBE, but there was one year of baseline data available for each 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 2016 could not be directly compared to the change at the reference station, REF-Marine 1, between 2009 and 2016. 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 14 year gap between the collection of before and after data. No BACI analysis could be performed for RBE because there was no suitable baseline sediment data collected near this exposure site.

3.4.3.1 Particle Size

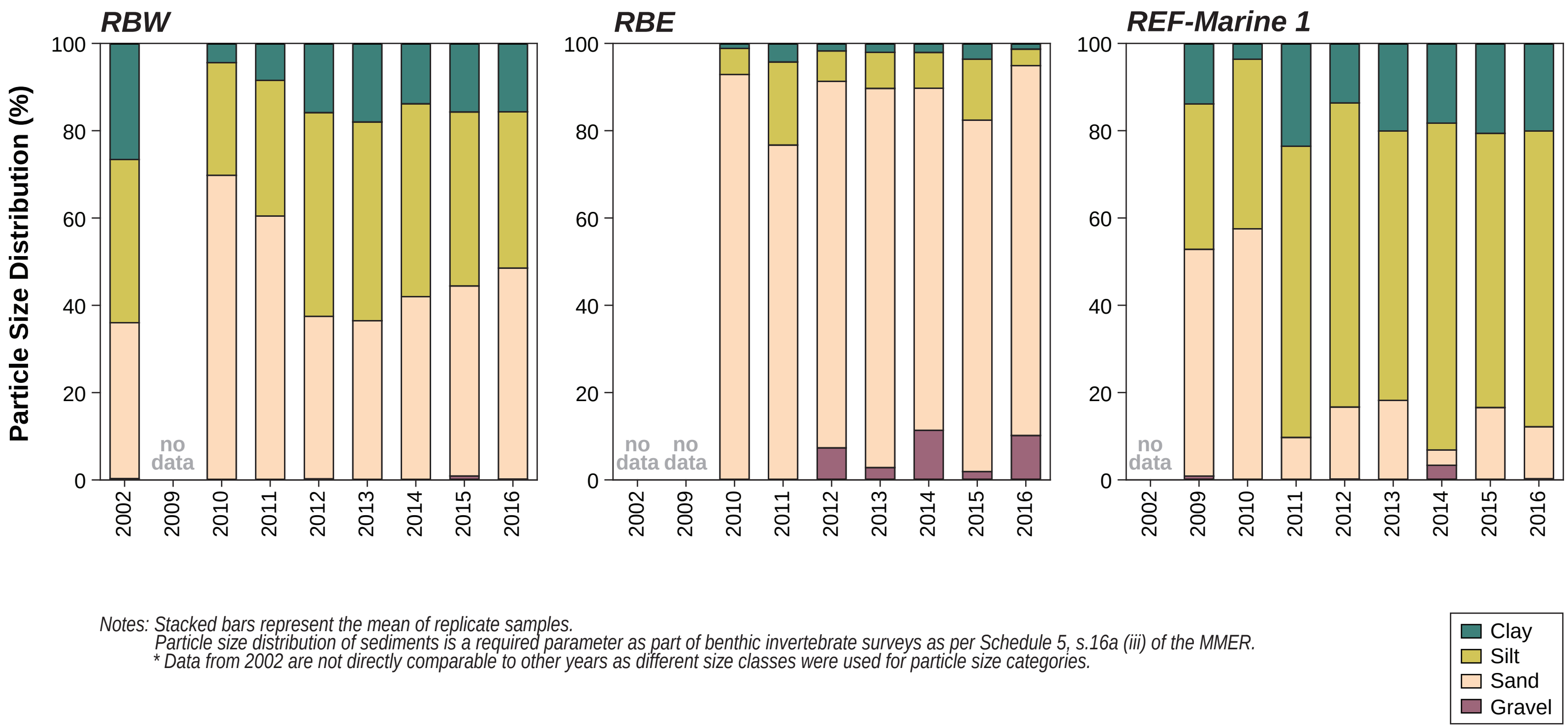
At site RBW in 2016, sediments consisted mostly of sand (48%) and silt (36%), with some clay (16%) and negligible amounts of gravel. The baseline samples collected in 2002 at RBW consisted of a relatively even mix of sand (36%) and silt (37%), with some clay (27%). However, the size classes used for the particle size categories in 2002 differed from those used from 2009 to 2016 (2002 size classes: clay = < 2 µm, silt = 2 to 53 µm, sand = 53 µm to 2 mm, gravel = > 2 mm; 2009 to 2016 size classes: clay = < 4 µm, silt = 4 to 63 µm, sand = 63 µm to 2 mm, gravel = > 2 mm), so these data are not directly comparable, and no before-after analysis was performed. In general, sediments were finer in 2002 than in 2016, which may complicate the interpretation of sediment quality variables as finer sediments tend to contain higher levels of TOC and metals (e.g., Lakhan, Cabana, and LaValle 2003; Secrieri and Oaie 2009; Yao et al. 2015). Differences in particle size composition between baseline years and 2016 are likely due to natural spatial heterogeneity rather than Project effects, particularly given that there was no discharge of TIA water in 2016.

In 2016, sediments collected from marine exposure site RBE consisted mainly of sand (85%), with some gravel (10%) and silt (4%), and little clay (1%). This is similar to the sediment composition observed annually at this site from 2010 to 2015, and there is no evidence of an effect of 2016 Project activities on the sediment particle size at this site (Figure 3.4-19).

Sediments collected at REF-Marine 1 in 2016 were finer than those collected from the marine exposure sites. REF-Marine 1 sediments in 2016 consisted mainly of silt (68%), with some clay (20%) and sand (12%), and negligible amounts of gravel. The before-after analysis showed that compared to 2009, the sediments collected in 2016 contained significantly more silt (p = 0.032); however, the increase in clay and decrease in sand content were not statistically significant (p = 0.47 for clay and p = 0.083 for sand). The finer nature of the sediments collected in 2016 compared to 2009 is a reflection of natural spatial heterogeneity in sediment composition as there are no possible Project effects on the marine reference site, but could complicate the interpretation of before-after and BACI results since metal and TOC concentrations would be expected to be higher in finer sediments such as those collected in 2016.

Figure 3.4-19

Particle Size Distribution in AEMP Marine Sediments, Doris Project, 2002 to 2016



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.
** Data from 2002 are not directly comparable to other years as different size classes were used for particle size categories.*

3.4.3.2 Total Organic Carbon

Overall, the TOC levels measured in marine site sediments appear to be mainly related to the particle size of the sediments, as the sand-dominated site RBE contained very little TOC, while RBW sediments consisting mainly of sand and silt (with some clay) had an intermediate level of TOC, and the silt-dominated REF-Marine 1 contained the highest proportion of TOC (Figures 3.4-19 and 3.4-20). This is the expected pattern as TOC levels are typically higher in finer sediments (e.g., Secrieri and Oaie 2009).

The mean TOC content in sediments from RBW increased slightly from below the detection limit of 0.5% in 2002 (these censored data were substituted with one half of the detection limit, i.e., 0.25%) to 0.46% in 2016 (Figure 3.4-20), and the before-after comparison indicated that this increase was statistically significant ($p < 0.0001$). However, this result was an artifact 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 ($p = 0.19$). Nevertheless, the BACI analysis showed that the increase in TOC from baseline years to 2016 at RBW parallel to the increase observed at the reference site ($p = 0.14$); therefore, any change in TOC was unrelated to Project activities.

As in previous years, the mean TOC content in sediments from RBE was very low (0.06%) in 2016 and was just above the detection limit of 0.05%.

3.4.3.3 Total Arsenic

The arsenic concentrations measured in exposure and reference site sediments in 2016 were below the CCME ISQG of 7.24 mg/kg and the PEL of 41.6 mg/kg. Mean arsenic concentrations in sediments from RBW increased significantly from 2.3 mg/kg in 2002 to 3.7 mg/kg in 2016 (before-after: $p = 0.0004$; Figure 3.4-21). Mean arsenic concentrations also increased significantly from 1.9 mg/kg in 2009 to 4.3 mg/kg in 2016 at REF-Marine 1 ($p = 0.022$), and the BACI analysis showed that there was no evidence of a differential increase in arsenic concentration in RBW sediments compared to the reference site ($p = 0.21$). Thus, any increase in arsenic levels in the sediments at site RBW was unrelated to the Project.

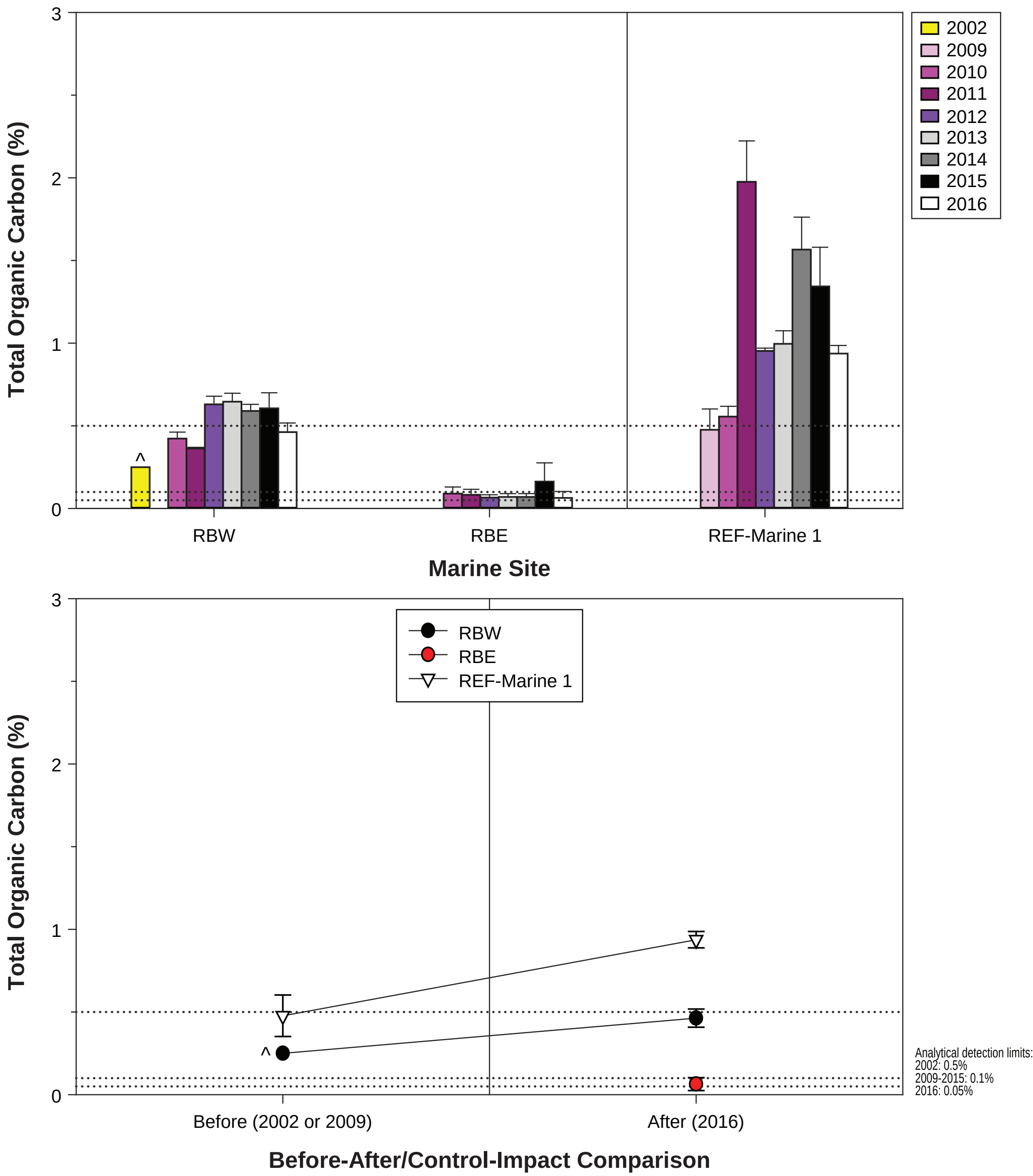
In sediments from site RBE, the mean 2016 arsenic concentration of 1.1 mg/kg was slightly lower than the mean arsenic concentrations measured in sediments at that site between 2010 and 2015, and consistently lower than mean concentrations at RBW and REF-Marine 1. Therefore, there was no evidence of an effect of 2016 Project activities on sediment arsenic concentrations at site RBE.

3.4.3.4 Total Cadmium

Cadmium concentrations were below the analytical detection limit (< 0.05 mg/kg) in all sediment samples collected from RBW and RBE in 2016 (Figure 3.4-22). All 2016 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 2016 Project activities had an effect on cadmium concentrations in sediments at the marine exposure sites.

Figure 3.4-20

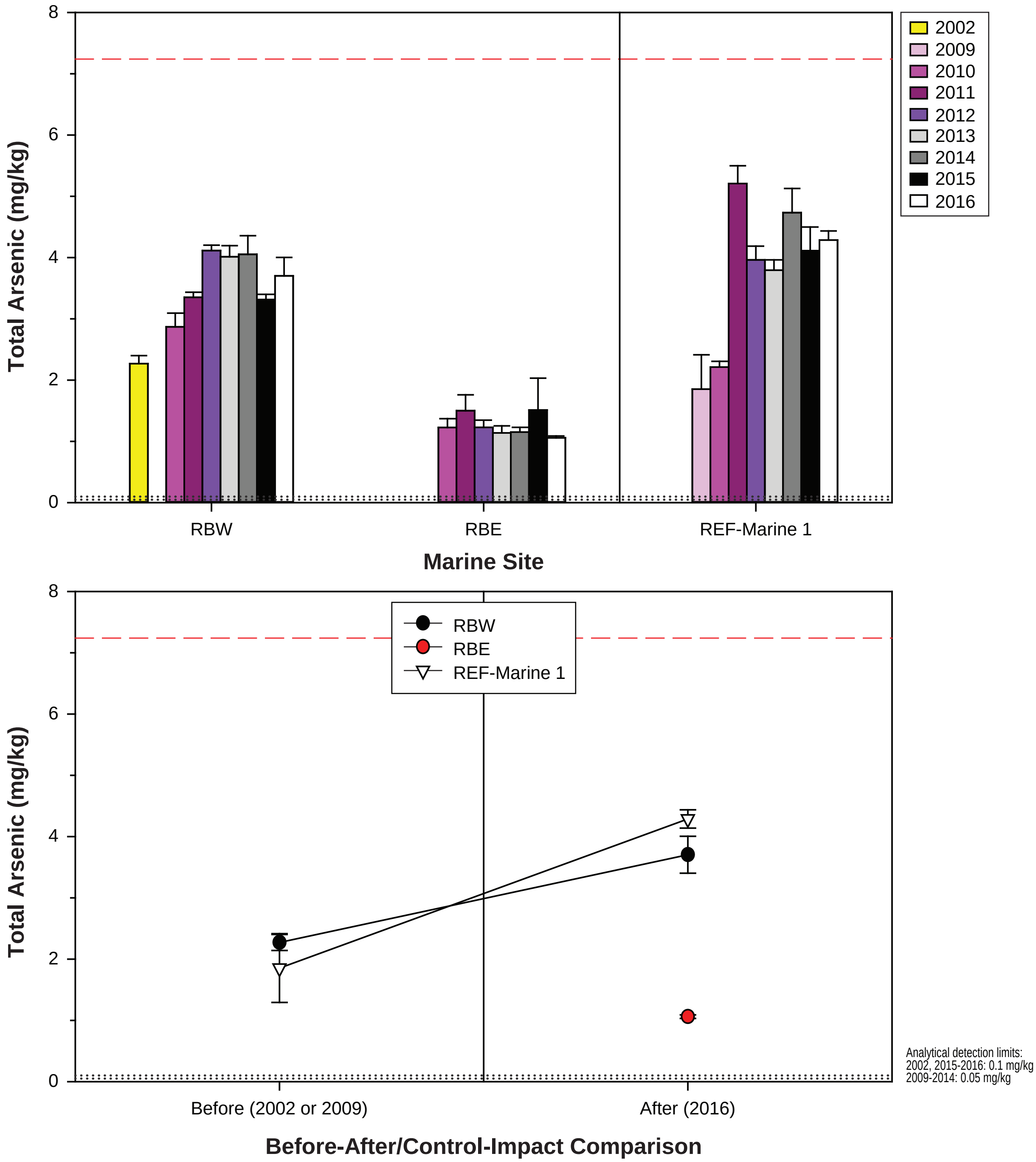
Total Organic Carbon Concentrations in AEMP Marine Sediments, Doris Project, 2002 to 2016



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

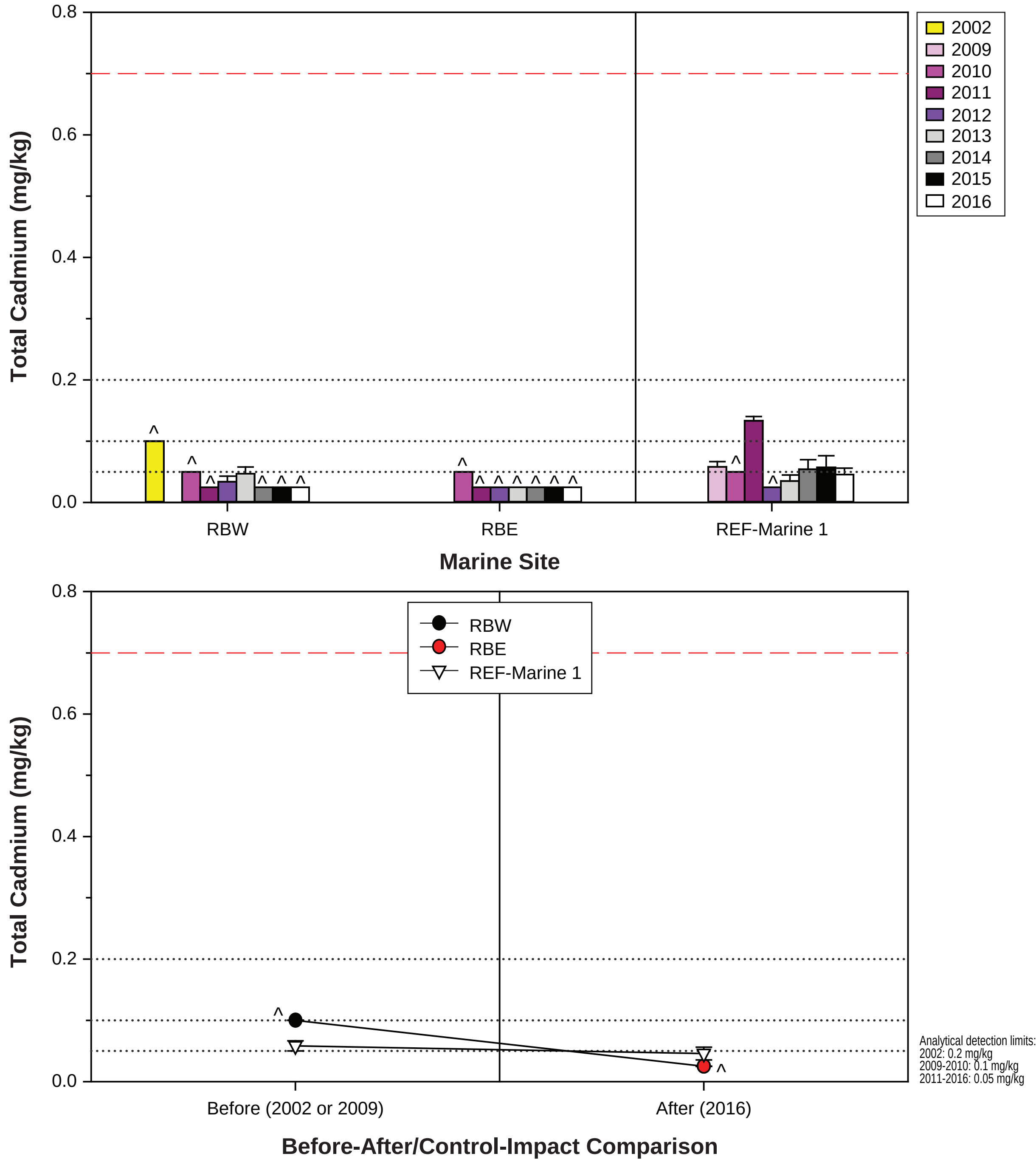
Total Arsenic Concentrations in AEMP Marine Sediments, Doris Project, 2002 to 2016



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

Figure 3.4-22

Total Cadmium Concentrations in AEMP Marine Sediments, Doris Project, 2002 to 2016



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

3.4.3.5 Total Chromium

Mean chromium concentrations in RBW sediments increased slightly but not significantly from 23.6 mg/kg in 2002 to 28.4 mg/kg in 2016 (before-after: $p = 0.21$; Figure 3.4-23). The mean chromium concentration in the sediments of RBW in 2016 remained below the CCME ISQG of 52.3 mg/kg and the PEL of 160 mg/kg and was lower than the mean reference site concentration (33.5 mg/kg), so it is unlikely that Project activities adversely affected sediment chromium concentrations at this exposure site.

No baseline data were available for comparison at RBE, but the mean 2016 chromium concentration in sediments (13.4 mg/kg) was lower than the mean 2016 concentrations in sediments from RBW and REF-Marine 1, and 2016 concentrations at RBE appeared to be similar to 2010 to 2015 concentrations (Figure 3.4-23). All 2016 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 2016 Project activities on sediment chromium concentrations at site RBE in Roberts Bay.

3.4.3.6 Total Copper

Mean copper concentrations in sediments from RBW increased from 11.0 mg/kg in 2002 to 17.6 mg/kg in 2016, which was below the CCME ISQG of 18.7 mg/kg and the PEL of 108 mg/kg (Figure 3.4-24). This increase was statistically significant ($p = 0.0027$) based on the before-after analysis. However, the BACI analysis showed that a parallel increase occurred at the reference site ($p = 0.38$). Thus, it is unlikely that 2016 Project activities are responsible for the increased concentrations of copper measured in the sediments of RBW relative to baseline concentrations.

There are no baseline data for RBE, but the mean 2016 copper concentration in sediments (8.5 mg/kg) was lower than mean concentration in sediments from RBW and REF-Marine 1, which is consistent with the coarser nature of the sediment at RBE (Figure 3.4-24). Copper concentrations at RBE were also relatively consistent over time between 2010 and 2016. Therefore, there was no indication that 2016 Project activities affected sediment copper concentrations at this marine exposure site.

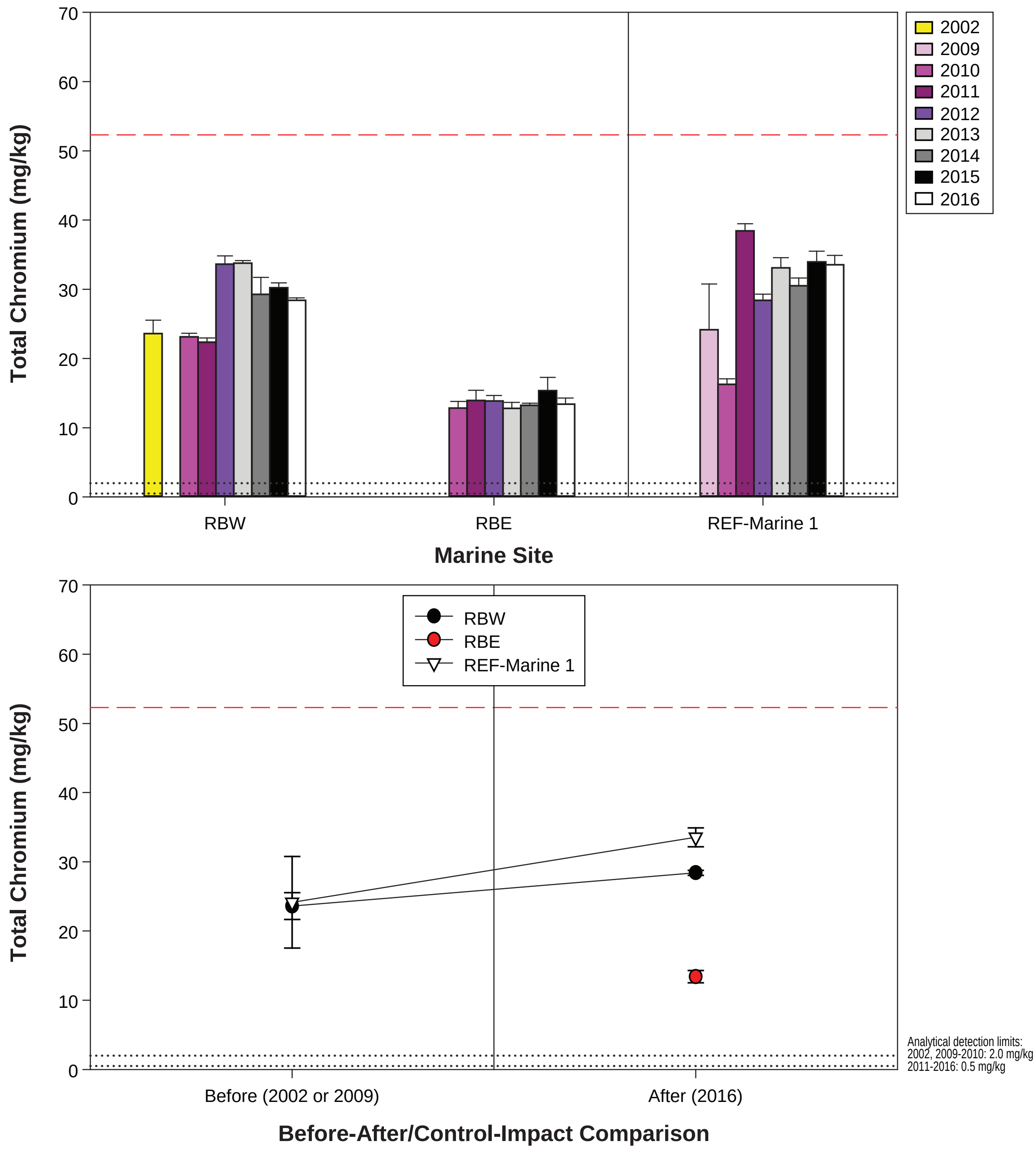
3.4.3.7 Total Lead

All 2016 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 before-after analysis showed that the mean 2016 lead concentration in RBW sediments of 3.8 mg/kg was not significantly different from the 2002 baseline mean of 3.1 mg/kg ($p = 0.16$; Figure 3.4-25). Therefore, Project activities did not adversely affect sediment lead concentrations at this exposure site.

Although no before data exist for RBE, sediments from RBE had the lowest mean 2016 concentration of lead (1.2 mg/kg) compared to the other marine sites, and concentrations were generally consistent over time from 2010 to 2016 (Figure 3.4-25). Thus, there was no apparent effect of 2016 activities on sediment lead concentrations at the marine exposure sites.

Figure 3.4-23

Total Chromium Concentrations in AEMP Marine Sediments, Doris Project, 2002 to 2016



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