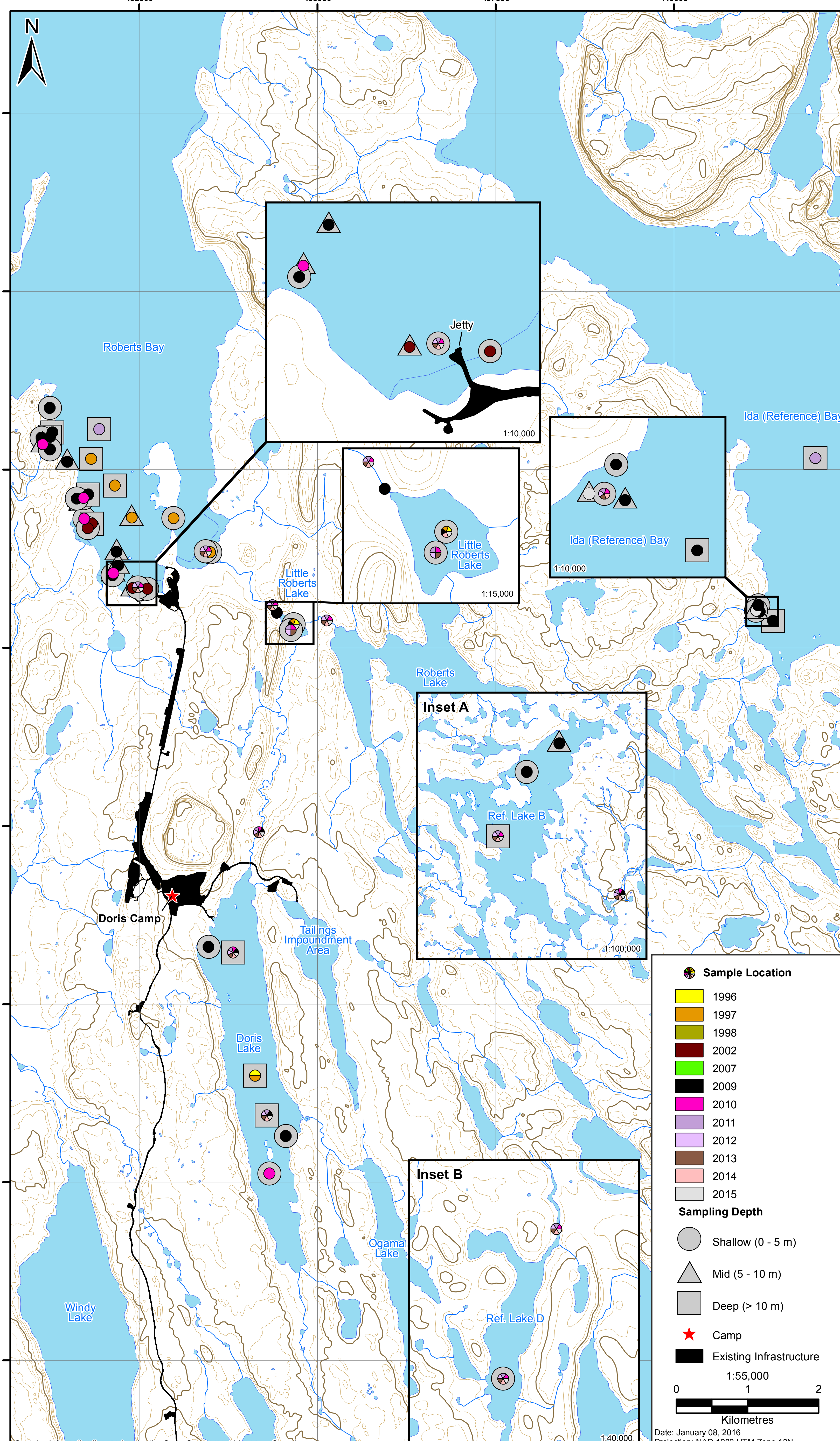
Figure 2.3-2
Sediment Quality Sampling Stations, Doris North Project, 1996 to 2015



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 2.3.2.2. Details specific to the sediment quality analyses are described below.

For lakes sites, there were no appropriate baseline sediment quality data available for the reference lakes; therefore, BACI comparisons of lake sediment quality variables were not possible, and only before-after comparisons were performed.

The key effect of interest in this BACI design is the interaction effect. If exposure site variables increase or decrease over time relative to reference sites (i.e., there is a significant interaction effect), the implication is that the Project may be having an effect on the surrounding sediments (i.e., a non-parallel effect). However, the change over time at exposure sites could also be due to natural episodic events (e.g., higher than average stream flow) or slight differences in sampling locations (leading to differences in grain size composition). Thus, professional judgment was used to determine if a statistically significant interaction effect was likely attributable to Project activities. For the marine environment, the baseline data used for before-after comparisons of exposure and reference sites were from different years (2002 data were used for the exposure site, RBW, and 2009 data were used for the reference site, REF-Marine 1).

For marine sediment quality variables, the before-after change for each exposure site was compared against the change at the corresponding reference site (REF-Marine 1) for the BACI analysis. For stream sediment quality variables, the before-after change for each exposure site was compared against the change obtained using data from both reference streams (Reference B Outflow and Reference D Outflow). Although no baseline data were available for Reference D Outflow, data collected from this site in 2015 contributed some information on the year-effect, which improved the precision of the BACI analysis.

Like water quality, highly censored variables (i.e., > 70% of data less than the detection limit) were considered unreliable and were not subjected to effects analysis. Censored data that were included in the analyses were substituted with a value equal to one half the detection limit.

2.3.2.5 Primary Producers

Data Selection

Primary producer (phytoplankton and periphyton) biomass sampling has been conducted in the Doris North Project area since 1997 (Figure 2.3-3). The main criteria for the selection of historical periphyton and phytoplankton biomass data for inclusion in the effects analysis was the proximity of baseline sampling sites to 2015 sampling sites, and the comparability of sampling methodologies (e.g., phytoplankton biomass samples collected throughout the euphotic zone using an integrated sampler were excluded from the effects analysis as these were not comparable to the discrete surface samples collected in 2015).

For Doris Lake South, historical phytoplankton biomass data collected in 1997 and 2000 were excluded from the effects analysis presented in the 2010 Program report 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 2.3-3). 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 2015 phytoplankton biomass data and were included in the 2015 effects analysis for Doris Lake South.

Effects Analysis

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 2015 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 (2015). 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 2.3.2.2. 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 was available for Reference D Outflow, data collected from this site in 2015 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.

2.3.2.6 Benthos

Data Selection

Benthos data have been collected since 1996 in the Project area (Figure 2.3-4). 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 North Project.

Figure 2.3-3
Phytoplankton and Periphyton Sampling Stations, Doris North Project, 1996 to 2015

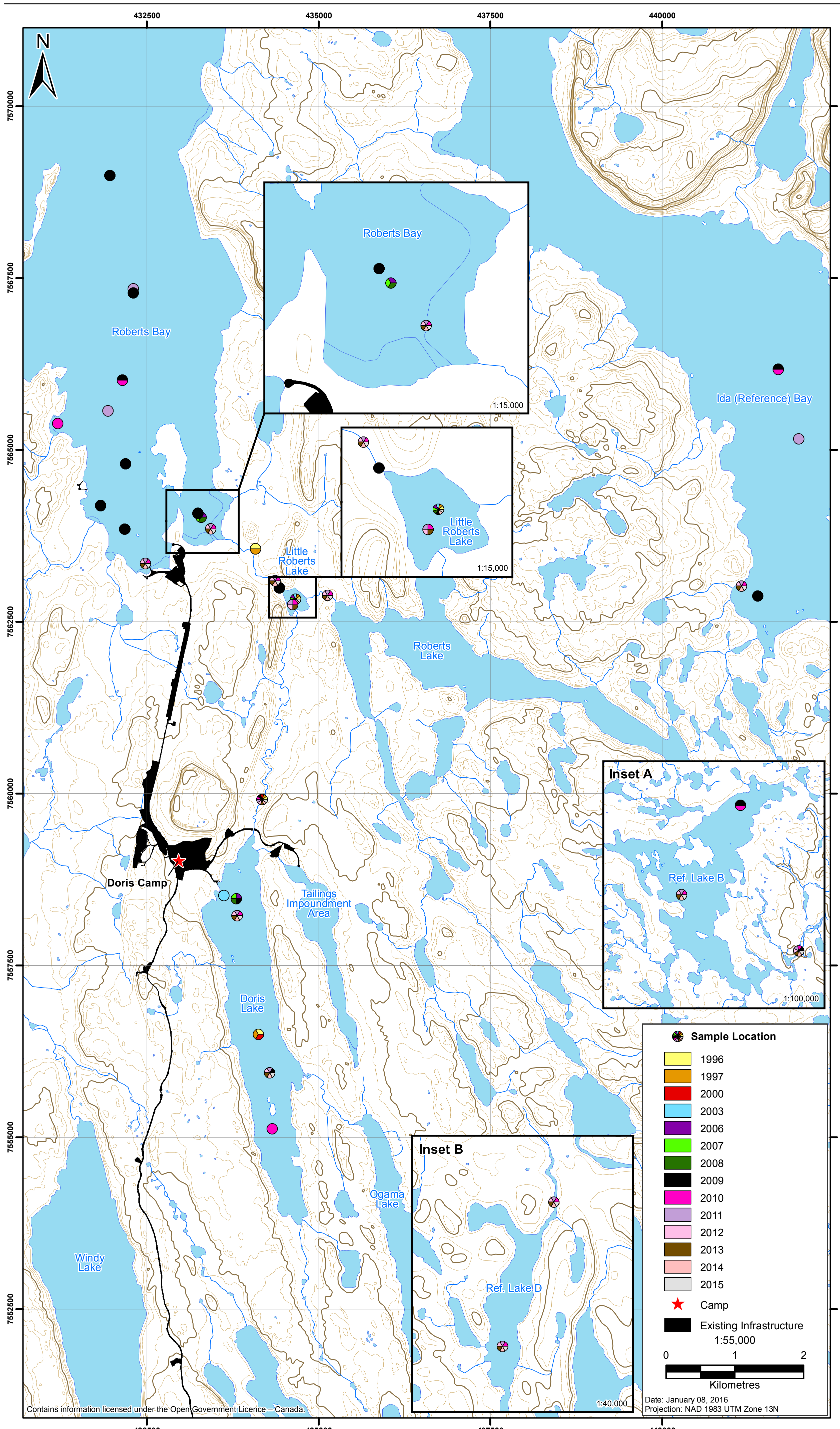
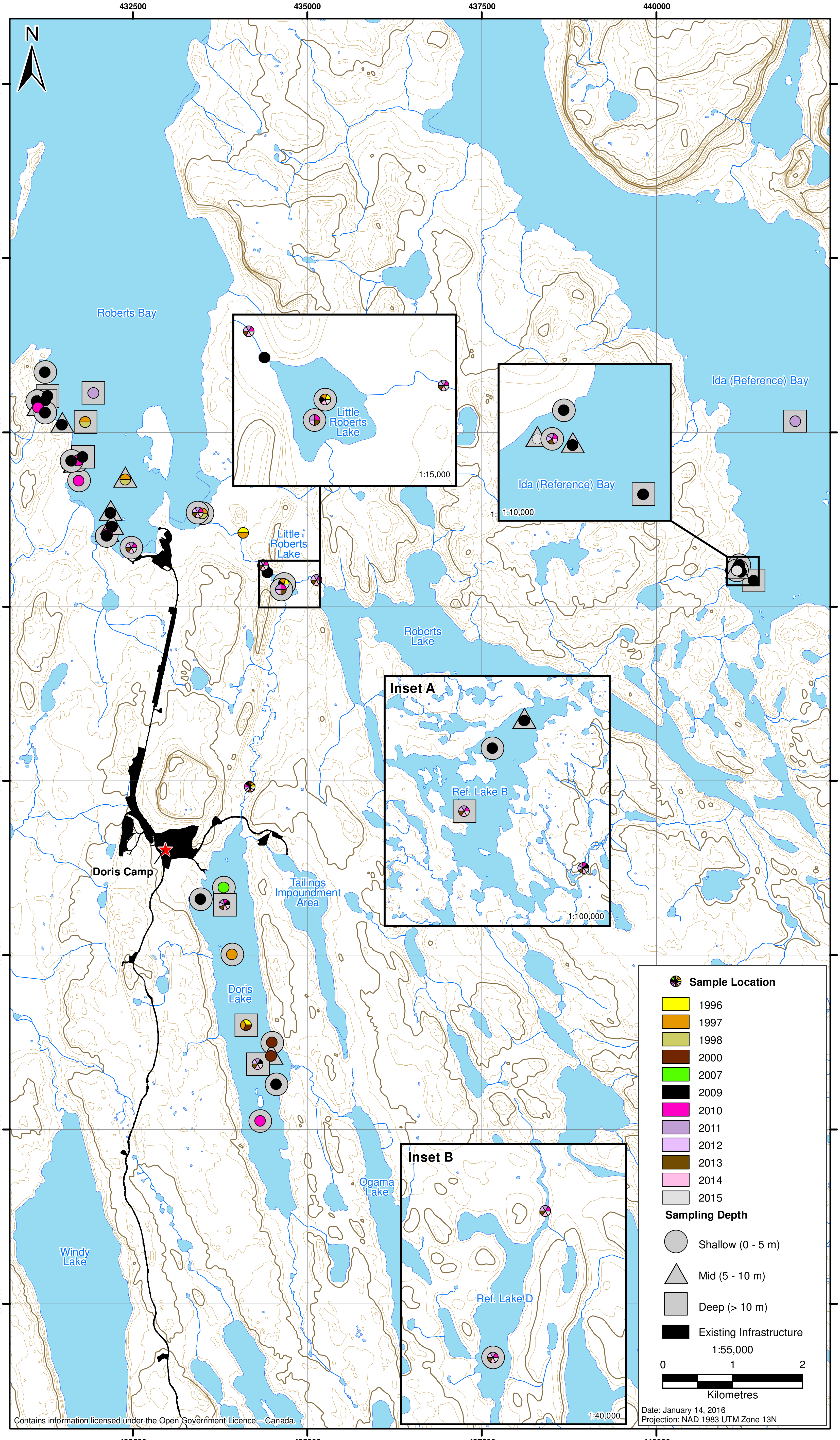


Figure 2.3-4
Benthic Invertebrate Sampling Stations, Doris North Project, 1996 to 2015



The 2010 to 2015 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 (1995-2009) benthos data were not considered comparable to data collected from 2010 to 2015.

Effects Analysis

Because of methodological differences, no baseline benthos data were available for comparison against 2015 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 2015). Because of the limited data available, evidence of non-parallelism between 2010 and 2015 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.

The impact level-by-time model included a *year* effect, a *class* effect (i.e., the classification of the waterbody as an exposure or a reference site), and a *year*class* interaction term, which was the effect of interest representing non-parallelism over time between the two classes of sites. A significance level of 0.05 was used when reviewing the results.

For lake and marine benthos data, the 2010 to 2015 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 2015 trend for each exposure site was compared against the 2010 to 2015 trend obtained using data from both reference streams (Reference B Outflow and Reference D Outflow).

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 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 (Rysgaard, Nielsen, and Hansen 1999; CCME 2015b). Ice cover usually forms in October or November in the Doris North region, and under-ice oxygen profiles were collected in April 2015. The formation of ice cover in November 2014 isolated lakes, streams, and Roberts Bay from any atmospheric inputs such as dust that could have been generated by Project activities between November 2014 and June/July 2015. Therefore, the water column that was profiled in April 2015 reflects activities from 2014 rather than 2015.

Figures 3.1-1 and 3.1-2 present the 2015 and historical under-ice dissolved oxygen profiles for lake and marine sites. 2015 under-ice profiles were collected in late April, and historical under-ice profiles were collected between late April and early June.

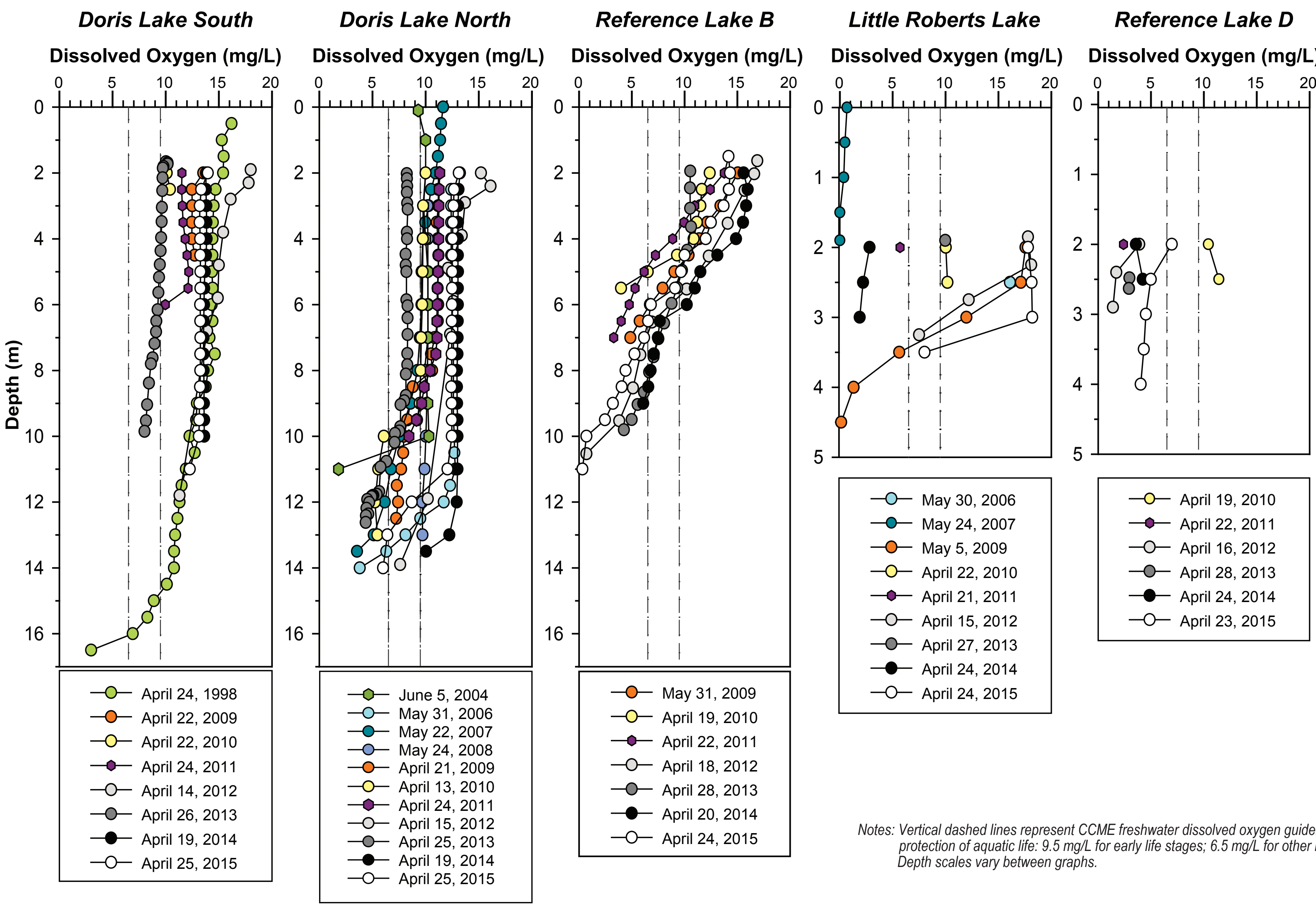
3.1.1 Lakes

The 2015 under-ice dissolved oxygen concentrations in Doris Lake North, Doris Lake South, and Reference Lake B were within the range or higher than concentrations observed during baseline years. At Doris Lake South, dissolved oxygen concentrations throughout the water column were greater than the CCME guideline for freshwater cold-water early life stages (9.5 mg/L; Figure 3.1-1). Dissolved oxygen concentrations decreased with depth in Doris Lake North and Reference Lake B, dropping below the 9.5 mg/L and 6.5 mg/L CCME guidelines for freshwater cold-water non-early life stages at depth, which was consistent with historical observations for these lakes (Figure 3.1-1). This dissolved oxygen decrease at depth is a common phenomenon in seasonally stratified lakes. Overall, the concentrations and trends in under-ice dissolved oxygen concentrations observed in Doris Lake North and South were generally similar to the trend seen in Reference Lake B; hence, no adverse changes to dissolved oxygen concentrations were detected in Doris Lake.

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 3.1-1). In 2015, dissolved oxygen concentrations in Little Roberts Lake were relatively high and above the CCME freshwater cold-water guideline for early life stages of 9.5 mg/L throughout most of the water column, dropping to 8.0 mg/L near the lake bottom. The 2015 winter dissolved oxygen concentrations measured in Little Roberts Lake were similar to baseline measurements in 2009. Thus, no adverse changes to 2015 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 2015 were within the historical range but below the CCME freshwater cold-water guideline for non-early life stages of 6.5 mg/L throughout most of the water column.

Figure 3.1-1

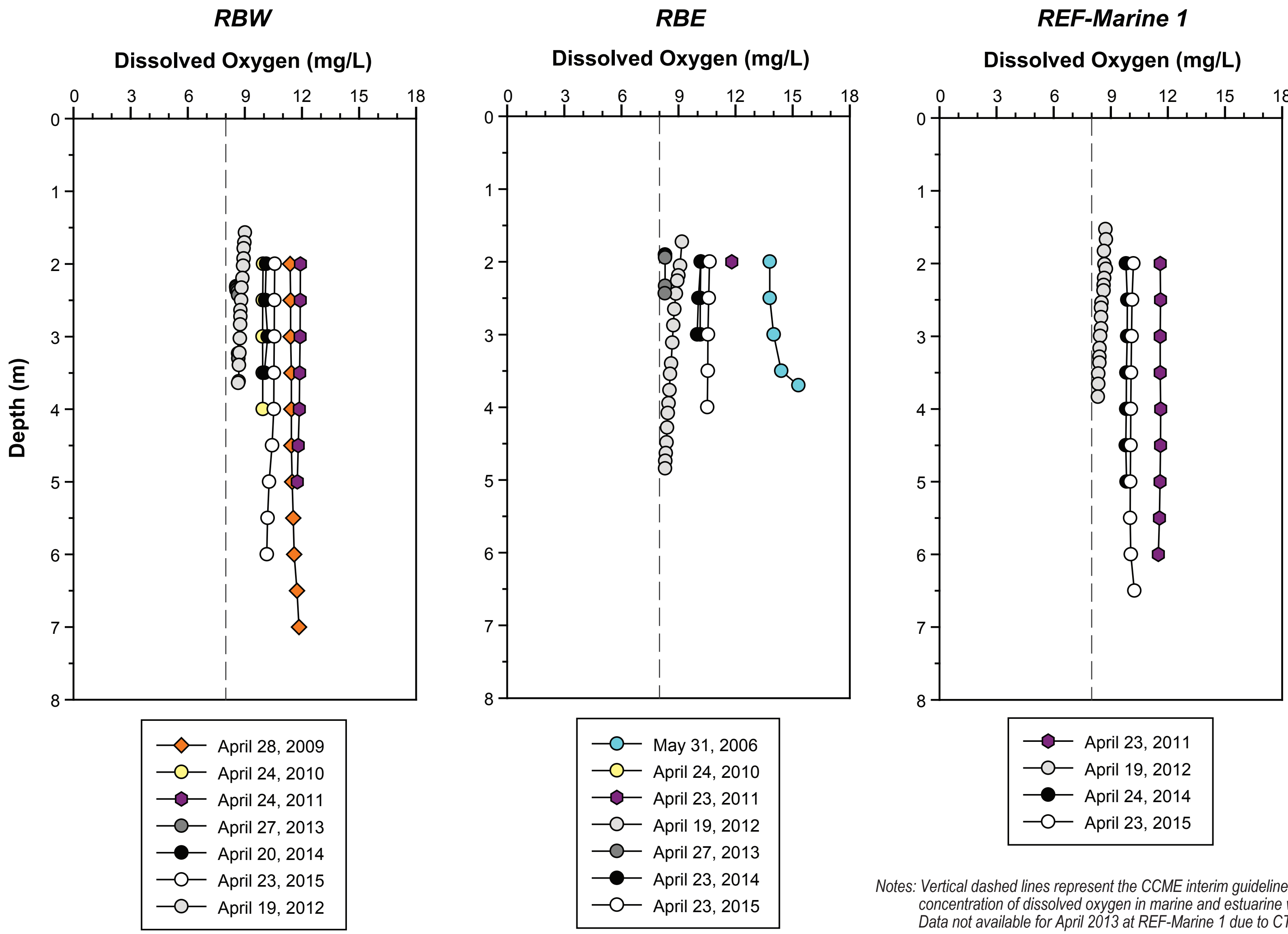
Winter Dissolved Oxygen Concentrations at AEMP Lake Sites, Doris North Project, 1998 to 2015



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

Figure 3.1-2

Winter Dissolved Oxygen Concentrations at AEMP Marine Sites, Doris North Project, 2006 to 2015



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.

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 2015 under-ice dissolved oxygen concentrations were similar at both of the marine exposure sites RBW and RBE, averaging 10.4 and 10.6 mg/L throughout the water column, respectively (Figure 3.1-2). These concentrations are above the CCME interim guideline for the minimum dissolved oxygen concentrations for the protection of aquatic life in marine and estuarine waters (8.0 mg/L). Baseline under-ice dissolved oxygen concentrations at the marine exposure sites in 2010 were similar to, or slightly lower than, 2015 concentrations. Under-ice dissolved oxygen concentrations at the reference site (REF-Marine 1) in April 2015 were similar to those observed at the exposure sites (mean: 10.1 mg/L). Thus, there was no evidence of adverse effects on marine dissolved oxygen levels as a result of Project activities.

3.2 SECCHI DEPTH

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

3.2.1 Lakes

Figure 3.2-1 shows the mean annual Secchi depth at lakes sites from 1995 to 2015. Mean annual Secchi depth was similar among years and among exposure lakes, generally ranging between 1.0 and 2.1 m at Doris Lake South, Doris Lake North, and Little Roberts Lake. The Secchi depth recorded at Doris Lake South in August 2000 (4.2 m) was greater than in other years. Mean annual Secchi depths were generally greater at the reference lakes, ranging from 5.4 to 7.5 m in Reference Lake B, and from 2.1 to 3.7 m in Reference Lake D.

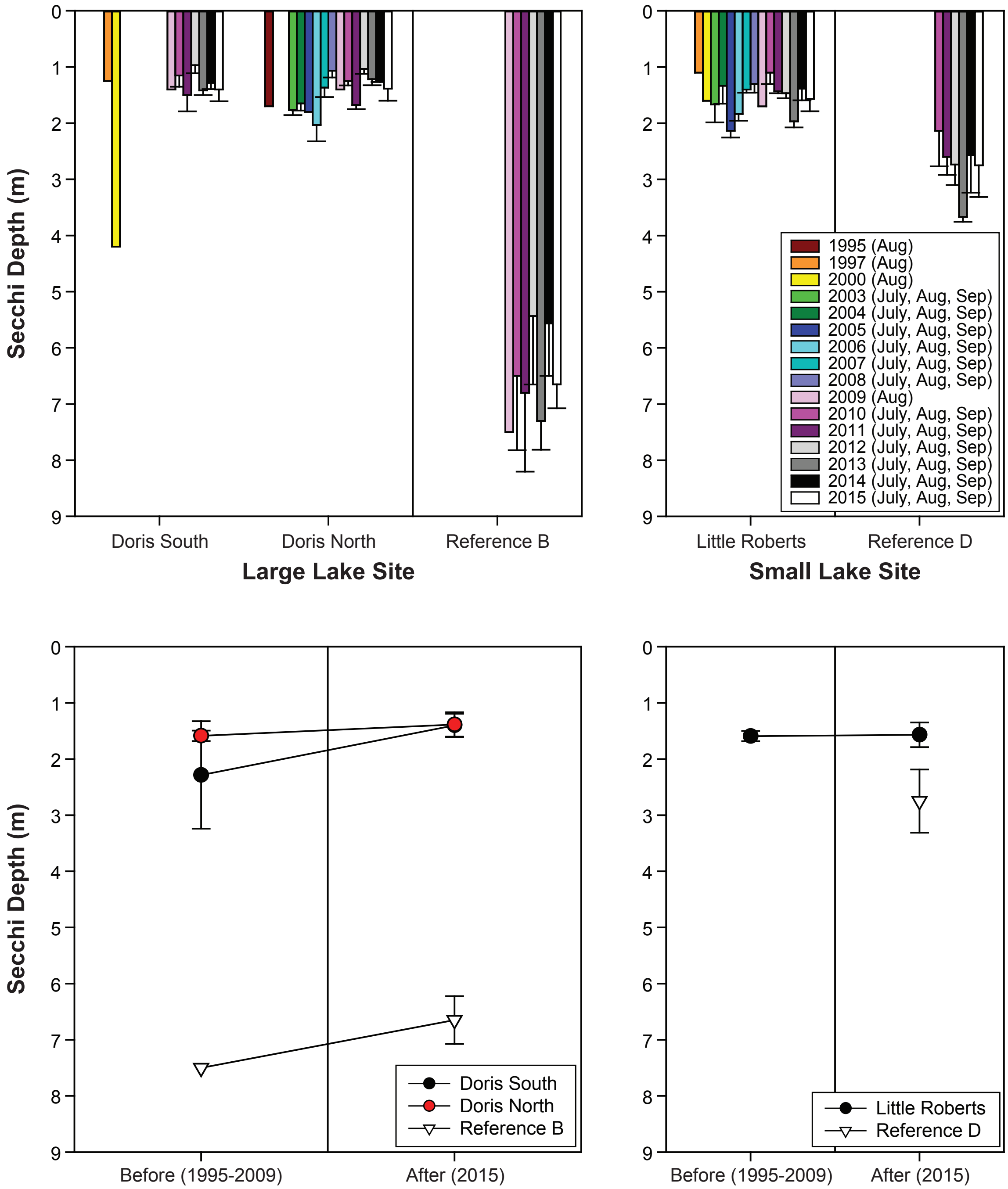
Mean 2015 Secchi depths in the exposure lakes were within the range of baseline measurements. The before-after comparison confirmed that the baseline mean Secchi depth was not distinguishable from the 2015 mean Secchi depth for any exposure lake ($p = 0.76$ for Doris Lake South, $p = 0.56$ for Doris Lake North, and $p = 0.97$ for Little Roberts Lake). Therefore, there was no apparent effect of Project activities on lake Secchi depth in 2015.

3.2.2 Marine

The Secchi depth at the shallow marine site RBE reached the bottom during July, August, and September of 2015 indicating that the euphotic zone extended throughout the entire water column (Appendix A). At site RBW, Secchi depths did not reach the bottom sediments in 2015 (Appendix A); however, the euphotic zone extended throughout the entire water column during August sampling. As there was no indication of water clarity concerns, Secchi depth was not evaluated for the Roberts Bay sites RBW and RBE.

Figure 3.2-1

Secchi Depth in AEMP Lake Sites, Doris North Project, 1995 to 2015



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

3.3 WATER QUALITY

A specific subset of water quality variables (see Table 2.3-1) was evaluated to determine whether 2015 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 2015b) 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

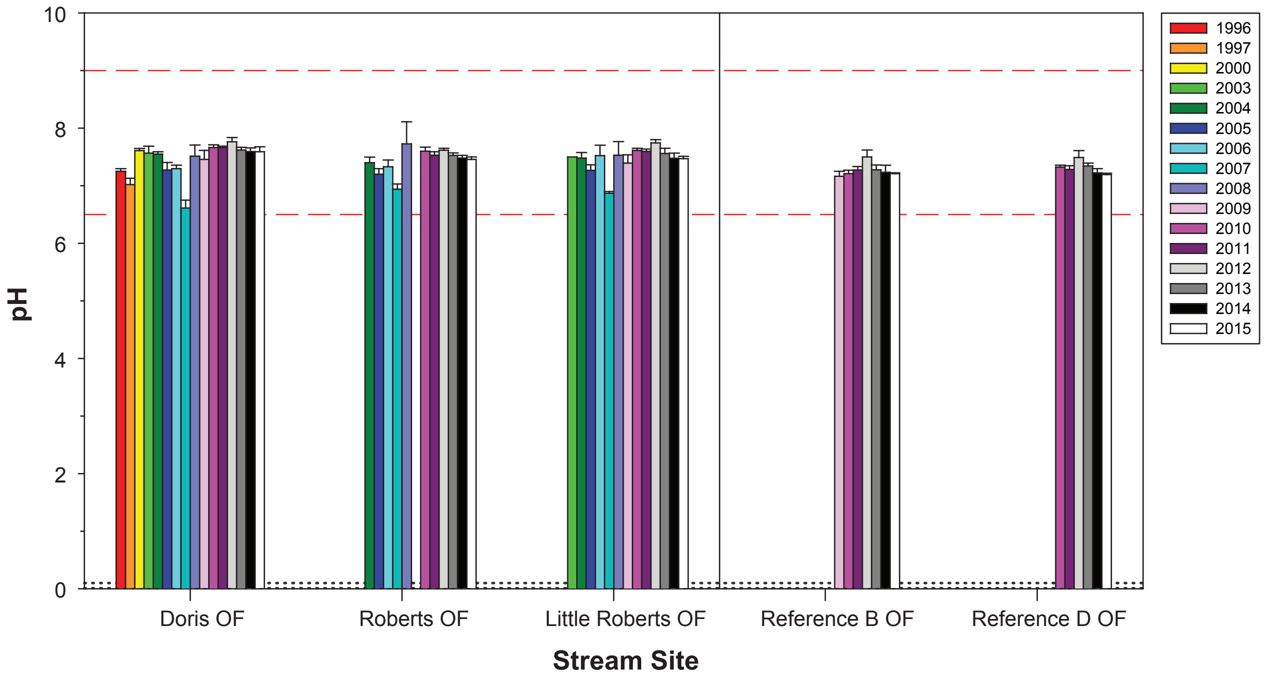
Water quality samples were collected from three exposure streams (Doris Outflow, Roberts Outflow, and Little Roberts Outflow) and two reference streams (Reference B Outflow and Reference D Outflow) in 2015. For the exposure streams, relevant baseline data are available from 1996, 1997, 2000, and 2003 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.

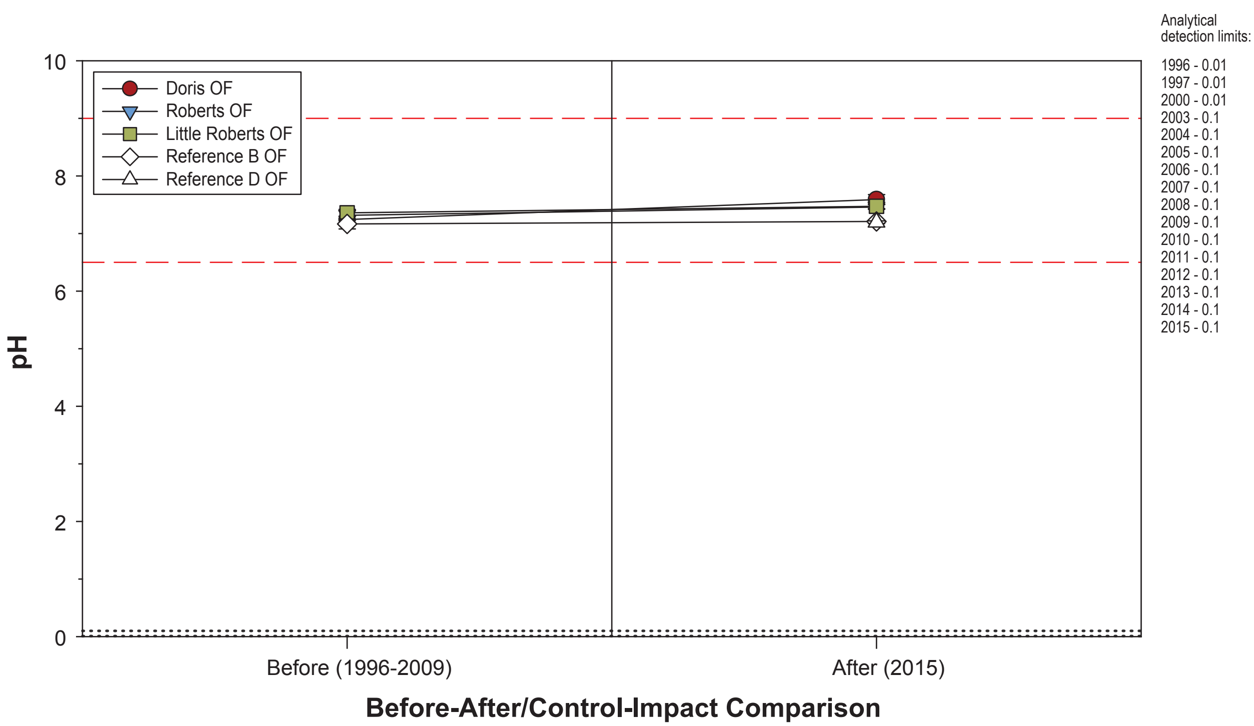
3.3.1.1 pH

pH is a required variable for water quality monitoring as per Schedule 5, s. 7(1)(c) of the MMER. 2015 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 2015 ranged from 7.3 to 7.8, while reference stream pH ranged from 7.2 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 2015 mean pH in either exposure stream ($p = 0.50$ for Doris Outflow and $p = 0.43$ for Little Roberts Outflow). Therefore, there were no apparent effects of 2015 Project activities on the pH of exposure streams.

Figure 3.3-1

pH in AEMP Stream Sites, Doris North Project, 1996 to 2015





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.

3.3.1.2 *Total Alkalinity*

Total alkalinity is a required variable for effluent characterization and water quality monitoring as per Schedule 5, s. 4(1) and s. 7(1)(c) of the MMER. Total alkalinity (as $CaCO_3$) varied among streams with consistently higher levels in the exposure streams than the reference streams (Figure 3.3-2). The before-after comparisons determined that there were no significant differences between the before and after periods for either of the exposure streams ($p = 0.52$ for Doris Outflow and $p = 0.36$ for Little Roberts Outflow). Thus, there was no apparent effect of 2015 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 ($p = 0.97$ for Doris Outflow and $p = 0.72$ for Little Roberts Outflow); therefore, there was no apparent effect of 2015 Project activities on stream hardness.

3.3.1.4 *Total Suspended Solids*

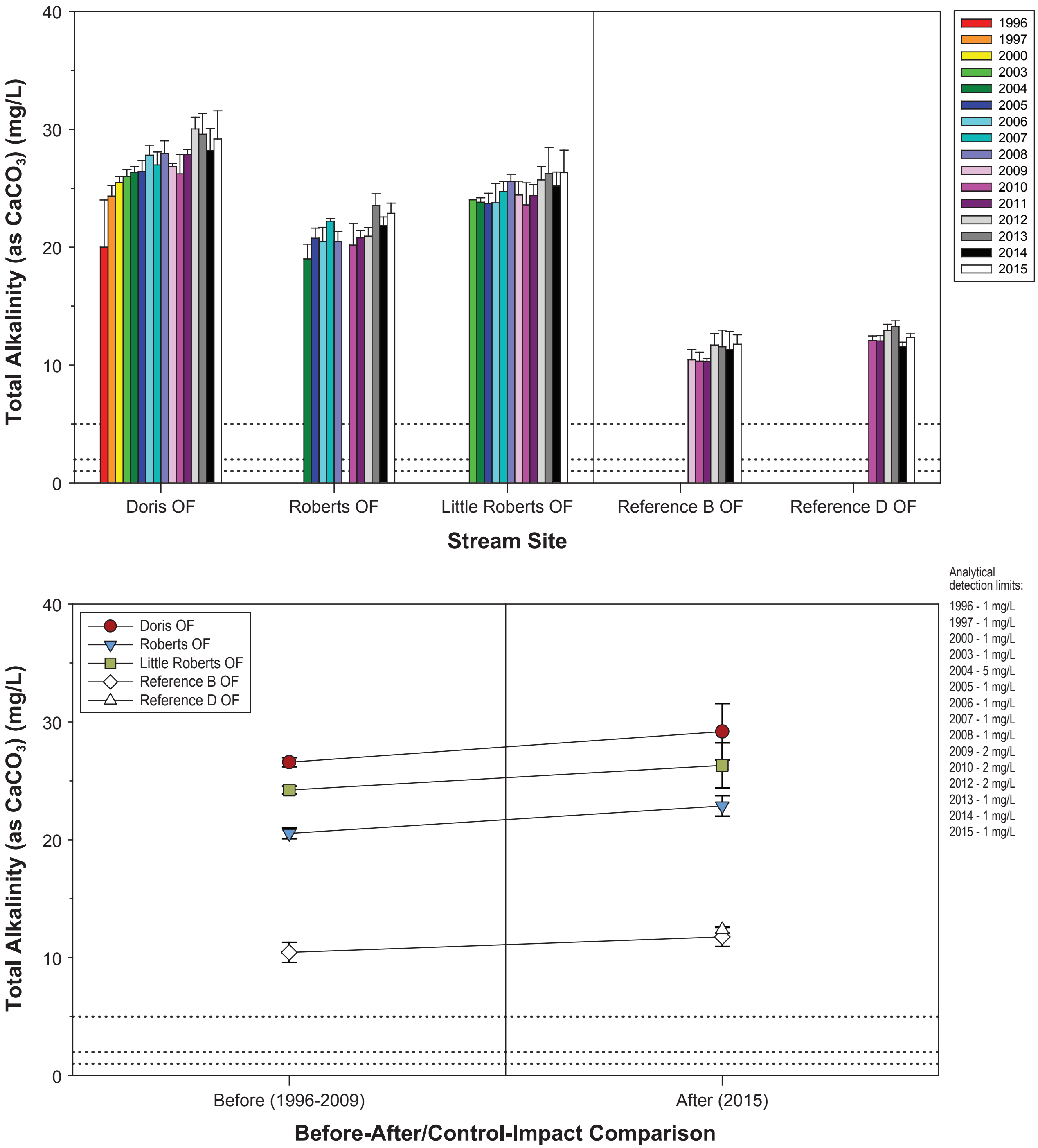
Total suspended solids (TSS) are regulated as deleterious substances in effluents as per Schedule 4 of the MMER. Mean TSS concentrations were variable among streams. Within each stream, there was also relatively high inter-annual and within-year variability (Figure 3.3-4). It is therefore difficult to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

The mean 2015 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 2015 and baseline concentrations in either of the exposure streams ($p = 0.93$ for Doris Outflow and $p = 0.56$ for Little Roberts Outflow). Therefore, there is no evidence of an effect of 2015 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 2015b). Because there was no significant increase in TSS concentrations from baseline levels in Doris or Little Roberts outflows, 2015 TSS concentrations in these streams were below the CCME guideline.

Figure 3.3-2

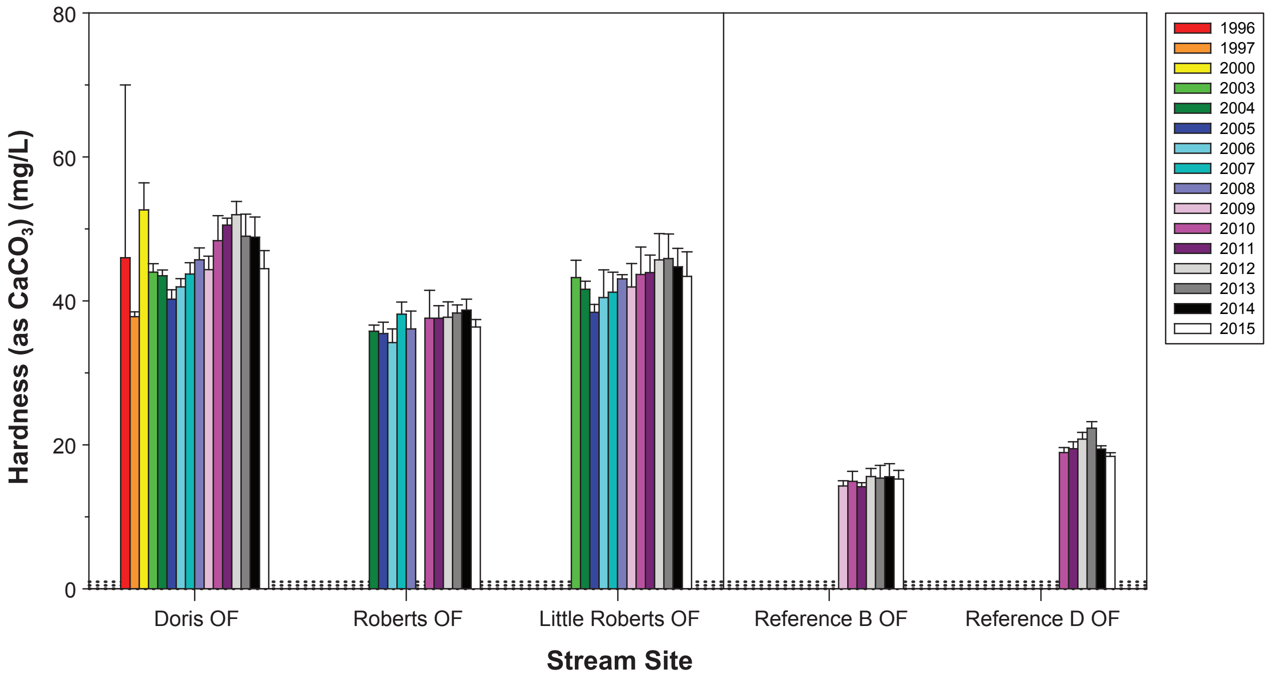
Total Alkalinity in AEMP Stream Sites, Doris North Project, 1996 to 2015

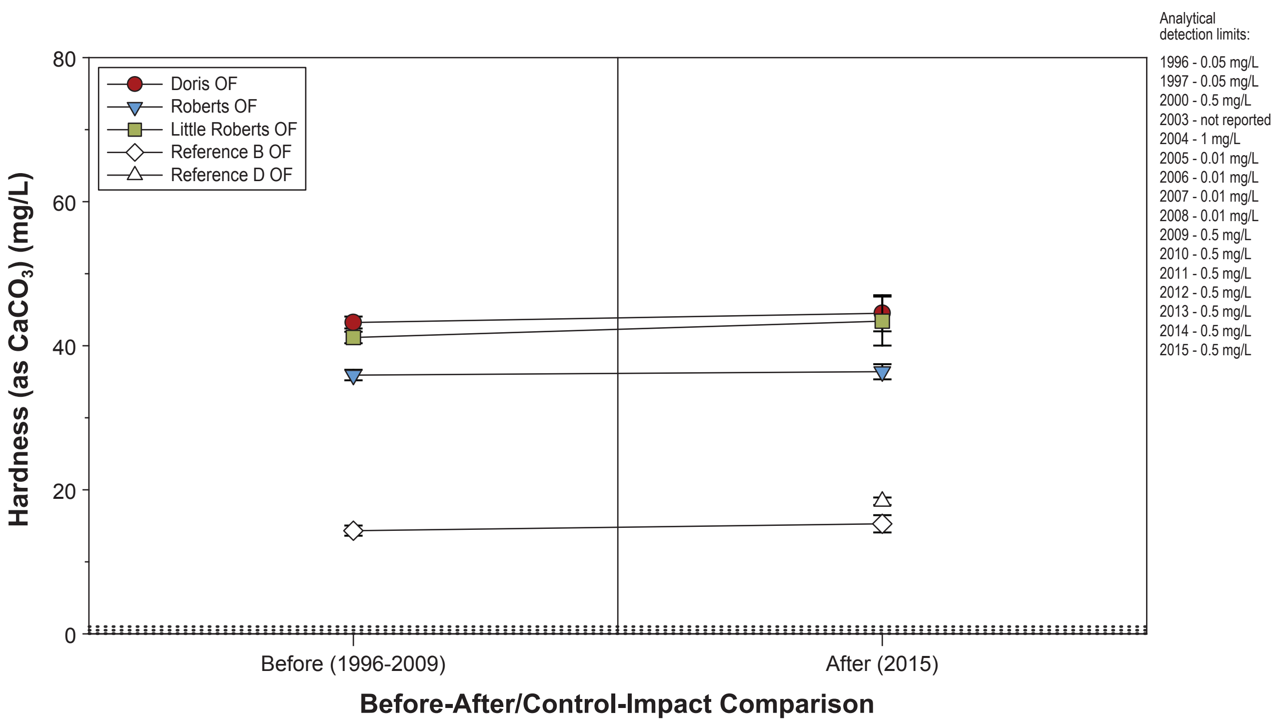


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Total alkalinity is a required parameter for effluent characterization and water quality monitoring as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

Figure 3.3-3

Hardness in AEMP Stream Sites, Doris North Project, 1996 to 2015

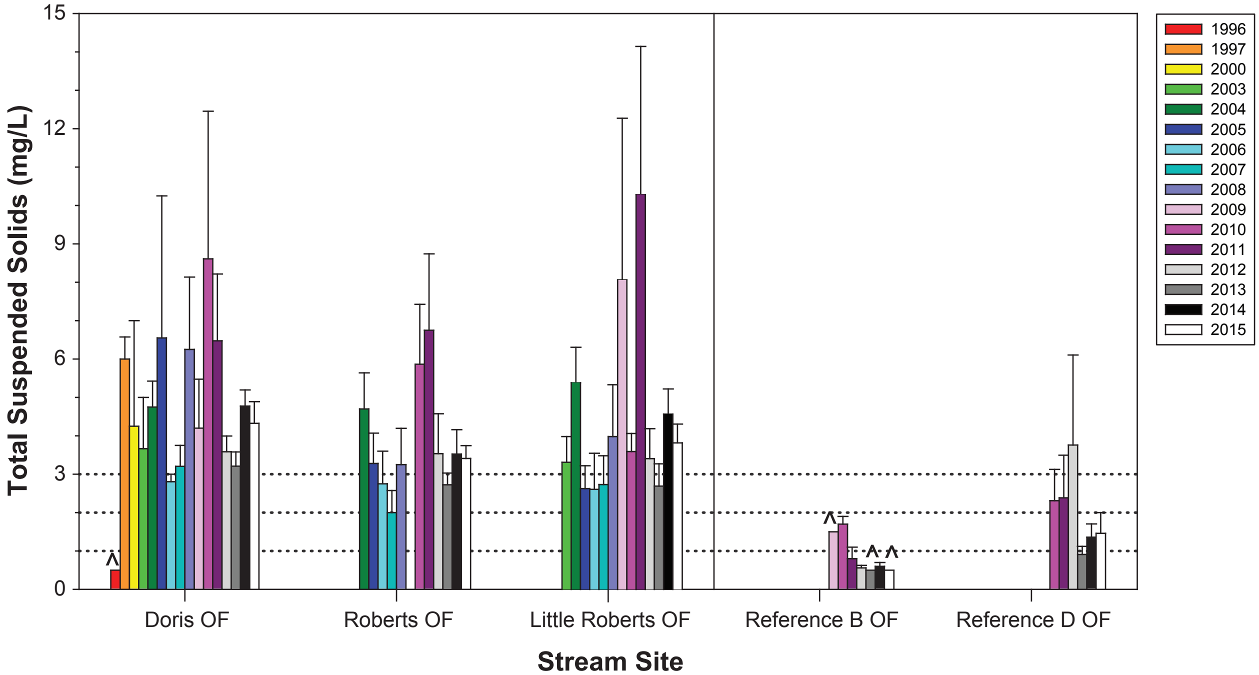


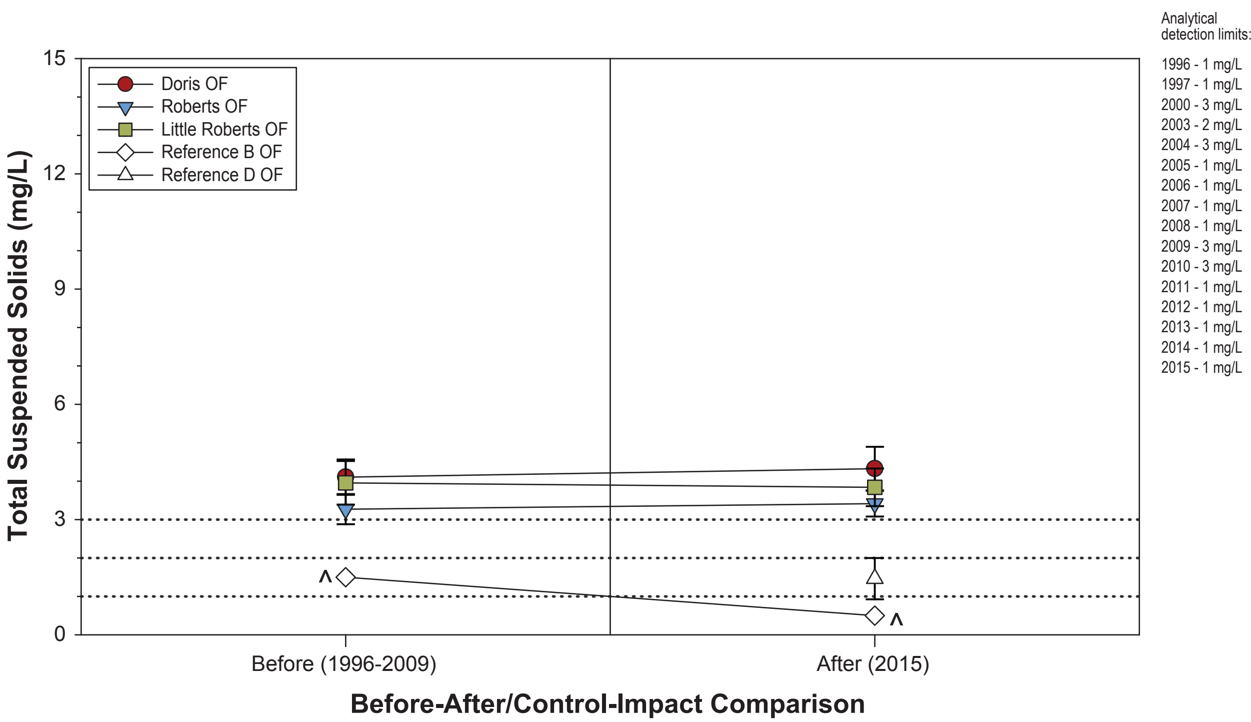


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits.
Hardness is a required parameter for effluent characterization and water quality monitoring as per Schedule 5, s. 4(1) and s. 7(1)(c) of the MMER.

Figure 3.3-4

Total Suspended Solids in AEMP Stream Sites, Doris North Project, 1996 to 2015





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 2015 concentrations of total ammonia in exposure and reference streams were well below the pH- and temperature-dependent CCME guideline (Figure 3.3-5). Mean 2015 total ammonia concentrations were also within the range of baseline concentrations at both exposure streams, suggesting that there was no effect of Project activities on ammonia concentrations (Figure 3.3-5). The before-after analysis confirmed that there was no significant difference between 2015 and baseline means in either exposure stream ($p = 0.57$ for Doris Outflow and $p = 0.51$ for Little Roberts Outflow).

3.3.1.6 *Nitrate*

Nitrate is a required variable for effluent characterization as per Schedule 5, s. 4(1) of the MMER. All 2015 nitrate concentrations in exposure streams 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 2015 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 2015 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 2015 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 2015 to allow for direct comparisons with the CCME guideline (0.005 mg/L as free cyanide). The free cyanide concentrations in 2015 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 2015 Project activities on free cyanide concentrations in the exposure streams.

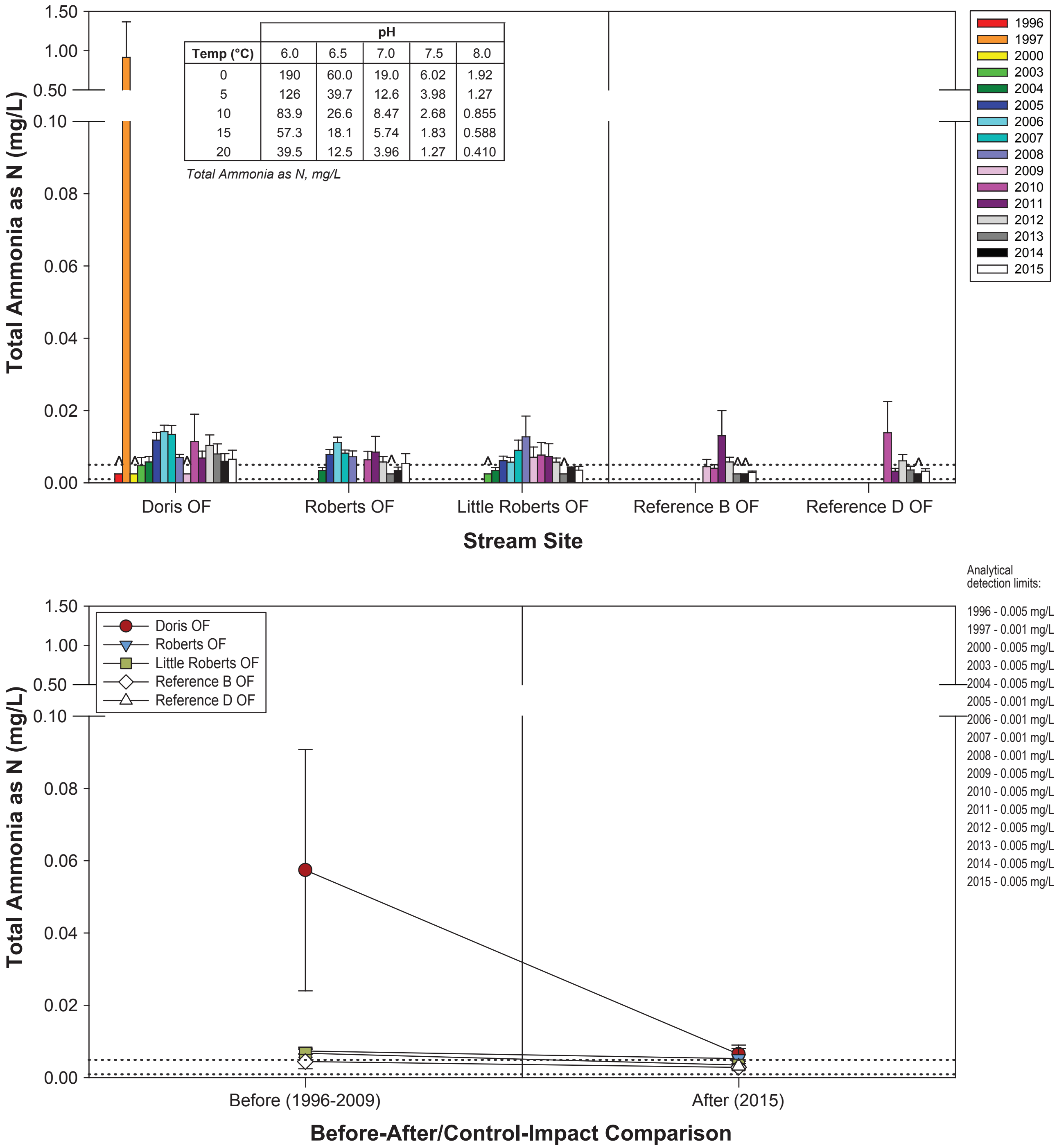
3.3.1.8 *Radium-226*

Radium-226 is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. All 2015 radium-226 concentrations in Doris Outflow, Little Roberts Outflow, and Reference D Outflow were below the analytical detection limit of 0.01 Bq/L, and 88% of radium-226 concentrations in Reference B Outflow were below this detection limit (Figure 3.3-8). Thus, there was no evidence of an effect of 2015 Project activities on radium-226 concentrations in any exposure stream.

Figure 3.3-5

Total Ammonia in AEMP Stream Sites, Doris North Project, 1996 to 2015

ERM



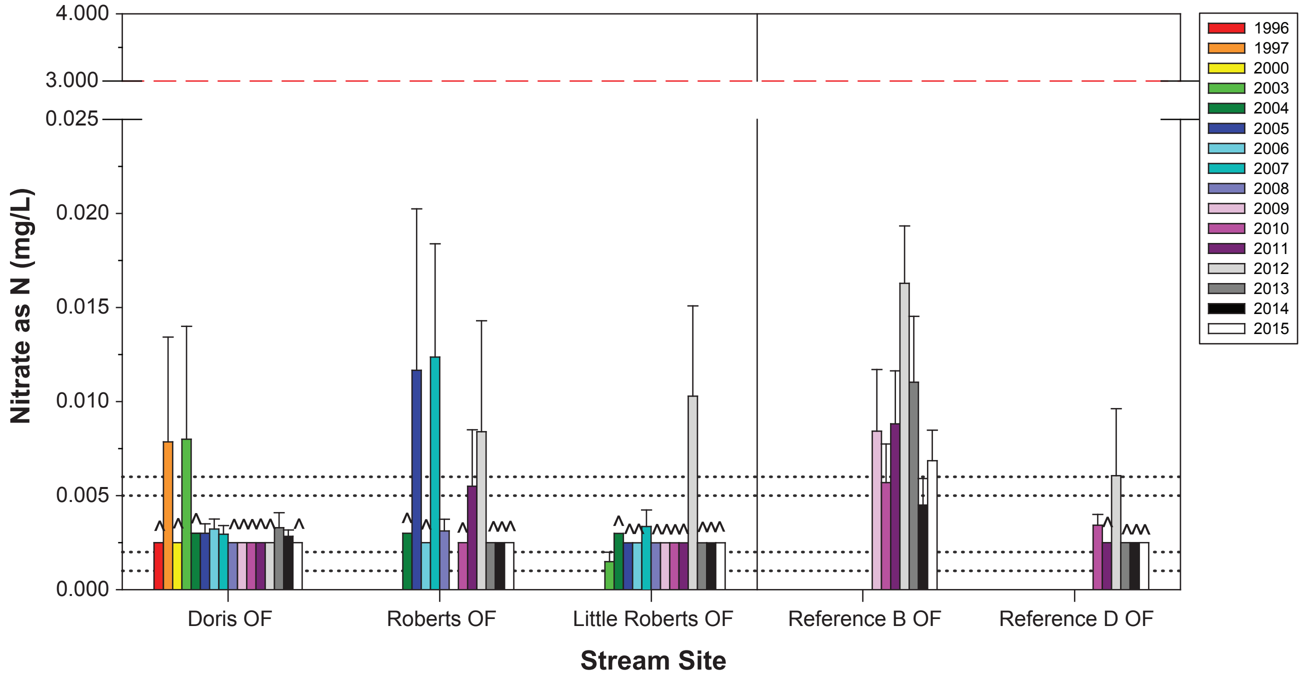
	pH				
Temp (°C)	6.0	6.5	7.0	7.5	8.0
0	190	60.0	19.0	6.02	1.92
5	126	39.7	12.6	3.98	1.27
10	83.9	26.6	8.47	2.68	0.855
15	57.3	18.1	5.74	1.83	0.588
20	39.5	12.5	3.96	1.27	0.410

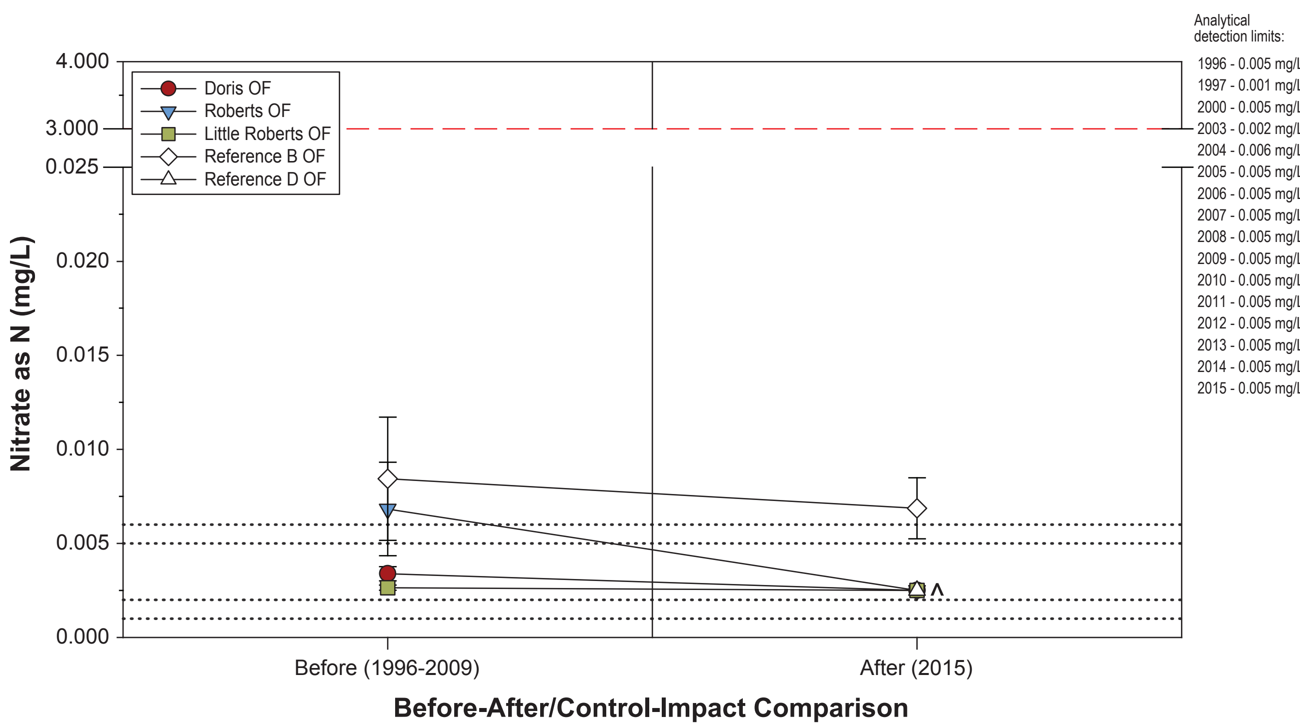
Total Ammonia as N, mg/L

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.

Figure 3.3-6

Nitrate in AEMP Stream Sites, Doris North Project, 1996 to 2015

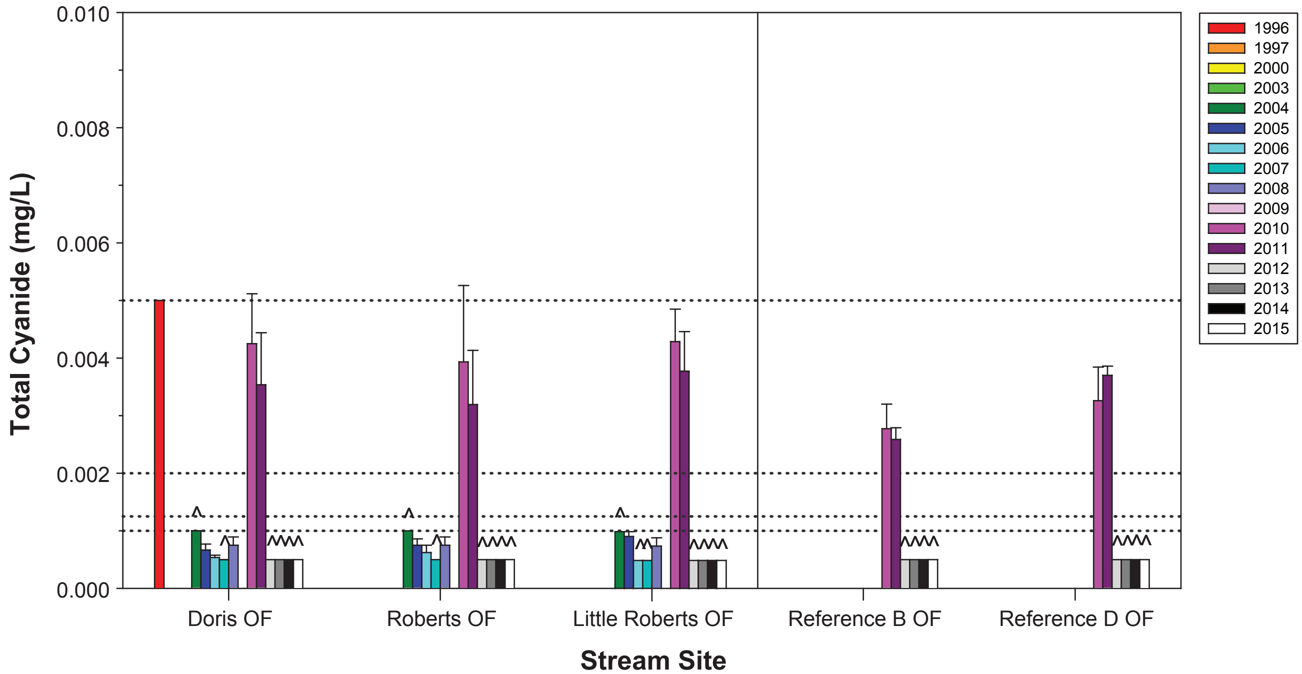


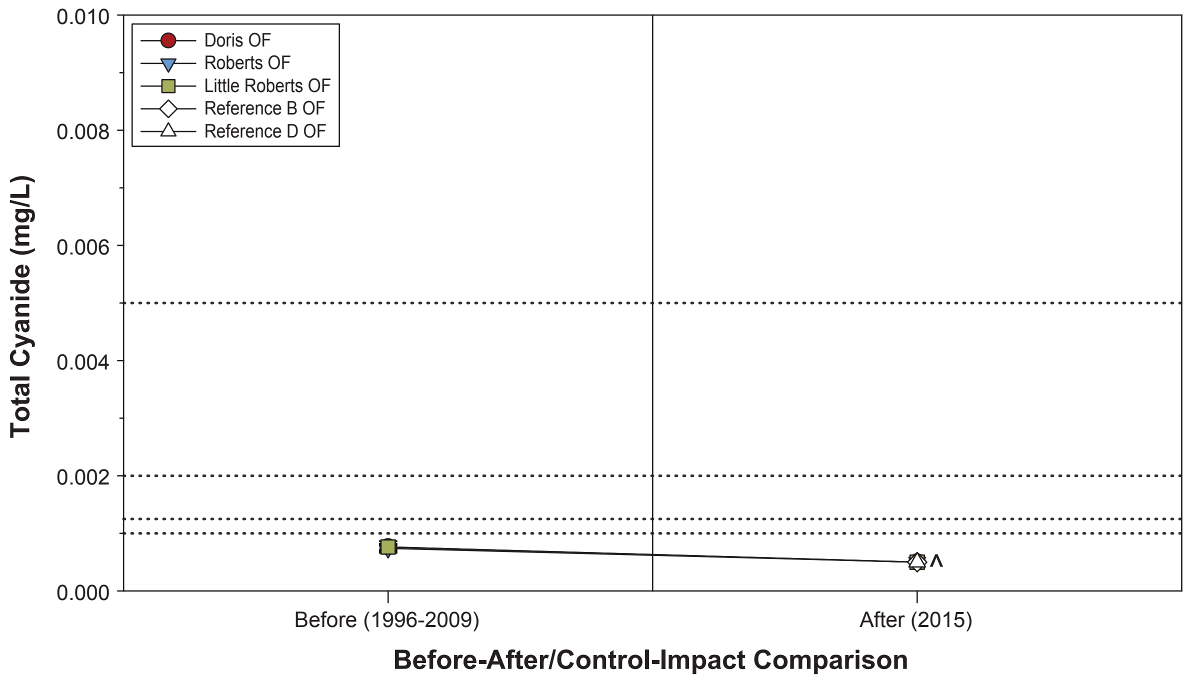


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
^ Indicates that concentrations were below the detection limit in all samples.
Red dashed line represents 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 in AEMP Stream Sites, Doris North Project, 1996 to 2015





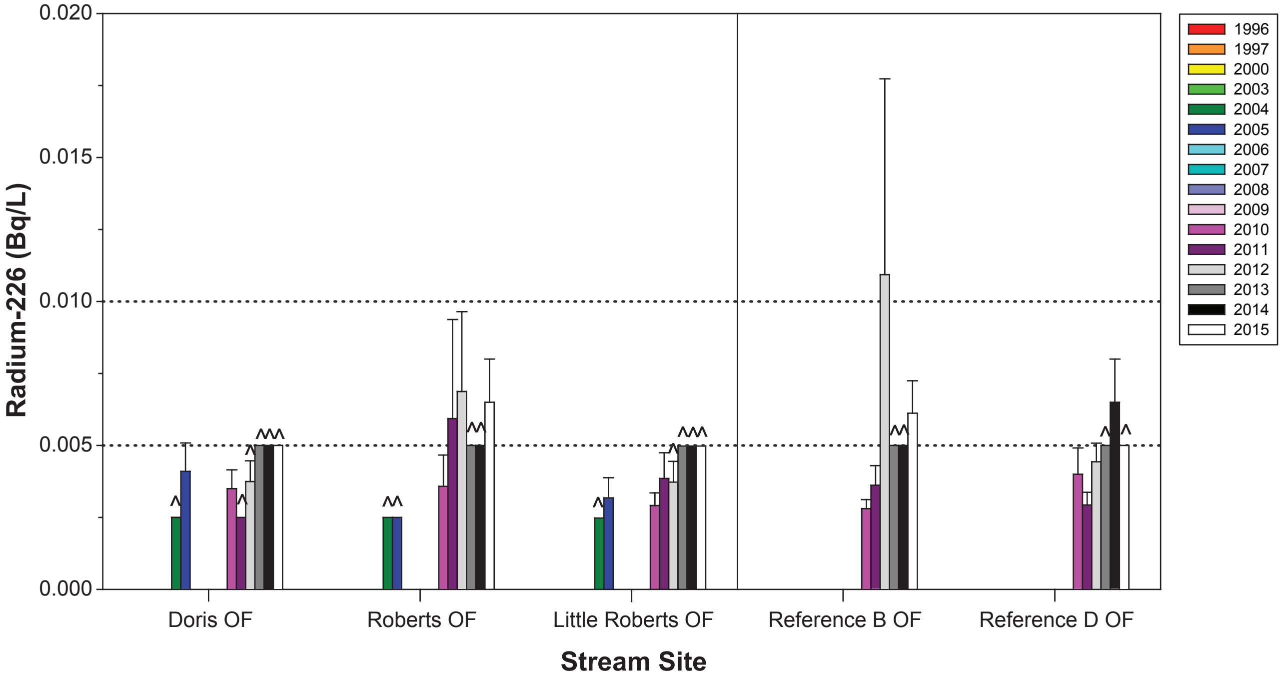
Analytical detection limits:

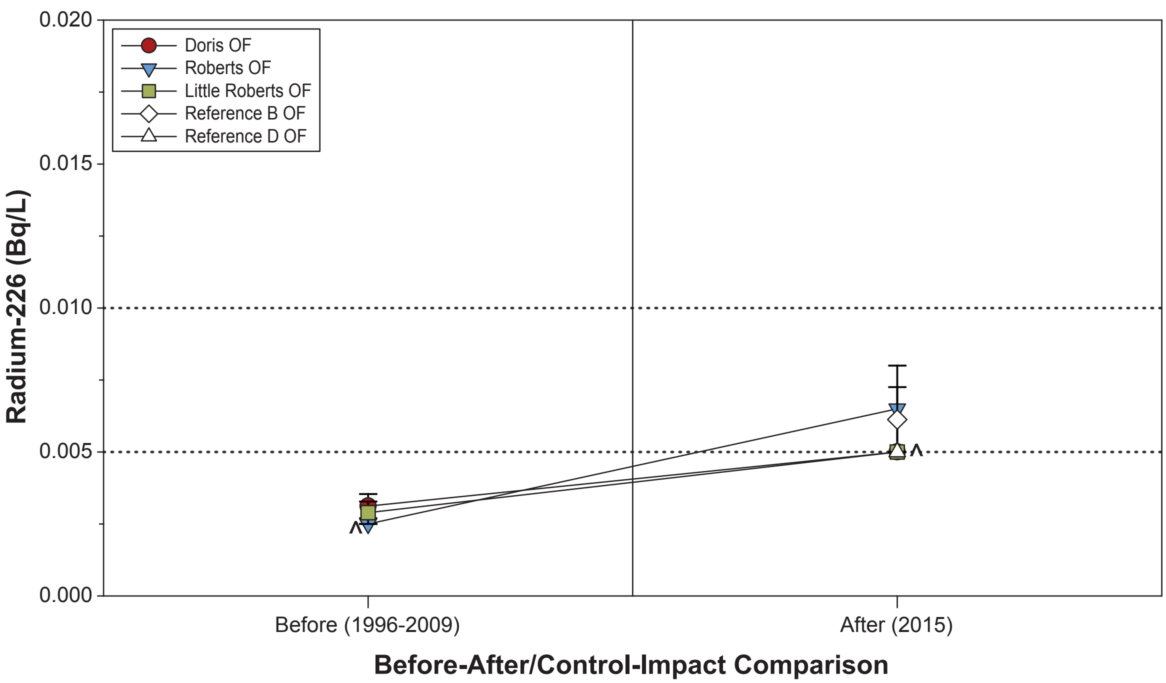
1996 - 0.005 mg/L
2004 - 0.002 mg/L
2005 - 0.001 mg/L
2006 - 0.001 mg/L
2007 - 0.001 mg/L
2008 - 0.001 mg/L
2010 - 0.001 mg/L
2011 - 0.001 to 0.00125 mg/L
2012 - 0.001 mg/L
2013 - 0.001 mg/L
2014 - 0.001 mg/L
2015 - 0.001 mg/L

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.
Total cyanide is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER.

Figure 3.3-8

Radium-226 in AEMP Stream Sites, Doris North Project, 1996 to 2015





Analytical detection limits:

2004 - 0.005 Bq/L
2005 - 0.005 Bq/L
2010 - 0.005 Bq/L
2011 - 0.005 Bq/L
2012 - 0.005 Bq/L to 0.010 Bq/L
2013 - 0.010 Bq/L
2014 - 0.010 Bq/L
2015 - 0.010 Bq/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.
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. In Doris Outflow, the mean 2015 total aluminum concentration was similar to the baseline mean, while in Little Roberts Outflow, the mean 2015 total aluminum concentration was lower than the baseline mean. The mean 2015 total aluminum concentration in Little Roberts Outflow was slightly above the pH-dependent CCME guideline of 0.1 mg/L, and the mean 2015 total aluminum concentration in Doris Outflow was slightly 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 (Figure 3.3-9).

The before-after analysis revealed that the mean 2015 total aluminum concentrations in exposure streams were not significantly different from baseline means ($p = 0.70$ for Doris Outflow and $p = 0.054$ for Little Roberts Outflow). Therefore, there was no indication that 2015 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 2015 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).

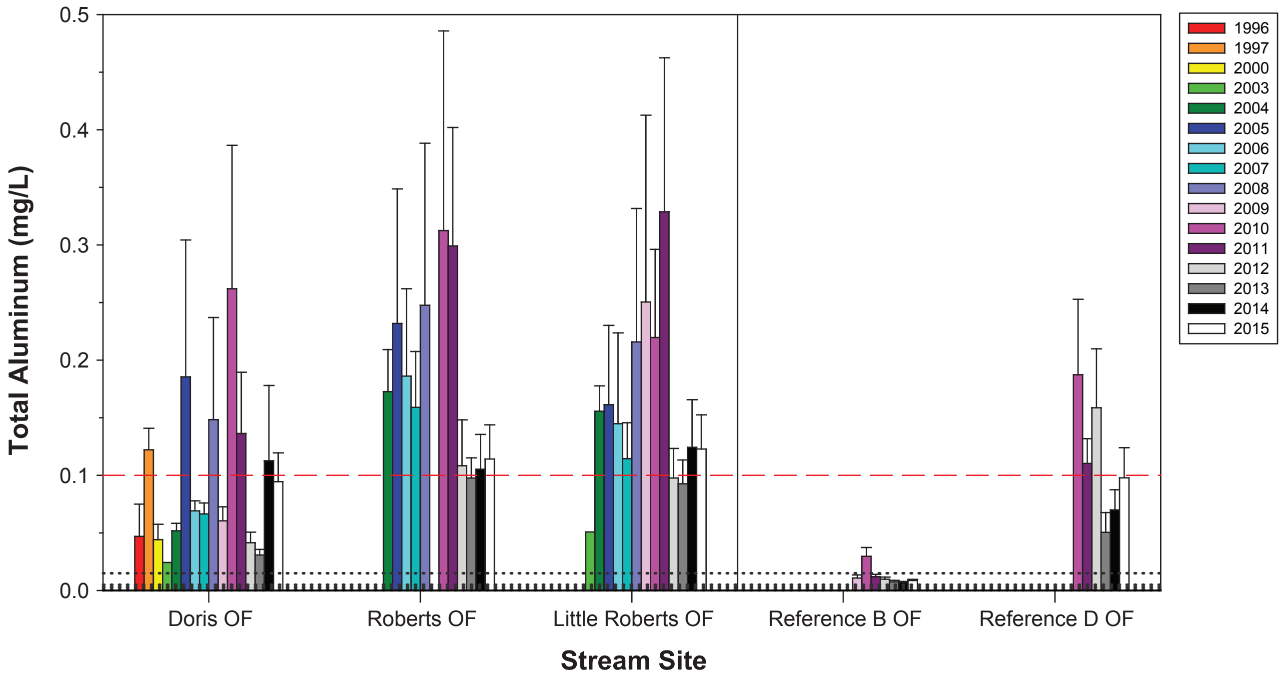
The before-after comparison indicated that 2015 mean total arsenic concentrations were not significantly different from baseline mean total arsenic concentrations for Doris Outflow ($p = 0.34$) and Little Roberts Outflow ($p = 0.24$). Therefore, there were no apparent adverse effects of Project activities on total arsenic concentrations in exposure streams in 2015.

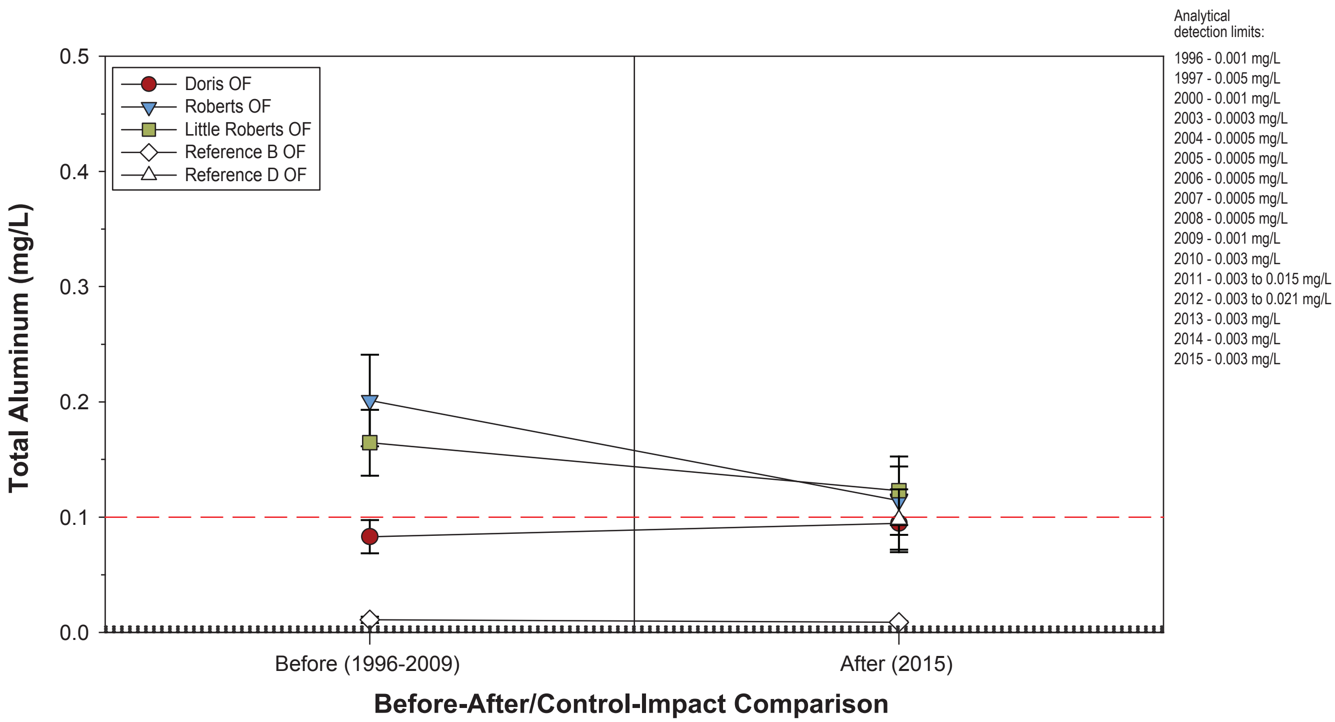
3.3.1.11 Total Cadmium

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 Doris Outflow in 2015 were below the analytical detection limit of 0.000005 mg/L (Figure 3.3-11; Appendix A). Although most (88%) of the total cadmium concentrations measured in Little Roberts Outflow were below detection in 2015, just under 70% of the concentrations in the combined baseline and 2015 dataset were below the detection limit, so statistical results are presented for this stream. The before-after analysis showed that there was no significant difference between baseline and 2015 mean total cadmium concentrations in Little Roberts Outflow ($p = 0.99$). Therefore, there was no evidence of an effect of 2015 Project activities on total cadmium concentrations in any of the exposure streams. All total cadmium concentrations measured in streams in 2015 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 North Project, 1996 to 2015

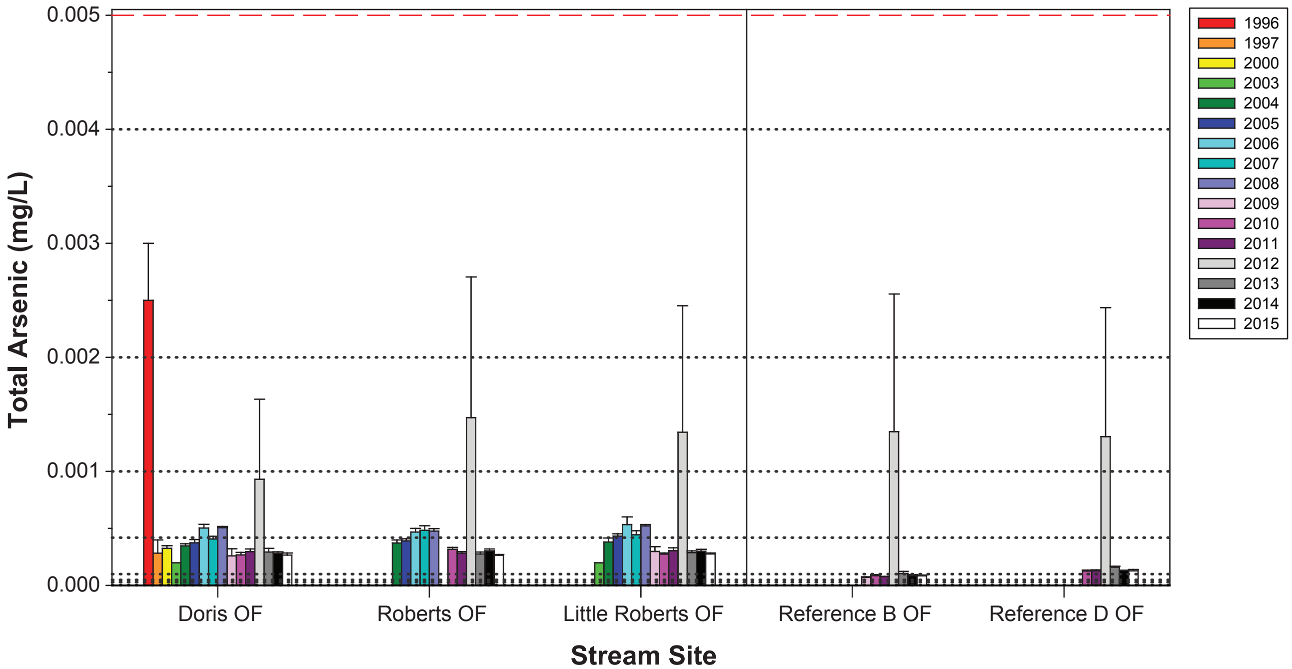


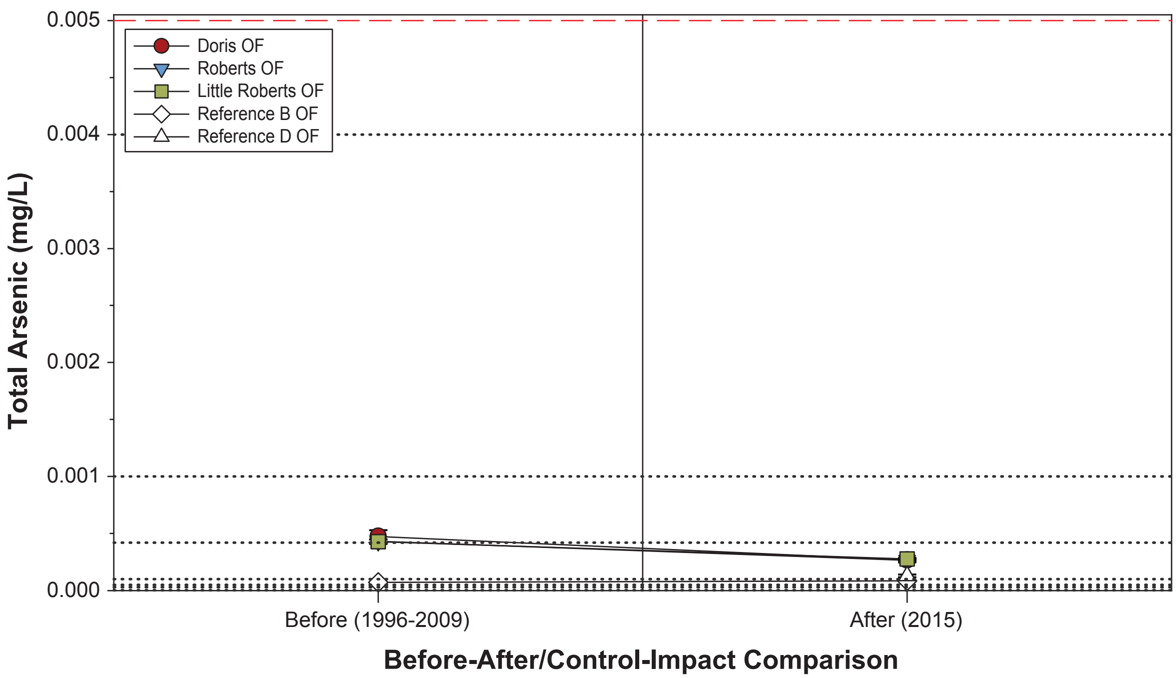


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Red dashed lines represent the pH-dependent CCME freshwater guideline for aluminum (0.005 mg/L at pH < 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 North Project, 1996 to 2015





Analytical detection limits:

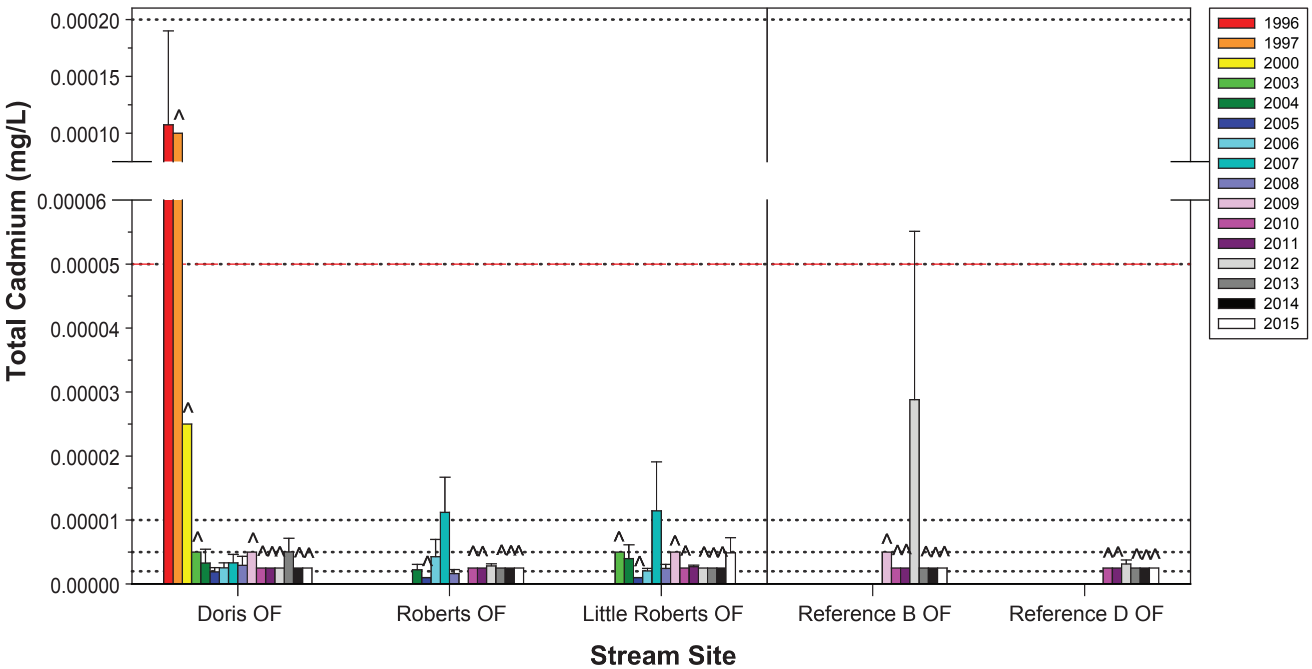
1996 - 0.001 to 0.004 mg/L
1997 - 0.0001 mg/L
2000 - 0.0001 mg/L
2003 - 0.0001 mg/L
2004 - 0.000002 mg/L
2005 - 0.000002 mg/L
2006 - 0.000002 mg/L
2007 - 0.000002 mg/L
2008 - 0.000002 mg/L
2009 - 0.00003 to 0.00042 mg/L
2010 - 0.00005 mg/L
2011 - 0.00005 mg/L
2012 - 0.00005 or 0.002 mg/L
2013 - 0.00005 mg/L
2014 - 0.00005 mg/L
2015 - 0.00005 mg/L

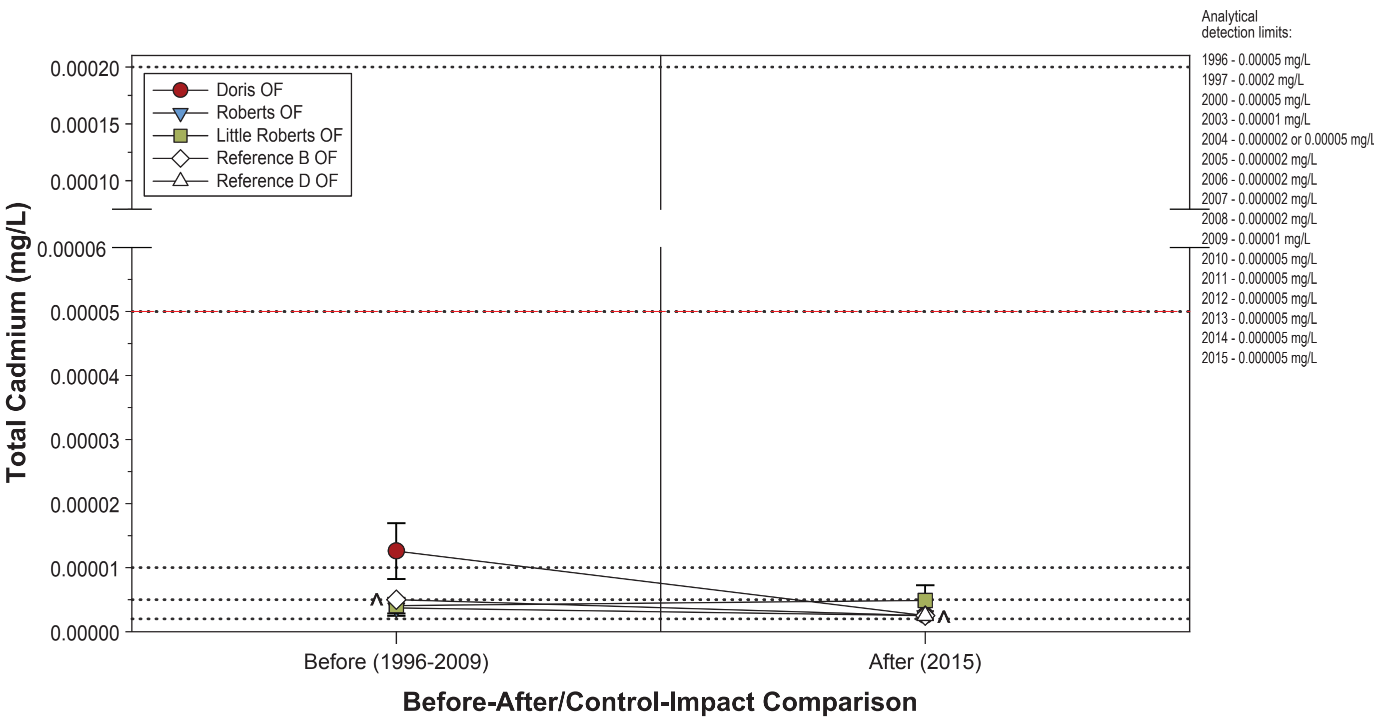
Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
Red dashed lines represent the CCME freshwater guideline for arsenic (0.005 mg/L).
Total arsenic is regulated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

Figure 3.3-11

Total Cadmium Concentration in AEMP Stream Sites, Doris North Project, 1996 to 2015

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.
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 2015 (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.

3.3.1.12 Total Copper

Total copper is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. In all exposure streams, mean total copper concentrations in 2015 were similar to or lower than in baseline years and were below the hardness-dependent CCME guideline (Figure 3.3-12). The before-after analysis indicated that there was no significant difference in the mean total copper concentration between baseline years and 2015 in Doris Outflow ($p = 0.66$); however, there was a significant difference between baseline and 2015 mean total copper concentrations in Little Roberts Outflow ($p = 0.025$). In this case, the mean 2015 copper concentration was lower than the mean baseline concentration, and a decrease in copper concentration is of no concern. Therefore, there was no indication of an adverse effect of 2015 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 2015 total iron concentrations in exposure streams were within the range of baseline means (Figure 3.3-13). The mean 2015 total iron concentrations in exposure streams were slightly below the CCME guideline concentration of 0.3 mg/L (Figure 3.3-13); however, total iron concentrations measured in June 2015 at all exposure streams were greater than the CCME guideline level (Appendix A). Total iron concentrations in baseline samples were also occasionally above the guideline (Figure 3.3-13).

The before-after analysis confirmed that there was no significant difference between baseline and 2015 means for any exposure stream ($p = 0.21$ for Doris Outflow and $p = 0.40$ for Little Roberts Outflow), suggesting that 2015 Project activities did not affect total iron concentrations in the exposure streams.

3.3.1.14 Total Lead

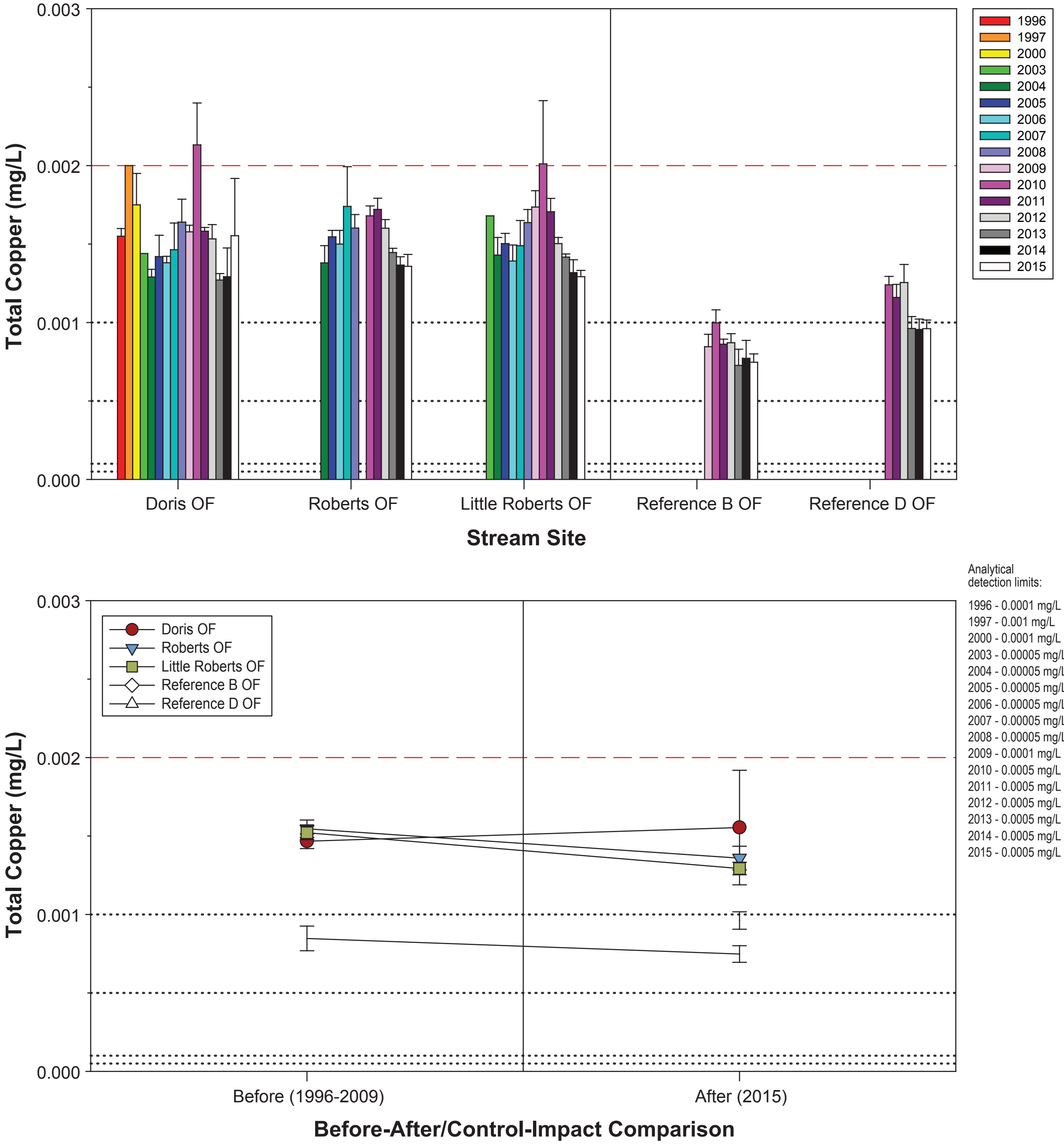
Total lead is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. Total lead concentrations in all streams were well below the hardness-dependent CCME guideline (Figure 3.3-14). Mean 2015 total lead concentrations in the exposure streams were lower than mean baseline levels. The before-after comparison indicated that 2015 mean total lead concentrations were not significantly different from baseline means for the exposure streams ($p = 0.57$ for Doris Outflow and $p = 0.22$ for Little Roberts Outflow). Thus, there was no evidence of Project-related effects on total lead in the exposure streams in 2015.

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 mean 2015 total mercury concentration in Little Roberts Outflow was well below the CCME guideline of 0.000026 mg/L, and similar to the baseline mean. The before-after analysis confirmed that the baseline and 2015 means for total mercury in Little Roberts Outflow were not significantly different ($p = 0.98$), suggesting that there was no effect of 2015 Project activities on total mercury concentrations in this stream (Figure 3.3-15).

Figure 3.3-12

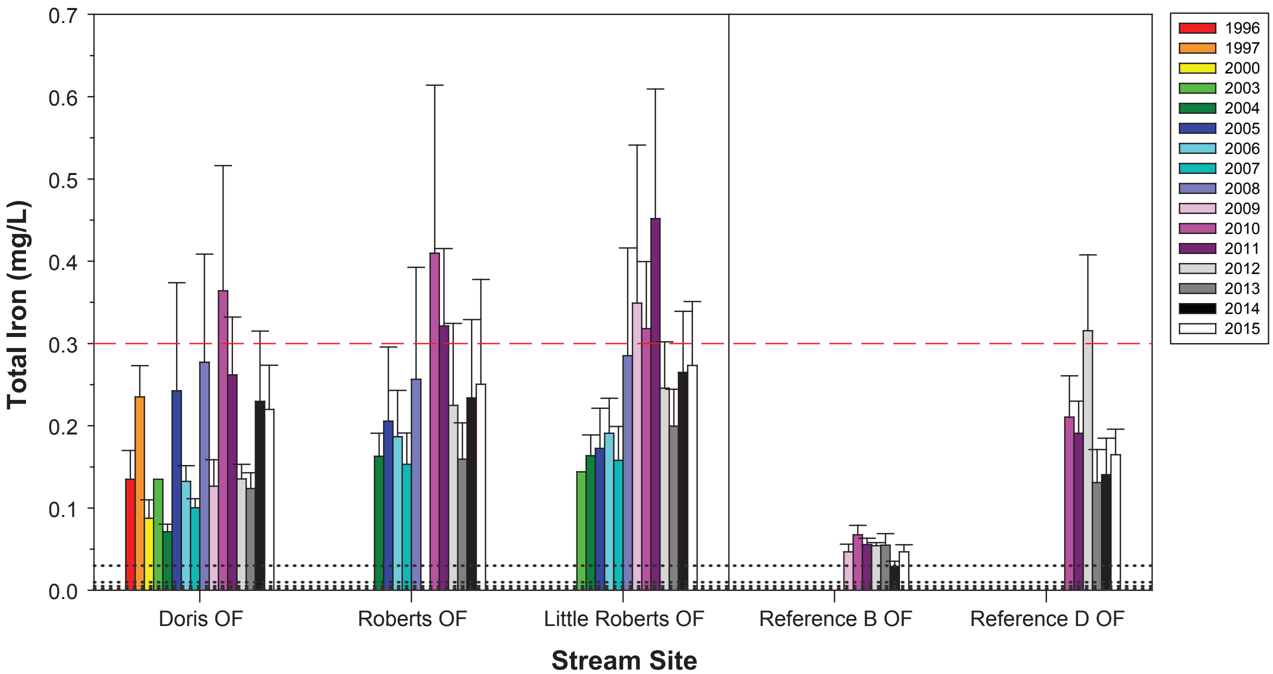
Total Copper Concentration in AEMP Stream Sites, Doris North Project, 1996 to 2015

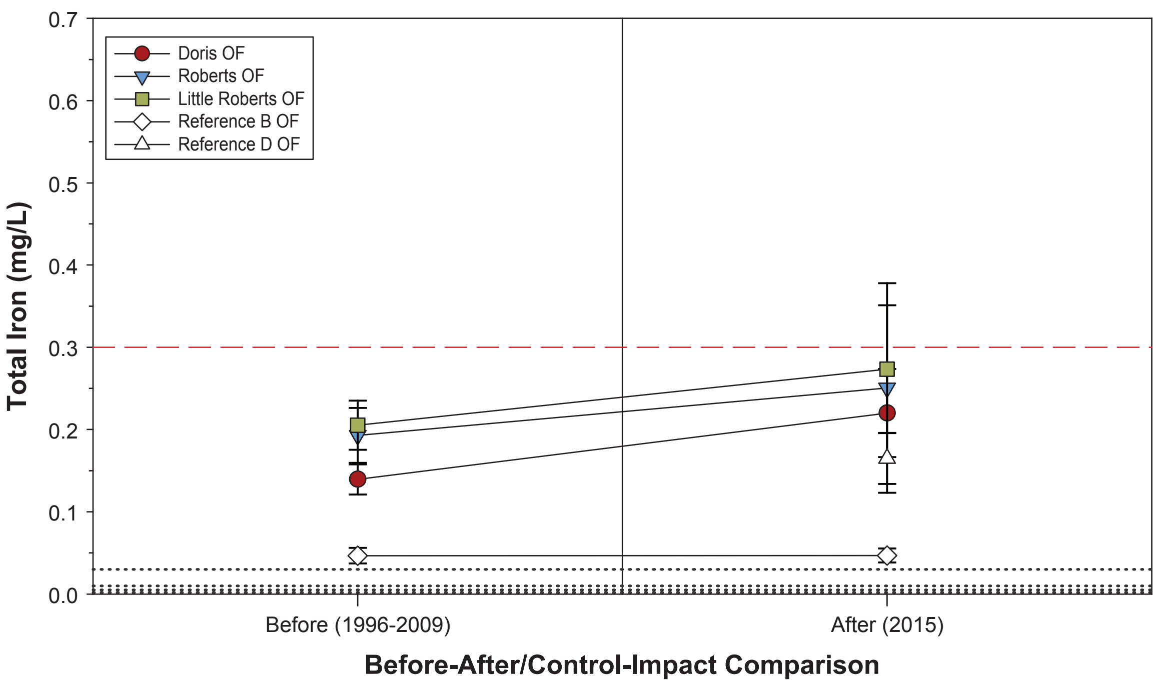


Notes: Error bars represent the standard error of the mean.
Black dotted lines represent analytical detection limits; values below detection limits are plotted at half the applicable detection limit.
The CCME freshwater guideline for copper is hardness dependent.
Red dashed lines represent the minimum 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 North Project, 1996 to 2015





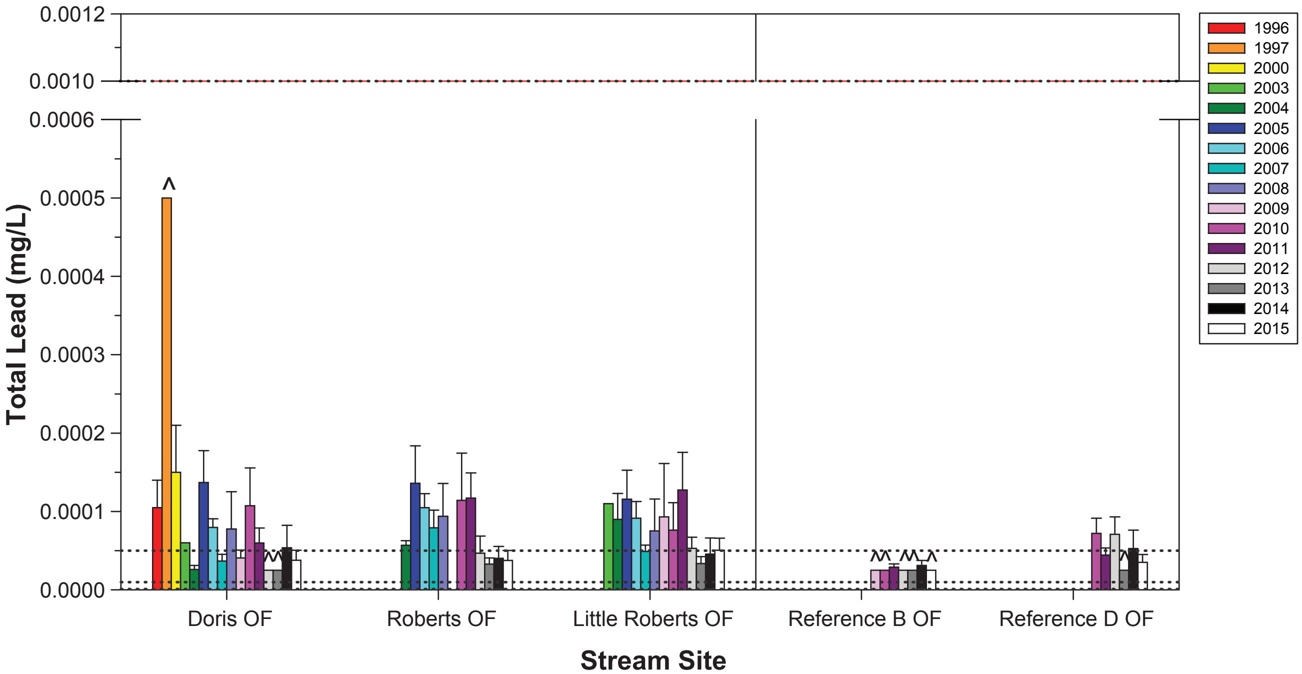
Analytical detection limits:

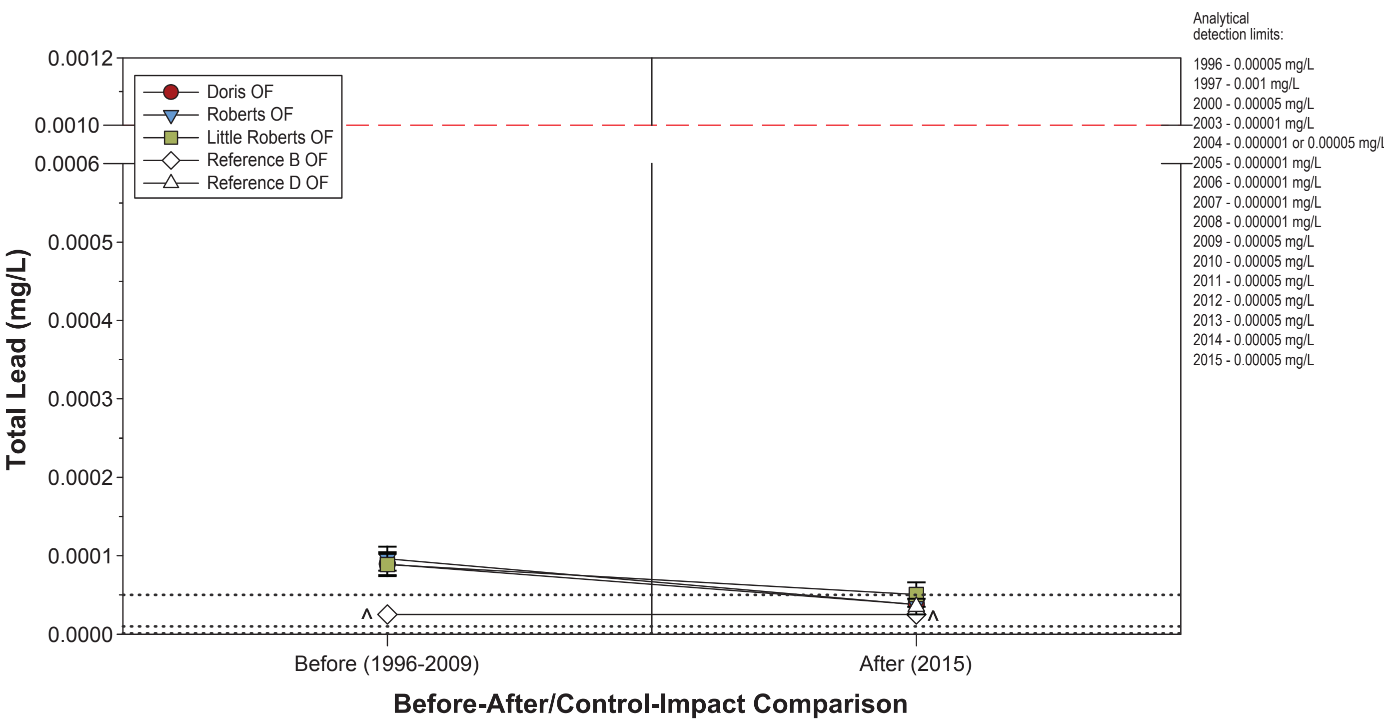
1996 - 0.01 mg/L
1997 - 0.01 mg/L
2000 - 0.03 mg/L
2003 - 0.005 mg/L
2004 - 0.002 mg/L
2005 - 0.002 mg/L
2006 - 0.002 mg/L
2007 - 0.002 mg/L
2008 - 0.002 mg/L
2009 - 0.01 mg/L
2010 - 0.03 mg/L
2011 - 0.03 mg/L
2012 - 0.03 mg/L
2013 - 0.03 mg/L
2014 - 0.03 mg/L
2015 - 0.03 mg/L

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

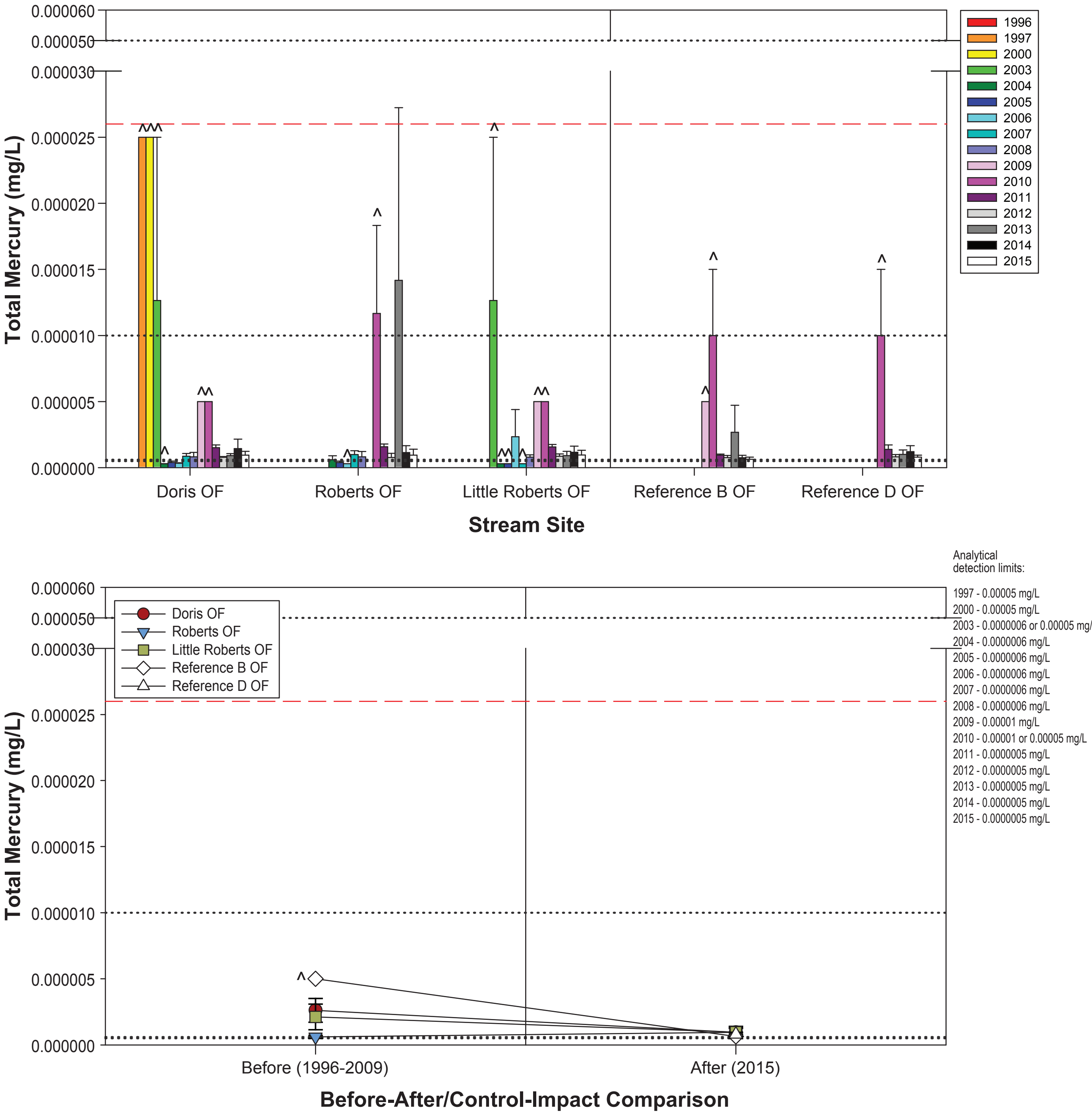
Total Lead Concentration in AEMP Stream Sites, Doris North Project, 1996 to 2015





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.

Total Mercury Concentration in AEMP Stream Sites, Doris North Project, 1996 to 2015



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 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.

For Doris Outflow, comparisons to baseline data are problematic because of the high proportion of concentrations in the combined baseline and 2015 dataset that were below detection limits (75%) and the widely variable historical detection limits. Thus, the results of the before-after comparison are considered unreliable and are not discussed (Figure 3.3-15). However, total mercury concentrations measured in 2015 in Doris Outflow are similar to some historical concentrations and also similar to concentrations measured in the reference streams. Thus, there was no evidence of an increase in total mercury concentrations in exposure streams as a result of 2015 Project activities.

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 2015 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 ($p = 0.84$) and Little Roberts Outflow ($p = 0.075$). There was no evidence of an increase in total molybdenum concentrations in either exposure stream due to 2015 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 2015 nickel concentrations in all streams were well below the hardness-dependent CCME guideline (Figure 3.3-17). In both exposure streams, concentrations in 2015 were similar to baseline concentrations (Figure 3.3-17), and the before-after analysis confirmed that there was no significant difference between mean baseline and mean 2015 total nickel concentrations for either exposure stream ($p = 0.38$ for Doris Outflow and $p = 0.98$ for Little Roberts Outflow). Therefore, there was no apparent effect of 2015 Project activities on total nickel concentrations in exposure streams.

3.3.1.18 Total Zinc

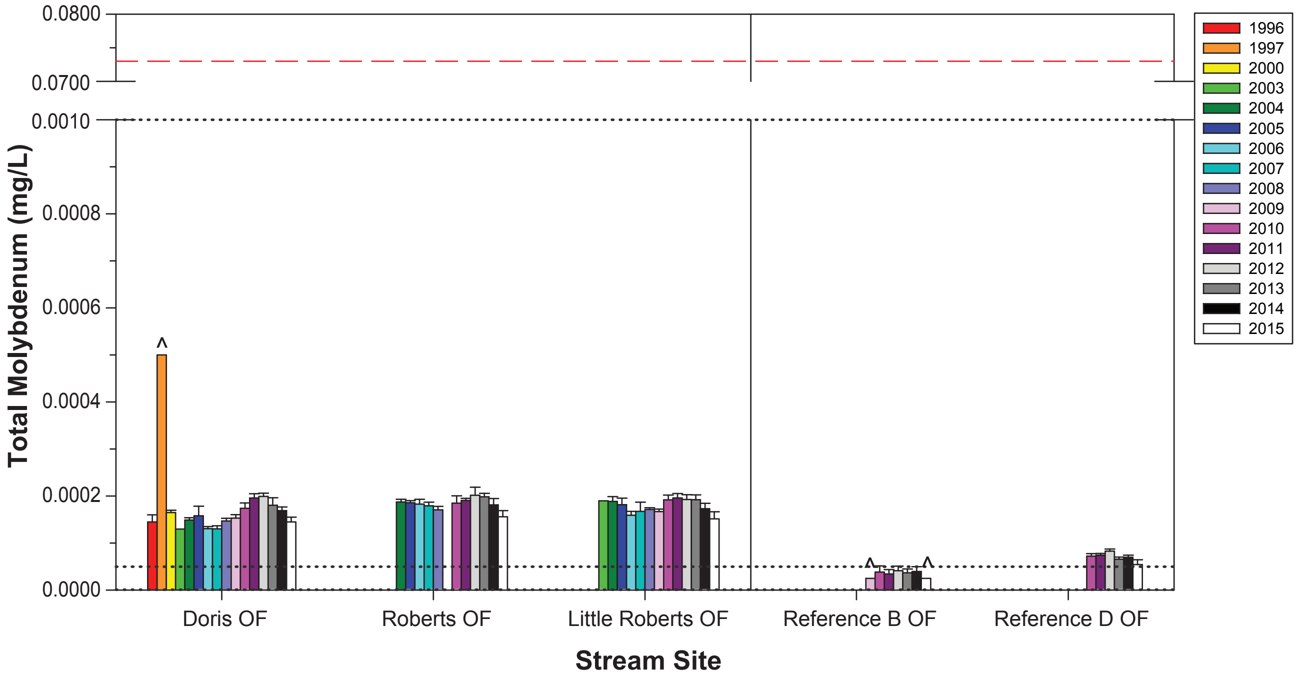
Total zinc is regulated as a deleterious substance in effluents as per Schedule 4 of the MMER. All 2015 total zinc concentrations in exposure and reference streams were below the detection limit of 0.003 mg/L, and well below the CCME guideline of 0.03 mg/L (Figure 3.3-18). Therefore, there was no evidence of an effect of 2015 Project activities on total zinc concentrations in the exposure streams.

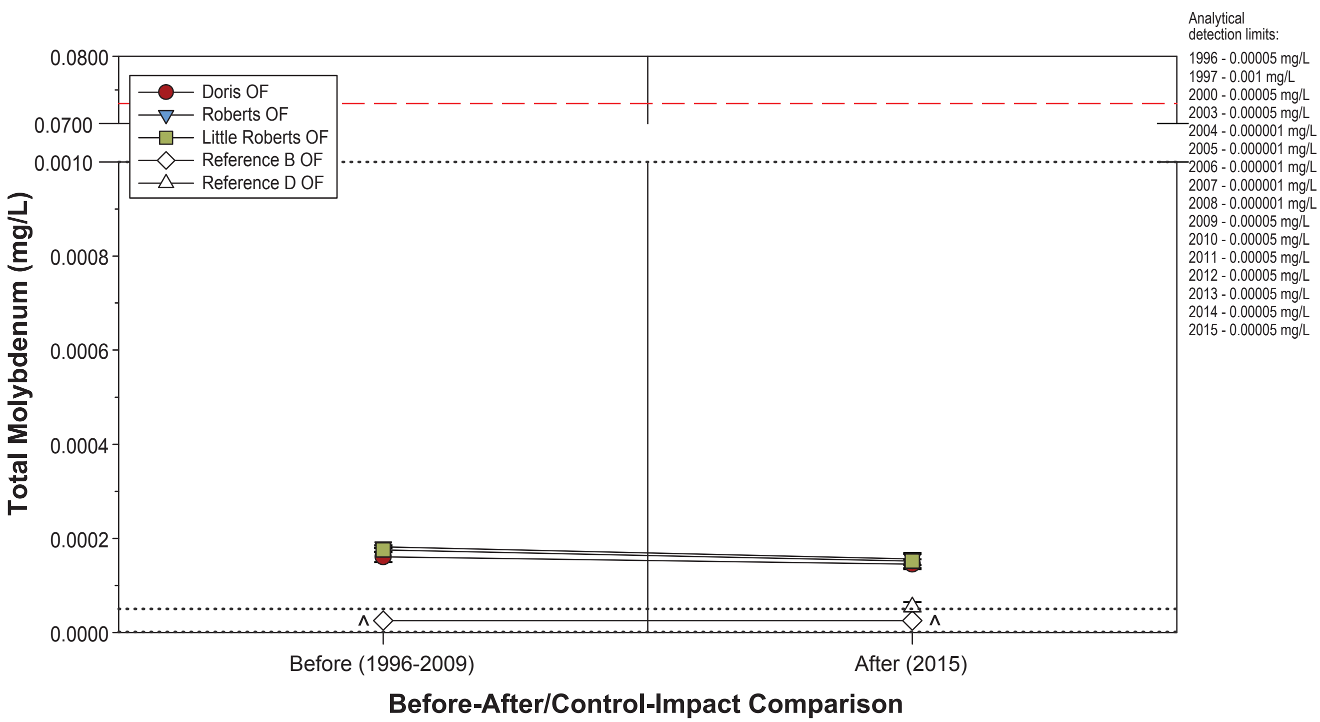
3.3.2 Lakes

Water quality samples from lakes were collected from three exposure lake sites (Doris Lake South, Doris Lake North, and Little Roberts Lake) and two reference lakes (Reference Lake B and Reference Lake D) in 2015. 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.

Figure 3.3-16

Total Molybdenum Concentration in AEMP Stream Sites, Doris North Project, 1996 to 2015





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 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.