Rio Tinto

B.C. Works SO_2 EEM Program – Technical Memo W10

Aquatic Ecosystems Actions and Analyses

April 2022

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1 Introduction

This Technical Memo provides additional information on the data and analyses in support of the 2021 requirements for the Aquatic Ecosystems component of the B.C. Works' Sulphur Dioxide Environmental Effects Monitoring (EEM) Program (draft SO_2 EEM Phase III Plan, ESSA et al. 2021). These data and analyses thus provide the foundation for Section 3.4 in the 2021 Annual Report.

This technical memo applies methods and approaches that have already been described in detail in other relevant documents. Most of the methods follow those employed in the SO_2 Technical Assessment Report (STAR) (ESSA et al. 2013), the Kitimat Airshed Assessment (KAA) (ESSA et al. 2014a) and the 2019 EEM Comprehensive Review Report (ESSA et al. 2020). Full details on the collection, processing and analysis of the water chemistry samples are reported in technical reports prepared by Limnotek for each year's sampling (Perrin et al. 2013; Perrin and Bennett 2015; Limnotek 2016; Bennett and Perrin 2017, 2018; Limnotek 2019, 2020, 2021, 2022). Wherever possible, the description of methods in this technical report refers to these reports instead of repeating information that is already well-documented elsewhere.

The following four documents (as described above) are listed here because they are referenced throughout this technical memo, often without their full citation:

- The STAR (ESSA *et al*. 2013)
- The KAA (ESSA *et al.* 2014a)
- 2019 EEM Comprehensive Review Report (ESSA et al. 2020)
- The EEM Phase III Plan (ESSA et al. 2021)

2 Methods

2.1 Water Chemistry Sampling

EEM Lakes

The EEM long-term sampling plan includes eleven lakes: seven sensitive lakes, one less sensitive lake, and three control lakes (ESSA et al. 2021). The three control lakes (NC184, NC194 and DCAS14A) are all located outside of the zone of sulphur deposition from B.C. Works, and have pre-KMP baseline data for 2013 from sampling as part of the KAA (ESSA et al., 2014a). The five lakes that were unable to be sampled in 2020 (due to COVID-related constraints on helicopter flights) were sampled again in 2021 as per previous years.

LAK027 was added for one-time sampling in 2021, as agreed to by ENV and Rio Tinto in May 2021. The intent was to resample one of the STAR lakes located relatively close to the smelter to check the validity of the conclusions made in the STAR, based on sampling completed in 2012, nine years prior to 2021. LAK027 was chosen because it was the only candidate that was moderately sensitive, whereas all the other lakes in the southern portion of the Kitimat Valley were determined to be insensitive based on the sampling during the STAR (except for LAK028, which was included in the EEM Program because of its sensitivity).

In 2021, Limnotek sampled the eleven EEM lakes plus LAK027 according to the 2021 Aquatics Work Plan. The sampling methodology is described in detail in Limnotek's technical report on the water quality monitoring (Limnotek 2022). Table 2-1 summarizes all of the EEM sites sampled during 2012-2021. Figure 2-1 shows a map of the lakes sampled in 2021.

Table 2-1. Summary of sampling sites within the EEM Phase III Program. The rationale for lakes included in the Phase III EEM program is described in ESSA et al. 2021.

Sample Site	Year of Sampling										Role in Phase III EEM Program and sampling in 2020.
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	
	STAR	EEM	EEM	EEM	EEM	EEM	EEM	EEM	EEM	EEM	
LAK006	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	EEM sensitive lake, included in Phase III
LAK012	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	EEM sensitive lake, included in Phase III
LAK022	✓	✓	✓	✓	✓	✓	✓	✓		✓	EEM sensitive lake only accessible by helicopter, included in Phase III.
LAK023	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	EEM sensitive lake, included in Phase III
LAK028	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	EEM sensitive lake, included in Phase III
LAK042	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	EEM sensitive lake, included in Phase III
LAK044	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	EEM sensitive lake, included in Phase III
LAK016	✓	✓	✓	✓	✓	✓	✓	✓		✓	EEM less sensitive lake, included in Phase III.
LAK027										✓	One-off resampling of STAR lake at southern end of valley.
NC184		✓†		✓	✓	✓	✓	✓		✓	EEM control lakes added to EEM in 2015. Only accessible by helicopter, included in Phase III.
NC194		✓†		✓	✓	✓	✓	✓		✓	
DCAS14A		✓†		✓	✓	✓	✓	✓		✓	

† Sampled as part of the Kitimat Airshed Assessment (ESSA et al. 2014a).

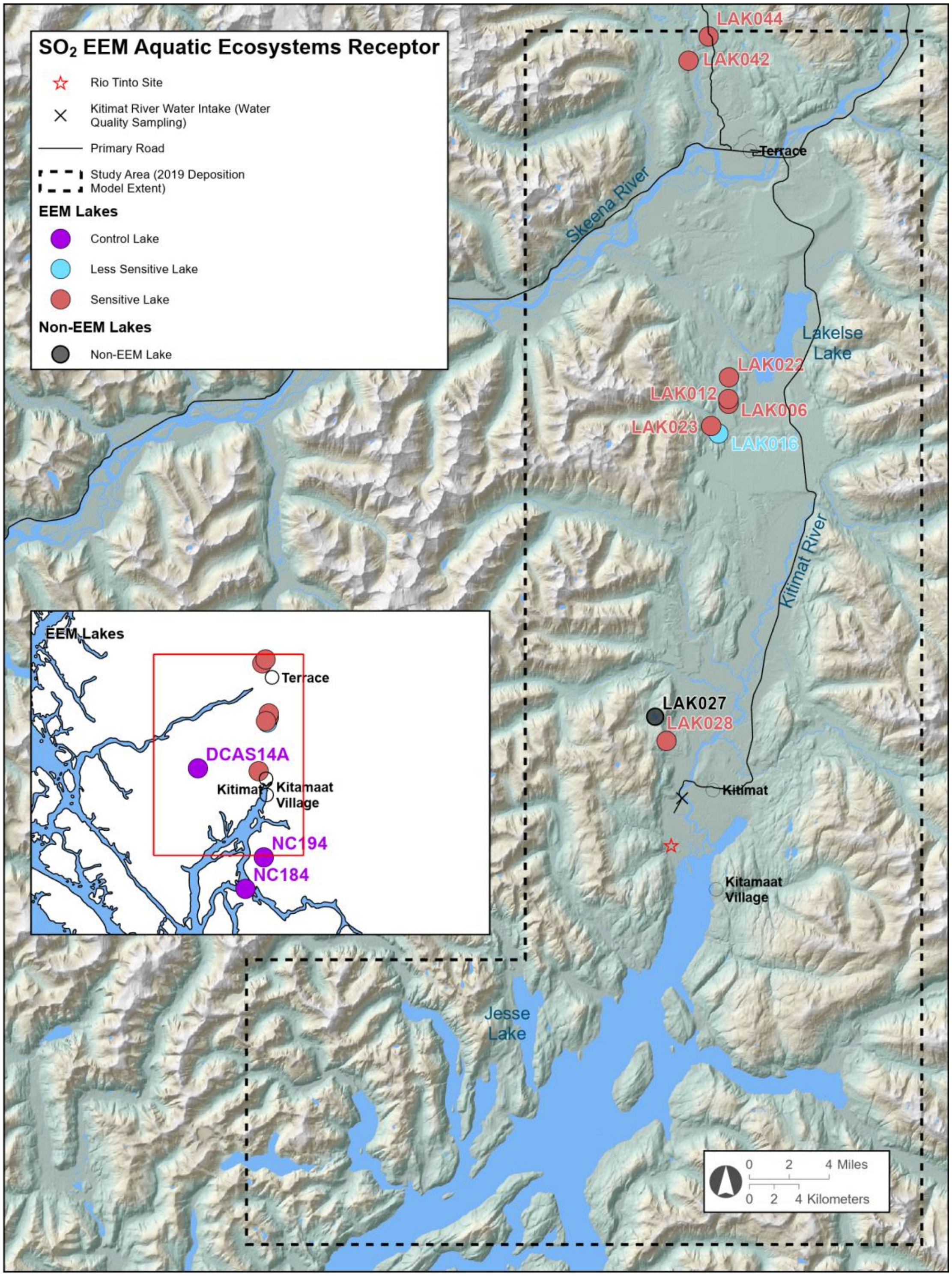


Figure 2-1. Location of the lakes in the EEM Program, including seven sensitive lakes (red), one less sensitive lake (blue) and three control lakes (purple). LAK027 was resampled in 2021 to compare with the STAR results.

Sampling frequency

The only change in sampling frequency from last year was a return to sampling the sensitive lakes LAK006, LAK012, LAK023, LAK028, LAK042, and LAK044 on 4 occasions within the Fall index period after a single-year reduction in sampling frequency in 2020 (3 times for LAK028, 2 times for the other lakes).

Continuous monitoring

Two lakes (LAK006, LAK028) had continuous monitoring of surface water pH, temperature and lake levels. LAK028 also had a similar instrument installed at depth. This work was planned, implemented and documented by Limnotek. The methods and results for 2021 are reported in Limnotek (2022).

Water chemistry data

There were no differences in the water chemistry analyses completed from the 2021 sampling compared to previous years. Continuing from 2020, the analyses of Gran ANC, pH and conductivity are now *only* performed by the BASL facility (University of Alberta).

In last year's EEM 2020 Annual Report, we recommended discontinuing the measurement of Al_{im} going forward; however, the field planning and purchasing was already set in place for the 2021 season.

Integrating laboratory measurements of pH and Gran ANC from Trent and BASL laboratories

The planned transition of laboratory analysis of pH and Gran ANC from Trent University to the BASL laboratory at the University of Alberta was completed in 2020. In 2019, duplicate samples were sent to both laboratories to facilitate cross-laboratory comparisons (see Limnotek 2020). In 2021, samples were analyzed only by BASL.

To facilitate analyses over the entire period of record, we need an "integrated" data series for each of the two metrics. As in the 2020 EEM report, we constructed an integrated time series by imputing Trent values for pH and Gran ANC for 2021 based on the regression of Trent values vs. BASL values from the 2019 data. This method was recommended and developed by Dr. Carl Schwarz (retired professor of statistics from Simon Fraser University) and is described in detail in the EEM 2020 Annual Report.

2.2 Empirical Changes in Water Chemistry

The methods applied for examining empirical changes are the same as described in the last several years. The analyses of inorganic aluminum are the same as those described in the past two years.

2.3 Statistical Analyses of Changes in Water Chemistry

The 2019 Comprehensive Review performed an extensive series of statistical analyses of changes in water chemistry and concluded that the results from the Bayesian statistical analyses provided the greatest ability to assess the level of support for different hypotheses of chemical change. The 2019 Comprehensive Review further recommended that these analyses be re-run on an annual basis to assess status and detect any anomalous patterns. This annual report represents the third iteration of re-running those analyses with more recent monitoring data. These methods are described in detail in Appendix F of the 2019 Comprehensive Review Report (see Bayesian Method 1 especially). The key metrics of interest are the differences in lake chemistry between the post-KMP average for the last three years (2019-2021) and the pre-KMP baseline (2012 for the sensitive and less sensitive lakes; 2013 for the control lakes). For the lakes that were not sampled in 2020, the post-KMP period used to compute average lake chemistry is still 2019-2021 and therefore only based on 2 years of data (2019 and 2021). Appendix 3 includes sensitivity analyses that examine the effect of using an alternative baseline representing the transition period as operations at the old smelter were wound down (2012-2014).

The results of the Bayesian statistical analyses are expressed in terms of: a) the % belief that the post-KMP values have exceeded the *level of protection* thresholds, and b) the % belief that the changes from the baseline period to the post-KMP period have exceeded the *change limit* thresholds. As applied in the 2019 Comprehensive Review, the % belief values are classified as low (< 20%), moderate (20% to <80%), or high (≥ 80%). This classification is done both for ease of interpretation, and to integrate the analyses for the two-threshold structure of the CBANC KPI and informative indicators into a single assessment for each indicator for each lake. As described in the Phase III Plan, the acidification indicators (CBANC, pH, Gran ANC and BCS) are only considered to be in exceedance if **both** thresholds are exceeded (i.e., the *level of protection* and the *change limit* thresholds). The single, integrated assessment of each of those indicators is determined according to the rules:

1. If the result for **either** threshold is **"low"**, then the overall assessment is **"low"**
2. The results for **both** thresholds must be **"high"** for an overall assessment of **"high"**
3. If result for **either** threshold is **"moderate"** and the results for the other threshold are "moderate" or "high", then the overall assessment is **"moderate"**.

As described in the EEM Phase III Plan, the two-threshold structure avoids creating false positives by simultaneously considering the two dimensions of importance to aquatic organisms – the absolute level and the relative change in the water chemistry metrics used as acidification indicators.

Appendix 4 includes the results of the sensitivity analyses for the uncertainty associated with the imputation procedure associated with developing integrated data series for pH and Gran ANC following the transition of laboratories (details in Section 2.1).

We also evaluated the differential trends between the sensitive lakes and the control lakes using the before-after control-impact (BACI) analysis methods as described in the 2019 Comprehensive Review (i.e., Method 3: BACI using mean values). Using this method, we evaluated the sensitive lakes individually and as a group, for both CBANC (as an informative method, as the KPI is not based on this method) and the pH informative indicator.

2.4 Environmental Data

This section includes supplementary environmental observations or data utilized in the interpretation of the water chemistry results (see Section 4.3).

Precipitation data from the Kitimat 2 and Terrace PCC climate stations[1] show that 2021, similar to 2020, had significantly more precipitation than 2019 during July through October; however, this precipitation was highly concentrated in September, which recorded levels approximately 60% higher than the previous year. At the Kitimat 2 climate monitoring station, total rainfall in September 2021 was 328.6 mm, compared with 221.7 mm in 2020 and 87.6 mm in 2019 (Table 2-2). Similar trends were observed at the Terrace PCC climate monitoring station with 163.1 mm of total rainfall measured in September 2021 compared to 101.0 mm in 2020 and 58.4 mm.

During the two weeks prior to the annual sampling date on October 4, 2021 (i.e., the date in which all lakes are sampled), the Kitimat 2 station measured 306.7 mm of rainfall and the Terrace PCC station measured 183.7 mm. For both stations, this represents approximately double the average for the entire month of September based on the previous 9 years.

Figure 2-2 shows that the summer-fall precipitation in the Kitimat Valley in 2021 was generally comparable to 2019 until mid-September when there was a major increase in precipitation.

Table 2-2. Total Monthly Precipitation (mm) at Kitimat 2 and Terrace PCC for 2019-2021.

	2019		2020		2021	
	Kitimat 2	Terrace PCC	Kitimat 2	Terrace PCC	Kitimat 2	Terrace PCC
July	60.8	80.2	67.6	50.6	15.2	40.7
August	63.8	39.0	212.0	160.3	43.5	24.7
September	87.6	58.4	221.7	101.0	348.6	163.1
October	178.6	121.8	169.6	121.6	145.3	83.2

[1] Source: Data accessed via Environment Canada's *Historical Climate Data* web portal (http://climate.weather.gc.ca)

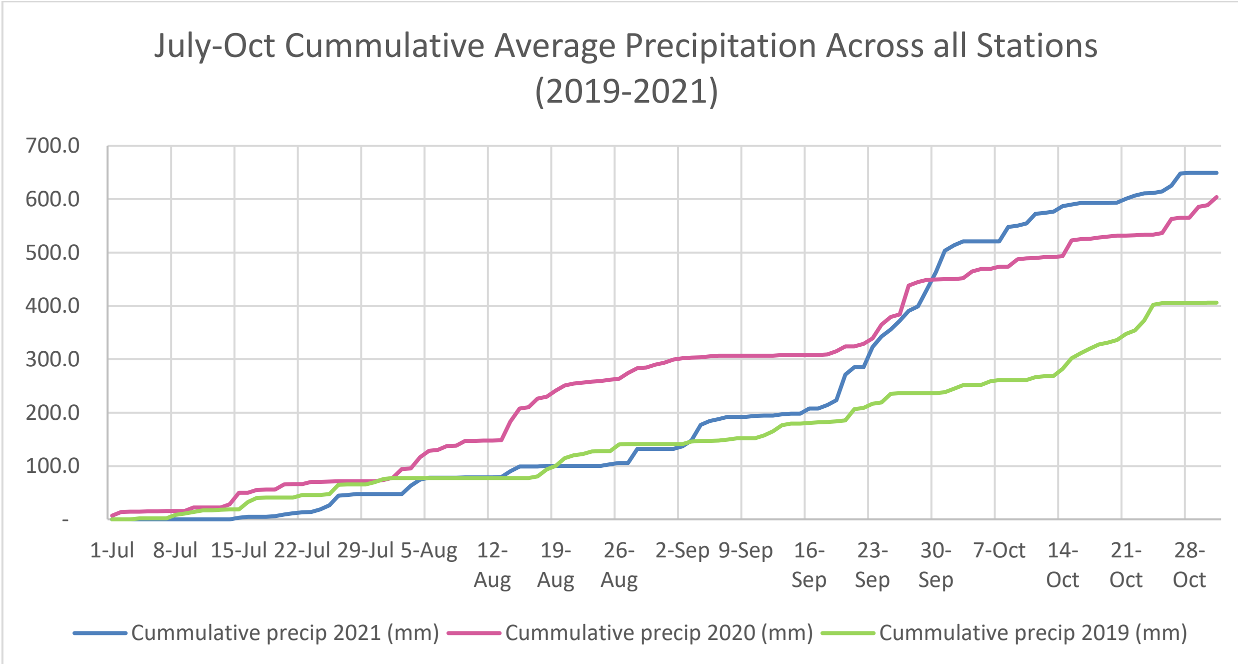


Figure 2-2. Cumulative precipitation for July-Oct in 2019, 2020 and 2021. These data are based on the average of the daily precipitation values across the four climate stations available in the region – Kitimat 2, Kitimat Townsite, Terrace A, and Terrace PCC.

2.5 Episodic Acidification

We reviewed the data record from the continuous pH monitors installed in LAK006 and LAK028 to identify any notable drops in pH. If any such changes were observed, we compared those results with the lake-level data to determine if they appeared to be correlated with high inflows to the lake.

2.6 Alignment of Evidentiary Framework with Phase III Indicators

The "Simple Evidentiary Framework" developed in the 2019 Comprehensive Review and subsequently built into the Phase III Plan only considered post-KMP changes in pH and ANC[2] (relative to pre-KMP conditions), especially relative to the *change limit* thresholds, but did not consider the post-KMP state of either of those metrics with respect to the *level of protection* thresholds. This is not consistent with the important advance in the EEM Phase III Plan of moving to a two-threshold structure for the KPI and the pH and ANC informative indicators that consider both relative change and the absolute level of those indicators.

To be consistent with the EEM Phase III Plan, we revised the Evidentiary Framework last year (i.e., EEM 2020 Annual Report) by adding an assessment node associated with the *level of protection* threshold (Figure 2-3). The new node was inserted earlier in the logic sequence than the two nodes assessing the level of change. In the two-threshold structure for the KPI and

[2] Gran ANC in the 2019 Comprehensive Review; CBANC in the Phase III Plan (consistent with the revised KPI).

informative indicators, neither of the thresholds takes precedence – an exceedance of the indicator requires that both thresholds are exceeded with a high percent belief. Therefore, there is no inherent sequence between evaluating the *change* limit and *level of protection* thresholds. However, in the Evidentiary Framework, there is an additional node that considers whether there has been any change in the indicator prior to assessing against the *change limit* threshold, which makes the framework more precautionary, so we believe it made more sense to have the *level of protection* node earlier in the sequence than the two change-based nodes.

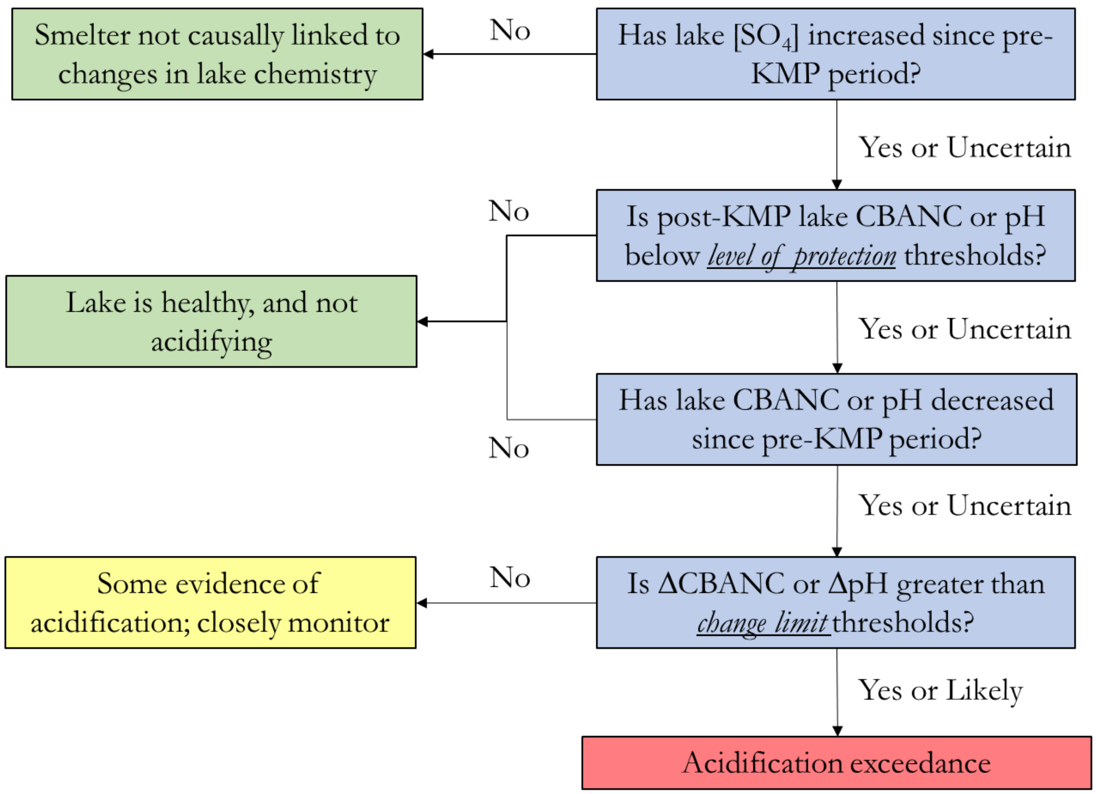


Figure 2-3. The Evidentiary Framework. The framework developed in the 2019 Comprehensive Review was revised in the EEM 2020 Annual Report order to align with the two-threshold structure for the KPI and informative indicators in the EEM Phase III Plan.

3 Results

3.1 Empirical Changes in Water Chemistry

Empirical changes in ANC, pH, SO_4^{2-}, DOC, sum of base cations, chloride, and calcium are shown in Table 3-1. Changes are reported in terms of the difference between the post-KMP average (2019-2021) and the pre-KMP baseline (2012 for the sensitive and less sensitive lakes; 2013 for the control lakes). The sensitive EEM lakes and less sensitive EEM lakes are presented separately within each of the tables. The inter-annual changes presented in this report use the mean annual values whenever multiple within-season samples were taken for a given lake in a given year.

Unlike the annual reports prior to the 2019 Comprehensive Review, the annual changes between individual years are no longer reported and analyzed. As already stated in previous years (e.g., ESSA 2018), year-to-year changes should be interpreted cautiously:

> *"… annual changes should be interpreted with substantial caution due to the combination of large natural variation (both within and between years) and limitations on measurement precision… multiple years of observations are required to reliably detect changes in mean pH, Gran ANC and SO4; it is risky to draw conclusions based only on annual changes"*.

Furthermore, in the December 2018 workshop on the terms of reference for the EEM comprehensive review, the ENV external acidification expert recommended that we stop reporting annual changes because inter-annual variability in lake chemistry is too variable to make any meaningful interpretation of the changes between two years.

The most notable changes in Table 3-1 are in LAK028, where mean [SO_4^{2-}] increased by 75 μeq/L since 2012, and total base cations (ΣBC*) increased by 67.9 μeq/L. The changes in ΣBC* and SO_4^{2-} largely explain the observed change in CBANC, a decline of 7.9 μeq/L. CBANC equals the sum of base cations minus the sum of strong acid anions, and $\Delta\Sigma BC^* - \Delta[SO_4^{2-}] = 67.9 – 75 = – 7.1$, close to the 7.9 μeq/L decline in CBANC. Gran ANC increased slightly (3.5 μeq/L) in LAK028 and there was no change in pH. LAK028 showed a decline in Base Cation Surplus (BCS) since the pre-KMP period, though BCS has shown considerable variation in LAK028, with its lowest value in 2013 (Table 3-5).

Figure 3-1 and Figure 3-2 show the changes in the same water chemistry parameters graphically. These figures allow an alternate visualization of the distribution and variability in the observed changes between 2012 and 2019-2021.

For additional reference, Table 3-2 and Table 3-3 shows the CBANC and pH values, respectively, over the period of record for EEM lakes, average values for the post-KMP period (2019-2021) and the differences between the post-KMP period and both the pre-KMP baseline (2012) and the transition period baseline (2012-2014). The changes in CBANC are similar using both the pre-KMP and the transition period as a baseline (Table 3-2), whereas the changes in pH were more negative using the 2012-2014 transition period as a baseline instead of the pre-KMP 2012 measurement (Table 3-3).

Appendix 2 provides a detailed set of figures showing the inter-annual changes in major water chemistry metrics (CBANC, Gran ANC, BCS, pH, SO_4^{2-}, base cations, calcium, chloride, and DOC) for each of the EEM lakes across the ten years of annual monitoring (2012-2021). Similar figures are also included for the three control lakes based on their seven years of annual monitoring (2013 and 2015-2021).

Table 3-1. Empirical changes in CBANC, Gran ANC, BCS, pH, SO_4^{2-}, DOC, base cations, chloride, calcium, and NO_3 for EEM lakes. These values represent the difference between the average of the post-KMP period (2019-2021) and the 2012 baseline. Numbers shown are the value in the later period minus the value in the earlier year. Increases are shaded in green; decreases are shaded in red. The Gran ANC and pH values are based on the "integrated" time series (i.e., values from the Trent University laboratory from 2012 to 2019 with the 2020 and 2021 values imputed from the values measured by the BASL laboratory ("integ"); see details in Section 2.1).

SITE	CBANC (µeq/L)	Gran ANC (integ) (µeq/L)	BCS (µeq/L)	pH (integ)	SO4* (µeq/L)	DOC (mg/L)	∑ BC* (µeq/L)	Cl (µeq/L)	Ca* (µeq/L)	NO_3 (µeq/L)
Lak006	18.1	9.3	13.3	0.2	5.2	1.0	23.4	0.9	12.4	0.2
LAK012	-1.2	5.8	-13.1	0.3	13.5	2.4	12.3	3.5	4.4	0.4
LAK022*	3.8	-0.9	1.5	-0.1	15.5	0.5	19.3	1.2	10.2	0.1
LAK023	13.8	3.0	5.1	0.1	-1.7	1.7	12.6	0.6	8.3	0.5
LAK028	-7.9	3.5	-20.5	0.0	75.0	2.5	67.9	4.3	49.5	0.2
LAK042	17.5	17.4	8.5	0.2	3.4	1.8	21.0	0.0	11.7	0.2
LAK044	7.5	3.0	5.3	0.1	-1.4	0.4	6.1	0.8	2.1	0.1
Total ↑	**5**	**6**	**5**	**5**	**5**	**7**	**7**	**6**	**7**	**7**
Total ↓	**2**	**1**	**2**	**2**	**2**	**0**	**0**	**1**	**0**	**0**
LAK016*	6.8	22.2	-7.5	0.0	20.3	2.9	27.5	2.3	16.1	0.7
Total ↑	**1**	**1**	**0**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Total ↓	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
DCAS14A*	19.0	3.1	16.7	-0.3	1.4	0.5	18.4	-0.8	10.5	-2.0
NC184*	-6.7	0.3	-1.0	-0.3	-0.4	-1.1	-7.2	-2.9	-2.7	-0.1
NC194*	5.5	-0.9	3.6	-0.4	-1.2	0.4	4.4	-0.1	3.7	0.1
Total ↑	**2**	**2**	**2**	**0**	**1**	**2**	**2**	**0**	**2**	**1**
Total ↓	**1**	**1**	**1**	**3**	**2**	**1**	**1**	**3**	**1**	**2**

** lakes not sampled in 2020*

Table 3-2. CBANC values over period of record for EEM lakes, average CBANC values for the post-KMP period and the relative change from the pre-KMP baseline and the transition period baseline. The post-KMP averaging period applied in the 2019 comprehensive review (CR) is also shown for reference. Green represents an increase and red represents a decrease. Bolded purple values are below the 20 μeq/L *level of protection* threshold for CBANC.

	Mean CBANC values (μeq/L)										Post-KMP averaging period		Change from baseline to current post-KMP average (2019-21)	
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2016-18 (CR)	2019-21 (current)	From pre-KMP baseline (2012)	From transition period baseline (2012-14)
LAK006	49.2	43.1	52.9	55.1	56.9	58.0	59.3	63.8	70.3	67.8	58.0	67.3	18.1	18.9
LAK012	114.5	97.5	99.8	106.1	103.2	101.1	90.4	96.5	142.1	101.2	98.2	113.3	-1.2	9.3
LAK022	67.9	62.0	76.1	75.2	80.3	70.4	76.6	74.8		68.8	75.8	71.8	3.8	3.1
LAK023	46.9	37.7	59.4	58.0	59.5	59.9	61.3	59.4	66.6	56.2	60.2	60.7	13.8	12.7
LAK028	**16.0**	**-8.1**	31.2	38.6	**12.3**	**0.7**	**8.4**	**4.5**	**8.0**	**11.7**	**7.1**	**8.1**	-7.9	-4.9
LAK042	47.2	55.1	51.6	55.4	64.0	63.1	50.4	52.1	79.5	62.4	59.2	64.7	17.5	13.4
LAK044	**8.0**	**8.9**	**12.6**	**16.4**	**13.9**	**13.8**	**13.2**	**14.8**	**14.5**	**17.1**	**13.6**	**15.5**	7.5	5.6
LAK016	127.2	108.7	132.5	147.1	140.8	125.3	138.1	129.8		138.1	134.7	134.0	6.8	11.2
DCAS14A		53.5		74.9	72.7	67.8	79.0	81.1		63.8	73.2	72.5	19.0	19.0
NC184		80.4		73.0	94.6	76.3	95.0	86.1		61.2	88.6	73.7	-6.7	-6.7
NC194		35.6		40.9	40.0	46.5	43.1	46.7		35.6	43.2	41.1	5.5	5.5

Table 3-3. pH values over period of record for EEM lakes, average pH values for the post-KMP period and the relative change from the pre-KMP baseline and the transition period baseline. The post-KMP averaging period applied in the 2019 comprehensive review (CR) is also shown for reference. Green represents an increase and red represents a decrease. Bolded purple values are below the *level of protection* threshold for pH (6.0). As explained in the STAR, the 2012 chemistry of most of the sensitive lakes was influenced by organic acids contributed by DOC. Mean DOC has not changed much in the sensitive lakes since 2012 (Figure 3-1).

	Mean pH values										Post-KMP averaging period		Change from baseline to current post-KMP average (2019-21)	
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2016-18 (CR)	2019-21 (current)	From pre-KMP baseline (2012)	From transition period baseline (2012-14)
LAK006	**5.8**	6.2	6.1	6.0	6.0	6.0	6.1	6.1	6.0	**5.8**	6.0	6.0	0.2	-0.0
LAK012	**5.6**	6.3	6.0	6.0	6.2	6.1	6.2	6.1	6.0	**5.7**	6.2	**5.9**	0.3	-0.1
LAK022	**5.9**	6.2	6.3	6.1	6.1	6.1	6.1	6.1		**5.4**	6.1	**5.8**	-0.1	-0.3
LAK023	**5.7**	6.0	**5.9**	**5.9**	**5.9**	**5.9**	6.0	**5.8**	**5.9**	**5.7**	**5.9**	**5.8**	0.1	-0.1
LAK028	**5.0**	**5.2**	**5.3**	**5.1**	**5.0**	**4.8**	**5.3**	**5.2**	**4.9**	**4.7**	**5.0**	**4.9**	0.0	-0.2
LAK042	**4.7**	**5.5**	**5.1**	**5.4**	**5.4**	**5.2**	**5.1**	**5.4**	**4.6**	**4.6**	**5.2**	**4.9**	0.2	-0.2
LAK044	**5.4**	**5.7**	**5.8**	**5.8**	**5.5**	**5.6**	**5.5**	**5.5**	**5.6**	**5.5**	**5.6**	**5.5**	0.1	-0.1
LAK016	6.3	6.7	6.7	6.8	6.6	6.7	6.7	6.6		6.1	6.7	6.3	0.0	-0.3
DCAS14A		6.5		6.6	6.6	6.6	6.8	6.6		5.9	6.6	6.2	-0.3	-0.3
NC184		5.7		5.5	5.8	5.4	6.2	5.7		5.1	5.8	**5.4**	-0.3	-0.3
NC194		6.6		6.5	6.4	6.4	6.5	6.4		5.9	6.4	6.1	-0.4	-0.4

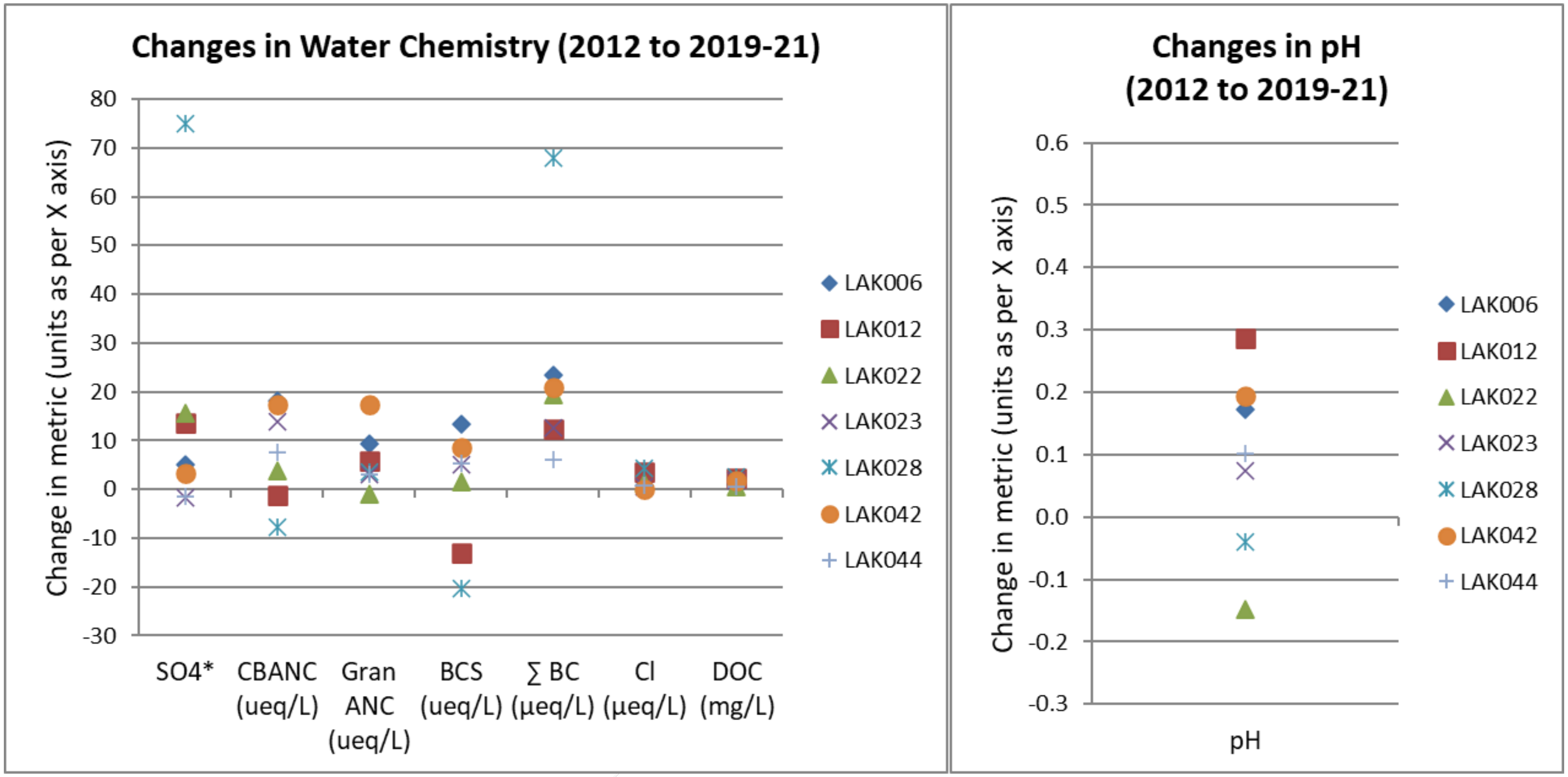


Figure 3-1. Changes in water chemistry metrics (left panel) and pH (right panel) across all of the sensitive EEM lakes, from 2012 to 2019-2021. Values shown are the mean 2019-2021 value minus the mean 2012 value. The large increase in lake SO_4^{2-} in LAK028 has been buffered by a large increase in base cations, due to cation exchange in watershed soils.

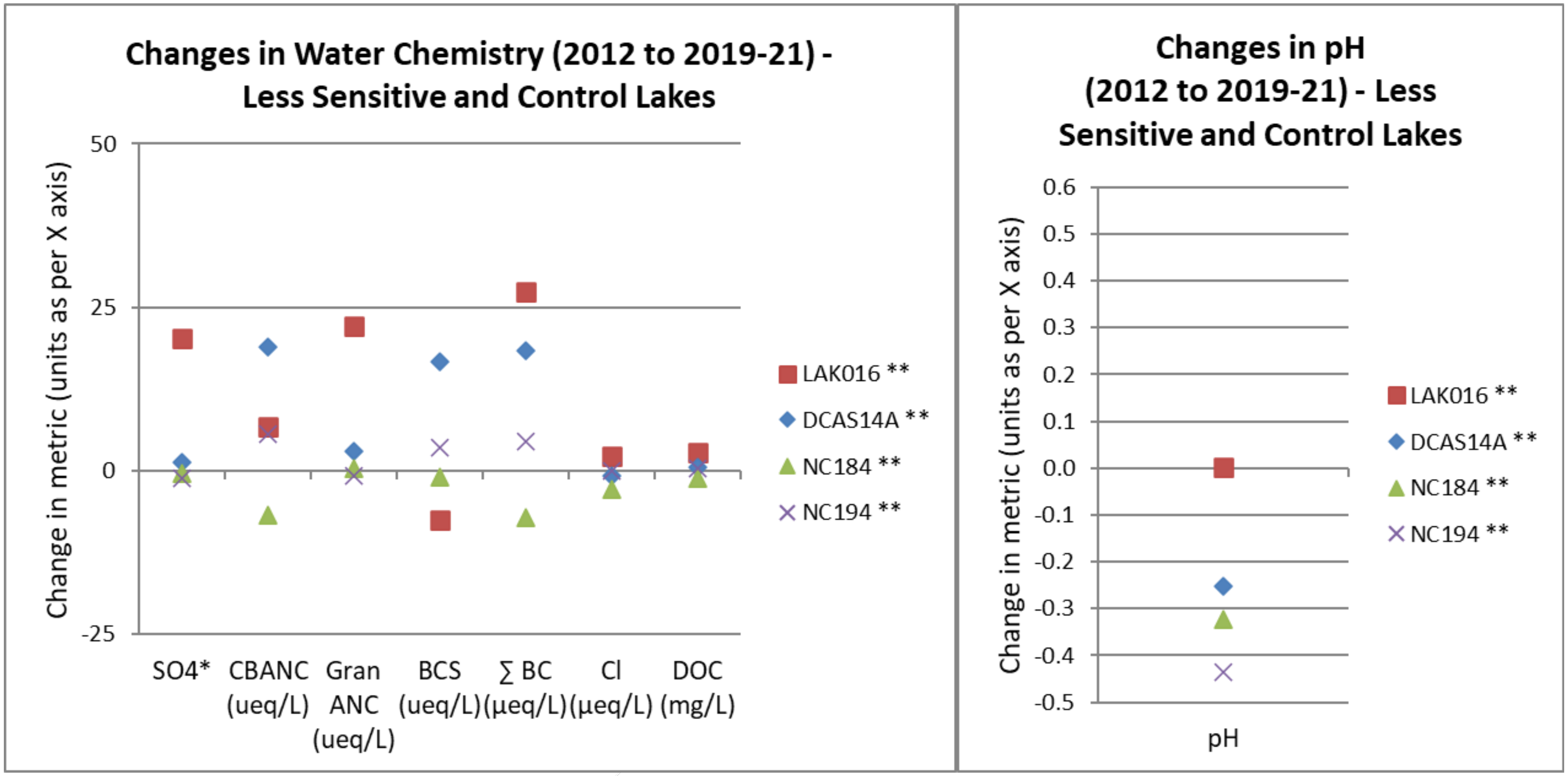
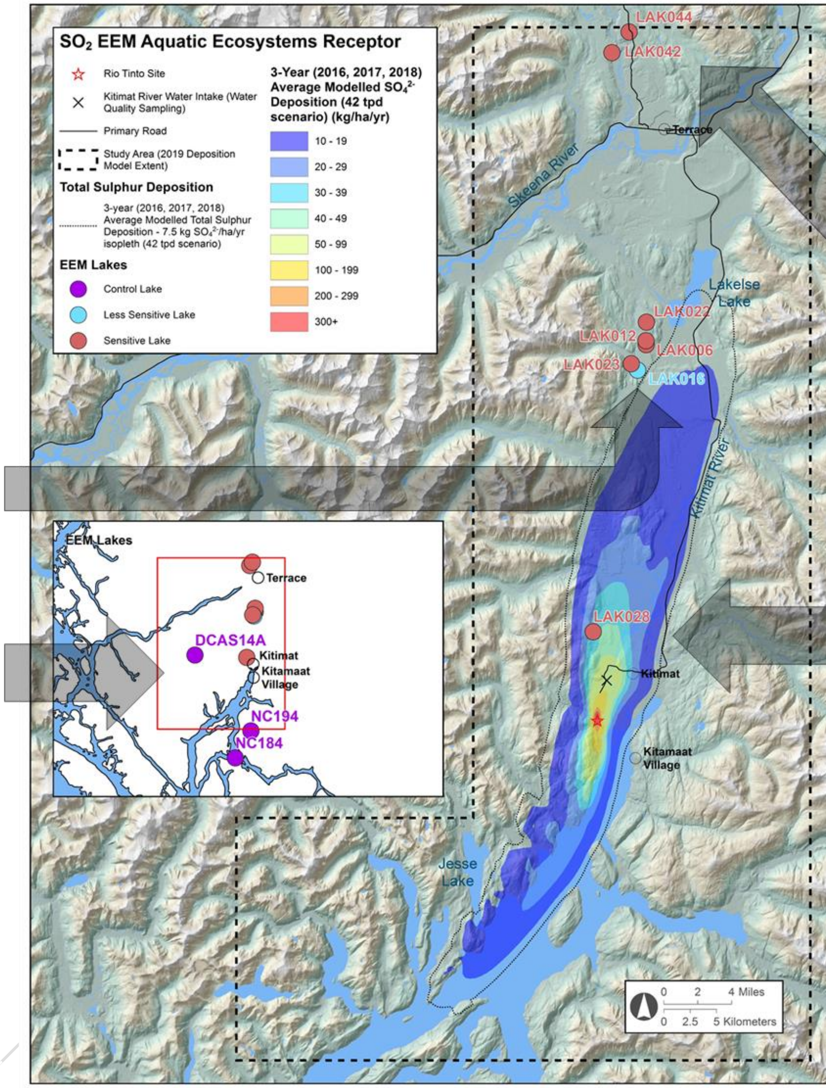


Figure 3-2. Changes in water chemistry metrics (left panel) and pH (right panel) across all of the less sensitive and control lakes, from 2012 to 2019-2021. Values shown are the mean 2019-2021 value minus the mean 2012 value.

	2012 to 2019-21		
LAKE	ΔSO_4^{2-}	Δ CBANC	ΔpH
Lak006	5.2	18.1	0.2
LAK012	13.5	-1.2	0.3
LAK022	15.5	3.8	-0.1
LAK023	-1.7	13.8	0.1
LAK016	20.3	6.8	0.0

	2012 to 2019-21		
LAKE	ΔSO_4^{2-}	Δ CBANC	ΔpH
DCAS14A	1.4	19.0	-0.3
NC184	-0.4	-6.7	-0.3
NC194	-1.2	5.5	-0.4



	2012 to 2019-21		
LAKE	ΔSO_4^{2-}	Δ CBANC	ΔpH
LAK042	3.4	17.5	0.2
LAK044	-1.4	7.5	0.1

	2012 to 2019-21		
LAKE	ΔSO_4^{2-}	Δ CBANC	ΔpH
LAK028	75.0	-7.9	0.0

Figure 3-3. Observed changes in SO_4^{2-}, CBANC and pH from the baseline period (2012) to the post-KMP period (2019-2021). Green cells indicate increases and red cells indicate decreases.

Resampling of LAK027

Table 3-4 shows the results for LAK027 for ANC, pH, SO_4^{2-}, DOC, sum of base cations, chloride, and calcium, including the results from the 2012 STAR sampling and the difference between the two sampling years. There were declines in both ΣBC* (-20 µeq/L) and SO_4^{2-} (-26.4 µeq/L), which explains the net decline in CBANC (-6.5 µeq/L).

Table 3-4. CBANC, Gran ANC, BCS, pH, SO42-, DOC, base cations, chloride, and calcium values for LAK027, from the 2012 STAR sampling and the 2021 resampling. Increases are shaded in green; decreases are shaded in red. The Gran ANC and pH values are based on the "integrated" time series (i.e., values from the Trent University laboratory from 2012 with the 2021 values imputed from the values measured by the BASL laboratory ("integ"); see details in Section 2.1). Note that the imputation uses the regression based on the 2019 data for the EEM Lakes (i.e., LAK027 did not contribute to the regression).

	CBANC (µeq/L)	Gran ANC (integ) (µeq/L)	BCS (µeq/L)	pH (integ)	SO4* (µeq/L)	DOC (mg/L)	∑ BC* (µeq/L)	Cl (µeq/L)	Ca* (µeq/L)
2012	101.3	69.8	98.8	6.6	110.4	1.1	211.6	3.2	189.3
2021	94.8	56.9	65.9	5.9	90.3	6.4	185.2	8.2	157.9
Change	-6.5	-12.9	-32.9	-0.7	-20.0	5.3	-26.4	5.0	-31.4

Inorganic Aluminum

The following graphs show the relationship between Al_{im} and total Al (Figure 3-4), pH (Figure 3-5), and BCS (Figure 3-6). The key observations from these graphs are as follows:

General patterns:

- Figure 3-4 shows a positive, potentially non-linear relationship between Al_{im} and total Al in 2013, 2019, 2020, and 2021. Only those sites with total Al values greater than 0.2 mg/L have appreciable levels of Al_{im}.
- Figure 3-5 shows that the expected pattern of increasing Al_{im} with decreasing pH is reflected in all four years.
- Similar to 2013, the 2019, 2020, and 2021 data show the expected pattern that Al_{im} is highest for sites where BCS < 0 µeq/L and is <0.06mg/L for sites where BCS > 50 µeq/L (Figure 3-6). One of the strengths of the BCS metric is that Al_{im} consistently increases as BCS declines below zero. The data show that DOC also plays a role, with higher concentrations of both total aluminum and Al_{im} in organically acidified lakes with low pH and high DOC (Figure 3-5). Higher concentrations of Al_{im} in organically acidified lakes suggests that the increase in total aluminum in these lakes due to organic acidity outweighs the complexation of inorganic aluminum by organic anions.

LAK028:

- With respect to key metrics related to aluminum (Total Al, Al_{im}, pH, BCS) LAK028 showed a similar status in 2021, 2020, and 2019 (Figure 3-4, Figure 3-5, Figure 3-6).

- With BCS < 0 μeq/L and Al_{im} > 0.30 mg/l in 2019-2021, there is consistent evidence of toxic levels of Al_{im} in LAK028 (Figure 3-6), based on Baldigo et al. 2009.
- The conditions in 2019-2021 appear to be generally similar to those in 2013 during the transition to the new smelter (2013 also had BCS <0 μeq/L and Al_{im} > 0.30 mg/l; Figure 3-6), though there was only one sample from LAK028 in 2013 so we have no estimate of within season variability.
- There has been considerable variability in mean BCS over time in LAK028 (Table 3-5). Section 3.3 includes statistical analyses of the changes in BCS between the pre-KMP baseline and the post-KMP period.

LAK042:

- LAK042 showed broadly similar conditions to previous years.
- DOC decreased by 2.7 mg/L between 2020 and 2021 (19.2 mg/L to 16.5 mg/L)
- pH stayed constant between 2020 and 2021 at 4.7 (Appendix 1).

Other lakes:

- None of the other lakes show levels of BCS < 0 or chronic toxic levels of Al_{im}.

Inorganic monomeric aluminum was measured in several individual years as a pilot to determine whether there are any lakes experiencing elevated levels of biologically-available aluminum that have not already been identified by the existing suite of lake chemistry metrics and analyses. Similar to the preliminary conclusions expressed in the 2019 Comprehensive Review and the conclusions presented in the 2019 and 2020 Annual Reports, the 2021 results show that the Al_{im} data align as expected with the BCS data and do not contribute novel information about lake chemistry. Therefore, discontinuing the measurement of Al_{im}, while continuing to estimate BCS, would not have any adverse impact on the monitoring program.

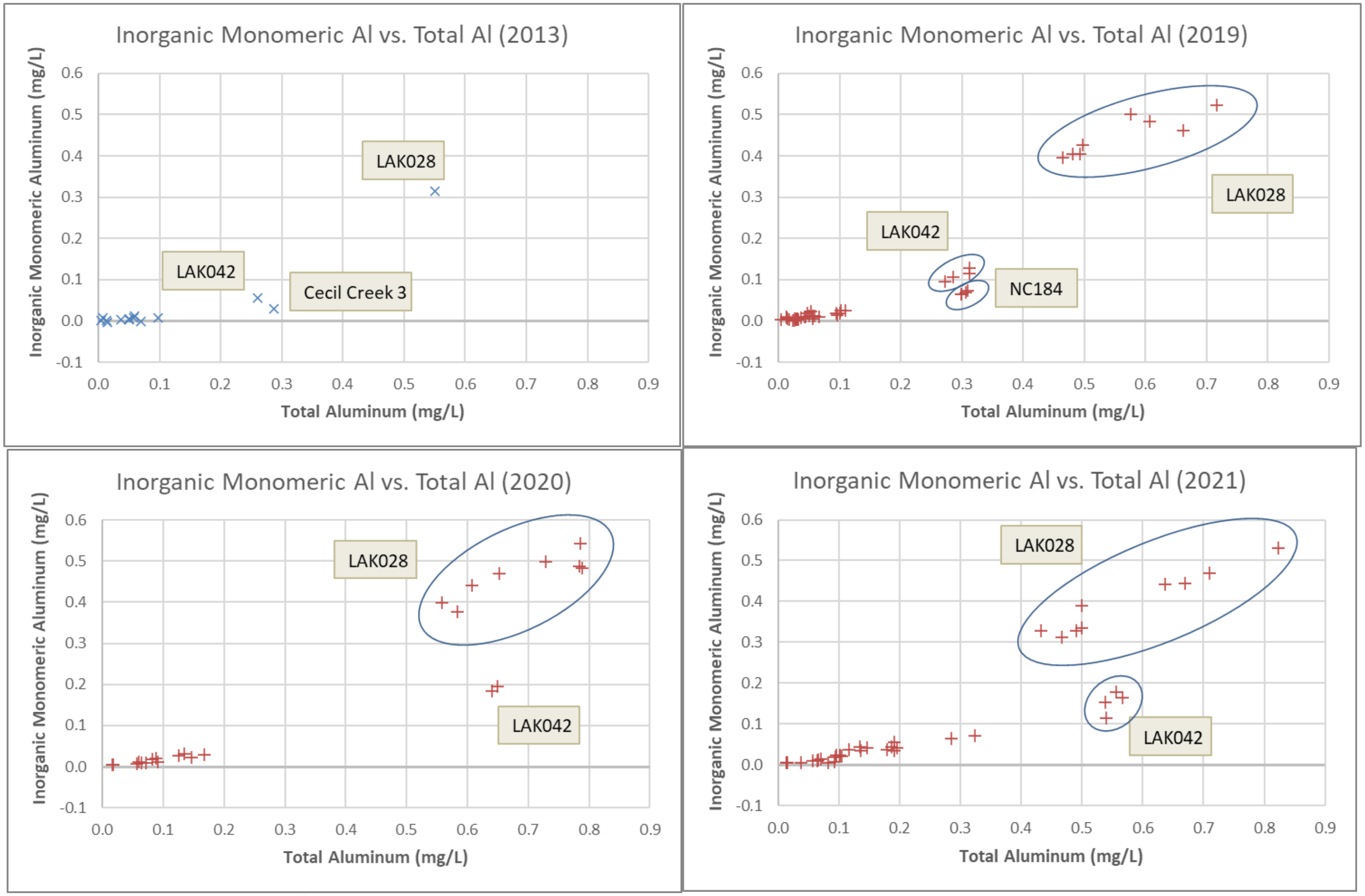


Figure 3-4. Inorganic monomeric aluminum versus total aluminum for 2013 samples (top left), 2019 samples (top right), 2020 samples (bottom left), and 2021 samples (bottom right). Lakes with higher aluminum values are indicated.

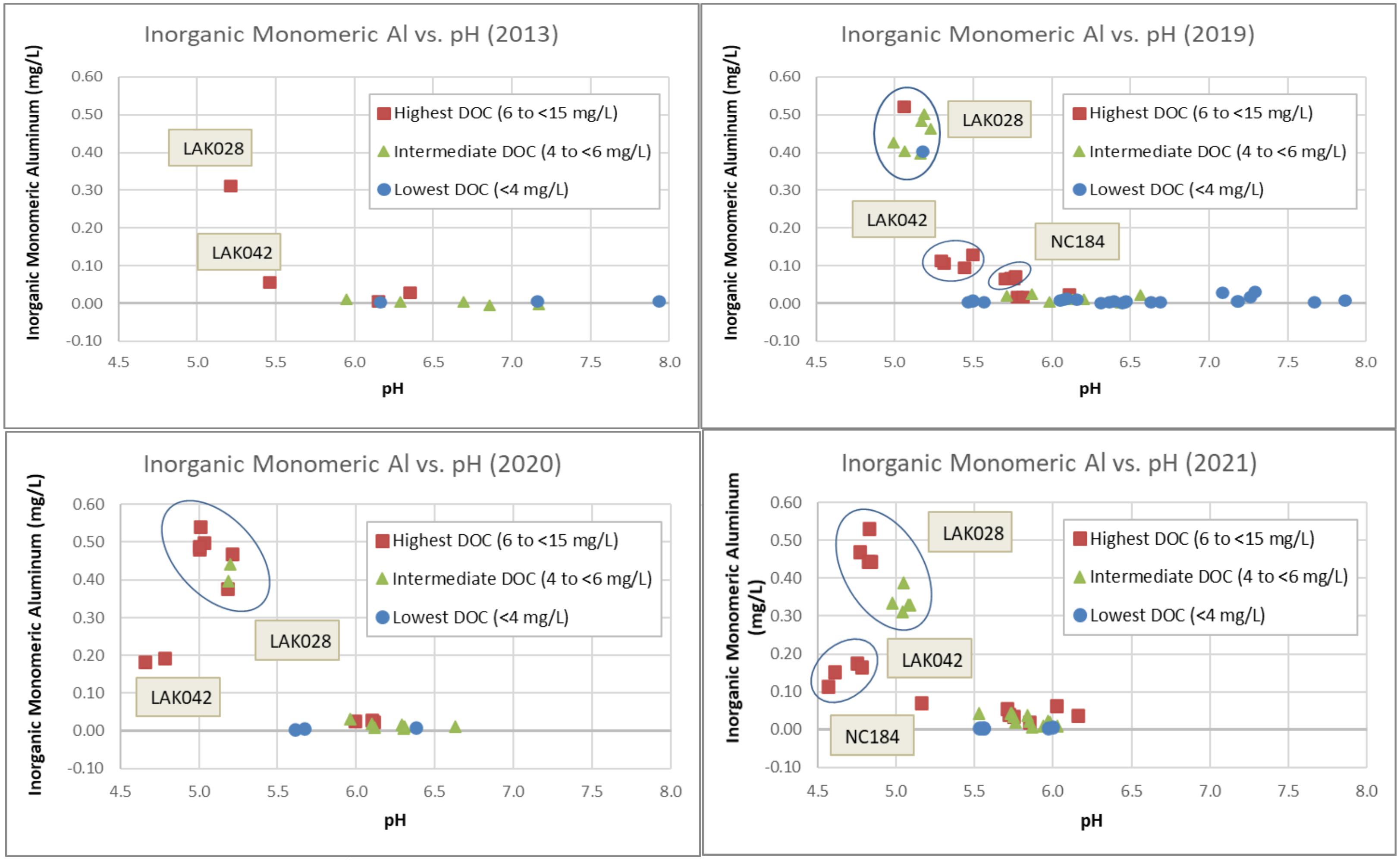


Figure 3-5. Inorganic monomeric aluminum versus pH for 2013 samples (top left), 2019 samples (top right), 2020 samples (bottom left), and 2021 samples (bottom right). The sites are stratified into three classes of DOC, which were applied in the Comprehensive Review based on natural breaks in the 2013 data.

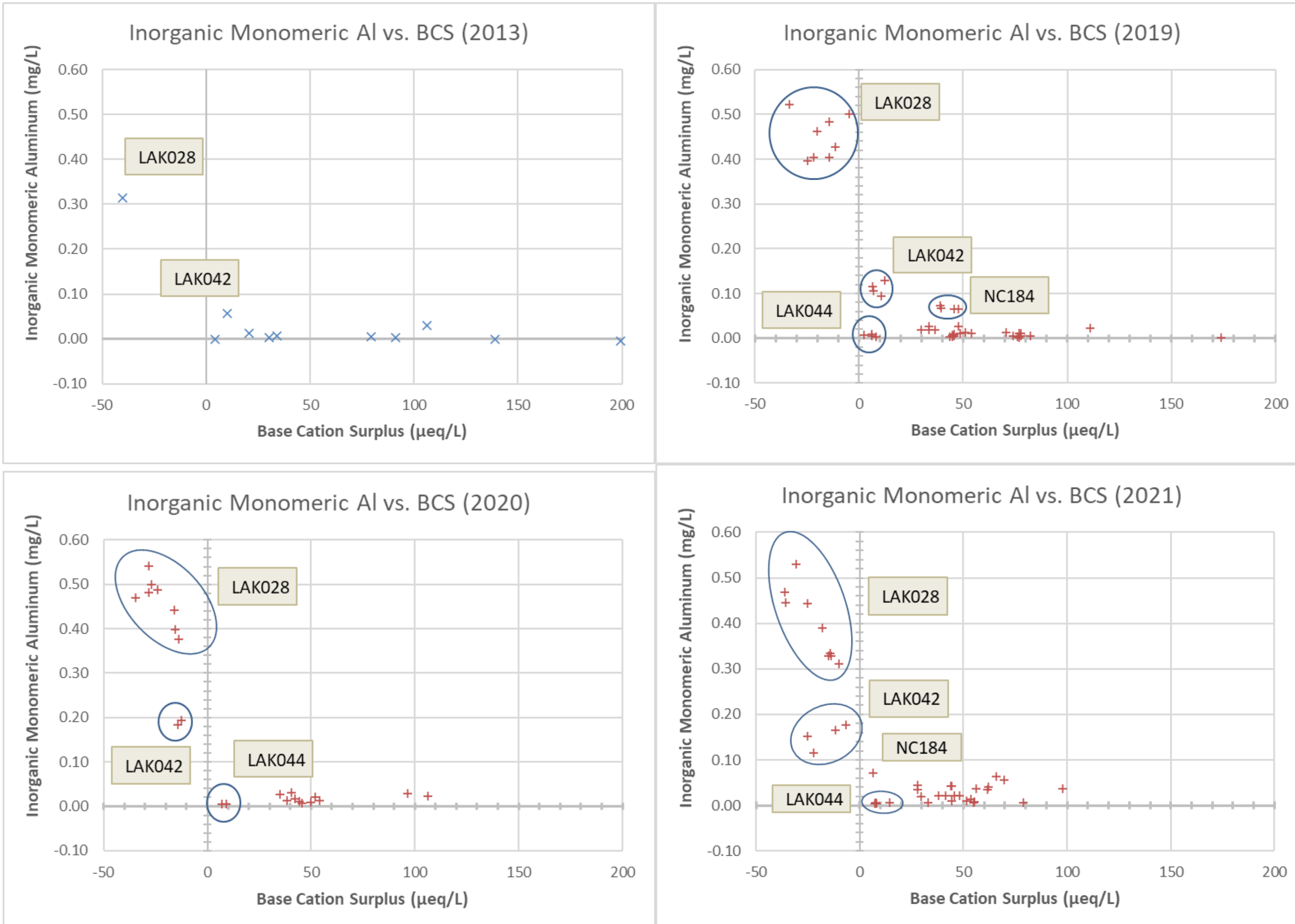


Figure 3-6. Inorganic monomeric aluminum versus Base Cation Surplus (BCS) for 2013 samples (top left), 2019 samples (top right), 2020 samples (bottom left), and 2021 samples (bottom right). The 2013 and 2019 data are limited to samples <200 µeq/L.

Table 3-5. Mean values of BCS in LAK028 by year. Units are μeq/L. Data from Appendix 1.

Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
BCS (μeq/L)	-5.1	-40.2	4.8	1.5	-24.9	-32.5	-8.4	-18.1	-26.7	-20.5

3.2 Water Chemistry Sampling Results

Appendix 1 reports the results of the water chemistry sampling for the EEM lakes and control lakes from the sampling conducted in 2021 (with the data from 2012-2021 included for reference), for major water chemistry metrics (ANC, pH, DOC, base cations, and major anions).

3.3 Statistical Analysis of Changes in Water Chemistry

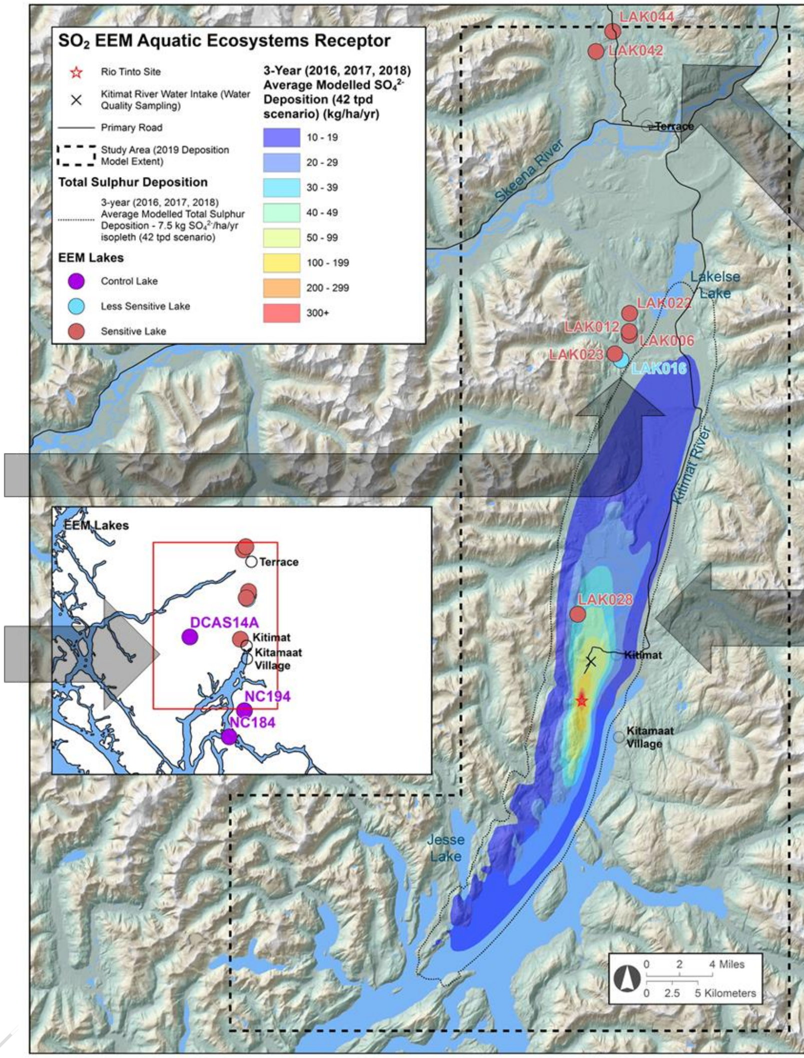
The key results of the statistical analyses of changes in lake chemistry across all the lakes in the EEM Program are summarized in Table 3-6 and Figure 3-7. These results applied Bayesian Method 1, described in Appendix F of the 2019 Comprehensive Review Report.

Table 3-6. Summary of findings across all lakes monitored in the EEM program. The % belief values are derived from the Bayesian version of Method 1, as described in Aquatic Appendix F of the 2019 Comprehensive Review Report. Values of % belief < 20% are coloured green, 20-80% yellow, and >80% red. Both the Gran ANC and pH results are based on the integrated ("integ") time series (as per Section 2.1). Note: because NC194 does not have a lake-specific *change limit* threshold for CBANC / Gran ANC, it is not possible to evaluate these indicators).

	Changes in SO4	Exceedance of *CHANGE LIMIT*				Exceedance of *LEVEL OF PROTECTION*				KPI and Informative Indicator Evaluation			
	(% belief that threshold exceeded; from Bayesian analysis method 1)	(% belief that metric value has decreased by more than the threshold; from Bayesian analysis method 1)				(% belief that metric value is below threshold; from Bayesian analysis method 1)				(Classification of % belief that both the change limit and level of protections thresholds are exceeded)			
Metric	**SO4**	**CBANC**	**Gran ANC (integ)**	**BCS**	**pH (integ)**	**CBANC**	**Gran ANC (integ)**	**BCS**	**pH (integ)**	**CBANC**	**Gran ANC (integ)**	**BCS**	**pH (integ)**
Threshold	Increase > 0	Lake-spec.	Lake-spec.	∆ 13 ueq/L	∆ 0.3 pH units	20 ueq/L	30.7 ueq/L	0 ueq/L	6.0 pH units	KPI	Inform. Indic.	Inform. Indic.	Inform. Indic.
LAK006	97%	1%	2%	0%	5%	0%	12%	0%	39%	LOW	LOW	LOW	LOW
LAK012	86%	35%	18%	51%	8%	0%	0%	0%	58%	LOW	LOW	LOW	LOW
LAK022	87%	11%	31%	9%	39%	0%	71%	0%	91%	LOW	MOD	LOW	MOD
LAK023	42%	3%	2%	2%	4%	0%	100%	0%	100%	LOW	LOW	LOW	LOW
LAK028	92%	15%	4%	79%	18%	100%	100%	100%	100%	LOW	LOW	MOD	LOW
LAK042	76%	6%	4%	15%	23%	0%	100%	94%	100%	LOW	LOW	LOW	MOD
LAK044	6%	1%	3%	0%	1%	100%	100%	0%	100%	LOW	LOW	LOW	LOW
LAK016	99%	7%	4%	36%	28%	0%	0%	0%	0%	LOW	LOW	LOW	LOW
DCAS14A	56%	10%	11%	18%	50%	0%	0%	0%	1%	LOW	LOW	LOW	LOW
NC184	50%	43%	28%	40%	48%	0%	100%	0%	100%	LOW	MOD	LOW	MOD
NC194	12%			16%	62%	0%	94%	0%	2%			LOW	LOW

	% belief in change		
LAKE	↑ SO_4^{2-}	↓ CBANC	↓ pH
LAK006	97%	1%	5%
LAK012	86%	35%	8%
LAK022	87%	11%	39%
LAK023	42%	3%	4%
LAK016	99%	7%	28%

	% belief in change		
LAKE	↑ SO_4^{2-}	↓ CBANC	↓ pH
DCAS14A	56%	10%	50%
NC184	50%	43%	48%
NC194	12%	n/a	62%



	% belief in change		
LAKE	↑ SO_4^{2-}	↓ CBANC	↓ pH
LAK042	76%	6%	23%
LAK044	6%	1%	1%

	% belief in change		
LAKE	↑ SO_4^{2-}	↓ CBANC	↓ pH
LAK028	92%	15%	18%

Figure 3-7. Spatial distribution of percent belief in chemical change. Numbers show % belief in: a) SO_4 increase (no threshold), b) CBANC decrease below lake-specific threshold, and c) pH decrease below 0.3 threshold. The % belief values are derived from the Bayesian version of Method 1, as described in Aquatic Appendix F of the 2019 Comprehensive Review Report. NC194 does not have an estimated ANC threshold because it did not have appropriate titration data available.

Before-After Control-Impact (BACI) Analyses

The results of the BACI analyses for CBANC, pH, Gran ANC, and BCS are shown in Table 3-7, Table 3-8, Table 3-9, and Table 3-10). None of the seven lakes showed statistically significant differences in Δ CBANC, Δ Gran ANC, or Δ BCS relative to the control lakes. Two lakes showed significantly more positive Δ pH over time than was observed in the control lakes, which is evidence against acidification.

Table 3-7. BACI analyses of mean CBANC for 7 sensitive and 3 control lakes. "BACI estimate" is a bit counter-intuitive: it is the Δ mean CBANC in the controls (i.e., $CBANC_{post\text{-}KMP}$ minus $CBANC_{pre\text{-}KMP}$), averaged over the 3 control lakes, minus the Δ mean CBANC in the sensitive lake. If BACI value is <0, then the Δ CBANC was lower in the controls than in the sensitive lake (and, equivalently, the Δ CBANC was greater (more positive) in the sensitive lake than in the controls), evidence against acidification (if statistically significant). If BACI value is >0, then Δ CBANC in the controls was greater than that in the sensitive lake (and, equivalently, the Δ CBANC was lower (less positive) in the sensitive lake than in the controls), evidence for acidification (if statistically significant). SE is the standard error of the BACI estimate. The p-value is the statistical significance of the test.

Site	BACI estimate	SE	p-value	Interpretation of BACI estimate
LAK006	-11.783	12.773	0.394	Change in CBANC was **more positive** in LAK006 than in the control lakes *(but not statistically significant)*
LAK012	19.401	13.834	0.218	Change in CBANC was **more negative** in LAK012 than in the control lakes *(but not statistically significant)*
LAK022	2.062	11.335	0.863	Change in CBANC was **similar** in LAK022 to changes in the control lakes *(but not statistically significant)*
LAK023	-6.559	11.642	0.596	Change in CBANC was **more positive** in LAK023 than in the control lakes *(but not statistically significant)*
LAK028	13.778	13.327	0.343	Change in CBANC was **more negative** in LAK028 to changes in the control lakes *(but not statistically significant)*
LAK042	-9.043	15.682	0.587	Change in CBANC was **more positive** in LAK042 than in the control lakes *(but not statistically significant)*
LAK044	-1.722	12.358	0.894	Change in CBANC was **similar** in LAK044 to changes in the control lakes *(but not statistically significant)*

Table 3-8. BACI analyses of mean pH (integrated) for 7 sensitive and 3 control lakes. "BACI estimate" is a bit counter-intuitive: it is the Δ mean pH in the controls (i.e., $pH_{post\text{-}KMP}$ minus $pH_{pre\text{-}KMP}$), averaged over the 3 control lakes, minus the Δ mean pH in the sensitive lake. If BACI value is <0, then the Δ pH was lower in the controls than in the sensitive lake (and, equivalently, the Δ pH was greater (more positive) in the sensitive lake than in the controls), evidence against acidification (if statistically significant). If BACI value is >0, then Δ pH in the controls was greater than that in the sensitive lake (and, equivalently, the Δ pH was lower (less positive) in the sensitive lake than in the controls), evidence for acidification (if statistically significant). SE is the standard error of the BACI estimate. The p-value is the statistical significance of the test.

Site	BACI estimate	SE	p-value	Interpretation of BACI estimate
LAK006	-0.485	0.152	0.023	Change in pH was **more positive** in LAK006 than in the control lakes *(but not statistically significant)*
LAK012	-0.583	0.121	0.005	Change in pH was **significantly more positive** in LAK012 than in the control lakes; *evidence against acidification*
LAK022	-0.188	0.101	0.122	Change in pH was **more positive** in LAK0022 than in the control lakes *(but not statistically significant)*
LAK023	-0.371	0.206	0.13	Change in pH was **more positive** in LAK023 than in the control lakes *(but not statistically significant)*
LAK028	-0.305	0.121	0.052	Change in pH was **more positive** in LAK028 than in the control lakes *(but not statistically significant)*
LAK042	-0.642	0.121	0.003	Change in pH was **significantly more positive** in LAK042 than in the control lakes; *evidence against acidification*
LAK044	-0.423	0.236	0.13	Change in pH was **more positive** in LAK044 than in the control lakes *(but not statistically significant)*

Table 3-9. BACI analyses of mean Gran ANC (integrated) for 7 sensitive and 3 control lakes. "BACI estimate" is a bit counter-intuitive: it is the Δ mean Gran ANC in the controls (i.e., Gran $ANC_{post\text{-}KMP}$ minus Gran $ANC_{pre\text{-}KMP}$), averaged over the 3 control lakes, minus the Δ mean Gran ANC in the sensitive lake. If BACI value is <0, then the Δ Gran ANC was lower in the controls than in the sensitive lake (and, equivalently, the Δ Gran ANC was greater (more positive) in the sensitive lake than in the controls), evidence against acidification (if statistically significant). If BACI value is >0, then Δ Gran ANC in the controls was greater than that in the sensitive lake (and, equivalently, the Δ Gran ANC was lower (less positive) in the sensitive lake than in the controls), evidence for acidification (if statistically significant). SE is the standard error of the BACI estimate. The p-value is the statistical significance of the test.

Site	BACI estimate	SE	p-value	Interpretation of BACI estimate
LAK006	-7.496	6.457	0.294	Change in Gran ANC was **more positive** in LAK006 than in the control lakes *(but not statistically significant)*
LAK012	4.09	4.669	0.421	Change in Gran ANC was **more negative** in LAK012 than in the control lakes *(but not statistically significant)*
LAK022	1.74	4.536	0.717	Change in Gran ANC was **similar** in LAK0022 than in the control lakes *(but not statistically significant)*
LAK023	-1.382	5.931	0.824	Change in Gran ANC was **similar** in LAK023 than in the control lakes *(but not statistically significant)*
LAK028	-2.361	3.822	0.563	Change in Gran ANC was **similar** in LAK028 than in the control lakes *(but not statistically significant)*
LAK042	-18.941	5.215	0.014	Change in Gran ANC was **more positive** in LAK042 than in the control lakes *(but not statistically significant)*
LAK044	-2.858	5.201	0.605	Change in Gran ANC was **similar** in LAK044 than in the control lakes *(but not statistically significant)*

Table 3-10. BACI analyses of mean BCS (base cation surplus) for 7 sensitive and 3 control lakes. "BACI estimate" is a bit counter-intuitive: it is the Δ mean BCS in the controls (i.e., $BCS_{post\text{-}KMP}$ minus $BCS_{pre\text{-}KMP}$), averaged over the 3 control lakes, minus the Δ mean BCS in the sensitive lake. If BACI value is <0, then the Δ BCS was lower in the controls than in the sensitive lake (and, equivalently, the Δ BCS was greater (more positive) in the sensitive lake than in the controls), evidence against acidification (if statistically significant). If BACI value is >0, then Δ BCS in the controls was greater than that in the sensitive lake (and, equivalently, the Δ BCS was lower (less positive) in the sensitive lake than in the controls), evidence for acidification (if statistically significant). SE is the standard error of the BACI estimate. The p-value is the statistical significance of the test.

Site	BACI estimate	SE	p-value	Interpretation of BACI estimate
LAK006	-6.851	12.663	0.61	Change in BCS was **more positive** in LAK006 than in the control lakes *(but not statistically significant)*
LAK012	27.541	12.496	0.077	Change in BCS was **more negative** in LAK012 than in the control lakes *(but not statistically significant)*
LAK022	4.879	12.948	0.722	Change in BCS was **more negative** in LAK0022 than in the control lakes *(but not statistically significant)*
LAK023	2.095	13.291	0.88	Change in BCS was **similar** in LAK023 than in the control lakes *(but not statistically significant)*
LAK028	26.505	10.928	0.057	Change in BCS was **more negative** in LAK028 than in the control lakes *(but not statistically significant)*
LAK042	-4.473	10.363	0.683	Change in BCS was **more positive** in LAK042 than in the control lakes *(but not statistically significant)*
LAK044	1.225	14.326	0.935	Change in BCS was **similar** in LAK044 than in the control lakes *(but NOT statistically significant)*

Table 3-11. BACI analysis of Δ CBANC, Δ pH (integrated), Δ Gran ANC, and Δ BCS, respectively, with all lakes combined. BACI estimate is the Δ mean in the 3 control lakes (i.e., post-KMP minus pre-KMP, averaged over the 3 control lakes), minus the Δ mean in the 7 sensitive lakes (i.e., post-KMP minus pre-KMP, averaged over the 7 sensitive lakes). SE is the standard error of the BACI estimate. The p-value is the statistical significance of the test.

Metric	BACI estimate	SE	p-value	Interpretation of BACI estimate
CBANC	1.822	7.958	0.821	Change in CBANC was **more negative** in the sensitive lakes than in the control lakes *(but not statistically significant)*
pH (integ)	-0.365	0.131	0.01	Change in pH was **significantly more positive** in the sensitive lakes than in the control lakes; *evidence against acidification.*
Gran ANC (integ)	-4.389	5.72	0.45	Change in Gran ANC was **more positive** in the sensitive lakes than in the control lakes *(but not statistically significant)*
BCS	7.204	8.318	0.396	Change in BCS was **more negative** in the sensitive lakes than in the control lakes *(but not statistically significant)*

For the BACI analyses of changes in CBANC:

- None of the lakes showed a statistically significant effect – i.e., before-after differences that were significantly different than the before-after changes in the control lake group (all lakes have p-values >0.01)
- Three of the seven sensitive lakes showed a ΔCBANC that was more positive than the ΔCBANC observed in the group of control lakes (negative effect in the BACI analysis), but none of these differences were statistically significant at p<0.01
- Two of the seven sensitive lakes showed a ΔCBANC that was more negative than the ΔCBANC observed in the group of control lakes (negative effect in the BACI analysis), but none of these differences were statistically significant at p<0.01
- No support for an effect across any of the lakes individually or an effect for all lakes combined.

For the BACI analyses of changes in pH:

- Two of the lakes showed a statistically significant effect (at alpha value of 0.01) – i.e., before-after differences that were significantly different than the before-after changes in the control lake group (LAK012 and LAK042)
    - The change in pH for LAK012 and LAK042 was more positive than in the control lakes, which is evidence against acidification
    - None of the other lakes showed a statistically significant effect
- When analyzed as a combined group, the sensitive lakes showed a statistically significant effect (at alpha value of 0.01) of a change that was more positive than in the control lakes, which is evidence against acidification.

For the BACI analyses of changes in Gran ANC:

- None of the lakes showed a statistically significant effect – i.e., before-after differences that were significantly different than the before-after changes in the control lake group (all lakes have p-values >0.01)
- Two of the seven sensitive lakes showed a Δ Gran ANC that was more positive than the Δ Gran ANC observed in the group of control lakes (negative effect in the BACI analysis), but none of these differences were statistically significant at p<0.01 (LAK042 was very close, with a p-value of 0.014)
- One of the seven sensitive lakes showed a Δ Gran ANC that was more negative than the Δ Gran ANC observed in the group of control lakes (negative effect in the BACI analysis), but this difference was not statistically significant at p<0.01
- No support for an effect across any of the lakes individually or an effect for all lakes combined.

For the BACI analyses of changes in BCS:

- None of the lakes showed a statistically significant effect – i.e., before-after differences that were significantly different than the before-after changes in the control lake group (all lakes have p-values >0.01)
- One lake (LAK042) had a p-value of 0.014 (very close to the threshold for significance), but the
- Two of the seven sensitive lakes showed a Δ Gran ANC that was more positive than the Δ Gran ANC observed in the group of control lakes (negative effect in the BACI analysis), but none of these differences were statistically significant at p<0.01 (LAK042 was very close, with a p-value of 0.014)
- Three of the seven sensitive lakes showed a Δ Gran ANC that was more negative than the Δ Gran ANC observed in the group of control lakes (negative effect in the BACI analysis), but none of these differences were statistically significant at p<0.01
- No support for an effect across any of the lakes individually or an effect for all lakes combined.

3.4 Episodic Acidification

We reviewed the data from the continuous pH monitors installed in LAK006 and LAK028 to identify any acidic episodes (Figure 3-8, Figure 3-9). The lake-level monitoring data is shown in Figure 3-10.

LAK006 did not have any notable, marked drops in pH. There was a decrease over the first half of August (≤0.3 pH units), but by early September the pH had returned to the same level. The pH level declined from early September through mid-October, which a) aligned with substantial increases in lake levels as the result of significant precipitation (see Section 2.4), and b) is consistent with the pattern observed in previous years of pH decreasing during the end of the monitoring season as precipitation events increase in frequency and magnitude.

LAK028 showed pronounced drops (0.3-0.4) pH units) in mid-September and late September. These observations align with periods of significantly elevated precipitation (see Section 2.4). The mid-September event is clearly visible in the lake-level data as a rapid increase of over 30 cm in LAK028. For the remainder of September, there is substantial variability in the level of LAK028 and therefore the increased precipitation in late September does not show as clear of a signal in the LAK028 lake-level data as it does in LAK006 (i.e., LAK028 shows multiple spikes in late September whereas LAK006 shows a consolidated increase).

Chemical changes in LAK028 prior, during and following the precipitation-driven acidic episode in mid-late September 2021 (Table 3-12; Appendix 6) indicate that CBANC actually increased during the episode, as increases in total base cations exceeded increases in SO_4*. It appears that the observed pH decline (from 5.1 to 4.8) was therefore likely driven by an increase in organic acids, as DOC increased from 5.7 mg/L on Sept. 7 to 8.8 on Sept. 28, and 10.1 on Oct. 4. The fact that Gran ANC (which includes organic anions) declined while CBANC (which excludes organic anions) increased, is further evidence that organic acids caused the pH decline. Inputs of sulphate to LAK028 may have originated from either the smelter or the watershed, but in either case they had no net acidification effect (no declines in CBANC) due to equivalent amounts of base cations entering the lake with the high runoff.

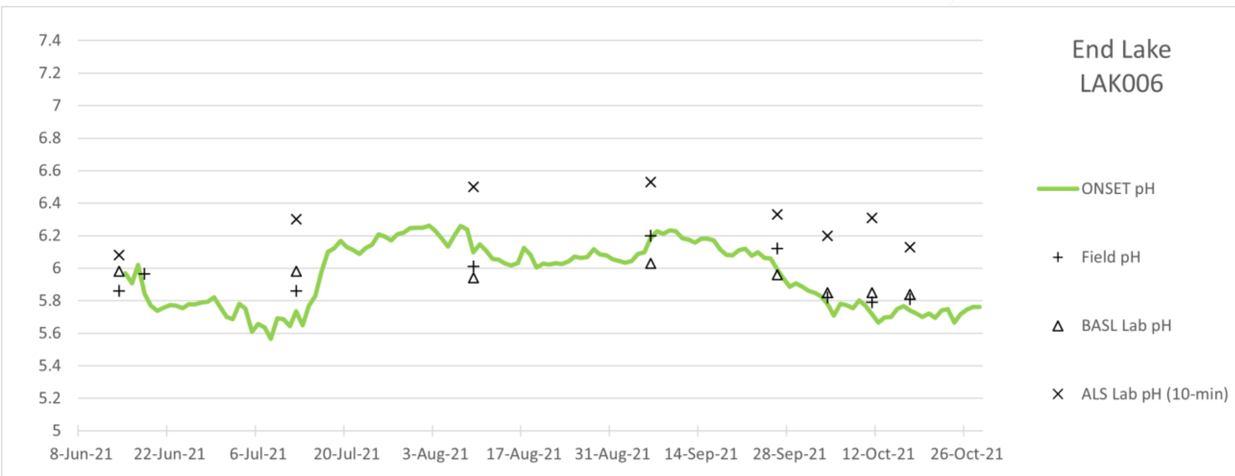


Figure 3-8. LAK006 pH measurements during the 2021 monitoring season, including continuous monitoring as well as field and laboratory measurements.

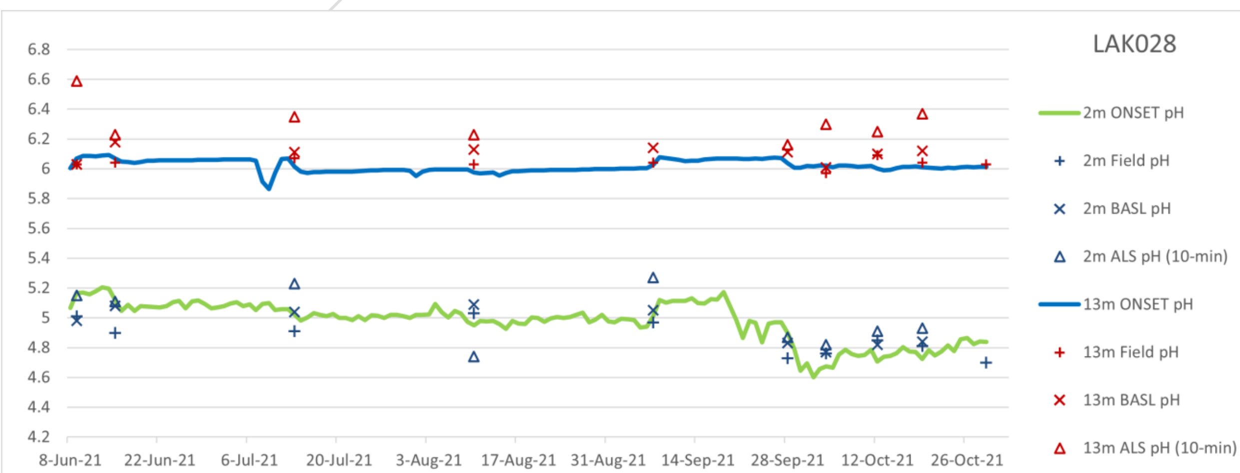


Figure 3-9. LAK028 pH measurements during the 2021 monitoring season, including continuous monitoring as well as field and laboratory measurements.

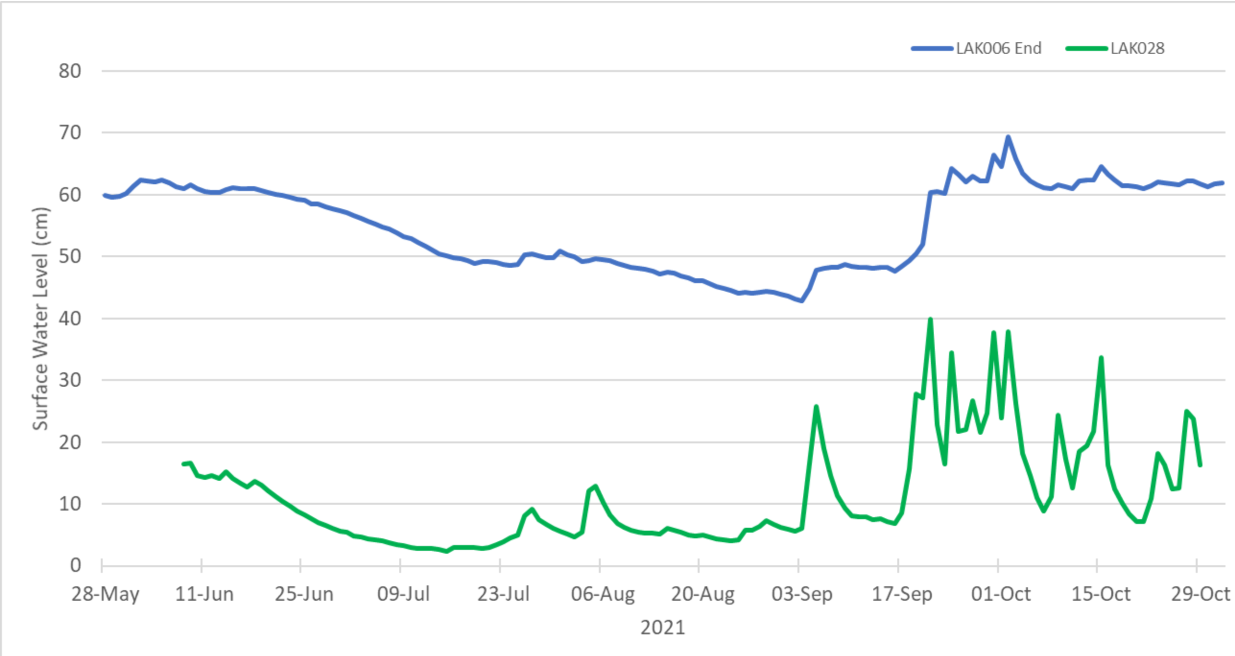


Figure 3-10. Water level during the 2021 monitoring season for LAK006 and LAK028.

Table 3-12. Chemical changes in LAK028 prior, during and following the precipitation-driven acidic episode from mid-late September 2021 (based on calibration samples for Sept. 7 and 28, and fall index samples for Oct. 4 and 12).

Date	CBANC (µeq/L)	Gran ANC (µeq/L)	pH (integ)	SO4* (µeq/L)	∑ BC* (µeq/L)	DOC (mg/L)
Sept. 7	7.1	1.6	5.1	97	107	5.7
Sept. 28	10.1	-3.0	4.8	116	128	8.8
Oct. 4	11.2	-6.8	4.8	89	101	10.1
Oct. 12	8.4	-6.2	4.8	97	107	9.5

4 Discussion

4.1 Separating Natural and Anthropogenic Factors: the Environmental Context

Although the EEM Program has moved away from reporting and analyzing the annual changes between individual years (due to challenges in interpretability associated with the high degree of variability), it is still useful to look at the year-to-year changes to assess whether there are any widespread patterns of significance that may influence our analyses and interpretation of long-term changes in water chemistry.

The graphs in Appendix 2 enable comparisons of the 2021 monitoring data to 2020 (or 2019 for the lakes not sampled in 2020). These graphs show that between 2019/2020 and 2021, pH declined in all 11 lakes, BCS and Gran ANC declined in 10 lakes, CBANC declined in 8 lakes, and DOC and BC each declined in 5 of 7 sensitive lakes; some of these declines were substantial. Since SO_4 also declined in 3 sensitive lakes and all 3 control lakes (and increased by only a small amount in 1 sensitive lake and 1 less sensitive lake), the declines in CBANC, Gran ANC and pH do not appear to be driven by changes in SO_4. The pattern of declines in ANC metrics and pH concurrent with declines in SO_4 and declines in BC is consistent with the effects of ion dilution following a major precipitation event. This is corroborated by the climate data presented in Section 2.4, which shows that mid-September through early October was a period of unusually high rainfall. The monthly total rainfall for September was the highest in the past decade for the Kitimat 2 and Terrace PCC stations.

Intra-annual changes in lake chemistry data in 2021 are shown in Appendix 6.

Environmentally mediated decrease in pH in LAK042 in 2020 – one year later

As described in detail in the 2020 EEM Report, LAK042 had a notable 1-year decrease in pH between 2019 and 2020 that was attributed to anomalous environmental conditions – i.e., high water levels flooding the shoreline and leading to a large increase in DOC and a concurrent drop in pH. If it were not for the significant precipitation events in 2021, as described above, we may have expected to see some recovery of the pH in LAK042. However, the pH in LAK042 remained at a very similar level in the fall of 2020 and 2021. Since LAK042 was not sampled in 2021 prior to September, it is not possible to determine whether its pH *remained* at a similar level since the fall of 2020, or increased in the spring/summer of 2021 and then declined *again* during the fall of 2021.

4.2 Empirical Changes in Lake Chemistry with respect to the Aquatic Key Performance Indicator

This section only addresses the CBANC KPI and the pH informative indicator (of specific interest as the prior KPI) as the statistical analyses represent the primary assessment of the KPI and informative indicators.

The mean values of CBANC indicate that there have been no exceedances of the KPI.

For the CBANC KPI, only 2 of the 7 sensitive lakes (LAK028 and LAK044) have post-KMP values below the *level of protection* threshold. Both of those lakes were already below that threshold in 2012 (and the alternate, transition period baseline) and neither of those lakes have exceeded the *change limit* threshold. None of the 7 sensitive lakes exceeded the *change limit* threshold and only 2 show any decrease in CBANC at all. In the sensitivity analyses with the alternate, transition period baseline (2012-2014), there are only 2 lakes with a decrease in CBANC (LAK012 and LAK028), but the magnitudes of these decreases (1.2 and 4.9 μeq/L, respectively) are less than the lake-specific thresholds (16.3 and 13.4 μeq/L, respectively; see Appendix 5). The empirical data therefore indicate that none of the lakes exceeded the KPI.

For the pH informative indicator, all 7 sensitive lakes (LAK006, LAK012, LAK022, LAK023, LAK028, LAK042, and LAK044) have post-KMP values below the *level of protection* threshold. All 7 lakes were already below that threshold in 2012, and four of the lakes have been at or below that threshold throughout the entire period of record. None of the sensitive lakes have exceeded the *change limit* threshold. Only one lake (LAK022) shows any decrease in pH relative to 2012. The empirical data therefore indicate that none of the lakes have exceeded the pH informative indicator.

In the sensitivity analyses with the alternate, transition period baseline (2012-2014), 4 sensitive lakes show decreases of <0.1 pH units, 2 lakes (LAK028, LAK042) show decreases of ~0.2 pH units, and 1 lake (LAK022) shows a decrease of ~0.3 pH units. The empirical data therefore indicate that one of the lakes exceeds the change limit for the pH informative indicator when evaluated against the alternate, transition period baseline.

The following section applies the statistical analyses to the same data to assess the percent belief that CBANC KPI and the pH, Gran ANC and BCS informative indicators could have been exceeded.

LAK027 – Comparison with STAR Results

The resampling of LAK027 showed significant changes between the 2012 values measured in the STAR and values measured in 2021. Although it is not possible to determine the when these changes occurred from only two data points, the common pattern of decline across most of the lake chemistry metrics in LAK027 directly align with the widespread patterns observed across all the EEM lakes in 2021. This provides a strong indication that the observations in LAK027 were likely driven by anomalously high precipitation in mid-late September 2021, rather than by longer-term factors. To obtain a more reliable assessment of the chemical status of LAK027, it would be prudent to resample this lake in 2022.

4.3 Statistical Analysis of Changes in Lake Chemistry

Table 4-1 shows the results from 2021 compared to the results reported in the previous two annual reports and the 2019 comprehensive review. For four of the lakes, the 2021 results are very similar to the previous results and do not show any substantial differences across any of the four metrics shown, which shows that the conclusions of the previous analyses continue to be strongly supported with additional years of monitoring data. The other seven lakes have at least one metric for which the 2021 results illustrate a notable change from previous years. However, all of these changes align with the widespread declines observed in 2021 across most lakes and metrics associated with anomalous hydrologic conditions (as described elsewhere in more detail). All of those changes are shifts from “low” to “moderate” or “high” to “moderate” in the case of SO_4, but there were no changes from “moderate” to “high”.

For SO_4^{2-}, the three lakes that increased from moderate to high % belief with the 2020 results (two controls and LAK042), decreased back to moderate. LAK023 increased from 0% belief in SO_4 increase to 42%, which represents a significant change but still not a strong indication of increase.

This is only the second year that the Bayesian analyses were performed on CBANC, so there is only one previous comparison for the CBANC results. Despite the widespread changes in numerous water chemistry metrics observed in 2021, the CBANC results are remarkably similar to the 2020 results for almost all of the lakes, possibly providing an indication of the resilience of the CBANC metric to anomalous environmental conditions.

For Gran ANC, two lakes (LAK022, NC194) showed increases from low to moderate, albeit still at the low end of the moderate range (31% and 28%, respectively).

For pH, six lakes (LAK022, LAK042, LAK016, all 3 controls) showed increases from low to moderate and the changes in % belief were generally larger than the changes seen in the other metrics. This is especially true for LAK022 and the 3 control lakes, which all showed substantial decreases in pH in 2021. However, these four lakes (plus LAK016) are the lakes that were not sampled in 2020 and therefore the “2020 results” are actually from 2019.

Table 4-1. Comparison of the results of the updated statistical analyses of the changes relative to the *change limit* to the results in the previous two reporting periods (i.e., 2019 Annual Report and the 2019 comprehensive review (CR)). The 2021 results are the same as Table 3-6. The % belief values are derived from the Bayesian version of Method 1, as described in Aquatic Appendix F of the 2019 Comprehensive Review Report. Values of % belief < 20% are coloured green, 20-80% yellow, and >80% red.

LAKE	Changes in CBANC (% belief that CBANC *change limit* threshold exceeded)		Changes in SO_4 (% belief in SO_4 increase > 0 µeq/L)				Changes in Gran ANC (% belief that Gran ANC *change limit* threshold exceeded)				Changes in pH (% belief that pH *change limit* threshold exceeded)			
	2020 Results	2021 Results	CR Results	2019 Results[1]	2020 Results	2021 Results	CR Results	2019 Results[1]	2020 Results	2021 Results	CR Results	2019 Results[1]	2020 Results	2021 Results
Sensitive Lakes														
LAK006	2%	1%	83%	85%	98%	97%	0%	0%	5%	2%	1%	0%	1%	5%
LAK012	40%	35%	91%	95%	99%	86%	1%	0%	19%	18%	1%	0%	1%	8%
LAK022 [2]	2%	11%	88%	89%	89%	87%	0%	0%	10%	31%	0%	0%	0%	39%
LAK023	2%	3%	5%	2%	0%	42%	0%	0%	3%	2%	1%	0%	3%	4%
LAK028	13%	15%	96%	97%	94%	92%	2%	1%	0%	4%	18%	6%	9%	18%
LAK042	9%	6%	36%	44%	81%	76%	0%	0%	2%	4%	2%	0%	13%	23%
LAK044	0%	1%	1%	0%	4%	6%	0%	0%	3%	3%	0%	0%	0%	1%
Less Sensitive Lakes														
LAK016 [2]	7%	7%	97%	81%	81%	99%	0%	0%	1%	4%	1%	0%	6%	28%
Control Lakes														
DCAS14A [2]	1%	10%	68%	75%	99%	56%	0%	0%	1%	11%	6%	0%	12%	50%
NC184 [2]	10%	43%	58% (in negligible increase)	69% (in negligible increase)	86%	50%	5%	4%	17%	28%	28%	14%	19%	48%
NC194 [2]	n/a		1%	1%	2%	12%	n/a	n/a	n/a	2%	12%	4%	17%	62%

[1] The 2019 Annual Report applied a 4-year post-KMP averaging period (i.e., 2016-2019; adding the new year of observations to the post-KMP period used in the CR), whereas the present 2020 Annual Report applies a 3-year post-KMP averaging period. Comparing the 2019 and 2020 results is thus comparing the difference between applying a 2016-2019 post-KMP averaging period versus a 2018-2020 post-KMP averaging period.

[2] For lakes not sampled in 2020, the comparison of the last 3 years of results represents a more significant difference – i.e., post-KMP averaging periods of 2016-2019 vs. 2018-2019 vs. 2019+2021.

4.4 Application of the Evidentiary Framework

We have applied the evidentiary framework, as described in Section 2.6, using the updated results of the statistical analyses. The results are shown in Figure 4-1. The underlying results are compiled in Table 4-2. The updated application of the simplified evidentiary framework show that: a) 1 sensitive lake and 3 control lakes[3] land within the first box, "smelter not causally linked to changes in lake chemistry"; b) 1 sensitive lake and 1 less sensitive lakes land within the second box, "lake is healthy, and not acidifying"; and c) 5 sensitive lakes (LAK006, LAK022, LAK023, LAK028 and LAK042) land within the third box, "some evidence of acidification".

For LAK028, this classification is based on: a) average post-KMP values below the *level of protection* for both CBANC and pH, and b) strong support for a decline in CBANC (88% belief) and intermediate support for declines in pH (55% belief), but with low support for exceedance of either *change limit* threshold (15% belief for CBANC and 18% belief for pH). This result is similar to last year, with small increases in the % belief of exceedance of the *change limit* thresholds got both metrics.

For LAK006, LAK022, LAK023, and LAK042, this classification is based on pH only. All four lakes have 0% belief in CBANC below the *level of protection.*

LAK022 and LAK042 show: a) average post-KMP values below the *level of protection* for pH only, and b) moderate support for declines in pH (60% and 39% belief, respectively), with moderate support for exceedance of the *change limit* threshold (39% and 23% belief, respectively).

LAK023 shows: a) average post-KMP values below the *level of protection* for pH only, and b) moderate support for declines in pH (31% belief), but with very low support for exceedance of the *change limit* threshold (5%).

LAK006 shows: a) only moderate belief in exceeding the *level of protection* for pH (39% belief), and b) low moderate support for declines in pH (23%), with very low support for exceedance of the *change limit* threshold (4%).

There are no lakes that have acidification exceedances.

[3] All of the control lakes are classified in the first box regardless of increases in sulphate because any such increases cannot be causally linked to the smelter due to their location well outside the smelter plume.

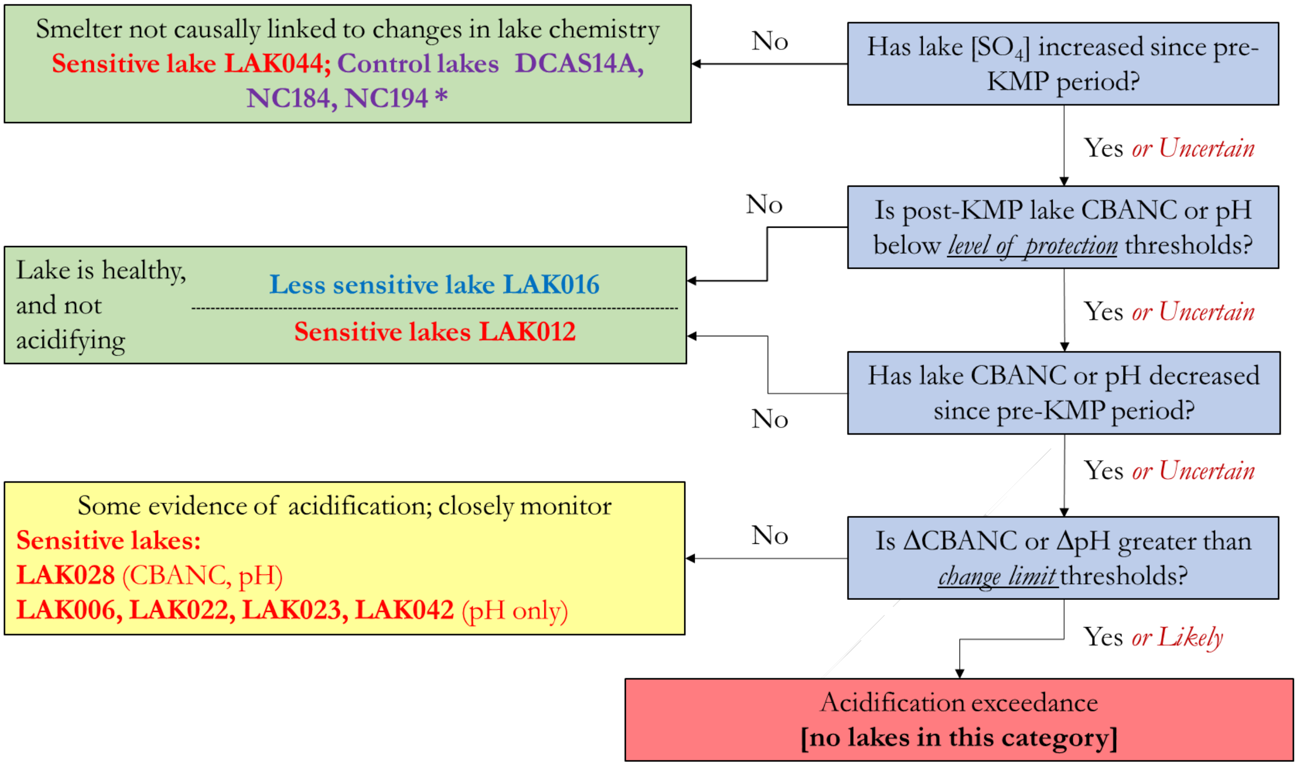


Figure 4-1. Classification of EEM lakes according to the simplified evidentiary framework. LAK028 has strong support for a decline in CBANC and moderate support for a decline in pH but low support for exceeding either *change limit* threshold. LAK006, LAK022, LAK023, and LAK042 have moderate support for declines pH with moderate to very low support for exceeding the *change limit* thresholds; however, they are all still above the CBANC *level of protection*. The control lakes (*) are all classified in the first box regardless of increases in sulphate because any such increases cannot be causally linked to the smelter due to their location well outside the smelter plume.

Table 4-2. Results used in the application of the simple evidentiary framework. The first four columns are identical to Table 3-6 but the last two show the results for the % belief of *any* change in Gran ANC and pH. The % belief values are derived from the Bayesian version of Method 1, as described in Aquatic Appendix F of the 2019 Comprehensive Review Report. Values of % belief < 20% are coloured green, 20-80% yellow, and >80% red.

LAKE	**Changes in SO_4** (% belief in SO_4 increase / decrease)	**State of post-KMP CBANC** (% belief that CBANC *level of protection* threshold exceeded)	**State of post-KMP pH** (% belief that pH *level of protection* threshold exceeded)	**Changes in CBANC** (% belief that CBANC *change limit* threshold exceeded)	**Changes in pH** (% belief that pH *change limit* threshold exceeded)	**Change in CBANC (no threshold)** (% belief that CBANC decreased)	**Change in pH (no threshold)** (% belief that pH decreased)
Threshold type	**Any change (increase)**	**Level of Protection**	**Level of Protection**	**Change Limit**	**Change Limit**	**Any change (decrease)**	**Any change (decrease)**
Sensitive Lakes							
LAK006	97%	0%	39%	1%	5%	2%	23%
LAK012	86%	0%	58%	35%	8%	50%	18%
LAK022	87%	0%	91%	11%	39%	28%	60%
LAK023	42%	0%	100%	3%	4%	7%	31%
LAK028	92%	100%	100%	15%	18%	88%	55%
LAK042	76%	0%	100%	6%	23%	19%	39%
LAK044	6%	100%	100%	1%	1%	2%	9%
Less Sensitive Lakes							
LAK016	99%	0%	0%	7%	28%	25%	51%
Control Lakes							
DCAS14A	56%	0%	1%	10%	50%	20%	62%
NC184	50%	0%	100%	43%	48%	60%	67%
NC194	12%	0%	2%	n/a	62%	30%	76%

5 Recommendations

We recommend discontinuing the measurement of inorganic monomeric Aluminum. The ongoing use of BCS as an informative indicator will be sufficient for evaluating risks to biota without additional monitoring of inorganic monomeric Aluminum. However, it is being measured in 2021 because the planning for the 2021 field season occurred earlier than the analyses presented in this Technical Memo, so this recommendation would come into effect for the 2022 field season.

We recommend sampling LAK027 again in 2022. The widely-observed storm-driven dilution event negated the ability of this year's sampling to provide a meaningful comparison against the initial STAR data as intended.

We do not recommend any other changes or adjustments to next year's program.

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Appendix 1: Water Chemistry Data from Annual Sampling, 2012-2021

The two tables below show the sample results for each of the EEM lakes and control lakes from annual monitoring conducted from 2012 to 2021, including charge balance ANC (CBANC), Gran ANC, base cation surplus (BCS), pH, dissolved organic carbon (DOC), and the concentration of major anions and cations, as well as the sum of all base cations (BC). The pH of the water samples has been measured by three different laboratories with (Trent University, 2012-2019; ALS, 2013-2021; BASL, 2019-2021). Gran ANC also transitioned from Trent University to BASL, overlapping in 2019.

The first table provides the mean annual value and standard error for each metric for lakes with multiple within-season samples, as calculated from all the within-season samples. Lakes with only a single annual sample will show the same value in both tables and no measure of variability. The second table presents the sampling data in its "raw" units, as measured, without converting concentration values to charge equivalents. Although acidification studies require converting measured concentrations to charge equivalents, these unconverted values may be more familiar and therefore easier to interpret for some audiences.

Mean Annual Values

The mean annual values and standard error have been calculated for all lakes with multiple within-season samples. Sample values with no standard error indicate that only a single annual sample was taken for that particular lake in that particular year.

Lake	Year	CBANC (μeq/L)	SE	Gran ANC (μeq/L) (Trent)	SE	Gran ANC (μeq/L) (BASL)	SE	BCS (μeq/L)	SE	pH (Trent)	SE	pH (ALS)	SE	pH (BASL)	SE	DOC (mg/L)	SE	SO4 * (μeq/L)	SE	Cl (μeq/L)	SE	F (μeq/L)	SE	Ca * (μeq/L)	SE	Mg * (μeq/L)	SE	K * (μeq/L)	SE	Na * (μeq/L)	SE	∑ BC * (μeq/L)	∑ Anions (μeq/L)
Lak006	2012	49.2		25.7				34.6		5.8						3.6		11.4		5.8		4.5		30.3		12.5		2.9		14.9		60.6	66.2
LAK007	2012	1452.4		1437.6				1452.5		8.0						0.6		51.4		24.6		2.8		1272.2		157.0		19.3		55.4		1503.9	1552.5
LAK012	2012	114.5		57.0				94.5		5.6						4.6		6.1		4.2		5.0		74.5		20.8		5.2		20.0		120.6	115.9
LAK016	2012	127.2		68.7				112.0		6.3						3.7		39.0		6.3		7.8		117.7		20.5		7.3		20.8		166.3	166.4
LAK022	2012	67.9		27.8				44.5		5.9						5.3		30.2		6.9		6.1		58.1		16.0		3.2		20.8		98.1	99.4
LAK023	2012	46.9		19.8				29.3		5.7						4.2		19.0		4.5		5.6		39.4		12.0		3.7		10.8		65.9	72.2
LAK024	2012	315.4		299.5				311.7		7.1						1.4		24.8		27.3		1.6		273.2		33.0		4.2		29.6		340.0	376.5
LAK028	2012	16.0		-4.0				-5.1		5.0						4.9		56.9		6.1		20.7		47.5		9.5		3.1		12.8		72.9	95.7
LAK034	2012	177.6		99.4				158.1		6.7						4.5		24.1		5.8		5.8		119.3		31.6		5.8		44.9		201.7	221.4
LAK042	2012	47.2		-20.4				-15.4		4.7						13.2		6.2		6.1		3.2		7.4		22.7		3.1		20.3		53.4	73.4
LAK044	2012	8.0		1.3				2.5		5.4						1.7		6.2		5.6		2.9		6.8		3.2		4.1		0.0		14.2	27.7
Lak006	2013	43.1		29.0				30.3		6.2		6.1				3.2		14.4		8.7		5.6		27.1		13.0		5.3		12.2		57.6	80.1
LAK007	2013	1385.6		1462.1				1388.3		7.9		8.1				0.1		66.5		36.3		3.7		1226.0		156.5		21.9		47.6		1452.0	1598.9
LAK012	2013	97.5		63.5				79.5		6.3		6.1				4.2		11.3		14.7		8.2		64.8		20.3		9.2		14.6		108.9	168.1
LAK016	2013	108.7		96.9				90.9		6.7		7.2				4.2		56.9		12.3		11.5		114.4		23.9		11.2		17.6		167.1	206.6
LAK022	2013	62.0		36.4				33.9		6.2		6.1				6.2		47.1		12.4		8.7		65.1		19.2		6.0		18.8		109.1	145.9
LAK023	2013	37.7		23.8				20.7		6.0		6.0				4.0		24.1		7.5		7.4		37.1		13.3		5.1		8.3		63.9	89.7
LAK024	2013																																
LAK028	2013	-8.1		4.8				-40.2		5.2		5.5				7.1		128.1		17.7		32.0		85.1		18.3		5.0		13.0		121.3	184.0
LAK034	2013	219.5		210.4				199.4		6.9		7.4				4.7		38.1		8.2		10.0		152.7		41.7		9.2		54.1		257.7	287.0
LAK042	2013	55.1		21.0				10.0		5.5		5.4				9.7		5.7		7.7		3.2		16.0		22.3		3.4		19.3		61.0	87.4
LAK044	2013	8.9		8.6				4.5		5.7		6.0				1.5		6.2		8.9		3.8		7.8		3.6		5.9		-2.0		15.3	35.0
Lak006	2014	52.9	2.0	38.8	0.6			37.2	2.6	6.1	0.1	6.6	0.2			3.8	0.3	12.1	0.6	8.1	1.2	4.8	0.1	31.7	0.5	14.6	0.4	4.7	0.3	14.5	1.2	65.5	84.2
LAK007	2014	1484.8		1445.7				1484.5		8.1		8.0				0.7		30.7		19.2		1.9		1276.8		156.7		20.2		61.8		1515.5	1527.8
LAK012	2014	99.8	3.1	68.8	6.8			71.8	7.9	6.0	0.1	6.7	0.2			6.3	1.0	15.8	5.2	10.3	2.2	5.2	0.2	69.3	1.6	21.3	0.6	7.3	0.5	18.3	1.6	116.1	135.7
LAK016	2014	132.5		105.7				115.6		6.7		6.7				4.0		48.2		9.3		9.5		122.4		25.0		10.1		23.3		180.8	194.2
LAK022	2014	76.1		46.9				51.0		6.3		6.4				5.7		37.8		9.0		6.9		68.5		18.9		5.2		21.4		114.0	133.0
LAK023	2014	59.4	3.3	32.1	1.1			34.3	2.1	5.9	0.1	6.7	0.3			5.7	0.4	18.9	1.0	6.1	0.3	6.2	0.2	49.3	3.9	14.9	0.4	4.0	0.1	10.8	0.3	79.0	93.0
LAK024	2014	473.4		472.1				468.1		7.6		7.5				1.7		37.2		65.7		2.3		402.3		50.1		7.8		50.2		510.4	617.9

Lake	Year	CBANC (µeq/L)	SE	Gran ANC (µeq/L) (Trent)	SE	Gran ANC (µeq/L) (BASL)	SE	BCS (µeq/L)	SE	pH (Trent)	SE	pH (ALS)	SE	pH (BASL)	SE	DOC (mg/L)	SE	SO4 * (µeq/L)	SE	Cl (µeq/L)	SE	F (µeq/L)	SE	Ca * (µeq/L)	SE	Mg * (µeq/L)	SE	K * (µeq/L)	SE	Na * (µeq/L)	SE	∑ BC * (µeq/L)	∑ Anions (µeq/L)
LAK028	2014	31.2		22.6				4.8		5.3		5.7				5.9		94.4		11.0		23.3		85.9		17.7		4.4		17.6		125.7	156.6
LAK034	2014	249.1		205.0				217.2		6.7		7.0				7.0		17.0		6.5		7.7		161.4		43.6		9.4		51.9		266.3	270.9
LAK042	2014	51.6		12.5				1.8		5.1		5.4				10.6		4.0		11.8		2.6		10.5		23.6		3.7		17.9		55.7	89.4
LAK044	2014	12.6		5.9				6.8		5.8		5.6				1.8		4.6		5.9		2.8		7.8		3.9		5.3		0.4		17.3	28.5
Lak006	2015	55.1	0.8	32.4	0.4			38.7	1.5	6.0	0.1	6.4	0.3			3.9	0.2	11.5	0.3	6.6	0.3	4.4	0.1	32.3	0.3	14.8	0.2	3.9	0.1	15.7	0.3	66.7	77.0
LAK007	2015	1461.9		1565.6				1463.9		8.0		7.9				0.3		45.6		24.0		2.6		1266.6		161.5		21.0		58.6		1507.7	1666.8
LAK012	2015	106.1	2.0	65.9	2.1			71.8	3.9	6.0	0.1	6.3	0.2			7.5	1.0	17.6	3.1	11.1	1.7	4.7	0.1	74.8	3.9	23.2	0.9	8.1	0.8	18.0	0.8	124.2	140.3
LAK016	2015	147.1		113.1				128.8		6.8		6.9				4.3		40.9		8.7		8.6		130.9		25.0		9.8		22.9		188.6	192.1
LAK022	2015	75.2		35.6				47.0		6.1		6.2				6.3		32.5		7.9		5.9		64.1		18.1		4.4		21.2		107.8	117.3
LAK023	2015	58.0	1.0	30.0	1.0			34.4	0.9	5.9	0.1	6.2	0.1			5.4	0.4	15.1	0.7	6.2	0.3	5.2	0.2	46.1	1.5	13.9	0.3	3.8	0.1	9.7	0.1	73.5	83.0
LAK024	2015	472.8		443.0				465.0		7.4		7.5				2.2		34.7		59.0		2.1		400.5		49.3		8.7		49.0		507.6	580.6
LAK028	2015	38.6		10.8				1.5		5.1		5.3				8.1		71.1		9.0		20.5		76.5		15.7		3.2		14.4		109.8	122.1
LAK034	2015	233.0		177.8				198.5		6.6		6.7				7.6		0.9		6.2		4.7		146.5		37.1		5.3		45.1		234.0	231.8
LAK042	2015	55.4		13.8				16.9		5.4		5.5				8.3		3.8		6.5		2.3		10.7		23.1		2.5		23.0		59.3	70.7
LAK044	2015	16.4		6.2				11.6		5.8		5.8				1.6		3.7		5.9		2.7		9.8		4.4		5.5		0.5		20.3	28.0
Lak006	2016	56.9	2.4	26.9	1.0			38.9	2.4	6.0	0.0	6.3	0.1			4.2	0.1	11.8	0.2	5.6	0.2	4.2	0.1	32.6	0.5	14.8	0.7	4.2	0.6	17.2	0.9	68.8	74.0
LAK007	2016	1495.8		1368.6				1495.2		8.0		8.1				0.8		46.7		25.4		2.6		1301.5		162.8		20.2		58.3		1542.8	1474.0
LAK012	2016	103.2	1.6	65.8	1.2			81.0	2.1	6.2	0.0	6.5	0.1			5.1	0.3	9.5	0.5	5.6	0.2	4.6	0.1	64.7	0.8	20.8	0.6	6.0	0.6	21.6	0.8	113.0	115.7
LAK016	2016	140.8		93.9				118.3		6.6		6.9				5.2		44.9		8.5		8.2		127.4		26.4		8.9		23.7		186.5	189.4
LAK022	2016	80.3		34.4				50.1		6.1		6.4				6.7		34.2		7.9		5.8		68.1		19.2		4.2		23.1		114.6	119.0
LAK023	2016	59.5	1.4	27.9	1.9			33.6	1.0	5.9	0.0	6.2	0.1			5.8	0.1	12.7	0.2	4.9	0.2	5.1	0.1	42.5	0.9	14.1	0.4	4.7	0.5	11.0	0.8	72.3	80.8
LAK024	2016	525.1		463.1				514.8		7.5		7.6				2.7		39.2		70.0		2.3		446.5		55.3		9.5		53.9		565.3	619.2
LAK028	2016	12.3	3.8	-4.9	6.2			-24.9	5.2	5.0	0.1	5.1	0.1			8.1	0.3	127.8	8.1	10.0	0.5	26.8	0.8	94.7	8.3	23.8	1.7	3.7	0.2	19.5	1.6	141.6	179.1
LAK034	2016	212.2		151.6				177.6		6.5		7.1				7.6		0.0		5.4		4.4		130.0		34.3		3.8		44.1		212.3	215.4
LAK042	2016	64.0	1.7	14.0	1.5			18.0	1.1	5.4	0.0	5.7	0.0			9.8	0.2	3.3	0.2	7.2	0.2	2.2	0.1	16.7	1.7	24.7	0.4	2.7	0.2	23.3	0.2	67.4	78.8
LAK044	2016	13.9	0.6	4.1	1.3			7.0	0.6	5.5	0.0	6.0	0.1			2.0	0.1	4.1	0.1	6.1	0.1	2.3	0.1	8.2	0.4	4.1	0.0	5.5	0.1	0.3	0.2	18.2	27.7
Lak006	2017	58.0	0.6	27.9	2.7			42.1	1.0	6.0	0.1	6.4	0.1			3.8	0.1	14.4	0.3	5.4	0.2	4.2	0.0	34.8	0.5	15.6	0.2	4.1	0.1	18.0	0.4	72.5	71.4
LAK007	2017	1402.3		1381.6				1404.3		8.0		8.0				0.3		47.1		25.9		2.4		1201.7		165.2		19.9		62.6		1449.4	1492.4
LAK012	2017	101.1	3.7	58.2	3.2			78.2	1.9	6.1	0.1	6.5	0.1			5.2	0.5	14.6	2.6	7.0	1.2	4.4	0.1	65.4	4.5	21.7	1.2	7.7	1.0	21.5	0.9	116.3	117.5
LAK016	2017	125.3		82.7				107.8		6.7		6.8				4.1		43.2		7.3		7.7		114.0		24.7		6.9		22.9		168.6	167.5
LAK022	2017	70.4		34.2				44.2		6.1		6.3				5.9		39.0		7.1		5.4		64.1		19.5		3.8		22.2		109.6	112.4
LAK023	2017	59.9	1.5	28.5	2.4			36.0	1.3	5.9	0.0	6.2	0.0			5.4	0.1	10.1	1.7	4.2	0.3	4.6	0.0	43.2	2.1	13.8	0.3	2.3	0.2	11.2	0.3	70.5	71.3
LAK024	2017	479.2		416.6				472.3		7.4		7.6				2.0		34.9		57.5		2.0		399.6		52.2		8.5		54.2		514.4	557.5
LAK028	2017	0.7	5.3	-9.9	4.5			-32.5	7.8	4.8	0.1	5.1	0.1			7.3	0.6	150.0	13.0	8.7	1.0	27.2	1.7	102.5	11.0	26.5	2.5	3.5	0.4	19.9	1.6	152.4	199.2
LAK034	2017	177.6		136.5				150.7		6.4		6.8				6.0		0.1		4.5		3.4		105.6		30.3		2.7		39.1		177.8	179.1
LAK042	2017	63.1	3.0	2.3	2.1			8.4	2.7	5.2	0.1	5.4	0.1			11.6	1.1	6.8	0.9	6.7	0.5	2.4	0.0	17.1	2.7	26.9	1.1	2.8	0.3	23.2	0.5	70.0	80.8
LAK044	2017	13.8	0.3	7.0	2.2			9.1	0.3	5.6	0.1	6.0	0.1			1.6	0.0	4.5	0.2	5.9	0.1	2.2	0.0	7.9	0.1	4.2	0.1	5.6	0.1	0.7	0.2	18.4	26.2
Lak006	2018	59.3	1.2	28.3	1.2			43.6	1.5	6.1	0.0	6.4	0.0			3.8	0.1	15.7	0.2	6.1	0.1	4.2	0.1	36.2	0.3	16.1	0.5	4.3	0.3	18.5	0.6	75.1	82.1
LAK007	2018	1443.8		1407.6				1445.7		8.1		8.1				0.3		47.1		27.9		2.6		1251.5		157.4		20.6		61.3		1490.8	1518.7
LAK012	2018	90.4	1.2	50.9	4.3			70.5	0.9	6.2	0.1	6.6	0.1			4.6	0.1	14.6	0.7	6.2	0.3	4.6	0.1	58.3	0.4	19.7	0.6	6.2	0.3	21.1	0.8	105.2	112.3
LAK016	2018	138.1		92.8				118.4		6.7		6.9				4.6		45.3		7.3		8.1		128.5		23.3		7.3		24.3		183.5	195.3

Lake	Year	CBANC (µeq/L)	SE	Gran ANC (µeq/L) (Trent)	SE	Gran ANC (µeq/L) (BASL)	SE	BCS (µeq/L)	SE	pH (Trent)	SE	pH (ALS)	SE	pH (BASL)	SE	DOC (mg/L)	SE	SO4 * (µeq/L)	SE	Cl (µeq/L)	SE	F (µeq/L)	SE	Ca * (µeq/L)	SE	Mg * (µeq/L)	SE	K * (µeq/L)	SE	Na * (µeq/L)	SE	∑ BC * (µeq/L)	∑ Anions (µeq/L)
LAK022	2018	76.6		30.3				51.8		6.1		6.3				5.6		43.2		7.3		5.8		72.1		19.3		4.2		24.4		119.9	120.1
LAK023	2018	61.3	0.7	23.0	0.7			36.3	1.6	6.0	0.1	6.4	0.1			5.6	0.2	14.1	0.9	4.9	0.2	4.9	0.1	45.9	0.3	15.0	0.3	3.3	0.2	11.4	0.4	75.5	78.6
LAK024	2018	553.5		509.9				548.8		7.6		7.6				1.6		42.6		77.3		2.4		472.7		56.4		9.4		57.2		595.7	680.2
LAK028	2018	8.4	1.8	4.2	1.6			-10.2	1.9	5.3	0.0	5.5	0.0			4.4	0.1	107.5	2.0	6.6	0.2	20.9	0.3	76.4	0.9	19.0	0.5	2.8	0.1	17.9	0.7	116.0	147.4
LAK034	2018	183.4		130.6				161.0		6.5		6.6				5.1		0.1		3.7		3.7		113.1		27.7		2.1		40.8		183.7	176.3
LAK042	2018	50.4	1.0	0.6	1.9			0.7	1.3	5.1	0.0	5.3	0.0			10.6	0.4	6.3	0.1	6.1	0.2	2.3	0.1	8.8	0.6	23.9	0.5	2.3	0.1	21.8	0.1	56.8	74.4
LAK044	2018	13.2	0.3	3.9	0.9			7.0	0.2	5.5	0.0	5.9	0.0			1.9	0.1	4.5	0.1	6.4	0.1	2.2	0.0	8.3	0.1	4.1	0.2	5.5	0.1	-0.2	0.3	17.7	27.5
Lak006	2019	63.8	2.2	31.6	2.7	40.0	1.1	49.7	1.8	6.1	0.0	6.5	0.1	6.2	0.0	3.5	0.2	16.8	0.6	6.7	0.6	4.0	0.2	38.0	0.6	17.8	0.4	5.1	0.2	19.9	0.9	80.8	74.1
LAK007	2019	1443.5		1374.5		1496.3		1445.4		8.1		8.1		8.0		0.3		43.0		27.1		2.4		1246.6		158.4		20.4		61.2		1486.5	1469.6
LAK012	2019	96.5	0.4	55.3	0.9	64.1	2.6	74.8	1.6	6.1	0.0	6.6	0.1	6.2	0.0	5.0	0.3	13.5	0.9	7.1	0.2	4.4	0.2	59.7	0.5	21.3	0.2	6.5	0.2	22.6	0.6	110.1	121.4
LAK016	2019	129.8		90.8		100.9		111.2		6.6		7.1		6.6		4.4		58.6		9.0		7.9		127.9		26.5		9.7		24.4		188.6	219.5
LAK022	2019	74.8		35.9		44.4		47.8		6.1		6.4		6.2		6.0		49.3		8.7		5.6		71.5		22.4		5.0		25.3		124.2	123.4
LAK023	2019	59.4	1.6	20.7	2.4	26.8	1.5	33.4	1.3	5.8	0.0	6.3	0.1	6.0	0.0	5.9	0.2	13.5	0.8	5.4	0.2	4.8	0.2	42.2	0.4	15.4	0.6	3.3	0.2	12.1	1.1	73.1	79.4
LAK024	2019	570.7		496.9		548.7		566.0		7.7		7.7		7.3		1.6		40.8		75.3		2.1		478.3		58.1		8.7		66.3		611.4	652.5
LAK028	2019	4.5	4.4	3.3	0.7	4.0	3.1	-18.1	6.0	5.2	0.0	5.4	0.0	5.1	0.0	5.2	0.3	148.5	4.0	11.3	0.6	25.8	1.1	103.5	1.2	26.6	0.5	3.7	0.2	20.0	0.9	153.7	200.1
LAK034	2019	196.8		148.9		166.9		173.8		6.4		7.0		6.6		5.3		0.9		4.5		4.1		122.1		30.4		1.8		43.5		197.8	195.9
LAK042	2019	52.1	2.1	10.1	0.6	16.5	1.0	9.1	1.4	5.4	0.0	5.6	0.1	5.4	0.0	9.2	0.5	7.6	0.6	6.2	0.3	2.3	0.1	12.6	1.8	23.1	0.6	2.2	0.3	22.0	0.3	59.9	77.1
LAK044	2019	14.8	0.6	6.1	0.4	6.6	0.3	5.7	1.2	5.5	0.0	5.9	0.1	5.7	0.0	2.5	0.3	4.7	0.3	6.5	0.3	2.3	0.1	8.9	0.2	4.5	0.2	6.0	0.2	0.3	0.2	19.6	32.0
Lak006	2020	70.3	1.5			44.7	1.3	48.1	3.8			6.3	0.0	6.1	0.0	5.1	0.5	15.3	0.5	6.5	0.6	4.0	0.1	44.9	1.3	17.6	0.7	4.7	0.4	18.6	0.4	85.7	91.4
LAK012	2020	142.1	6.4			93.1	9.0	101.4	4.9			6.4		6.1	0.0	8.8		15.6		9.3		5.0		97.5		28.1		7.8		24.5		157.9	165.7
LAK016	2020																																
LAK022	2020																																
LAK023	2020	66.6	0.5			29.6	1.6	37.6	2.8			6.1		6.0	0.0	6.4		13.9		5.1		4.8		49.0		15.7		3.7		12.2		80.6	80.5
LAK028	2020	8.0	1.4			0.5	0.6	-26.7	1.5			5.0	0.0	5.0	0.0	7.6	0.2	149.1	4.2	9.8	0.2	24.3	0.9	110.6	3.2	24.5	0.6	3.4	0.2	20.3	0.9	158.8	193.3
LAK042	2020	79.5	0.4			-10.0	3.6	-13.2	0.9			4.8		4.7	0.1	19.2		7.6		6.5		2.5		23.6		33.2		2.9		27.5		87.2	102.9
LAK044	2020	14.5	0.9			2.4	1.6	8.1	1.1			5.7	0.1	5.6	0.0	1.9	0.0	5.2	0.2	6.9	0.1	2.1	0.1	8.4	0.2	4.6	0.1	6.6	0.0	0.3	0.5	19.9	21.8
Lak006	2021	67.8	3.6			39.1	0.8	46.0	3.8			6.3	0.1	5.9	0.0	5.0	0.5	17.5	0.5	6.8	0.5	4.0	0.2	45.0	1.8	17.2	0.7	4.9	0.2	18.3	0.8	85.4	91.3
LAK012	2021	101.2	2.6			58.7	6.9	68.1	4.1			6.3	0.0	5.8	0.0	7.3	0.7	28.7	2.6	6.5	0.9	4.2	0.2	79.4	2.7	23.9	0.6	6.0	0.2	21.6	0.8	130.8	133.3
LAK016	2021	138.1				95.9		97.9				6.7		6.2		8.7		59.5		8.2		8.7		139.4		28.0		8.2		23.3		198.8	213.4
LAK022	2021	68.8				20.6		44.2				5.4		5.5		5.6		41.9		7.6		5.6		65.1		20.1		3.9		21.8		110.8	104.5
LAK023	2021	56.2	3.9			24.9	1.0	32.4	3.9			6.1	0.1	5.7	0.0	5.4	0.3	24.5	1.1	4.7	0.3	4.6	0.3	51.9	2.8	15.1	0.6	3.5	0.2	11.5	0.5	81.9	82.0
LAK028	2021	11.7	1.9			-5.7	0.9	-31.9	2.5			4.9	0.1	4.8	0.0	9.4	0.3	96.9	6.8	10.2	0.5	19.4	0.3	76.5	3.7	17.9	1.4	2.7	0.1	12.9	1.2	110.0	141.1
LAK042	2021	62.4	4.3			-11.8	3.8	-16.5	4.3			4.7	0.1	4.7	0.1	16.5	0.6	13.5	1.1	5.6	0.3	2.3	0.2	20.9	1.8	28.2	0.6	2.7	0.1	24.3	0.8	76.1	100.5
LAK044	2021	17.1	1.4			5.4	1.9	9.5	1.6			5.5	0.1	5.5	0.0	2.2	0.2	4.2	0.3	5.6	0.1	1.8	0.1	9.4	1.4	4.4	0.3	6.5	0.2	1.1	0.3	21.5	25.6
NC184	2012																																
NC194	2012																																
DCAS14A	2012																																
NC184	2013	80.4		16.2				25.6		5.7						11.6		5.7		24.0		0.3		50.5		17.5		4.4		13.8		86.2	132.0
NC194	2013	35.6		28.0				35.3		6.6						0.7		3.6		7.6		0.3		23.2		3.4		5.2		7.4		39.2	59.3
DCAS14A	2013	53.5		50.6				49.9		6.5						1.4		33.4		9.2		0.6		63.9		10.3		10.3		6.1		90.6	115.6

Lake	Year	CBANC (µeq/L)	SE	Gran ANC (µeq/L) (Trent)	SE	Gran ANC (µeq/L) (BASL)	SE	BCS (µeq/L)	SE	pH (Trent)	SE	pH (ALS)	SE	pH (BASL)	SE	DOC (mg/L)	SE	SO4 * (µeq/L)	SE	Cl (µeq/L)	SE	F (µeq/L)	SE	Ca * (µeq/L)	SE	Mg * (µeq/L)	SE	K * (µeq/L)	SE	Na * (µeq/L)	SE	∑ BC * (µeq/L)	∑ Anions (µeq/L)
NC184	2014																																
NC194	2014																																
DCAS14A	2014																																
NC184	2015	73.0		18.4				27.2		5.5		5.6				9.8		5.7		21.7		0.5		48.8		16.1		2.9		10.8		78.7	104.6
NC194	2015	40.9		33.0				40.2		6.5		6.5				0.8		2.3		7.3		0.5		26.9		4.4		4.3		7.9		43.4	56.3
DCAS14A	2015	74.9						73.6		6.6		6.7				0.9		35.7		7.3		0.5		77.6		12.4		11.2		9.9		111.0	49.0
NC184	2016	94.6		27.3				44.9		5.8		6.2				10.6		5.5		21.2		0.5		62.6		19.3		2.7		15.5		100.1	120.5
NC194	2016	40.0		28.7				35.1		6.4		6.6				1.6		2.3		7.9		0.5		26.4		4.3		3.8		7.9		42.4	55.4
DCAS14A	2016	72.7		57.5				68.3		6.6		6.8				1.5		36.8		8.5		0.5		77.5		11.8		10.5		9.7		109.6	116.1
NC184	2017	76.3		9.8				13.0		5.4		6.0				13.3		4.7		14.7		0.5		45.2		17.4		2.5		15.9		81.0	104.6
NC194	2017	46.5		12.4				44.8		6.4		6.4				1.0		2.5		4.8		0.5		29.9		5.7		3.6		9.9		49.1	39.4
DCAS14A	2017	67.8		51.0				63.3		6.6		6.7				1.5		31.1		5.6		0.5		68.2		11.8		9.1		9.9		99.0	99.0
NC184	2018	95.0		44.0				63.1		6.2		6.4				7.0		8.3		16.6		0.5		67.8		17.3		3.1		15.3		103.4	113.3
NC194	2018	43.1		26.1				45.0		6.5		6.7				0.3		2.6		5.1		0.5		28.3		4.3		4.1		9.1		45.8	45.6
DCAS14A	2018	79.0		59.3				77.3		6.8		6.8				1.0		41.3		7.3		0.5		85.6		12.6		11.5		10.7		120.4	124.2
NC184	2019	86.1	*1.7*	24.9	*1.5*	47.3	*14.2*	42.9	*2.2*	5.7	*0.0*	6.1	*0.1*	5.9	*0.0*	9.3	*0.3*	7.1	*0.2*	23.2	*1.0*	0.5	*0.0*	58.3	*0.3*	19.0	*0.6*	2.6	*0.1*	13.5	*1.1*	93.3	114.5
NC194	2019	46.7	*0.6*	30.4	*5.3*	41.4	*0.2*	44.7	*0.4*	6.4	*0.0*	6.6	*0.1*	6.5	*0.0*	1.0	*0.2*	2.7	*0.3*	9.2	*0.4*	0.5	*0.0*	31.4	*0.6*	4.8	*0.1*	4.7	*0.2*	8.5	*0.3*	49.4	50.0
DCAS14A	2019	81.1	*1.5*	58.6	*5.9*	73.0	*0.3*	78.3	*1.4*	6.6	*0.1*	6.8	*0.0*	6.6	*0.0*	1.2	*0.0*	41.0	*0.9*	8.8	*1.0*	0.5	*0.0*	85.3	*1.2*	13.7	*0.2*	11.9	*0.3*	11.9	*0.3*	122.8	138.6
NC184	2020																																
NC194	2020																																
DCAS14A	2020																																
NC184	2021	61.2				9.2		6.4				5.1		5.2		11.6		3.5		18.9		0.3		37.3		13.5		2.0		11.8		64.7	100.8
NC194	2021	35.6				27.4		33.1				6.2		6.0		1.1		2.1		5.9		0.3		22.4		3.9		3.8		7.7		37.8	54.9
DCAS14A	2021	63.8				55.6		55.0				6.6		6.0		2.4		28.5		7.9		0.6		63.6		11.9		10.2		9.4		95.1	101.0

[1] SE = standard error

Sampling Data in "Raw" Units

The annual or mean annual values (depending on whether the lake had multiple within-season samples) are presented in their "raw" units, as measured, without converting concentration values to charge equivalents.

Lake	Year	Gran Alkalinity (mg/L) (Trent)	Gran Alkalinity (mg/L) (BASL)	pH (Trent)	pH (ALS)	pH (BASL)	DOC (mg/L)	Conductivity (µS/s)	SO4 (mg/L)	Cl (mg/L)	F (mg/L)	NO3 (µg/L)	NH4 (µg/L)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	Fe (mg/L)	Al (mg/L)	Mn (mg/L)
Lak006	2012	1.3		5.8			3.6	6.7	0.6	0.2	0.1	0.1	3.0	0.6	0.2	0.1	0.5	0.0	0.1	0.0
Lak007	2012	71.9		8.0			0.6	148.9	2.6	0.9	0.1	4.7	1.8	25.5	2.0	0.8	1.8	0.0	0.0	0.0
LAK012	2012	2.9		5.6			4.6	12.7	0.3	0.1	0.1	0.7	3.4	1.5	0.3	0.2	0.5	0.7	0.1	0.2
LAK016	2012	3.4		6.3			3.7	17.9	1.9	0.2	0.1	0.8	3.9	2.4	0.3	0.3	0.6	0.0	0.1	0.0
LAK022	2012	1.4		5.9			5.3	10.7	1.5	0.2	0.1	0.7	3.7	1.2	0.2	0.1	0.6	0.0	0.1	0.0
LAK023	2012	1.0		5.7			4.2	7.5	0.9	0.2	0.1	0.3	3.3	0.8	0.2	0.1	0.3	0.0	0.1	0.0
LAK024	2012	15.0		7.1			1.4	40.0	1.3	1.0	0.0	0.4	2.4	5.5	0.5	0.2	1.2	0.0	0.0	0.0
LAK028	2012	-0.2		5.0			4.9	12.2	2.8	0.2	0.4	1.5	3.4	1.0	0.1	0.1	0.4	0.1	0.4	0.0
LAK034	2012	5.0		6.7			4.5	22.4	1.2	0.2	0.1	1.6	4.9	2.4	0.4	0.2	1.1	0.0	0.0	0.0
LAK042	2012	-1.0		4.7			13.2	11.9	0.3	0.2	0.1	0.7	8.5	0.2	0.3	0.1	0.6	0.6	0.4	0.0
LAK044	2012	0.1		5.4			1.7	3.1	0.3	0.2	0.1	0.4	3.0	0.1	0.1	0.2	0.1	0.0	0.0	0.0
Lak006	2013	1.5		6.2	6.1		3.2	7.0	0.7	0.3	0.1	2.5	2.5	0.5	0.2	0.2	0.5	0.0	0.0	0.0
Lak007	2013	73.2		7.9	8.1		0.1	147.0	3.4	1.3	0.1	2.5	2.5	24.6	2.0	0.9	1.8	0.0	0.0	0.0
LAK012	2013	3.2		6.3	6.1		4.2	12.8	0.6	0.5	0.2	2.5	2.5	1.3	0.3	0.4	0.6	0.4	0.1	0.0
LAK016	2013	4.9		6.7	7.2		4.2	20.3	2.8	0.4	0.2	22.7	7.1	2.3	0.3	0.4	0.6	0.0	0.0	0.0
LAK022	2013	1.8		6.2	6.1		6.2	13.8	2.3	0.4	0.2	2.5	2.5	1.3	0.3	0.2	0.7	0.1	0.1	0.0
LAK023	2013	1.2		6.0	6.0		4.0	9.6	1.2	0.3	0.1	30.1	2.5	0.7	0.2	0.2	0.3	0.0	0.1	0.0
LAK024	2013																			
LAK028	2013	0.2		5.2	5.5		7.1	20.3	6.2	0.6	0.6	20.4	2.5	1.7	0.3	0.2	0.6	0.2	0.6	0.0
LAK034	2013	10.5		6.9	7.4		4.7	28.3	1.9	0.3	0.2	2.5	2.5	3.1	0.5	0.4	1.4	0.0	0.0	0.0
LAK042	2013	1.1		5.5	5.4		9.7	8.0	0.3	0.3	0.1	2.5	2.5	0.3	0.3	0.1	0.6	0.3	0.3	0.0
LAK044	2013	0.4		5.7	6.0		1.5	3.3	0.3	0.3	0.1	2.5	2.5	0.2	0.1	0.2	0.1	0.0	0.0	0.0
Lak006	2014	1.9		6.1	6.6		3.8	8.5	0.6	0.3	0.1	7.7	40.5	0.6	0.2	0.2	0.5	0.0	0.1	0.0
Lak007	2014	72.4		8.1	8.0		0.7	154.2	1.6	0.7	0.0	2.5	2.5	25.6	2.0	0.8	1.8	0.0	0.0	0.0
LAK012	2014	3.4		6.0	6.7		6.3	13.9	0.8	0.4	0.1	7.6	5.3	1.4	0.3	0.3	0.6	0.3	0.1	0.0
LAK016	2014	5.3		6.7	6.7		4.0	21.5	2.4	0.3	0.2	2.5	6.7	2.5	0.3	0.4	0.7	0.0	0.1	0.0
LAK022	2014	2.3		6.3	6.4		5.7	14.4	1.9	0.3	0.1	2.5	2.5	1.4	0.3	0.2	0.7	0.1	0.1	0.0
LAK023	2014	1.6		5.9	6.7		5.7	9.3	0.9	0.2	0.1	10.9	5.3	1.0	0.2	0.2	0.4	0.0	0.1	0.0
LAK024	2014	23.6		7.6	7.5		1.7	63.1	2.1	2.3	0.0	5.1	2.5	8.1	0.8	0.4	2.5	0.0	0.0	0.0
LAK028	2014	1.1		5.3	5.7		5.9	20.2	4.6	0.4	0.4	2.5	2.5	1.7	0.2	0.2	0.6	0.1	0.5	0.0
LAK034	2014	10.3		6.7	7.0		7.0	27.5	0.9	0.2	0.1	2.5	2.5	3.2	0.5	0.4	1.3	0.1	0.0	0.0
LAK042	2014	0.6		5.1	5.4		10.6	10.8	0.3	0.4	0.1	2.5	2.5	0.2	0.3	0.2	0.6	0.4	0.3	0.0
LAK044	2014	0.3		5.8	5.6		1.8	3.6	0.3	0.2	0.1	2.5	2.5	0.2	0.1	0.2	0.1	0.0	0.0	0.0
Lak006	2015	1.6		6.0	6.4		3.9	5.6	0.6	0.2	0.1	3.4	5.4	0.7	0.2	0.2	0.5	0.1	0.1	0.0
Lak007	2015	78.4		8.0	7.9		0.3	151.2	2.3	0.9	0.0	5.6	2.5	25.4	2.0	0.8	1.8	0.0	0.0	0.0
LAK012	2015	3.3		6.0	6.3		7.5	10.1	0.9	0.4	0.1	8.3	8.0	1.5	0.3	0.3	0.6	0.3	0.1	0.0
LAK016	2015	5.7		6.8	6.9		4.3	20.7	2.0	0.3	0.2	7.9	2.5	2.6	0.3	0.4	0.7	0.0	0.1	0.0
LAK022	2015	1.8		6.1	6.2		6.3	12.8	1.6	0.3	0.1	2.5	2.5	1.3	0.2	0.2	0.6	0.1	0.1	0.0
LAK023	2015	1.5		5.9	6.2		5.4	5.9	0.8	0.2	0.1	6.3	2.5	0.9	0.2	0.2	0.3	0.0	0.1	0.0

Lake	Year	Gran Alkalinity (mg/L) (Trent)	Gran Alkalinity (mg/L) (BASL)	pH (Trent)	pH (ALS)	pH (BASL)	DOC (mg/L)	Conductivity (µS/s)	SO4 (mg/L)	Cl (mg/L)	F (mg/L)	NO3 (µg/L)	NH4 (µg/L)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	Fe (mg/L)	Al (mg/L)	Mn (mg/L)
LAK024	2015	22.2		7.4	7.5		2.2	58.7	2.0	2.1	0.0	8.1	2.5	8.1	0.7	0.4	2.3	0.1	0.0	0.0
LAK028	2015	0.5		5.1	5.3		8.1	17.8	3.5	0.3	0.4	2.5	2.5	1.5	0.2	0.1	0.5	0.2	0.6	0.0
LAK034	2015	8.9		6.6	6.7		7.6	22.3	0.1	0.2	0.1	2.5	2.5	2.9	0.5	0.2	1.2	0.1	0.0	0.0
LAK042	2015	0.7		5.4	5.5		8.3	8.1	0.2	0.2	0.0	2.5	2.5	0.2	0.3	0.1	0.7	0.2	0.3	0.0
LAK044	2015	0.3		5.8	5.8		1.6	3.5	0.2	0.2	0.1	2.5	2.5	0.2	0.1	0.2	0.1	0.0	0.0	0.0
Lak006	2016	1.3		6.0	6.3		4.2	7.8	0.6	0.2	0.1	2.5	2.5	0.7	0.2	0.2	0.5	0.0	0.1	0.0
Lak007	2016	68.5		8.0	8.1		0.8	153.7	2.4	0.9	0.1	6.5	2.5	26.1	2.0	0.8	1.8	0.0	0.0	0.0
LAK012	2016	3.3		6.2	6.5		5.1	12.4	0.5	0.2	0.1	5.0	4.7	1.3	0.3	0.2	0.6	0.3	0.1	0.0
LAK016	2016	4.7		6.6	6.9		5.2	20.8	2.2	0.3	0.2	10.9	2.5	2.6	0.3	0.4	0.7	0.0	0.1	0.0
LAK022	2016	1.7		6.1	6.4		6.7	13.7	1.7	0.3	0.1	2.5	2.5	1.4	0.3	0.2	0.7	0.1	0.1	0.0
LAK023	2016	1.4		5.9	6.2		5.8	9.1	0.6	0.2	0.1	2.5	5.1	0.9	0.2	0.2	0.4	0.0	0.1	0.0
LAK024	2016	23.2		7.5	7.6		2.7	66.3	2.2	2.5	0.0	20.7	2.5	9.0	0.8	0.4	2.6	0.1	0.0	0.0
LAK028	2016	-0.2		5.0	5.1		8.1	23.7	6.2	0.4	0.5	21.5	2.5	1.9	0.3	0.2	0.6	0.1	0.7	0.0
LAK034	2016	7.6		6.5	7.1		7.6	22.1	0.0	0.2	0.1	2.5	2.5	2.6	0.4	0.2	1.1	0.1	0.0	0.0
LAK042	2016	0.7		5.4	5.7		9.8	8.8	0.2	0.3	0.0	2.5	3.7	0.3	0.3	0.1	0.7	0.2	0.3	0.0
LAK044	2016	0.2		5.5	6.0		2.0	3.9	0.2	0.2	0.0	2.5	2.5	0.2	0.1	0.2	0.1	0.0	0.0	0.0
Lak006	2017	1.4		6.0	6.4		3.8	8.8	0.7	0.2	0.1	2.5	2.5	0.7	0.2	0.2	0.5	0.0	0.1	0.0
Lak007	2017	69.1		8.0	8.0		0.3	149.0	2.4	0.9	0.0	2.5	2.5	24.1	2.1	0.8	2.0	0.0	0.0	0.0
LAK012	2017	2.9		6.1	6.5		5.2	12.9	0.7	0.2	0.1	9.7	5.6	1.3	0.3	0.3	0.6	0.3	0.1	0.0
LAK016	2017	4.1		6.7	6.8		4.1	18.5	2.1	0.3	0.1	2.5	2.5	2.3	0.3	0.3	0.7	0.0	0.1	0.0
LAK022	2017	1.7		6.1	6.3		5.9	12.8	1.9	0.3	0.1	2.5	2.5	1.3	0.3	0.2	0.6	0.0	0.1	0.0
LAK023	2017	1.4		5.9	6.2		5.4	7.9	0.5	0.2	0.1	7.7	2.5	0.9	0.2	0.1	0.3	0.0	0.1	0.0
LAK024	2017	20.9		7.4	7.6		2.0	57.4	2.0	2.0	0.0	11.2	2.5	8.1	0.8	0.4	2.4	0.1	0.0	0.0
LAK028	2017	-0.5		4.8	5.1		7.3	26.9	7.2	0.3	0.5	25.3	3.3	2.1	0.3	0.1	0.6	0.1	0.7	0.0
LAK034	2017	6.8		6.4	6.8		6.0	17.6	0.0	0.2	0.1	2.5	2.5	2.1	0.4	0.1	1.0	0.1	0.0	0.0
LAK042	2017	0.1		5.2	5.4		11.6	9.8	0.4	0.2	0.0	2.5	5.4	0.3	0.3	0.1	0.7	0.3	0.4	0.0
LAK044	2017	0.4		5.6	6.0		1.6	4.4	0.2	0.2	0.0	2.5	2.5	0.2	0.1	0.2	0.1	0.0	0.0	0.0
Lak006	2018	1.4		6.1	6.4		3.8	8.8	0.8	0.2	0.1	2.5	2.5	0.7	0.2	0.2	0.5	0.0	0.1	0.0
Lak007	2018	70.4		8.1	8.1		0.3	147.4	2.4	1.0	0.0	2.5	2.5	25.1	2.0	0.8	2.0	0.0	0.0	0.0
LAK012	2018	2.5		6.2	6.6		4.6	11.5	0.7	0.2	0.1	2.5	2.5	1.2	0.3	0.2	0.6	0.3	0.1	0.0
LAK016	2018	4.6		6.7	6.9		4.6	20.0	2.2	0.3	0.2	2.5	2.5	2.6	0.3	0.3	0.7	0.0	0.1	0.0
LAK022	2018	1.5		6.1	6.3		5.6	13.4	2.1	0.3	0.1	2.5	2.5	1.5	0.3	0.2	0.7	0.0	0.1	0.0
LAK023	2018	1.1		6.0	6.4		5.6	9.4	0.7	0.2	0.1	2.5	2.5	0.9	0.2	0.1	0.4	0.0	0.1	0.0
LAK024	2018	25.5		7.6	7.6		1.6	70.2	2.4	2.7	0.0	2.5	2.5	9.5	0.9	0.4	2.8	0.0	0.0	0.0
LAK028	2018	0.2		5.3	5.5		4.4	17.7	5.2	0.2	0.4	2.5	3.3	1.5	0.2	0.1	0.5	0.1	0.5	0.0
LAK034	2018	6.5		6.5	6.6		5.1	17.8	0.0	0.1	0.1	2.5	2.5	2.3	0.3	0.1	1.0	0.0	0.0	0.0
LAK042	2018	0.0		5.1	5.3		10.6	8.6	0.3	0.2	0.0	2.5	2.5	0.2	0.3	0.1	0.6	0.3	0.4	0.0
LAK044	2018	0.2		5.5	5.9		1.9	3.6	0.2	0.2	0.0	2.5	2.5	0.2	0.1	0.2	0.1	0.0	0.0	0.0
Lak006	2019	1.6	2.0	6.1	6.5	6.2	1.1	8.3	0.8	0.2	0.1	2.5	2.5	0.8	0.2	0.2	0.6	0.0	0.0	0.0
Lak007	2019	68.8	74.9	8.1	8.1	8.0	0.3	147.2	2.2	1.0	0.0	2.5	2.5	25.0	2.0	0.8	1.9	0.0	0.0	0.0
LAK012	2019	2.8	3.2	6.1	6.6	6.2	1.8	11.0	0.7	0.3	0.1	3.2	2.5	1.2	0.3	0.3	0.7	0.2	0.0	0.0

Lake	Year	Gran Alkalinity (mg/L) (Trent)	Gran Alkalinity (mg/L) (BASL)	pH (Trent)	pH (ALS)	pH (BASL)	DOC (mg/L)	Conductivity (µS/s)	SO4 (mg/L)	Cl (mg/L)	F (mg/L)	NO3 (µg/L)	NH4 (µg/L)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	Fe (mg/L)	Al (mg/L)	Mn (mg/L)
LAK016	2019	4.5	5.1	6.6	7.1	6.6	2.5	19.8	2.9	0.3	0.2	2.5	6.2	2.6	0.3	0.4	0.7	0.0	0.1	0.0
LAK022	2019	1.8	2.2	6.1	6.4	6.2	1.3	13.6	2.4	0.3	0.1	2.5	2.5	1.4	0.3	0.2	0.8	0.1	0.1	0.0
LAK023	2019	1.0	1.3	5.8	6.3	6.0	1.0	7.1	0.7	0.2	0.1	2.5	3.6	0.9	0.2	0.1	0.4	0.0	0.1	0.0
LAK024	2019	24.9	27.5	7.7	7.7	7.3	6.9	66.8	2.3	2.7	0.0	8.0	2.5	9.6	0.9	0.4	3.0	0.0	0.0	0.0
LAK028	2019	0.2	0.2	5.2	5.4	5.1	5.4	24.0	7.2	0.4	0.5	11.9	5.2	2.1	0.4	0.2	0.7	0.1	0.6	0.0
LAK034	2019	7.5	8.4	6.4	7.0	6.6	3.0	17.8	0.1	0.2	0.1	2.5	2.5	2.5	0.4	0.1	1.1	0.0	0.0	0.0
LAK042	2019	0.5	0.8	5.4	5.6	5.4	1.5	6.6	0.4	0.2	0.0	4.3	2.5	0.3	0.3	0.1	0.6	0.2	0.3	0.0
LAK044	2019	0.3	0.3	5.5	5.9	5.7	1.5	2.4	0.3	0.2	0.0	2.5	2.5	0.2	0.1	0.2	0.1	0.0	0.0	0.0
Lak006	2020		2.2		6.3	6.1	5.1	8.5	0.8	0.2	0.1	2.5	2.5	0.9	0.2	0.2	0.6	0.1	0.1	0.0
LAK012	2020		4.7		6.4	6.1	8.8	15.1	0.8	0.3	0.1	2.5	2.5	2.0	0.4	0.3	0.7	0.5	0.1	0.1
LAK016	2020																			
LAK022	2020																			
LAK023	2020		1.5		6.1	6.0	6.4	7.3	0.7	0.2	0.1	2.5	2.5	1.0	0.2	0.1	0.4	0.0	0.1	0.0
LAK028	2020		0.0		5.0	5.0	7.6	25.0	7.2	0.3	0.5	25.4	3.8	2.2	0.3	0.1	0.7	0.1	0.7	0.0
LAK042	2020		-0.5		4.8	4.7	19.2	14.2	0.4	0.2	0.0	2.5	2.5	0.5	0.4	0.1	0.8	0.6	0.6	0.0
LAK044	2020		0.2		5.6	5.6	1.9	2.5	0.1	0.1	0.0	2.5	2.5	0.2	0.1	0.2	0.1	0.0	0.0	0.0
Lak006	2021		2.0		6.3	5.9	5.0	8.3	0.9	0.2	0.1	2.5	5.3	0.9	0.2	0.2	0.6	0.1	0.1	0.0
LAK012	2021		2.9		6.3	5.8	7.3	13.1	1.4	0.2	0.1	12.9	4.8	1.6	0.3	0.2	0.6	0.4	0.1	0.0
LAK016	2021		4.8		6.7	6.2	8.7	20.5	2.9	0.3	0.2	18.1	2.5	2.8	0.4	0.3	0.7	0.1	0.2	0.0
LAK022	2021		1.0		5.4	5.5	5.6	12.6	2.1	0.3	0.1	2.5	2.5	1.3	0.3	0.2	0.7	0.1	0.2	0.0
LAK023	2021		1.2		6.1	5.7	5.4	8.3	1.2	0.2	0.1	18.7	3.3	1.0	0.2	0.1	0.4	0.0	0.1	0.0
LAK028	2021		-0.3		4.9	4.8	9.4	20.4	4.7	0.4	0.4	20.5	3.2	1.5	0.2	0.1	0.5	0.2	0.7	0.0
LAK042	2021		-0.6		4.7	4.7	16.5	14.5	0.7	0.2	0.0	2.5	4.1	0.4	0.4	0.1	0.7	0.5	0.5	0.0
LAK044	2021		0.3		5.5	5.5	2.2	2.7	0.2	0.2	0.0	2.5	2.5	0.2	0.1	0.3	0.1	0.0	0.0	0.0
NC184	2012																			
NC194	2012																			
DCAS14A	2012																			
NC184	2013	0.8		5.7			11.6	10.0	0.4	0.9	0.0	5.0	1.0	1.0	0.3	0.2	0.8			
NC194	2013	1.4		6.6			0.7	3.9	0.2	0.3	0.0	1.0	1.0	0.5	0.1	0.2	0.3			
DCAS14A	2013	2.5		6.5			1.4	10.6	1.7	0.3	0.0	52.6	2.5	1.3	0.1	0.4	0.3	0.0	0.0	0.0
NC184	2014																			
NC194	2014																			
DCAS14A	2014																			
NC184	2015	0.9		5.5	5.6		9.8	11.6	0.4	0.8	0.0	2.5	2.5	1.0	0.2	0.1	0.7	0.2	0.3	0.0
NC194	2015	1.7		6.5	6.5		0.8	5.4	0.1	0.3	0.0	2.5	2.5	0.5	0.1	0.2	0.3	0.0	0.0	0.0
DCAS14A	2015			6.6	6.7		0.9	14.0	1.8	0.3	0.0	6.8	2.5	1.6	0.2	0.4	0.4	0.0	0.0	0.0
NC184	2016	1.4		5.8	6.2		10.6	12.8	0.4	0.8	0.0	2.5	2.5	1.3	0.3	0.1	0.8	0.1	0.3	0.0
NC194	2016	1.4		6.4	6.6		1.6	5.9	0.1	0.3	0.0	2.5	2.5	0.5	0.1	0.2	0.3	0.0	0.0	0.0
DCAS14A	2016	2.9		6.6	6.8		1.5	14.8	1.8	0.3	0.0	2.5	2.5	1.6	0.2	0.4	0.4	0.0	0.0	0.0
NC184	2017	0.5		5.4	6.0		13.3	11.4	0.3	0.5	0.0	2.5	2.5	0.9	0.2	0.1	0.7	0.2	0.3	0.0
NC194	2017	0.6		6.4	6.4		1.0	4.9	0.1	0.2	0.0	2.5	2.5	0.6	0.1	0.1	0.3	0.0	0.0	0.0

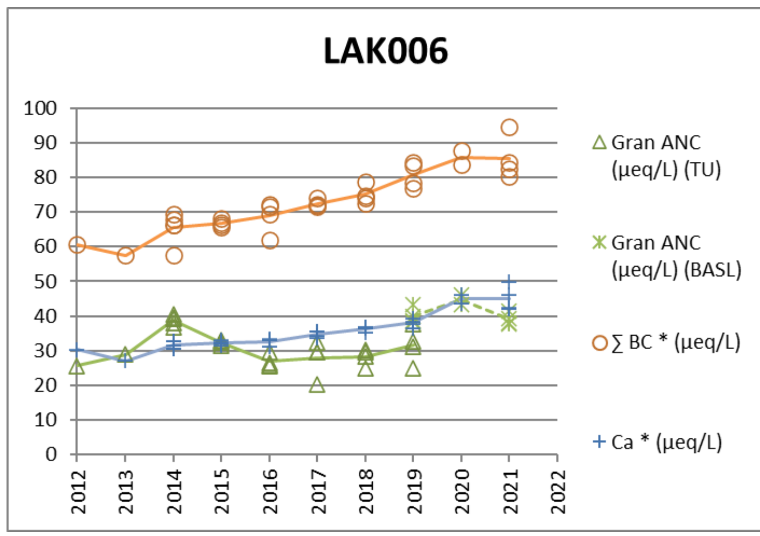
Lake	Year	Gran Alkalinity (mg/L) (Trent)	Gran Alkalinity (mg/L) (BASL)	pH (Trent)	pH (ALS)	pH (BASL)	DOC (mg/L)	Conductivity (µS/s)	SO4 (mg/L)	Cl (mg/L)	F (mg/L)	NO3 (µg/L)	NH4 (µg/L)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	Fe (mg/L)	Al (mg/L)	Mn (mg/L)
DCAS14A	2017	2.6		6.6	6.7		1.5	11.7	1.5	0.2	0.0	2.5	2.5	1.4	0.2	0.4	0.3	0.0	0.0	0.0
NC184	2018	2.2		6.2	6.4		7.0	12.3	0.5	0.6	0.0	2.5	2.5	1.4	0.3	0.1	0.7	0.1	0.2	0.0
NC194	2018	1.3		6.5	6.7		0.3	5.4	0.2	0.2	0.0	2.5	2.5	0.6	0.1	0.2	0.3	0.0	0.0	0.0
DCAS14A	2018	3.0		6.8	6.8		1.0	14.7	2.0	0.3	0.0	2.5	2.5	1.7	0.2	0.5	0.4	0.0	0.0	0.0
NC184	2019	1.2	2.4	5.7	6.1	5.9	1.1	11.1	0.5	0.8	0.0	3.7	2.5	1.2	0.3	0.1	0.8	0.1	0.3	0.0
NC194	2019	1.5	2.1	6.4	6.6	6.5	0.9	5.3	0.2	0.3	0.0	2.5	2.5	0.6	0.1	0.2	0.4	0.0	0.0	0.0
DCAS14A	2019	2.9	3.7	6.6	6.8	6.6	1.4	13.7	2.0	0.3	0.0	10.3	2.5	1.7	0.2	0.5	0.4	0.0	0.0	0.0
NC184	2020																			
NC194	2020																			
DCAS14A	2020																			
NC184	2021		0.5		5.1	5.2	11.6	9.5	0.3	0.7	0.0	2.5	2.5	0.8	0.2	0.1	0.6	0.2	0.3	0.0
NC194	2021		1.4		6.2	6.0	1.1	3.3	0.1	0.2	0.0	2.5	2.5	0.5	0.1	0.2	0.3	0.0	0.0	0.0
DCAS14A	2021		2.8		6.6	6.0	2.4	10.8	1.4	0.3	0.0	39.8	2.5	1.3	0.2	0.4	0.4	0.0	0.0	0.0

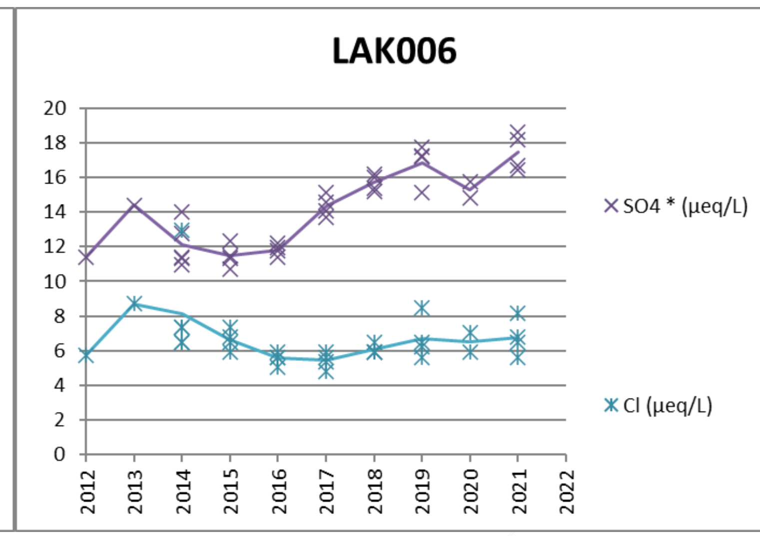
Appendix 2: Changes in Ion Concentrations from 2012 to 2021

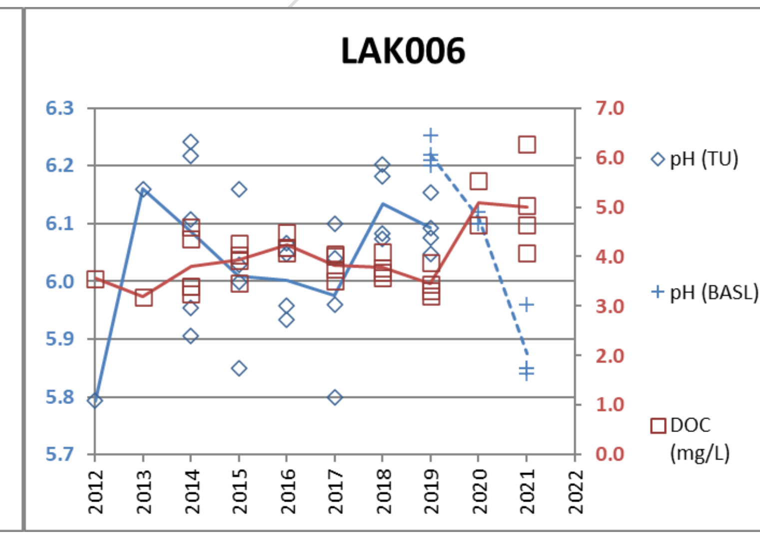
For each of the EEM lakes, the figures in this appendix show the inter-annual changes in six major water chemistry metrics from 2012 to 2021: Gran ANC, base cations and calcium (left panel), sulfate and chloride (centre panel), and pH and dissolved organic carbon (right panel). The selection of each pair of metrics is solely based on optimizing graphical representation across all metrics and lakes (i.e., metrics with somewhat similar numeric ranges are shown together). The right panel has two Y-axes. The axis for pH does not start at zero – be aware that this can make relatively minor changes appear to be much more substantial than they are. Due to large variation among the lakes for some of the metrics, the Y-axis is not consistent across the lakes, therefore extra caution is required for making comparisons among lakes with respect to the magnitude of changes. However, these graphs are especially useful for looking at the patterns of changes for individual lakes across the sampling record and determining whether similar patterns are observed across lakes and/or metrics.

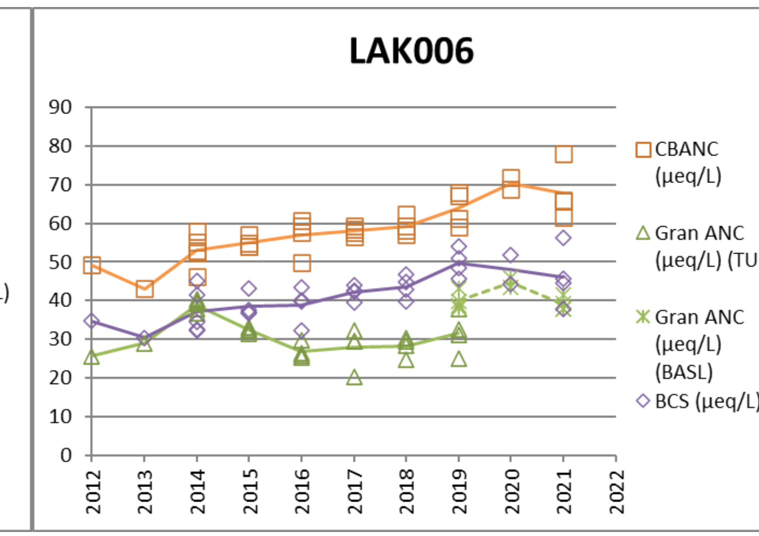
These figures show the results for all of the sampling events for each lake in each year, whether that included multiple within-season samples or only a single annual sample. The points represent the values for individual sampling events. The solid lines represent the annual trend, based on either the single annual sample or the average of all the within-season samples, as appropriate for the lake and year. For the sensitive lakes (the only lakes where intensive, within-season sampling was conducted), the point markers have been made hollow so that it is possible to see if there were multiple within-season samples with similar values.

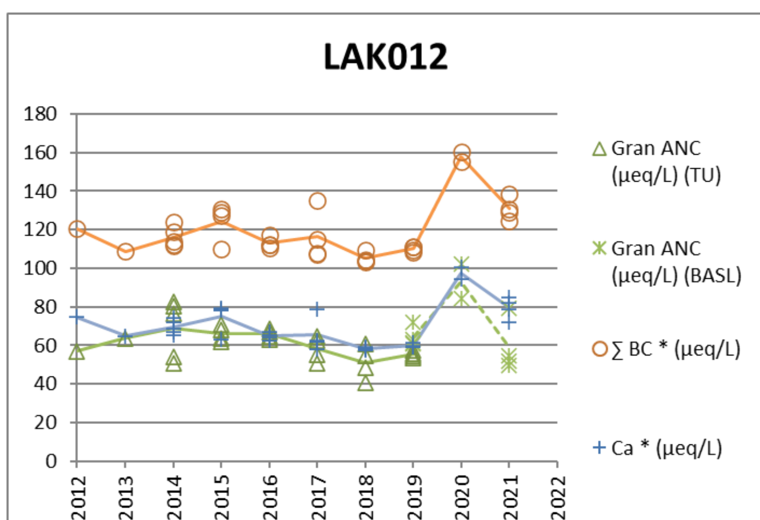
Sensitive Lakes

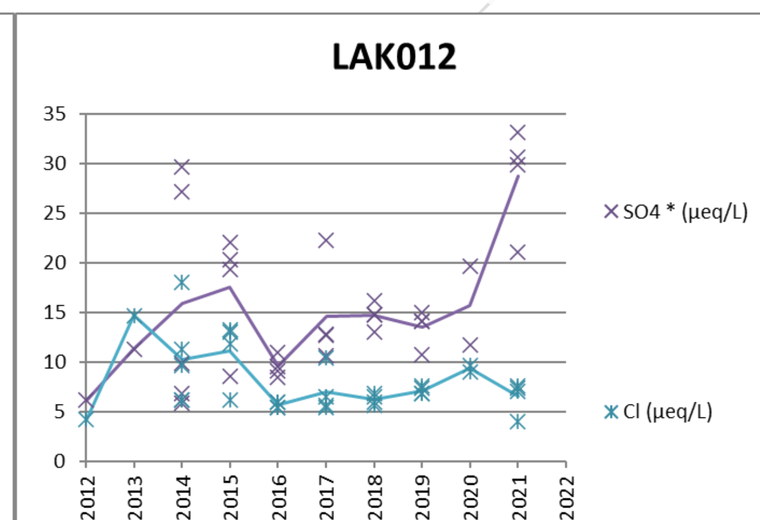


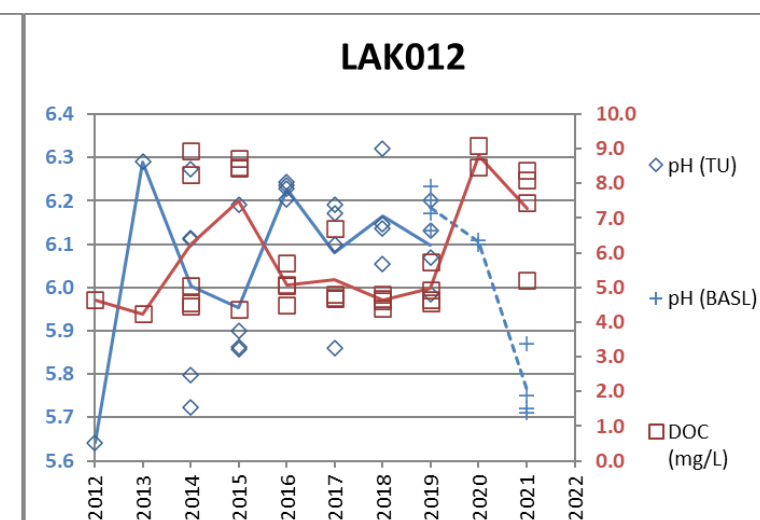


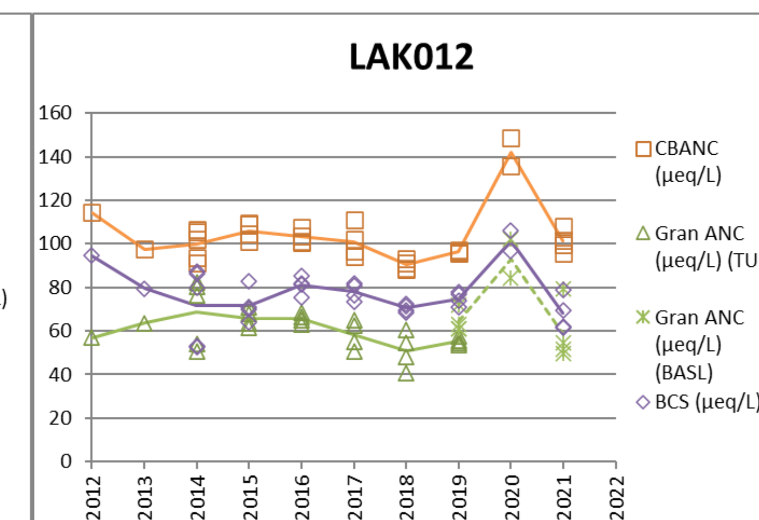


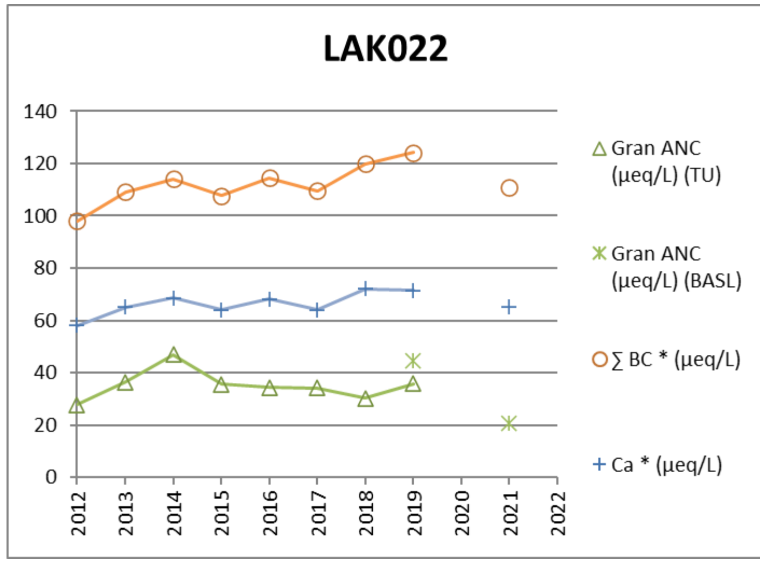


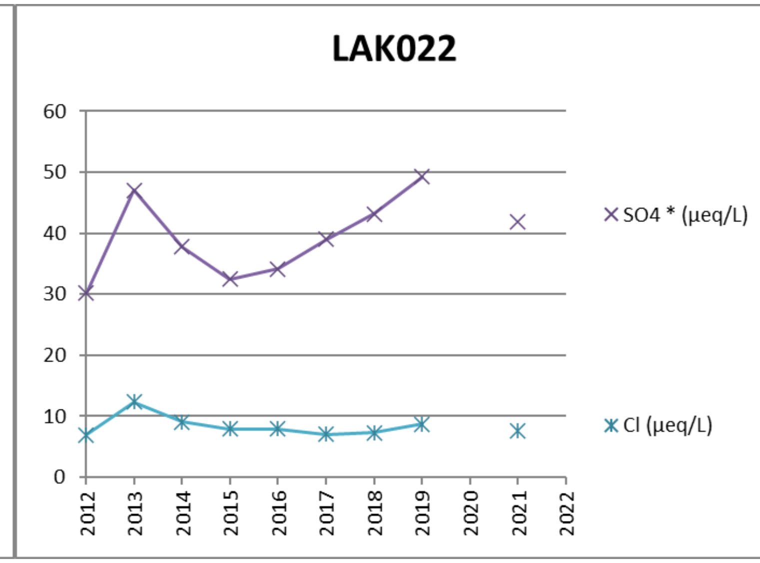


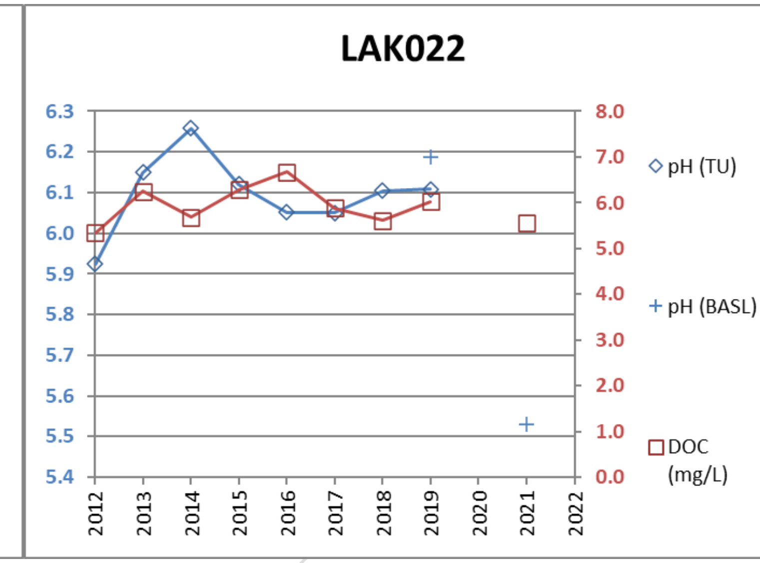


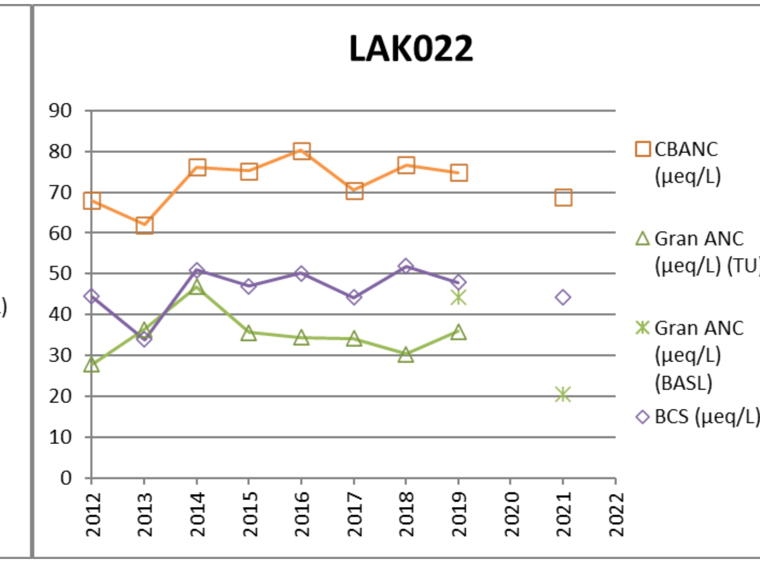


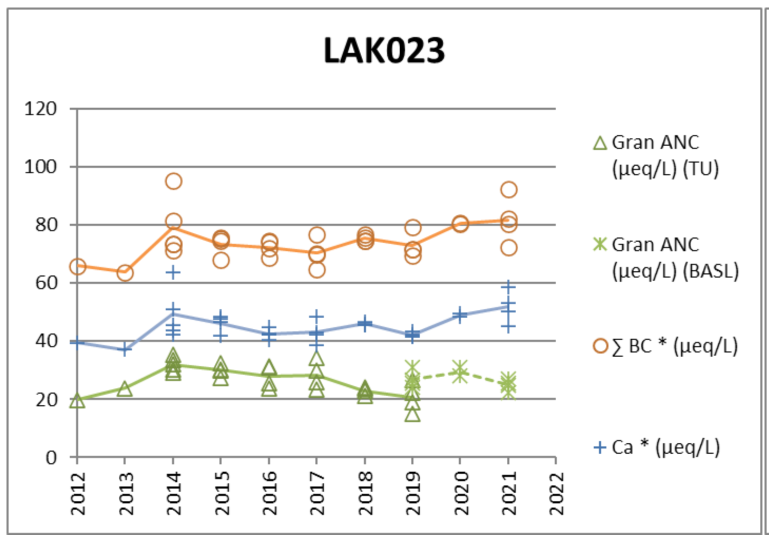


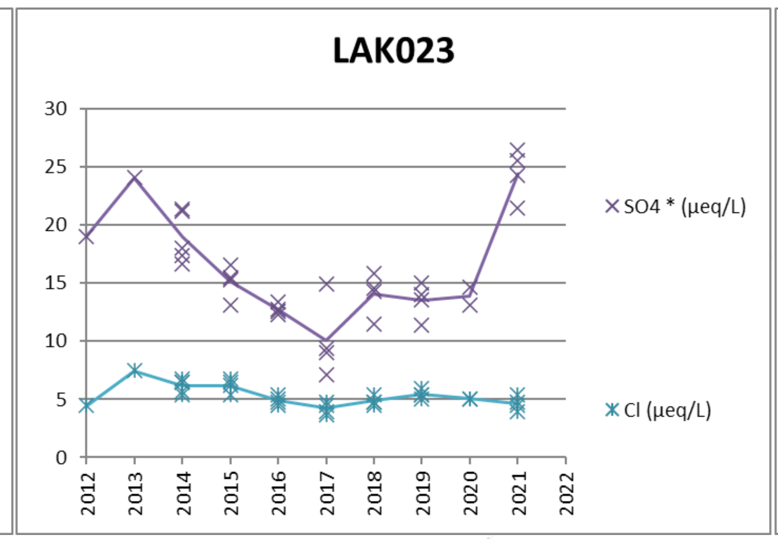

LAK022
Gran ANC (μeq/L) (TU)
Gran ANC (μeq/L) (BASL)
∑ BC * (μeq/L)
Ca * (μeq/L)

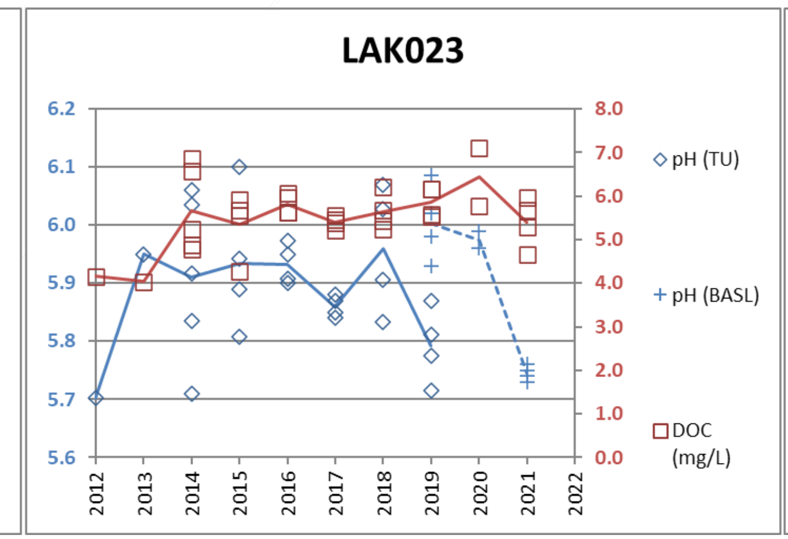

LAK022
SO4 * (μeq/L)
Cl (μeq/L)

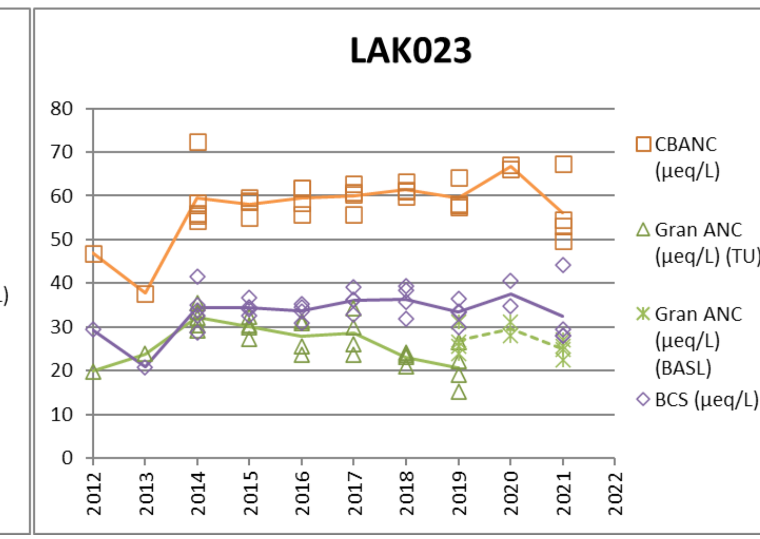

LAK022
pH (TU)
pH (BASL)
DOC (mg/L)

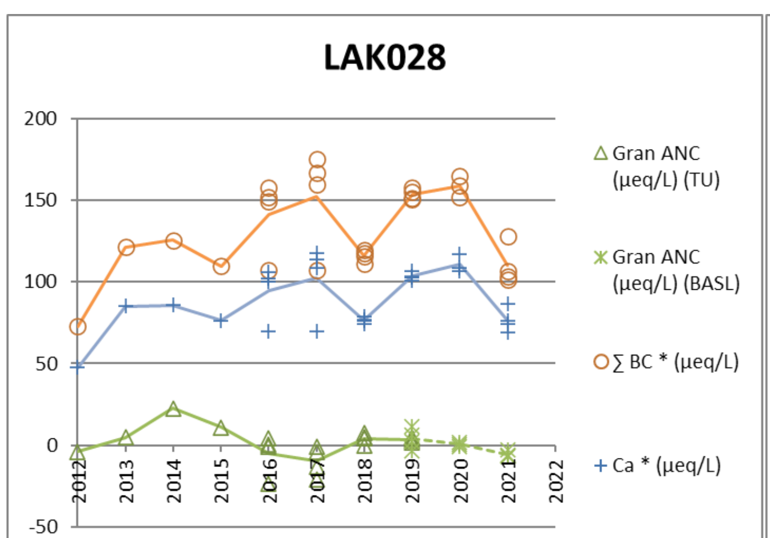

LAK022
CBANC (μeq/L)
Gran ANC (μeq/L) (TU)
Gran ANC (μeq/L) (BASL)
BCS (μeq/L)

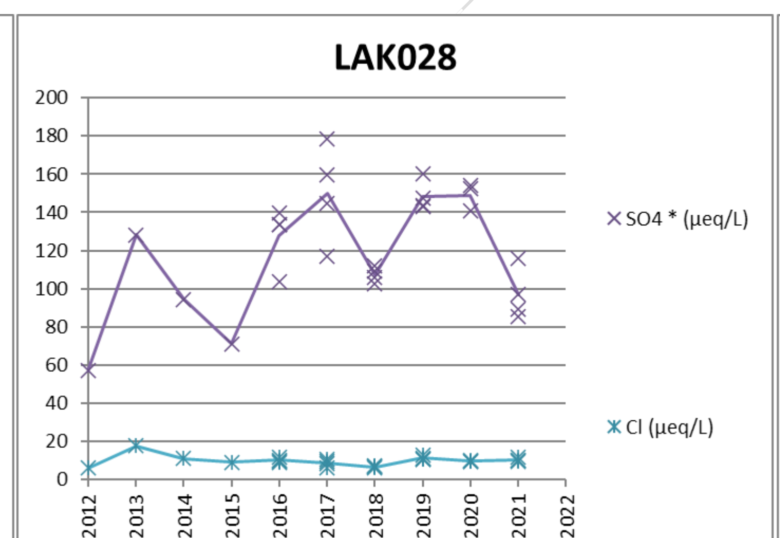

LAK023
Gran ANC (μeq/L) (TU)
Gran ANC (μeq/L) (BASL)
∑ BC * (μeq/L)
Ca * (μeq/L)

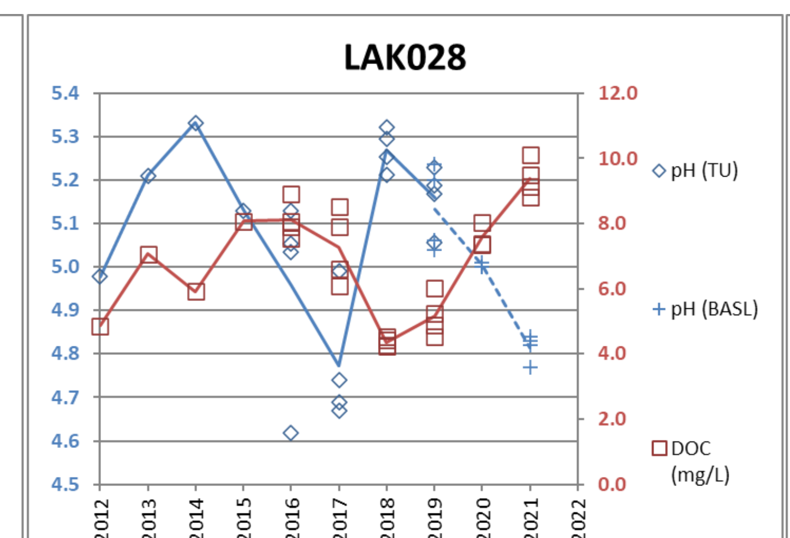

LAK023
SO4 * (μeq/L)
Cl (μeq/L)

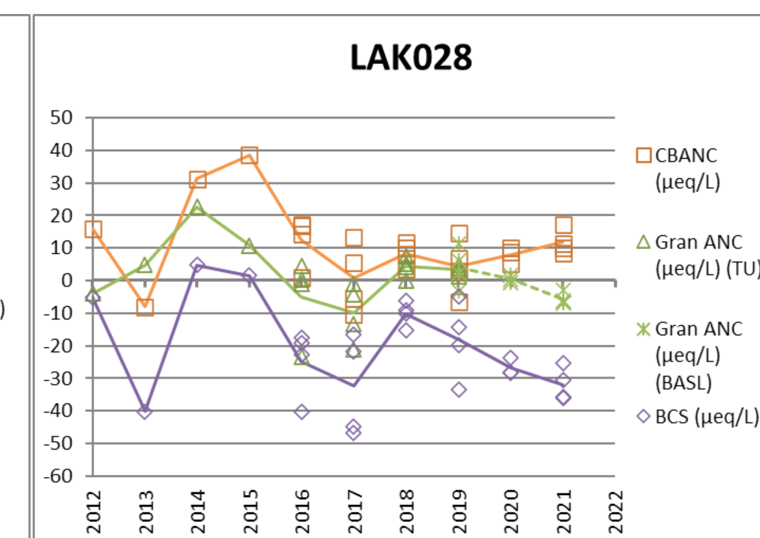

LAK023
pH (TU)
pH (BASL)
DOC (mg/L)

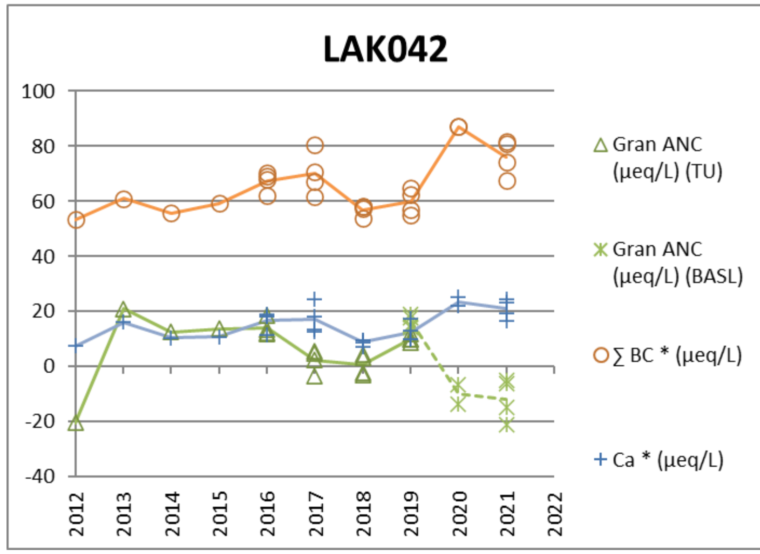

LAK023
CBANC (μeq/L)
Gran ANC (μeq/L) (TU)
Gran ANC (μeq/L) (BASL)
BCS (μeq/L)

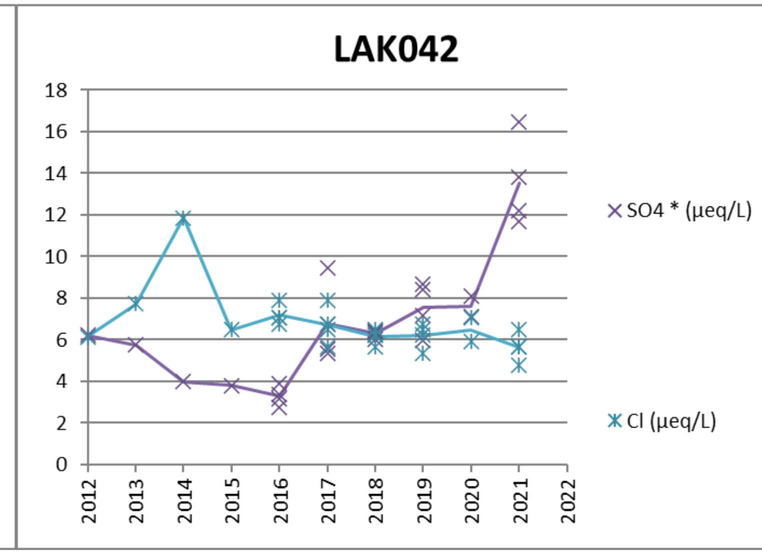

LAK028
Gran ANC (μeq/L) (TU)
Gran ANC (μeq/L) (BASL)
∑ BC * (μeq/L)
Ca * (μeq/L)

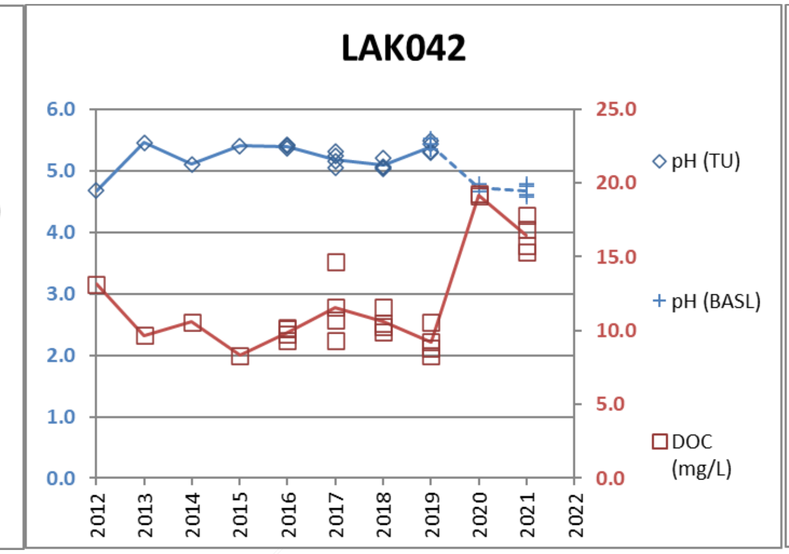

LAK028
SO4 * (μeq/L)
Cl (μeq/L)

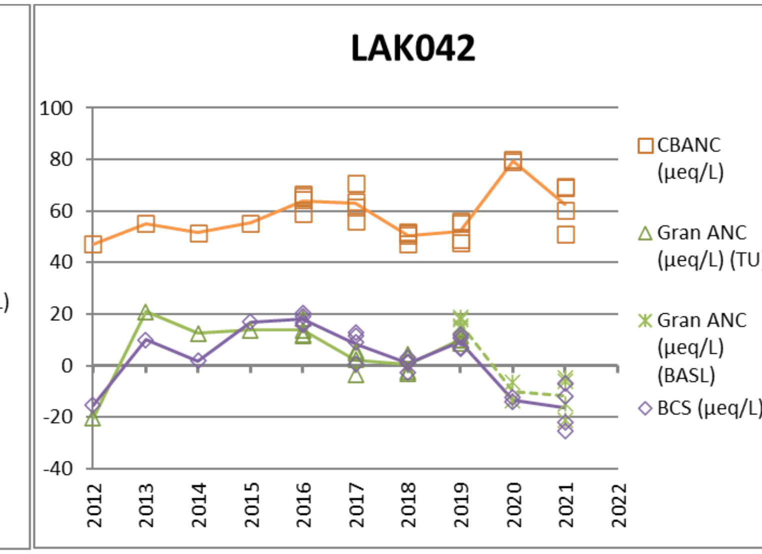

LAK028
pH (TU)
pH (BASL)
DOC (mg/L)

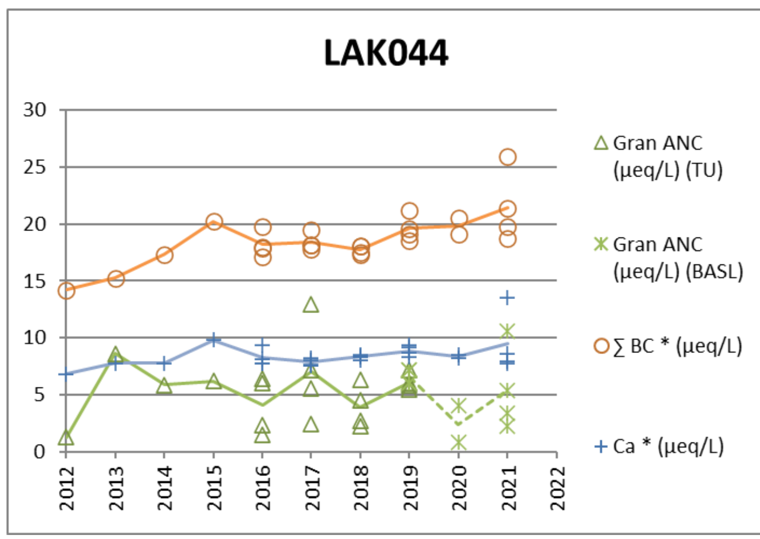

LAK028
CBANC (μeq/L)
Gran ANC (μeq/L) (TU)
Gran ANC (μeq/L) (BASL)
BCS (μeq/L)

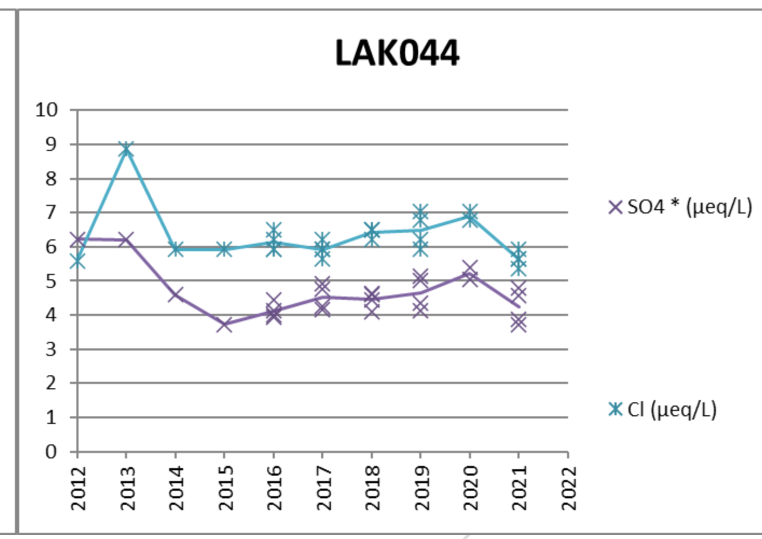

LAK042
Gran ANC (µeq/L) (TU)
Gran ANC (µeq/L) (BASL)
∑ BC * (µeq/L)
Ca * (µeq/L)

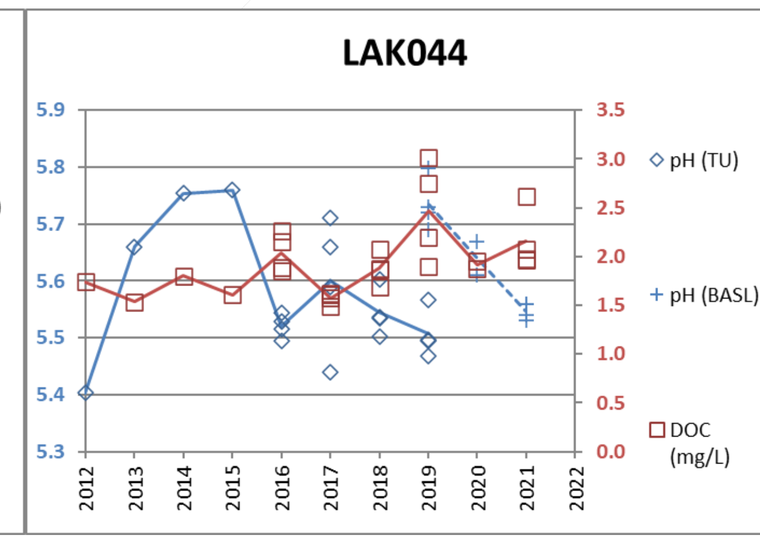

LAK042
SO4 * (µeq/L)
Cl (µeq/L)

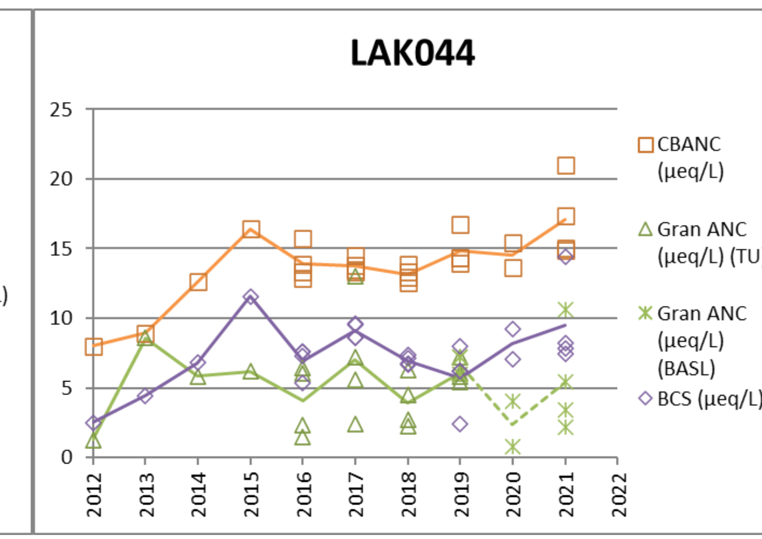

LAK042
pH (TU)
pH (BASL)
DOC (mg/L)


LAK042
CBANC (µeq/L)
Gran ANC (µeq/L) (TU)
Gran ANC (µeq/L) (BASL)
BCS (µeq/L)

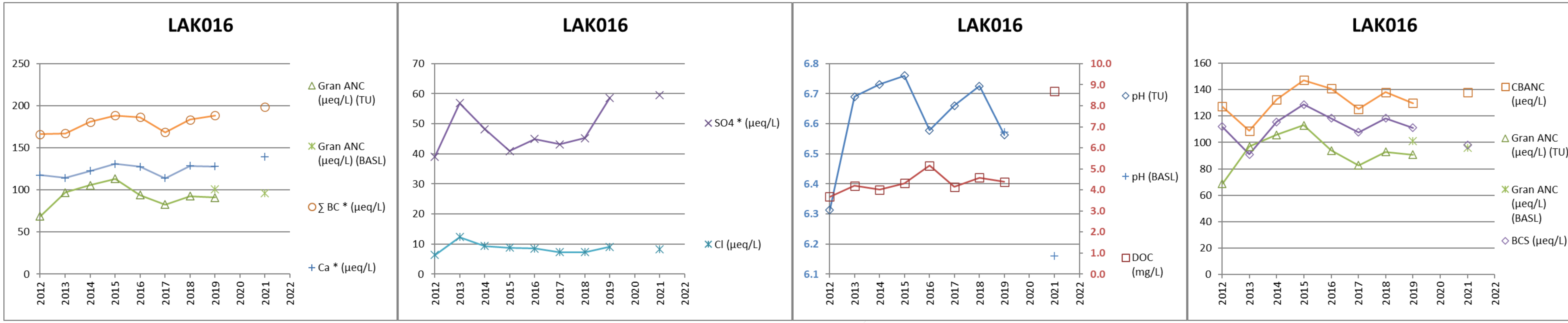

LAK044
Gran ANC (µeq/L) (TU)
Gran ANC (µeq/L) (BASL)
∑ BC * (µeq/L)
Ca * (µeq/L)


LAK044
SO4 * (µeq/L)
Cl (µeq/L)

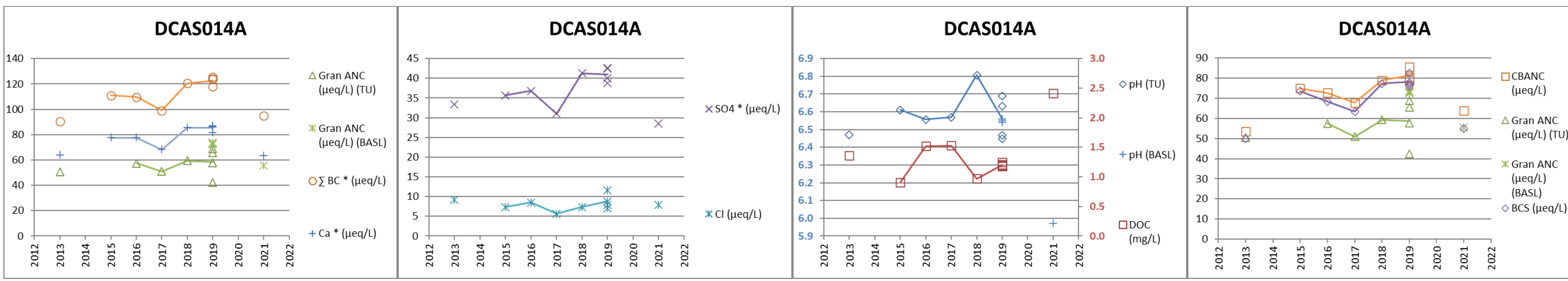

LAK044
pH (TU)
pH (BASL)
DOC (mg/L)

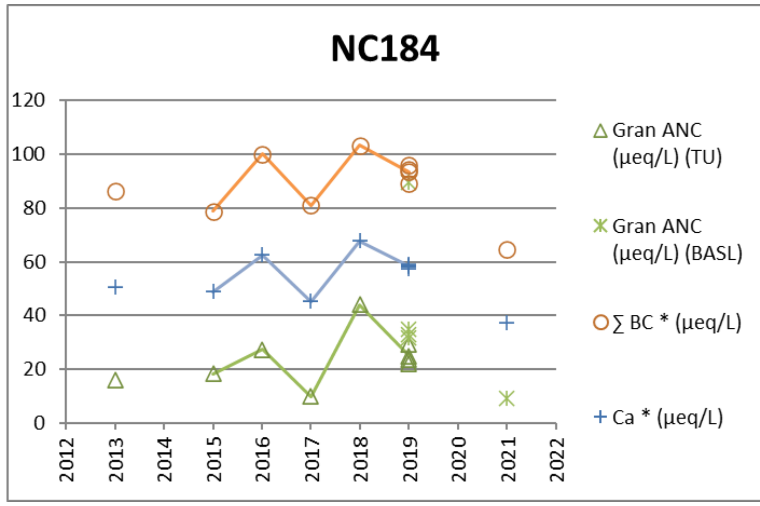

LAK044
CBANC (µeq/L)
Gran ANC (µeq/L) (TU)
Gran ANC (µeq/L) (BASL)
BCS (µeq/L)

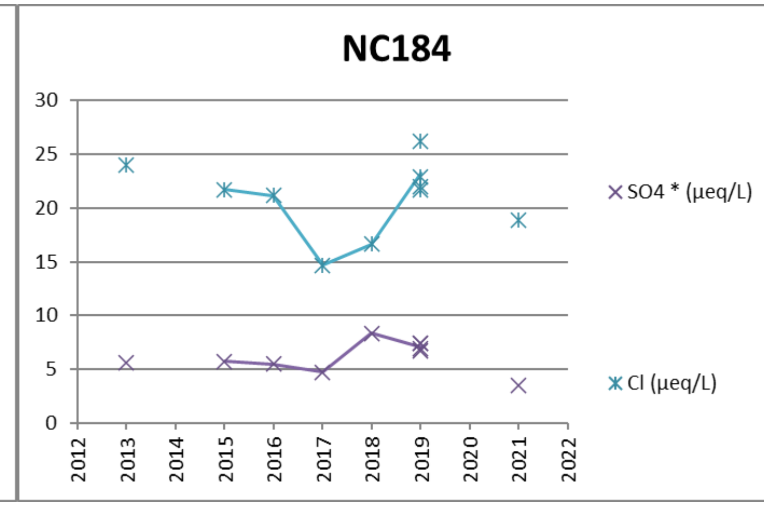
Less Sensitive Lakes

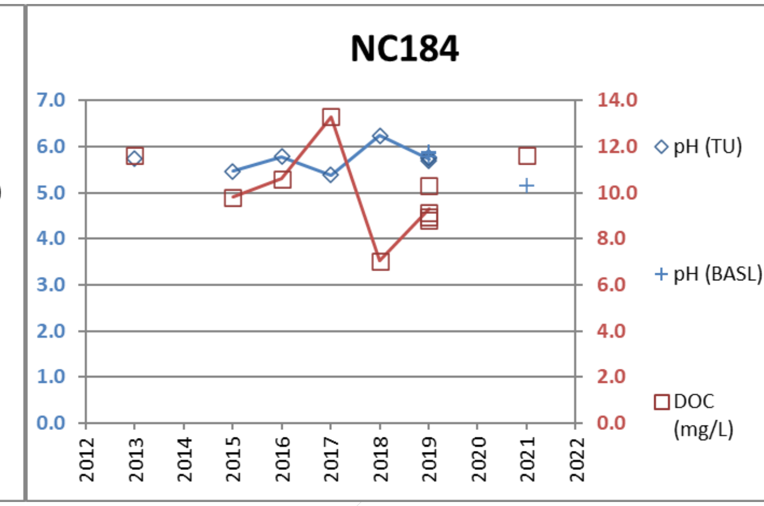


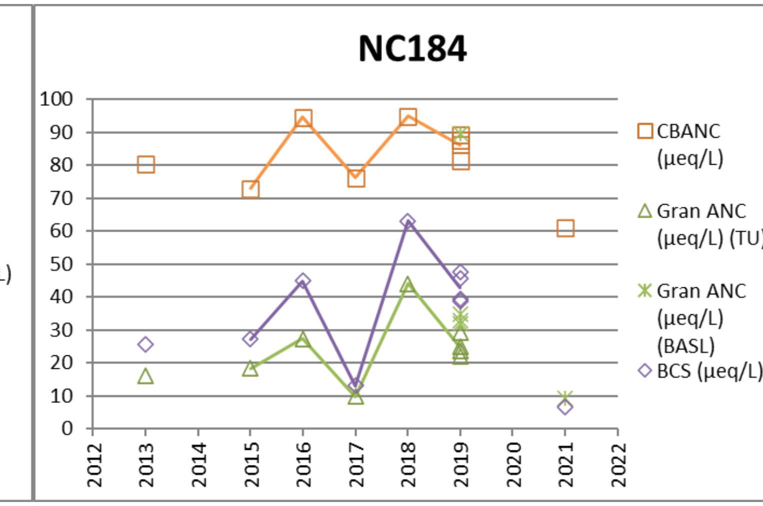
Control Lakes

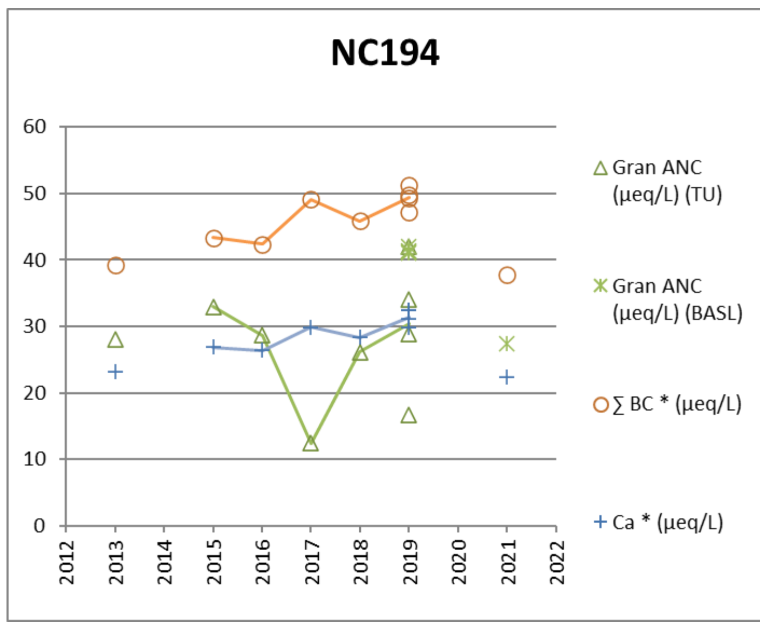


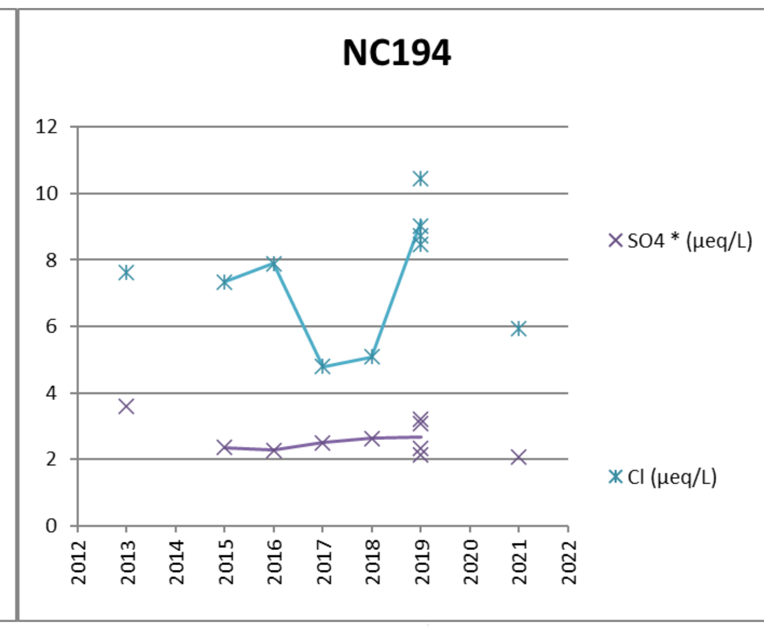

NC184
Gran ANC (µeq/L) (TU)
Gran ANC (µeq/L) (BASL)
∑ BC * (µeq/L)
Ca * (µeq/L)

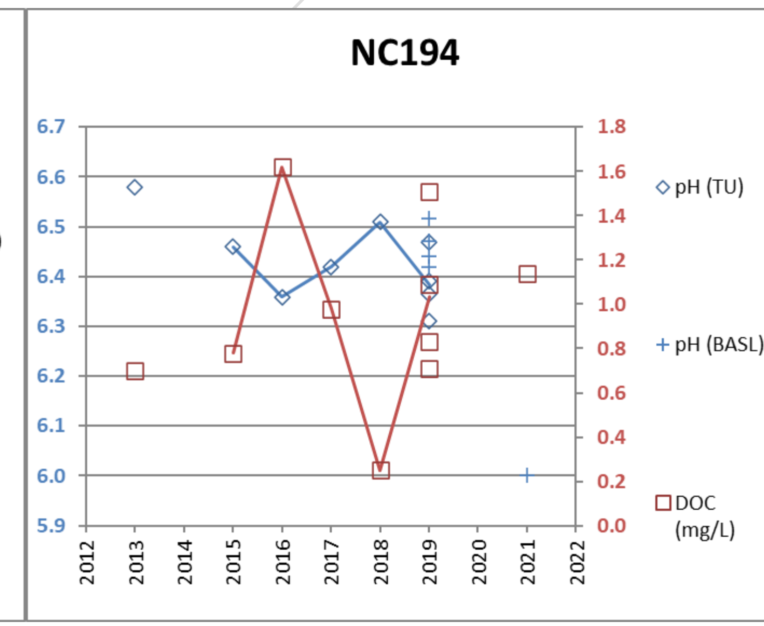

NC184
SO4 * (µeq/L)
Cl (µeq/L)

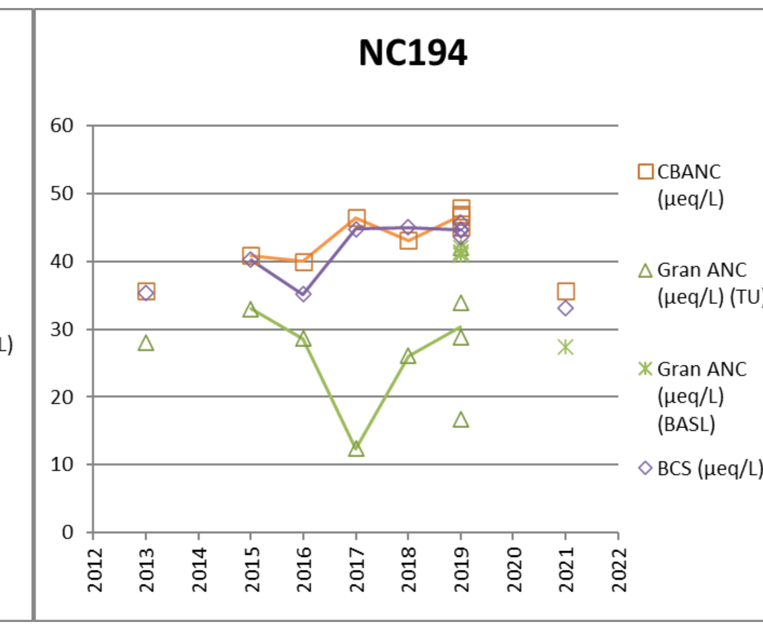

NC184
pH (TU)
pH (BASL)
DOC (mg/L)


NC184
CBANC (µeq/L)
Gran ANC (µeq/L) (TU)
Gran ANC (µeq/L) (BASL)
BCS (µeq/L)


NC194
Gran ANC (µeq/L) (TU)
Gran ANC (µeq/L) (BASL)
∑ BC * (µeq/L)
Ca * (µeq/L)


NC194
SO4 * (µeq/L)
Cl (µeq/L)


NC194
pH (TU)
pH (BASL)
DOC (mg/L)


NC194
CBANC (µeq/L)
Gran ANC (µeq/L) (TU)
Gran ANC (µeq/L) (BASL)
BCS (µeq/L)

Appendix 3: Sensitivity Analyses for Statistical Analyses of Post-KMP Changes in Lake Chemistry

This appendix includes the results of the primary statistical analyses presented in Section 3.3 alongside the results of the sensitivity analyses performed using the alternate transition period baseline (2012-2014, as compared to the 2012 pre-KMP baseline applied in the base case). The upper panel shows the % belief in an exceedance of the *change limit*, the middle panel shows the % belief in an exceedance of the *level of protection*, and the bottom panel indicates the level of support for an overall exceedance of each indicator (based on the approach described in the main text).

SUMMARY OF EXCEEDANCES - *of CHANGE LIMIT* (from statistical analyses)

Scenario	BASE CASE				SENSITIVITY - alternative baseline			
Post-KMP	2019-2021				2019-2021			
Baseline	2012				2012-2014			
Metric	CBANC	Gran ANC	BCS	pH (imputed)	CBANC	Gran ANC	BCS	pH (imputed)
Thresholds	Lake-spec	Lake-spec	Δ 13 ueq/L	Δ 0.3 pH units	Lake-spec	Lake-spec	Δ 13 ueq/L	Δ 0.3 pH units
LAK006	1%	2%	0%	5%	0%	1%	0%	8%
LAK012	35%	18%	51%	8%	8%	9%	19%	16%
LAK022	11%	31%	9%	39%	4%	43%	5%	53%
LAK023	3%	2%	2%	4%	1%	6%	1%	4%
LAK028	15%	4%	79%	18%	25%	28%	46%	37%
LAK042	6%	4%	15%	23%	0%	13%	29%	39%
LAK044	1%	3%	0%	1%	0%	5%	0%	8%
LAK016	7%	4%	36%	28%	2%	11%	21%	47%
DCAS14A	10%	11%	18%	50%	12%	10%	18%	46%
NC184	43%	28%	40%	48%	45%	31%	40%	49%
NC194			16%	62%			18%	60%

SUMMARY OF EXCEEDANCES - *of LEVEL OF PROTECTION* (from statistical analyses

Scenario	BASE CASE			
Post-KMP	2019-2021			
Metric	CBANC	Gran ANC	BCS	pH (imputed)
Thresholds	20 ueq/L	30.7 ueq/L	0 ueq/L	6.0 pH units
LAK006	0%	12%	0%	39%
LAK012	0%	0%	0%	58%
LAK022	0%	71%	0%	91%
LAK023	0%	100%	0%	100%
LAK028	100%	100%	100%	100%
LAK042	0%	100%	94%	100%
LAK044	100%	100%	0%	100%
LAK016	0%	0%	0%	0%
DCAS14A	0%	0%	0%	1%
NC184	0%	100%	0%	100%
NC194	0%	94%	0%	2%

Note: This row of tables (i.e., *level of protection*) is not missing a table – there is no "alternative baseline" scenario because the *level of protection* is solely based on the post-KMP status. Therefore, the overall assessment under the alternative baseline scenario (i.e., middle table in last row of tables) is based on the alternative baseline scenario the *change limit* assessment and the base case scenario for the *level of protection* assessment.

KPI & INFORM. INDICATOR EVALUATION - Exceedance of Level of Protection AND Change Limit

Scenario	BASE CASE				SENSITIVITY - alternative baseline			
Post-KMP	2019-2021				2019-2021			
Baseline	2012				2012-2014			
Metric	CBANC	Gran ANC	BCS	pH (imputed)	CBANC	Gran ANC	BCS	pH (imputed)
Thresholds	Lake-spec	Lake-spec	Δ 13 ueq/L	Δ 0.3 pH units	Lake-spec	Lake-spec	Δ 13 ueq/L	Δ 0.3 pH units
LAK006	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
LAK012	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
LAK022	LOW	MOD	LOW	MOD	LOW	MOD	LOW	MOD
LAK023	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
LAK028	LOW	LOW	MOD	LOW	MOD	MOD	MOD	MOD
LAK042	LOW	LOW	LOW	MOD	LOW	LOW	MOD	MOD
LAK044	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
LAK016	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
DCAS14A	LOW	LOW	LOW	LOW	LOW	LOW	LOW	LOW
NC184	LOW	MOD	LOW	MOD	LOW	MOD	LOW	MOD
NC194	noRel	noRel	LOW	LOW	noRel	noRel	LOW	LOW

Appendix 4: Sensitivity Analyses on Imputation of Gran ANC and pH Values for Integrated Time Series

This appendix includes the results of the Bayesian statistical analyses for Gran ANC and pH using alternate values for the imputed 2020 and 2021 values in order to explore the sensitivity of the results to the uncertainty in the imputation process (see description in Section 2.1 of the EEM 2020 Aquatic Technical Memo for full details). Results are shown for the range of data series for Gran ANC and pH across the base case scenario, the alternative baseline scenario, and the alternative post-KMP period scenario. For each scenario, the tables below show the results across all lakes for each data series and the range of results across all of the permutations of a particular metric for each lake.

SUMMARY OF EXCEEDANCES - *of CHANGE LIMIT* (from statistical analyses)

Scenario	BASE CASE											
Post-KMP	2019-2021										2019-2021	
Baseline	2012										2012	
Metric	Gran ANC (imputed)	Gran ANC (imp+1SD)	Gran ANC (imp+2SD)	Gran ANC (imp-1SD)	Gran ANC (imp-2SD)	pH (imputed)	pH (imp+1SD)	pH (imp+2SD)	pH (imp-1SD)	pH (imp-2SD)	Gran ANC	pH
Thresholds	Lake-spec	Lake-spec	Lake-spec	Lake-spec	Lake-spec	Δ 0.3 pH units	Δ 0.3 pH units	Δ 0.3 pH units	Δ 0.3 pH units	Δ 0.3 pH units	Range (max-min)	
LAK006	2%	2%	2%	3%	2%	5%	4%	3%	12%	16%	1%	13%
LAK012	18%	17%	19%	20%	17%	8%	4%	3%	12%	16%	3%	13%
LAK022	31%	29%	31%	34%	33%	39%	38%	32%	46%	46%	5%	14%
LAK023	2%	3%	3%	3%	2%	4%	4%	5%	10%	16%	1%	12%
LAK028	4%	4%	4%	4%	4%	18%	12%	6%	32%	36%	0%	30%
LAK042	4%	3%	5%	3%	4%	23%	16%	12%	26%	30%	2%	18%
LAK044	3%	3%	2%	3%	4%	1%	1%	3%	3%	8%	2%	7%
LAK016	4%	2%	2%	5%	5%	28%	26%	20%	35%	40%	3%	20%
DCAS14A	11%	10%	9%	11%	12%	50%	44%	40%	49%	56%	3%	16%
NC184	28%	26%	29%	28%	32%	48%	48%	46%	54%	56%	6%	10%
NC194						62%	57%	54%	63%	62%	0%	9%

Scenario	SENSITIVITY - alternative baseline													
Post-KMP	2019-2021												2019-2021	
Baseline	2012-2014												2012	
Metric	Gran ANC (avg)	Gran ANC (imputed)	Gran ANC (imp+1SD)	Gran ANC (imp+2SD)	Gran ANC (imp-1SD)	Gran ANC (imp-2SD)	pH (avg)	pH (imputed)	pH (imp+1SD)	pH (imp+2SD)	pH (imp-1SD)	pH (imp-2SD)	Gran ANC	pH
Thresholds	Lake-spec	Lake-spec	Lake-spec	Lake-spec	Lake-spec	Lake-spec	Δ 0.3 pH units	Δ 0.3 pH units	Δ 0.3 pH units	Δ 0.3 pH units	Δ 0.3 pH units	Δ 0.3 pH units	Range (max-min)	
LAK006	1%	1%	1%	2%	1%	2%	8%	8%	4%	3%	16%	25%	1%	13%
LAK012	8%	9%	10%	8%	10%	10%	16%	16%	13%	9%	23%	31%	3%	13%
LAK022	39%	43%	42%	44%	46%	45%	55%	53%	49%	42%	57%	62%	5%	14%
LAK023	4%	6%	6%	5%	5%	6%	3%	4%	2%	1%	11%	24%	1%	12%
LAK028	32%	28%	26%	29%	29%	30%	55%	37%	20%	10%	52%	62%	0%	30%
LAK042	18%	13%	16%	17%	14%	14%	46%	39%	34%	26%	47%	54%	2%	18%
LAK044	7%	5%	4%	5%	5%	6%	6%	8%	4%	2%	16%	30%	2%	7%
LAK016	11%	11%	11%	9%	10%	13%	44%	47%	34%	31%	52%	53%	3%	20%
DCAS14A	17%	10%	10%	10%	11%	14%	46%	46%	42%	40%	50%	52%	3%	16%
NC184	32%	31%	29%	29%	30%	30%	46%	49%	49%	45%	55%	56%	6%	10%
NC194							58%	60%	60%	56%	59%	61%	0%	9%

SUMMARY OF EXCEEDANCES - *of LEVEL OF PROTECTION* (from statistical analyses)

Scenario	BASE CASE													
Post-KMP	2019-2021												2019-2021	
Metric	Gran ANC (avg)	Gran ANC (imputed)	Gran ANC (imp+1SD)	Gran ANC (imp+2SD)	Gran ANC (imp-1SD)	Gran ANC (imp-2SD)	pH (avg)	pH (imputed)	pH (imp+1SD)	pH (imp+2SD)	pH (imp-1SD)	pH (imp-2SD)	Gran ANC	pH
Thresholds	30.7 ueq/L	30.7 ueq/L	30.7 ueq/L	30.7 ueq/L	30.7 ueq/L	30.7 ueq/L	6.0 pH units	6.0 pH units	6.0 pH units	6.0 pH units	6.0 pH units	6.0 pH units	Range (max-min)	
LAK006	0%	12%	9%	8%	16%	18%	12%	39%	18%	14%	60%	62%	10%	48%
LAK012	0%	0%	0%	0%	0%	0%	52%	58%	26%	28%	66%	89%	0%	63%
LAK022	41%	71%	76%	72%	79%	80%	64%	91%	83%	73%	81%	90%	9%	18%
LAK023	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	0%
LAK028	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	0%
LAK042	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	0%
LAK044	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	0%	0%
LAK016	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%	10%	0%	10%
DCAS14A	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	1%	3%	0%	3%
NC184	24%	100%	100%	100%	100%	100%	98%	100%	100%	100%	99%	99%	0%	1%
NC194	1%	94%	91%	93%	93%	91%	0%	2%	0%	0%	2%	12%	3%	12%

Appendix 5: Lake-specific thresholds for change limits for CBANC

The lake-specific CBANC thresholds for the *change limit* are shown in the table below. The table and caption below are directly copied from Table 5-1 in EEM Phase III Plan.

Lake-specific thresholds for change limits in CBANC. Values calculated from analyses of the titration data, showing the change in CBANC associated with a pH decline of 0.3 pH units from the 2012 (or 2013 for control lakes) pH value for each lake. A lake-specific threshold cannot be estimated for control lake NC194 given limited data.

	EEM Group	Lake-specific CBANC threshold (μeq/L)
LAK006	Sensitive Lake	-10.8
LAK012	Sensitive Lake	-16.3
LAK022	Sensitive Lake	-11.5
LAK023	Sensitive Lake	-10.5
LAK028	Sensitive Lake	-13.4
LAK042	Sensitive Lake	-24.4
LAK044	Sensitive Lake	-6.2
LAK016	Less Sensitive Lake	-25.6
DCAS14A	Control Lake	-21.7
NC184	Control Lake	-10.8
NC194	Control Lake	n.a.

Appendix 6: Intra-annual Changes in Ion Concentrations During 2021

The following graphs show the time series of select water chemistry metrics over all observations during 2021.