KMP SO_2 EEM Program – Technical Memo W08

Aquatic Ecosystems Actions and Analyses

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1 Introduction

This Technical Memo provides additional information on the data and analyses in support of the 2019 requirements for the Aquatic Ecosystems component of the KMP SO_2 Environmental Effects Monitoring (EEM) program (ESSA et al. 2014b). These data and analyses thus provide the foundation for Section 3.5 in the 2019 Annual Report (ESSA et al. 2020).

Relative to previous years, this Technical Memo is streamlined to focus primarily on the data and analyses relevant to the evaluation of the KPI.

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; Bennett and Perrin 2018, Limnotek 2019, Limnotek 2020). 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 extensively throughout this technical memo, often without their full citation:

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

2 Methods

2.1 Water Chemistry Sampling

EEM Lakes

In 2019, Limnotek sampled 14 lakes as part of the EEM long-term sampling plan. These lakes included the seven sensitive lakes and three less sensitive lakes identified in the EEM Plan, the high recreational value LAK024 (Lakelse Lake; added to the EEM in 2014), and three additional control lakes added to the EEM in 2015. The three control lakes (NC184, NC194 and DCAS14A) are all located outside of the KMP-influenced airshed and have baseline data for 2013 from sampling as part of the KAA (ESSA et al., 2014a). The sampling methodology is described in detail in Limnotek's technical report on the water quality monitoring (Limnotek 2020). Table 2-1 summarizes all of the EEM sites sampled during 2012-2019. Figure 2-1 shows a map of the lakes sampled in 2019.

Table 2-1. Summary of sites sampled within the EEM Program.

Sample Site	Year of Sampling								Rationale for sampling
	2012 STAR	2013 EEM	2014 EEM	2015 EEM	2016 EEM	2017 EEM	2018 EEM	2019 EEM	
Lake 006	✓	✓	✓	✓	✓	✓	✓	✓	EEM sensitive lake
Lake 012	✓	✓	✓	✓	✓	✓	✓	✓	EEM sensitive lake
Lake 022	✓	✓	✓	✓	✓	✓	✓	✓	EEM sensitive lake
Lake 023	✓	✓	✓	✓	✓	✓	✓	✓	EEM sensitive lake
Lake 028	✓	✓	✓	✓	✓	✓	✓	✓	EEM sensitive lake
Lake 042	✓	✓	✓	✓	✓	✓	✓	✓	EEM sensitive lake
Lake 044	✓	✓	✓	✓	✓	✓	✓	✓	EEM sensitive lake
Lake 007	✓	✓	✓	✓	✓	✓	✓	✓	EEM less sensitive lake
Lake 016	✓	✓	✓	✓	✓	✓	✓	✓	EEM less sensitive lake
Lake 034	✓	✓	✓	✓	✓	✓	✓	✓	EEM less sensitive lake
Lake 024	✓		✓	✓	✓	✓	✓	✓	Added to the EEM long-term monitoring lake set due to public importance
NC184		✓[1]		✓	✓	✓	✓	✓	Control lakes added to EEM in 2015
NC194		✓[1]		✓	✓	✓	✓	✓	
DCAS14A		✓[1]		✓	✓	✓	✓	✓	
MOE3		✓							Potentially sensitive lakes / streams not previously sampled
Cecil Creek 1		✓							
Cecil Creek 2		✓							
Cecil Creek 3		✓							
MOE6			✓						
Goose Creek tributaries									
GC1			✓						
GC2			✓						
GC2us							✓	✓	
GC3							✓		
GC4			✓						
GC5			✓				✓		
GC6			✓				✓	✓	
GC7			✓						
GC8							✓		
GCNT1				✓			✓		
GCNT2				✓			✓	✓	

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

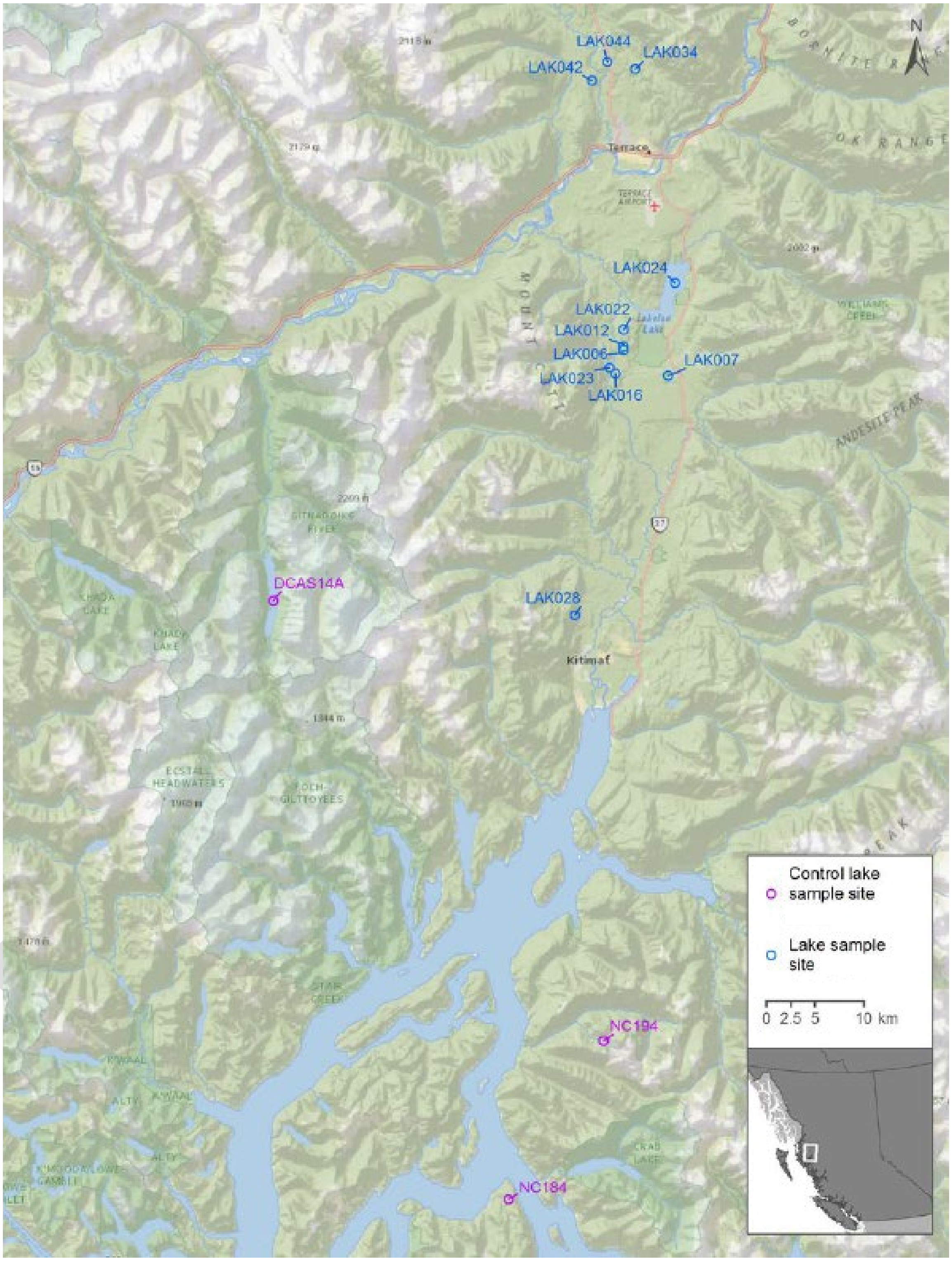


Figure 2-1. Location of the lakes that were sampled in 2019. The three control lakes are labelled with purple text (Source: Bennett and Perrin 2018).

Sampling frequency

The only differences in sampling frequency from the last several years were:

- The three EEM control lakes were each sampled three times in October rather than just once, to assess variability in lake chemistry within the October sampling period
- LAK028 had four additional samples with full chemistry analysis taken over June through early September, to assess seasonal variability in lake chemistry
- LAK028 had deep water samples with full chemistry analysis taken concurrent to each of the surface water samples, to assess hypolimnetic processes such as bacterial sulphate reduction

Continuous monitoring

Four lakes (LAK006, LAK012, LAK023, 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 2019 are reported in Limnotek (2020).

Water chemistry data

The only difference in the water chemistry data from the 2019 sample compared to previous years is that all the samples taken during the fall index period had duplicate samples sent to an additional laboratory (BASL, University of Alberta) for analysis of pH, Gran ANC and conductivity. More details, including a cross-lab comparison, are reported in Limnotek (2020).

2.2 Empirical Changes in Water Chemistry

The methods applied for examining empirical changes are the same as described in the last several 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 first iteration of re-running those analyses with an additional year of monitoring data. These methods are described in detail in the Appendix F of the 2019 Comprehensive Review Report (see Bayesian Method 1 especially).

3 Results

3.1 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 2019 (with the data from 2012-2018 included for reference), for major water chemistry metrics (pH, DOC, Gran ANC, base cations, and major anions).

3.2 Empirical Changes in Water Chemistry

Empirical changes in pH, Gran ANC, 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 (2016-2019) 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 previous annual reports, 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.

Figure 3-1 and Figure 3-2 show the changes in the same water chemistry parameters graphically. These figures allow better visualization of the distribution and variability in the observed changes between 2012 and 2016-2019.

For additional reference, Table 3-2 shows the pH values over period of record for EEM lakes and average pH values for both the full post-KMP period (i.e., 2016-2019) and the post-KMP period applied in the 2019 comprehensive review (i.e., 2016-2018). These data facilitate comparison to the results of the 2019 comprehensive review and explicitly illustrate how the 2019 data relates to those previously reported results.

Appendix 2 provides a detailed set of figures showing the inter-annual changes in major water chemistry metrics (Gran ANC, base cations, calcium, SO_4^{2-}, chloride, pH and DOC) for each of the EEM lakes across the eight years of annual monitoring (2012-2019). Similar figures are also included for the three control lakes based on their six years of annual monitoring (2013 and 2015-2019).

Table 3-1. Empirical changes in pH, Gran ANC, SO_4^{2-}, DOC, base cations, chloride, and calcium for EEM lakes, 2012-2019. Both the differences across the full record of sampling and from 2012 to the average of the post-KMP period (2016-2019) are shown. 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 pink.

SITE	pH (TU)	Gran ANC (µeq/L)	SO_4^{2-} (µeq/L)	DOC (mg/L)	∑ BC (µeq/L)	Cl (µeq/L)	Ca (µeq/L)
Lak006	0.3	3.0	3.3	0.3	13.7	0.2	5.1
LAK012	0.5	0.5	6.9	0.3	-9.5	2.3	-12.5
LAK022	0.2	5.9	11.2	0.7	18.9	0.8	10.8
LAK023	0.2	5.2	-6.4	1.5	6.9	0.4	4.1
LAK028	0.1	2.2	76.5	1.4	68.0	3.1	46.7
LAK042	0.6	27.2	-0.2	-2.8	10.2	0.4	6.4
LAK044	0.1	4.0	-1.8	0.3	4.3	0.7	1.5
Total ↑	**7**	**7**	**4**	**6**	**6**	**7**	**6**
Total ↓	**0**	**0**	**3**	**1**	**1**	**0**	**1**
LAK007	0.1	-54.5	-5.4	-0.2	-11.6	2.0	-21.9
LAK016	0.3	21.4	9.0	0.9	15.5	1.7	6.8
LAK024	0.4	172.2	14.5	0.6	231.7	42.8	176.1
LAK034	-0.3	42.5	-23.8	1.5	-8.8	-1.3	-1.6
Total ↑	**3**	**3**	**2**	**3**	**2**	**3**	**2**
Total ↓	**1**	**1**	**2**	**1**	**2**	**1**	**2**
DCAS14A	0.2	6.0	4.1	-0.1	22.4	-1.6	15.3
NC184	0.1	10.3	0.8	-1.5	8.3	-5.1	7.9
NC194	-0.2	-3.6	-1.1	0.3	7.5	-0.9	5.8
Total ↑	**2**	**2**	**2**	**1**	**3**	**0**	**3**
Total ↓	**1**	**1**	**1**	**2**	**0**	**3**	**0**

Table 3-2. pH values over period of record for EEM lakes and average pH values for the post-KMP period. For easier reference to the results described in the 2019 comprehensive review, the post-KMP averaging period applied in the CR (2016-2018) is shown as well as the difference between those values and the new empirical data from 2019.

									Post-KMP averaging period		Difference between 2019 and 2016-18 CR averaging period
	2012	2013	2014	2015	2016	2017	2018	2019	2016-18	2016-19	
LAK006	5.8	6.2	6.1	6.0	6.0	6.0	6.1	6.1	6.0	6.1	0.1
LAK012	5.6	6.3	6.0	6.0	6.2	6.1	6.2	6.1	6.2	6.1	-0.1
LAK022	5.9	6.2	6.3	6.1	6.1	6.1	6.1	6.1	6.1	6.1	0.0
LAK023	5.7	6.0	5.9	5.9	5.9	5.9	6.0	5.8	5.9	5.9	-0.1
LAK028	5.0	5.2	5.3	5.1	5.0	4.8	5.3	5.2	5.0	5.0	0.2
LAK042	4.7	5.5	5.1	5.4	5.4	5.2	5.1	5.4	5.2	5.3	0.2
LAK044	5.4	5.7	5.8	5.8	5.5	5.6	5.5	5.5	5.6	5.5	0.0
LAK007	8.0	7.9	8.1	8.0	8.0	8.0	8.1	8.1	8.0	8.0	0.1
LAK016	6.3	6.7	6.7	6.8	6.6	6.7	6.7	6.6	6.7	6.6	-0.1
LAK024	7.1		7.6	7.4	7.5	7.4	7.6	7.7	7.5	7.5	0.2
LAK034	6.7	6.9	6.7	6.6	6.5	6.4	6.5	6.4	6.4	6.4	0.0
DCAS14A		6.5		6.6	6.6	6.6	6.8	6.6	6.6	6.6	-0.1
NC184		5.7		5.5	5.8	5.4	6.2	5.7	5.8	5.8	-0.1
NC194		6.6		6.5	6.4	6.4	6.5	6.4	6.4	6.4	0.0

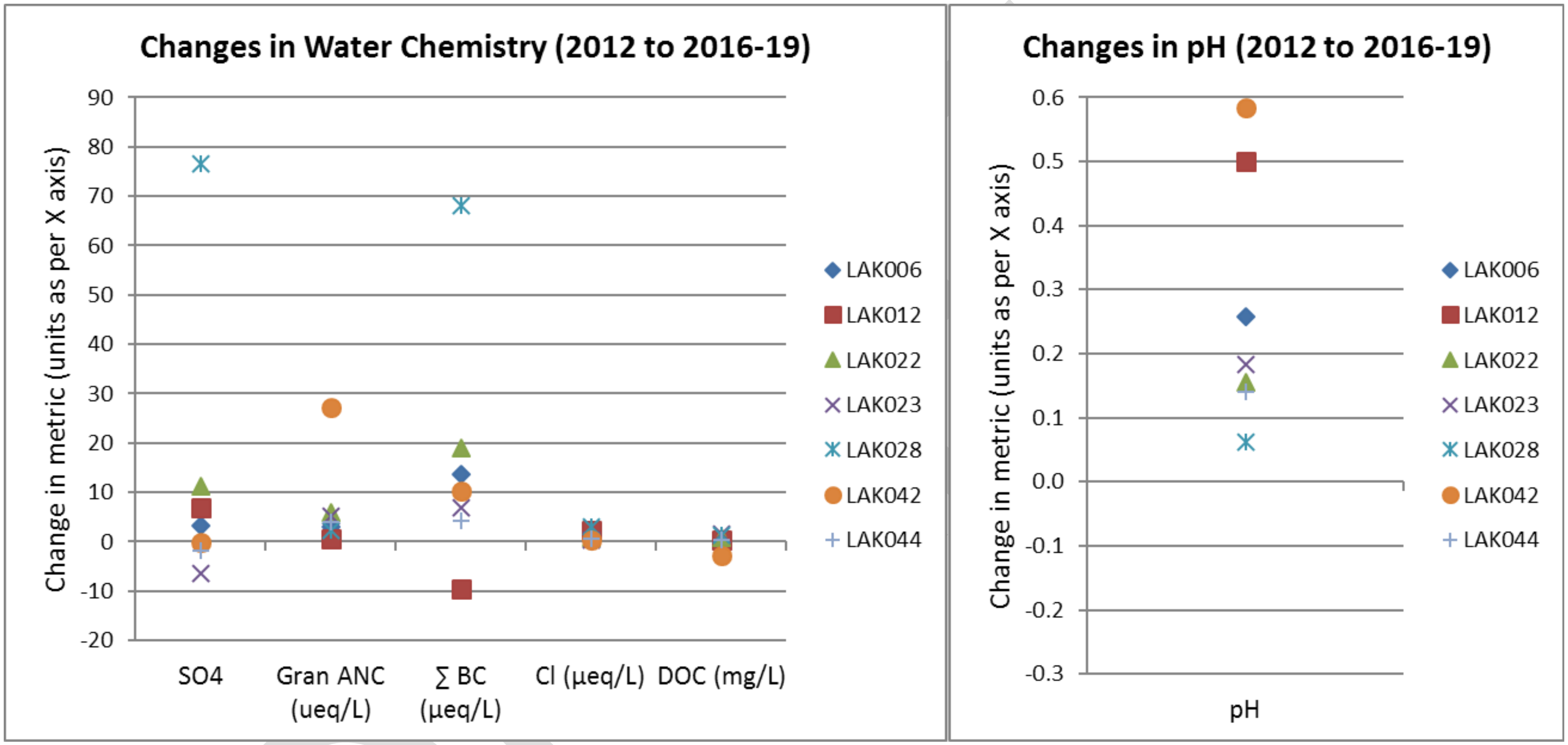


Figure 3-1. Changes in water chemistry metrics (left panel) and pH (right panel) across all of the sensitive EEM lakes, from 2012 to 2016-2019. Values shown are the mean 2016-2019 value minus the mean 2012 value. The large increase in lake SO_4^{2-} in LAK028 has been buffered by a large increase in base cations, due to cation exchange in watershed soils.

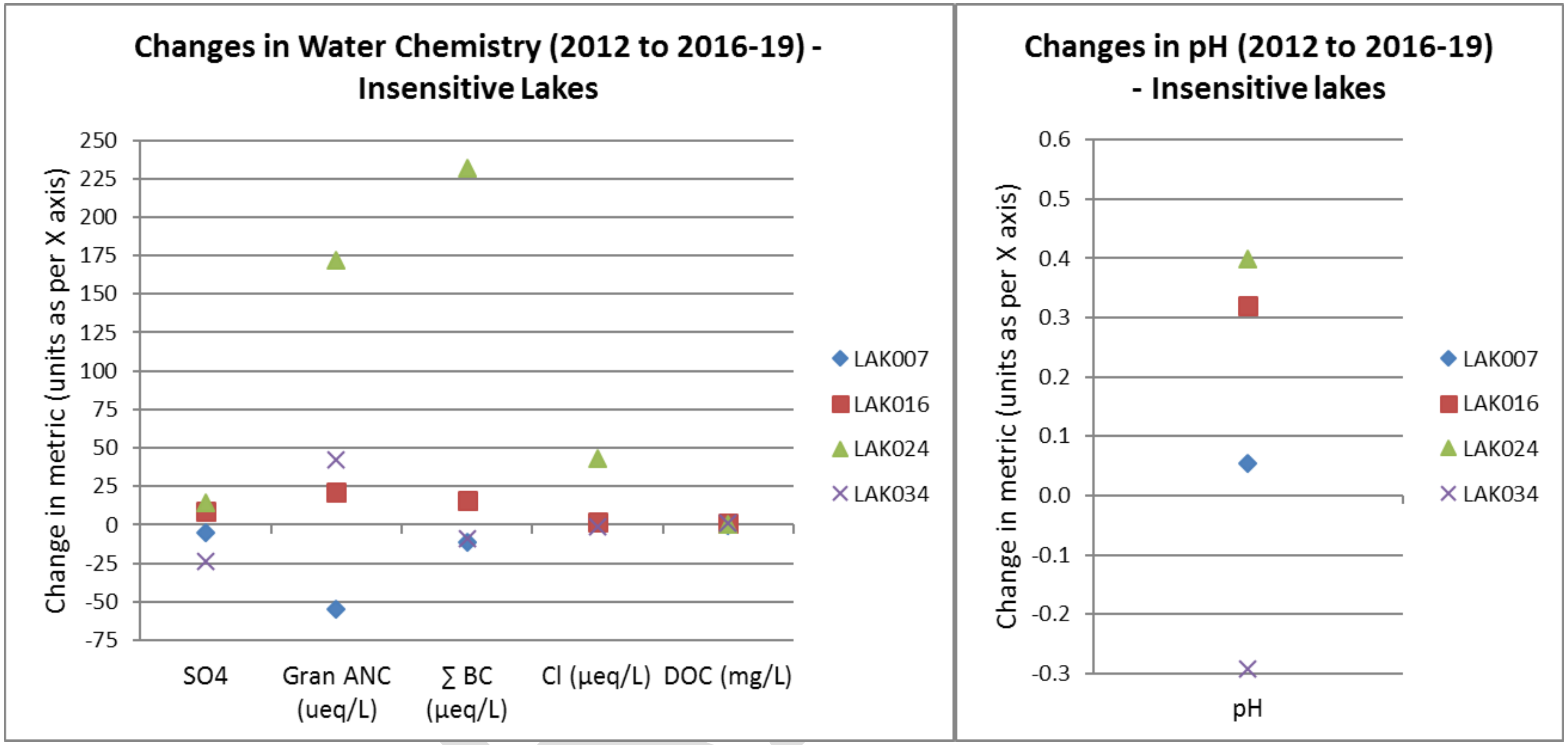
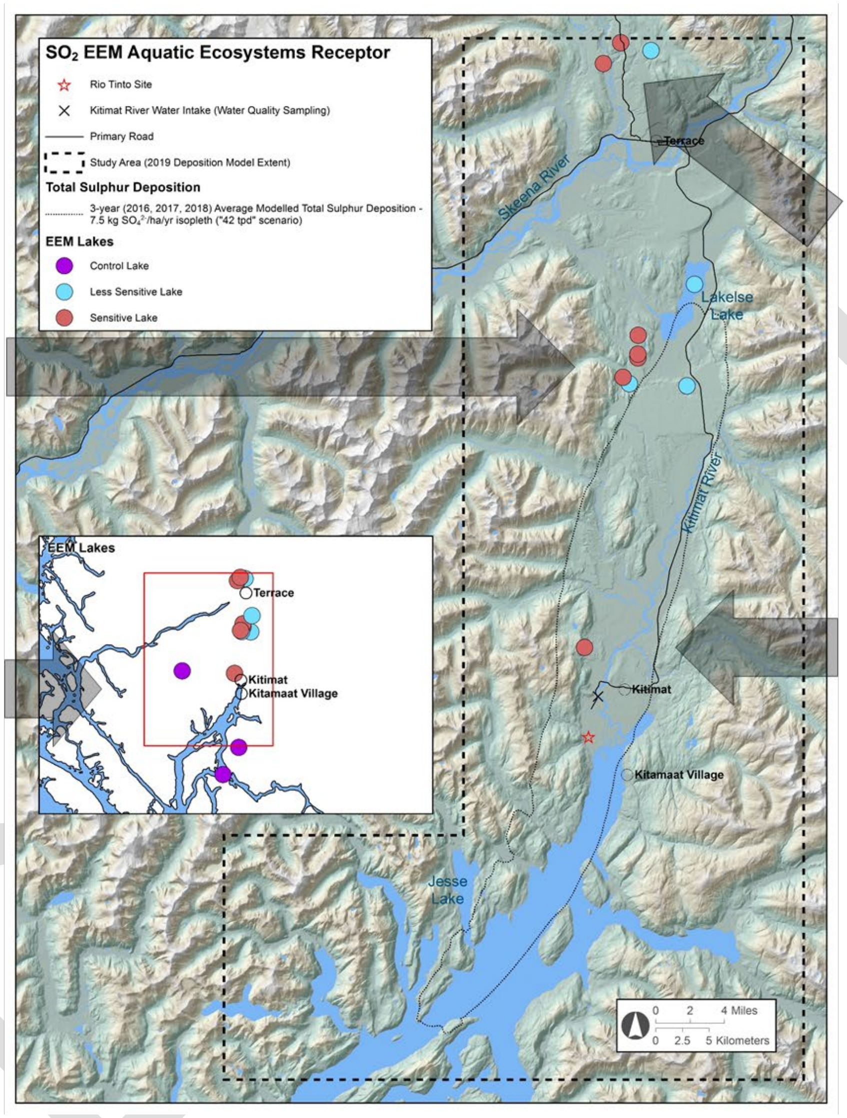


Figure 3-2. Changes in water chemistry metrics (left panel) and pH (right panel) across all of the less sensitive EEM lakes, from 2012 to 2016-2019. Values shown are the mean 2016-2019 value minus the mean 2012 value. The decline in Gran ANC in LAK007, and the decline in pH in LAK034 are both not related to the smelter as SO_4^{2-} declined.

	2012 to 2016-19		
LAKE	ΔSO_4^{2-}	ΔANC	ΔpH
Lak006	3.3	3.0	0.3
LAK012	6.9	0.5	0.5
LAK022	11.2	5.9	0.2
LAK023	-6.4	5.2	0.2
LAK007	-5.4	-54.5	0.1
LAK016	9.0	21.4	0.3
LAK024	14.5	172.2	0.4

	2013 to 2016-19		
LAKE	Δ SO_4^{2-}	Δ ANC	Δ pH
DCAS14A	4.1	6.0	0.2
NC184	0.8	10.3	0.1
NC194	-1.1	-3.6	-0.2



	2012 to 2016-19		
LAKE	Δ SO_4^{2-}	Δ ANC	Δ pH
LAK042	-0.2	27.2	0.6
LAK044	-1.8	4.0	0.1
LAK034	-23.8	42.5	-0.3

	2012 to 2016-19		
LAKE	Δ SO_4^{2-}	Δ ANC	Δ pH
LAK028	76.5	2.2	0.1

Figure 3-3. Observed changes in SO_4^{2-}, Gran ANC and pH from the baseline period (2012) to the post-KMP period (2016-2019). Green cells indicate increases and red cells indicate decreases.

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 3-3 and Figure 3-4. These results applied Bayesian Method 1, described in Appendix F of the 2019 Comprehensive Review Report.

Table 3-3. 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.

LAKE	Changes in SO_4 (% belief in SO_4 increase / decrease from Bayesian analysis - Method 1 violin plot)	Changes in Gran ANC (% belief that ANC threshold exceeded, from Bayesian analysis - Method 1 violin plot)	Changes in pH (% belief that pH threshold exceeded, from Bayesian analysis - Method 1 violin plot)	OVERALL INTERPRETATION
Sensitive Lakes				
LAK006	85% belief in increase	0%	0%	SO_4 increase; no evidence of S-induced acidification
LAK012	95% belief in increase	1%	0%	SO_4 increase; no evidence of S-induced acidification
LAK022	89% belief in increase	0%	0%	SO_4 increase; no evidence of S-induced acidification
LAK023	2% belief in increase	0%	0%	SO_4 decrease; no evidence of S-induced acidification
LAK028	97% belief in increase	2%	6%	SO_4 increase; very limited evidence of S-induced acidification; low belief in exceeding pH and ANC thresholds; conditions were potentially damaging to biota pre-KMP and remained so (see section 7.3.4.2 of 2019 Comprehensive Review report).
LAK042	44% belief in increase	0%	0%	No clear change in SO_4; no evidence of S-induced acidification
LAK044	0% belief in increase	0%	0%	SO_4 decrease; no evidence of S-induced acidification
Less Sensitive Lakes				
LAK007	4% belief in increase	58%	1%	SO_4 decrease; no evidence of S-induced acidification
LAK016	81% belief in increase	0%	0%	SO_4 increase; no evidence of S-induced acidification
LAK024	98% belief in increase	1%	0%	SO_4 increase; no evidence of S-induced acidification
LAK034	0% belief in increase	0%	39% [1]	SO_4 decrease; no evidence of S-induced acidification
Control Lakes				
DCAS14A	75% belief in increase [2]	0%	0%	No clear change in SO_4; no evidence of S-induced acidification
NC184	69% belief in negligible increase [2]	5%	14%	No clear change in SO_4; no evidence of S-induced acidification
NC194	1% belief in increase	TBD [3]	4%	SO_4 decrease; no evidence of S-induced acidification

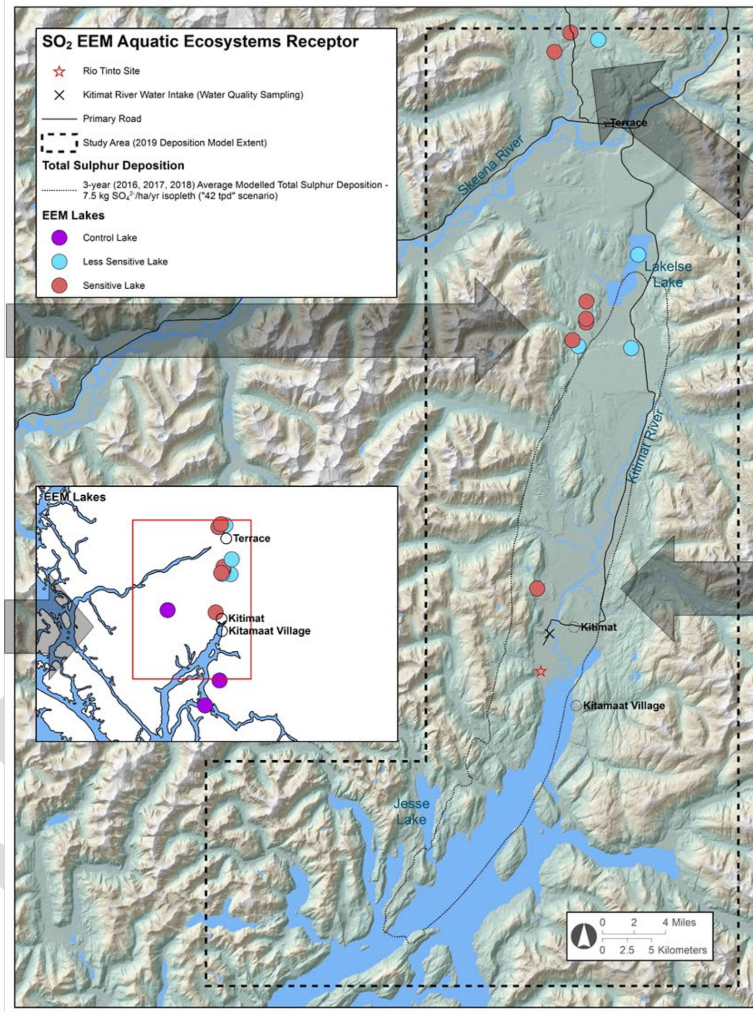
[1] Not related to S deposition as lake SO_4 has declined in LAK034.

[2] Magnitude of increase in [SO_4] between 2013 and 2016-2019 is small in DCAS14A (4.1 μeq/L) and very small in NC184 (0.8 μeq/L).

[3] Lake NC194 did not have a lab titration from which we could determine an ANC threshold. It had a 57% belief in an ANC decline (about 3.6 μeq/L between 2013 and 2016-2019), though very low belief (1%) in a SO_4 increase, so the ANC decline was not related to SO_4.

	% belief in change		
LAKE	↑ SO_4^{2-}	↓ ANC	↓ pH
LAK006	85%	0%	0%
LAK012	95%	0%	0%
LAK022	89%	0%	0%
LAK023	2%	0%	0%
LAK007	4%	58%	1%
LAK016	81%	0%	0%
LAK024	98%	0%	0%

	% belief in change		
LAKE	↑ SO_4^{2-}	↓ ANC	↓ pH
DCAS14A	75%**	0%	6%
NC184	69%**	4%	28%
NC194	1%	TBD	12%



	% belief in change		
LAKE	↑ SO_4^{2-}	↓ ANC	↓ pH
LAK042	44%	0%	0%
LAK044	0%	0%	0%
LAK034	0%	0%	39%

	% belief in change		
LAKE	↑ SO_4^{2-}	↓ ANC	↓ pH
LAK028	97%	1%	6%

Figure 3-4. Spatial distribution of percent belief in chemical change. Numbers show % belief in: a) SO4 increase (no threshold), b) pH decrease below 0.3 threshold, and c) Gran ANC decrease below lake-specific 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. **The increase in SO_4^{2-} in control lake DCAS014A was only ~4.1 μeq/L, and only 0.8 μeq/L in NC184.

4 Discussion

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

The mean values of pH and Gran ANC indicate that there have been no exceedances of the KPI thresholds.

None of the 7 sensitive EEM lakes show any decrease in pH from the 2012 baseline to the post-KMP period of 2016-2019. The empirical data indicate that none of the lakes have exceeded the threshold of a 0.3 unit decline in pH associated with the KPI.

Similarly, none of the 7 sensitive EEM lakes show any decrease in Gran ANC over this timeframe either and thus the empirical data indicate that none of the lakes have exceeded the lake-specific thresholds of decline put forward in the comprehensive review.

The following section applies statistical analyses to the same data to assess the percent belief that KPI thresholds could have been exceeded.

4.2 Statistical Analysis of Changes in Lake Chemistry

Table 4-1 shows the results from 2019 compared to the results reported in the 2019 comprehensive review. The results were **very** similar, which shows that the conclusions of the comprehensive review are strongly supported with an additional year of monitoring data. For SO_4^{2-}, only two lakes had changes in % belief of greater than 10% - less sensitive lake LAK016 decreased from a 97% belief in an increase to an 81% belief and control lake NC184 increased from a 58% belief to a 69% belief in an increase (of negligible magnitude). For Gran ANC, none of the lakes had changes in % belief of greater than 1%. For pH, only two lakes had changes in % belief of greater than 10% - sensitive lake LAK028 decreased from an 18% belief to a 6% belief in exceeding the pH threshold (i.e., decreasing in pH by >0.3 pH units) and control lake NC184 decreased from a 28% belief to a 14% belief. The decrease in percent belief for LAK028 is an important result. LAK028 is the only lake which showed evidence of sulphur-induced acidification (both pre- and post-KMP). It previously showed low support for an exceedance of the pH KPI threshold (18%), and it now shows very low support (6%). Out of 14 total lakes, the number that showed differences in % belief of <5% were 10 for SO_4^{2-}, all 14 for Gran ANC, and 10 for pH.

Table 4-1. Comparison of the results of the updated statistical analyses including the 2019 data to the results presented in the 2019 comprehensive review (CR). The 2019 results are the same as Table 3-3. 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 from Bayesian analysis - Method 1 violin plot)		Changes in Gran ANC (% belief that ANC threshold exceeded, from Bayesian analysis - Method 1 violin plot)		Changes in pH (% belief that pH threshold exceeded, from Bayesian analysis - Method 1 violin plot)	
	CR Results	**2019 Results**	**CR Results**	**2019 Results**	**CR Results**	**2019 Results**
Sensitive Lakes						
LAK006	83% belief in increase	85% belief in increase	0%	0%	1%	0%
LAK012	91% belief in increase	95% belief in increase	1%	0%	1%	0%
LAK022	88% belief in increase	89% belief in increase	0%	0%	0%	0%
LAK023	5% belief in increase	2% belief in increase	0%	0%	1%	0%
LAK028	96% belief in increase	97% belief in increase	2%	1%	18%	6%
LAK042	36% belief in increase	44% belief in increase	0%	0%	2%	0%
LAK044	1% belief in increase	0% belief in increase	0%	0%	0%	0%
Less Sensitive Lakes						
LAK007	0% belief in increase	4% belief in increase	58%	58%	2%	1%
LAK016	97% belief in increase	81% belief in increase	0%	0%	1%	0%
LAK024	96% belief in increase	98% belief in increase	1%	0%	1%	0%
LAK034	0% belief in increase	0% belief in increase	0%	0%	43%	39%
Control Lakes						
DCAS14A	68% belief in increase	75% belief in increase	0%	0%	6%	0%
NC184	58% belief in negligible increase	69% belief in negligible increase	5%	4%	28%	14%
NC194	1% belief in increase	1% belief in increase	TBD	TBD	12%	4%

4.3 Application of the Evidentiary Framework

We have applied the simplified evidentiary framework, as described in the 2019 Comprehensive Review Report, 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) 2 sensitive lakes, 2 less sensitive lakes, and all 3 control lakes[2] land within the first box, "smelter not causally linked to changes in lake chemistry"; b) 3 sensitive lakes and 2 less sensitive lakes all land within the second box, "lake is healthy, and not acidifying"; and c) 2 sensitive lakes (LAK012 and LAK028) land within "some evidence of acidification". For LAK012, this classification is based on intermediate support for a decline in Gran ANC (47% belief) but zero support for a decline in pH. For LAK028, this classification is based on low-intermediate support for declines in Gran ANC (37% belief) and pH (35% belief). However, both lakes have very low to zero support for declines exceeding their Gran ANC and pH thresholds. The classification of LAK042 is also based on only intermediate support for an increase in SO_4^{2-} (44% belief). These results completely mirror those presented in the 2019 comprehensive review. None of the lakes have moved positions within the framework.

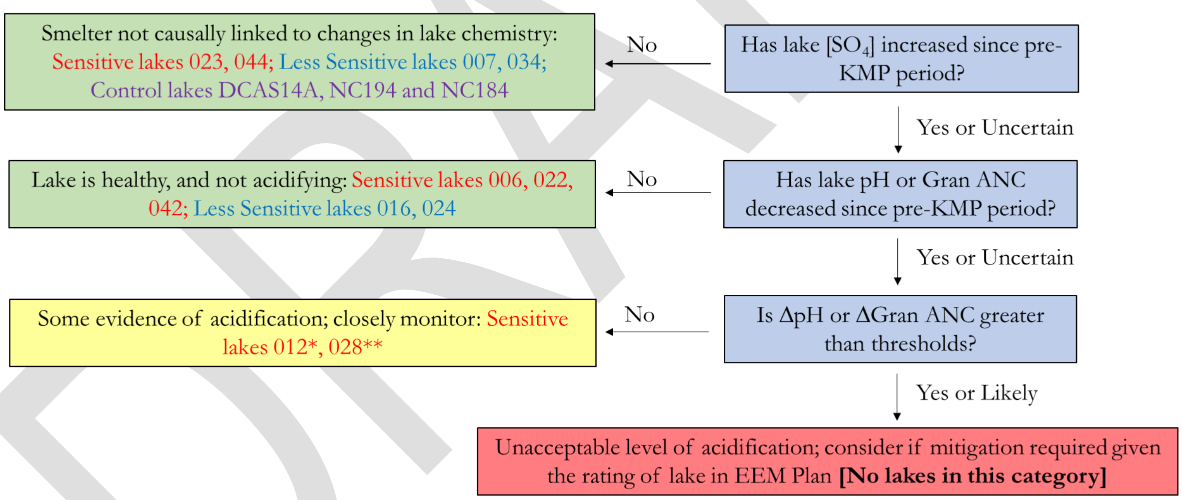


Figure 4-1. Classification of EEM lakes according to the simplified evidentiary framework. * LAK012 has intermediate support for decline in Gran ANC but no support for exceeding the threshold. ** LAK028 has low-intermediate support for declines in Gran ANC and pH but very low support for exceeding the thresholds.

[2] 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.

Table 4-2. Results used in the application of the simplified evidentiary framework. The first four columns are identical to Table 3-3 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)	**Changes in Gran ANC** (% belief that ANC threshold exceeded)	**Changes in pH** (% belief that pH threshold exceeded)		**Change in Gran ANC (no threshold)** (% belief that ANC decreased)	**Change in pH (no threshold)** (% belief that pH decreased)
	(% belief values from Bayesian analysis – Method 1 violin plots)					
Sensitive Lakes						
LAK006	85% belief in increase	0%	0%		7%	0%
LAK012	95% belief in increase	1%	0%		45%	0%
LAK022	89% belief in increase	0%	0%		6%	1%
LAK023	2% belief in increase	0%	0%		9%	1%
LAK028	97% belief in increase	2%	6%		37%	35%
LAK042	44% belief in increase	0%	0%		0%	0%
LAK044	0% belief in increase	0%	0%		1%	0%
Less Sensitive Lakes						
LAK007	4% belief in increase	58%	1%		96%	28%
LAK016	81% belief in increase	0%	0%		1%	2%
LAK024	98% belief in increase	1%	0%		2%	4%
LAK034	0% belief in increase	0%	39%		1%	100%
Control Lakes						
DCAS14A	75% belief in increase	0%	0%		4%	12%
NC184	69% belief in negligible increase	5%	14%		20%	47%
NC194	1% belief in increase	TBD [3]	4%		57%	99%

5 Recommendations

The 2019 EEM Comprehensive Review Report provides extensive recommendations with respect to the aquatic ecosystems component of the EEM Program. These recommendations will be reviewed in depth during the forthcoming discussions on the design of the EEM Phase II update.

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Appendix 1: Water Chemistry Data from Annual Sampling, 2012-2019

The two tables below shows the sample results for each of the EEM lakes and control lakes from annual monitoring conducted from 2012 to 2019, including pH, dissolved organic carbon (DOC), Gran ANC, and the concentration of major anions and cations, as well as the sum of all base cations (BC). In 2013-2019, the pH of the water samples was measured by two different laboratories (Trent University and ALS).

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	pH TU	SE[1]	pH ALS	SE	DOC mg/L	SE	Gran ANC µeq/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
LAK006	2012	5.8				3.6		25.7		11.4		5.8		4.5		30.3		12.5		2.9		14.9		60.6
LAK007	2012	8.0				0.6		1437.6		51.4		24.6		2.8		1272.2		157.0		19.3		55.4		1503.9
LAK012	2012	5.6				4.6		57.0		6.1		4.2		5.0		74.5		20.8		5.2		20.0		120.6
LAK016	2012	6.3				3.7		68.7		39.0		6.3		7.8		117.7		20.5		7.3		20.8		166.3
LAK022	2012	5.9				5.3		27.8		30.2		6.9		6.1		58.1		16.0		3.2		20.8		98.1
LAK023	2012	5.7				4.2		19.8		19.0		4.5		5.6		39.4		12.0		3.7		10.8		65.9
LAK024	2012	7.1				1.4		299.5		24.8		27.3		1.6		273.2		33.0		4.2		29.6		340.0
LAK028	2012	5.0				4.9		-4.0		56.9		6.1		20.7		47.5		9.5		3.1		12.8		72.9
LAK034	2012	6.7				4.5		99.4		24.1		5.8		5.8		119.3		31.6		5.8		44.9		201.7
LAK042	2012	4.7				13.2		-20.4		6.2		6.1		3.2		7.4		22.7		3.1		20.3		53.4
LAK044	2012	5.4				1.7		1.3		6.2		5.6		2.9		6.8		3.2		4.1		0.0		14.2
LAK006	2013	6.2		6.1		3.2		29.0		14.4		8.7		5.6		27.1		13.0		5.3		12.2		57.6
LAK007	2013	7.9		8.1		0.1		1462.1		66.5		36.3		3.7		1226.0		156.5		21.9		47.6		1452.0
LAK012	2013	6.3		6.1		4.2		63.5		11.3		14.7		8.2		64.8		20.3		9.2		14.6		108.9
LAK016	2013	6.7		7.2		4.2		96.9		56.9		12.3		11.5		114.4		23.9		11.2		17.6		167.1
LAK022	2013	6.2		6.1		6.2		36.4		47.1		12.4		8.7		65.1		19.2		6.0		18.8		109.1
LAK023	2013	6.0		6.0		4.0		23.8		24.1		7.5		7.4		37.1		13.3		5.1		8.3		63.9
LAK024	2013																							
LAK028	2013	5.2		5.5		7.1		4.8		128.1		17.7		32.0		85.1		18.3		5.0		13.0		121.3
LAK034	2013	6.9		7.4		4.7		210.4		38.1		8.2		10.0		152.7		41.7		9.2		54.1		257.7
LAK042	2013	5.5		5.4		9.7		21.0		5.7		7.7		3.2		16.0		22.3		3.4		19.3		61.0
LAK044	2013	5.7		6.0		1.5		8.6		6.2		8.9		3.8		7.8		3.6		5.9		-2.0		15.3

Lake	Year	pH TU	SE[1]	pH ALS	SE	DOC mg/L	SE	Gran ANC µeq/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
LAK006	2014	6.1	*0.1*	6.6	*0.6*	3.8	*1.0*	38.8	*2.5*	12.1	*2.2*	8.1	*0.6*	4.8	*0.5*	31.7	*8.7*	14.6	*0.8*	4.7	*0.2*	14.5	*0.6*	65.5
LAK007	2014	8.1		8.0		0.7		1445.7		30.7		19.2		1.9		1276.8		156.7		20.2		61.8		1515.5
LAK012	2014	6.0	*0.2*	6.7	*0.4*	6.3	*2.2*	68.8	*15.2*	15.8	*11.6*	10.3	*4.9*	5.2	*0.5*	69.3	*3.5*	21.3	*1.3*	7.3	*1.1*	18.3	*3.6*	116.1
LAK016	2014	6.7		6.7		4.0		105.7		48.2		9.3		9.5		122.4		25.0		10.1		23.3		180.8
LAK022	2014	6.3		6.4		5.7		46.9		37.8		9.0		6.9		68.5		18.9		5.2		21.4		114.0
LAK023	2014	5.9	*0.1*	6.7	*0.6*	5.7	*1.0*	32.1	*2.5*	18.9	*2.2*	6.1	*0.6*	6.2	*0.5*	49.3	*8.7*	14.9	*0.8*	4.0	*0.2*	10.8	*0.6*	79.0
LAK024	2014	7.6		7.5		1.7		472.1		37.2		65.7		2.3		402.3		50.1		7.8		50.2		510.4
LAK028	2014	5.3		5.7		5.9		22.6		94.4		11.0		23.3		85.9		17.7		4.4		17.6		125.7
LAK034	2014	6.7		7.0		7.0		205.0		17.0		6.5		7.7		161.4		43.6		9.4		51.9		266.3
LAK042	2014	5.1		5.4		10.6		12.5		4.0		11.8		2.6		10.5		23.6		3.7		17.9		55.7
LAK044	2014	5.8		5.6		1.8		5.9		4.6		5.9		2.8		7.8		3.9		5.3		0.4		17.3
LAK006	2015	6.0	*0.1*	6.4	*0.6*	3.9	*0.3*	32.4	*0.7*	11.5	*0.7*	6.6	*0.6*	4.4	*0.2*	32.3	*0.6*	14.8	*0.3*	3.9	*0.1*	15.7	*0.6*	66.7
LAK007	2015	8.0		7.9		0.3		1565.6		45.6		24.0		2.6		1266.6		161.5		21.0		58.6		1507.7
LAK012	2015	6.0	*0.2*	6.3	*0.3*	7.5	*2.1*	65.9	*4.2*	17.6	*6.1*	11.1	*3.3*	4.7	*0.3*	74.8	*7.8*	23.2	*1.8*	8.1	*1.6*	18.0	*1.6*	124.2
LAK016	2015	6.8		6.9		4.3		113.1		40.9		8.7		8.6		130.9		25.0		9.8		22.9		188.6
LAK022	2015	6.1		6.2		6.3		35.6		32.5		7.9		5.9		64.1		18.1		4.4		21.2		107.8
LAK023	2015	5.9	*0.1*	6.2	*0.1*	5.4	*0.7*	30.0	*2.0*	15.1	*1.5*	6.2	*0.6*	5.2	*0.3*	46.1	*3.0*	13.9	*0.6*	3.8	*0.1*	9.7	*0.2*	73.5
LAK024	2015	7.4		7.5		2.2		443.0		34.7		59.0		2.1		400.5		49.3		8.7		49.0		507.6
LAK028	2015	5.1		5.3		8.1		10.8		71.1		9.0		20.5		76.5		15.7		3.2		14.4		109.8
LAK034	2015	6.6		6.7		7.6		177.8		0.9		6.2		4.7		146.5		37.1		5.3		45.1		234.0
LAK042	2015	5.4		5.5		8.3		13.8		3.8		6.5		2.3		10.7		23.1		2.5		23.0		59.3
LAK044	2015	5.8		5.8		1.6		6.2		3.7		5.9		2.7		9.8		4.4		5.5		0.5		20.3
LAK006	2016	6.0	*0.1*	6.3	*0.2*	4.2	*0.2*	26.9	*2.0*	11.8	*0.3*	5.6	*0.4*	4.2	*0.2*	32.6	*1.0*	14.8	*1.3*	4.2	*1.2*	17.2	*1.8*	68.8
LAK007	2016	8.0		8.1		0.8		1368.6		46.7		25.4		2.6		1301.5		162.8		20.2		58.3		1542.8
LAK012	2016	6.2	*0.0*	6.5	*0.2*	5.1	*0.5*	65.8	*2.3*	9.5	*1.1*	5.6	*0.3*	4.6	*0.2*	64.7	*1.7*	20.8	*1.2*	6.0	*1.2*	21.6	*1.6*	113.0
LAK016	2016	6.6		6.9		5.2		93.9		44.9		8.5		8.2		127.4		26.4		8.9		23.7		186.5
LAK022	2016	6.1		6.4		6.7		34.4		34.2		7.9		5.8		68.1		19.2		4.2		23.1		114.6
LAK023	2016	5.9	*0.0*	6.2	*0.1*	5.8	*0.2*	27.9	*3.8*	12.7	*0.4*	4.9	*0.4*	5.1	*0.2*	42.5	*1.8*	14.1	*0.9*	4.7	*1.1*	11.0	*1.5*	72.3
LAK024	2016	7.5		7.6		2.7		463.1		39.2		70.0		2.3		446.5		55.3		9.5		53.9		565.3
LAK028	2016	5.0	*0.2*	5.1	*0.2*	8.1	*0.6*	-4.9	*12.5*	127.8	*16.3*	10.0	*1.1*	26.8	*1.7*	94.7	*16.7*	23.8	*3.5*	3.7	*0.4*	19.5	*3.2*	141.6
LAK034	2016	6.5		7.1		7.6		151.6		0.0		5.4		4.4		130.0		34.3		3.8		44.1		212.3
LAK042	2016	5.4	*0.0*	5.7	*0.1*	9.8	*0.4*	14.0	*3.1*	3.3	*0.5*	7.2	*0.5*	2.2	*0.2*	16.7	*3.4*	24.7	*0.7*	2.7	*0.4*	23.3	*0.4*	67.4
LAK044	2016	5.5	*0.0*	6.0	*0.3*	2.0	*0.2*	4.1	*2.6*	4.1	*0.2*	6.1	*0.3*	2.3	*0.1*	8.2	*0.8*	4.1	*0.1*	5.5	*0.2*	0.3	*0.4*	18.2
LAK006	2017	6.0	*0.1*	6.4	*0.2*	3.8	*0.2*	27.9	*5.3*	14.4	*0.6*	5.4	*0.5*	4.2	*0.1*	34.8	*0.9*	15.6	*0.5*	4.1	*0.2*	18.0	*0.8*	72.5
LAK007	2017	8.0		8.0		0.3		1381.6		47.1		25.9		2.4		1201.7		165.2		19.9		62.6		1449.4
LAK012	2017	6.1	*0.2*	6.5	*0.1*	5.2	*1.0*	58.2	*6.5*	14.6	*5.2*	7.0	*2.4*	4.4	*0.1*	65.4	*9.0*	21.7	*2.3*	7.7	*1.9*	21.5	*1.9*	116.3
LAK016	2017	6.7		6.8		4.1		82.7		43.2		7.3		7.7		114.0		24.7		6.9		22.9		168.6
LAK022	2017	6.1		6.3		5.9		34.2		39.0		7.1		5.4		64.1		19.5		3.8		22.2		109.6
LAK023	2017	5.9	*0.0*	6.2	*0.1*	5.4	*0.1*	28.5	*4.7*	10.1	*3.4*	4.2	*0.5*	4.6	*0.1*	43.2	*4.2*	13.8	*0.7*	2.3	*0.5*	11.2	*0.6*	70.5
LAK024	2017	7.4		7.6		2.0		416.6		34.9		57.5		2.0		399.6		52.2		8.5		54.2		514.4
LAK028	2017	4.8	*0.1*	5.1	*0.1*	7.3	*1.1*	-9.9	*9.0*	150.0	*25.9*	8.7	*1.9*	27.2	*3.4*	102.5	*21.9*	26.5	*5.0*	3.5	*0.7*	19.9	*3.1*	152.4
LAK034	2017	6.4		6.8		6.0		136.5		0.1		4.5		3.4		105.6		30.3		2.7		39.1		177.8
LAK042	2017	5.2	*0.1*	5.4	*0.3*	11.6	*2.3*	2.3	*4.2*	6.8	*1.9*	6.7	*0.9*	2.4	*0.1*	17.1	*5.5*	26.9	*2.3*	2.8	*0.5*	23.2	*0.9*	70.0
LAK044	2017	5.6	*0.1*	6.0	*0.2*	1.6	*0.1*	7.0	*4.4*	4.5	*0.4*	5.9	*0.2*	2.2	*0.0*	7.9	*0.3*	4.2	*0.2*	5.6	*0.2*	0.7	*0.4*	18.4

Lake	Year	pH TU	SE[1]	pH ALS	SE	DOC mg/L	SE	Gran ANC µeq/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
LAK006	2018	6.1	*0.0*	6.4	*0.0*	3.8	*0.1*	28.3	*1.2*	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
LAK007	2018	8.1		8.1		0.3		1407.6		47.1		27.9		2.6		1251.5		157.4		20.6		61.3		1490.8
LAK012	2018	6.2	*0.1*	6.6	*0.1*	4.6	*0.1*	50.9	*4.3*	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
LAK016	2018	6.7		6.9		4.6		92.8		45.3		7.3		8.1		128.5		23.3		7.3		24.3		183.5
LAK022	2018	6.1		6.3		5.6		30.3		43.2		7.3		5.8		72.1		19.3		4.2		24.4		119.9
LAK023	2018	6.0	*0.1*	6.4	*0.1*	5.6	*0.2*	23.0	*0.7*	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
LAK024	2018	7.6		7.6		1.6		509.9		42.6		77.3		2.4		472.7		56.4		9.4		57.2		595.7
LAK028	2018	5.3	*0.0*	5.5	*0.0*	4.4	*0.1*	4.2	*1.6*	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
LAK034	2018	6.5		6.6		5.1		130.6		0.1		3.7		3.7		113.1		27.7		2.1		40.8		183.7
LAK042	2018	5.1	*0.0*	5.3	*0.0*	10.6	*0.4*	0.6	*1.9*	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
LAK044	2018	5.5	*0.0*	5.9	*0.0*	1.9	*0.1*	3.9	*0.9*	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
LAK006	2019	6.1	*0.0*	6.5	*0.1*	3.5	*0.2*	31.6	*2.7*	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
LAK007	2019	8.1		8.1		0.3		1374.5		43.0		27.1		2.4		1246.6		158.4		20.4		61.2		1486.5
LAK012	2019	6.1	*0.0*	6.6	*0.1*	5.0	*0.3*	55.3	*0.9*	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
LAK016	2019	6.6		7.1		4.4		90.8		58.6		9.0		7.9		127.9		26.5		9.7		24.4		188.6
LAK022	2019	6.1		6.4		6.0		35.9		49.3		8.7		5.6		71.5		22.4		5.0		25.3		124.2
LAK023	2019	5.8	*0.0*	6.3	*0.1*	5.9	*0.2*	20.7	*2.4*	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
LAK024	2019	7.7		7.7		1.6		496.9		40.8		75.3		2.1		478.3		58.1		8.7		66.3		611.4
LAK028	2019	5.2	*0.0*	5.4	*0.0*	5.2	*0.3*	3.3	*0.7*	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
LAK034	2019	6.4		7.0		5.3		148.9		0.9		4.5		4.1		122.1		30.4		1.8		43.5		197.8
LAK042	2019	5.4	*0.0*	5.6	*0.1*	9.2	*0.5*	10.1	*0.6*	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
LAK044	2019	5.5	*0.0*	5.9	*0.1*	2.5	*0.3*	6.1	*0.4*	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
NC184	2013	5.7				11.6		16.2		5.7		24.0		0.3		50.5		17.5		4.4		13.8		86.2
NC194	2013	6.6				0.7		28.0		3.6		7.6		0.3		23.2		3.4		5.2		7.4		39.2
DCAS14A	2013	6.5				1.4		50.6		33.4		9.2		0.6		63.9		10.3		10.3		6.1		90.6
NC184	2015	5.5		5.6		9.8		18.4		5.7		21.7		0.5		48.8		16.1		2.9		10.8		78.7
NC194	2015	6.5		6.5		0.8		33.0		2.3		7.3		0.5		26.9		4.4		4.3		7.9		43.4
DCAS14A	2015	6.6		6.7		0.9				35.7		7.3		0.5		77.6		12.4		11.2		9.9		111.0
NC184	2016	5.8		6.2		10.6		27.3		5.5		21.2		0.5		62.6		19.3		2.7		15.5		100.1
NC194	2016	6.4		6.6		1.6		28.7		2.3		7.9		0.5		26.4		4.3		3.8		7.9		42.4
DCAS14A	2016	6.6		6.8		1.5		57.5		36.8		8.5		0.5		77.5		11.8		10.5		9.7		109.6
NC184	2017	5.4		6.0		13.3		9.8		4.7		14.7		0.5		45.2		17.4		2.5		15.9		81.0
NC194	2017	6.4		6.4		1.0		12.4		2.5		4.8		0.5		29.9		5.7		3.6		9.9		49.1
DCAS14A	2017	6.6		6.7		1.5		51.0		31.1		5.6		0.5		68.2		11.8		9.1		9.9		99.0
NC184	2018	6.2		6.4		7.0		44.0		8.3		16.6		0.5		67.8		17.3		3.1		15.3		103.4
NC194	2018	6.5		6.7		0.3		26.1		2.6		5.1		0.5		28.3		4.3		4.1		9.1		45.8
DCAS14A	2018	6.8		6.8		1.0		59.3		41.3		7.3		0.5		85.6		12.6		11.5		10.7		120.4
NC184	2019	5.7	*0.0*	6.1	*0.1*	9.3	*0.3*	24.9	*1.5*	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
NC194	2019	6.4	*0.0*	6.6	*0.1*	1.0	*0.2*	30.4	*5.3*	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
DCAS14A	2019	6.6	*0.1*	6.8	*0.0*	1.2	*0.0*	58.6	*5.9*	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

[1] SE = standard deviation

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	pH (TU)	pH (ALS)	DOC (mg/L)	Gran Alkalinity (mg/L)	Conduct-ivity (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	5.8		3.6	1.3	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	8.0		0.6	71.9	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	5.6		4.6	2.9	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	6.3		3.7	3.4	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	5.9		5.3	1.4	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	5.7		4.2	1.0	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	7.1		1.4	15.0	40.0	1.3	1.0	0.0	0.4	2.4	5.5	0.5	0.2	1.2	0.0	0.0	
LAK028	2012	5.0		4.9	-0.2	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	6.7		4.5	5.0	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	4.7		13.2	-1.0	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	5.4		1.7	0.1	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	6.2	6.1	3.2	1.5	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	7.9	8.1	0.1	73.2	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	6.3	6.1	4.2	3.2	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	6.7	7.2	4.2	4.9	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	6.2	6.1	6.2	1.8	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	6.0	6.0	4.0	1.2	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	5.2	5.5	7.1	0.2	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	6.9	7.4	4.7	10.5	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	5.5	5.4	9.7	1.1	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	5.7	6.0	1.5	0.4	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	6.1	6.6	3.8	1.9	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	8.1	8.0	0.7	72.4	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	6.0	6.7	6.3	3.4	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	6.7	6.7	4.0	5.3	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	6.3	6.4	5.7	2.3	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	5.9	6.7	5.7	1.6	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	7.6	7.5	1.7	23.6	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	5.3	5.7	5.9	1.1	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	6.7	7.0	7.0	10.3	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	5.1	5.4	10.6	0.6	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	5.8	5.6	1.8	0.3	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	6.0	6.4	3.9	1.6	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	8.0	7.9	0.3	78.4	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	6.0	6.3	7.5	3.3	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	6.8	6.9	4.3	5.7	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	6.1	6.2	6.3	1.8	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

Lake	Year	pH (TU)	pH (ALS)	DOC (mg/L)	Gran Alkalinity (mg/L)	Conduct-ivity (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)
LAK023	2015	5.9	6.2	5.4	1.5	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
LAK024	2015	7.4	7.5	2.2	22.2	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	5.1	5.3	8.1	0.5	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	6.6	6.7	7.6	8.9	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	5.4	5.5	8.3	0.7	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	5.8	5.8	1.6	0.3	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	6.0	6.3	4.2	1.3	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	8.0	8.1	0.8	68.5	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	6.2	6.5	5.1	3.3	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	6.6	6.9	5.2	4.7	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	6.1	6.4	6.7	1.7	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	5.9	6.2	5.8	1.4	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	7.5	7.6	2.7	23.2	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	5.0	5.1	8.1	-0.2	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	6.5	7.1	7.6	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	5.4	5.7	9.8	0.7	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	5.5	6.0	2.0	0.2	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	6.0	6.4	3.8	1.4	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	8.0	8.0	0.3	69.1	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	6.1	6.5	5.2	2.9	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	6.7	6.8	4.1	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	6.1	6.3	5.9	1.7	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	5.9	6.2	5.4	1.4	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	7.4	7.6	2.0	20.9	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	4.8	5.1	7.3	-0.5	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	6.4	6.8	6.0	6.8	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	5.2	5.4	11.6	0.1	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	5.6	6.0	1.6	0.4	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	6.1	6.4	3.8	1.4	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	8.1	8.1	0.3	70.4	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	6.2	6.6	4.6	2.5	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	6.7	6.9	4.6	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	6.1	6.3	5.6	1.5	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	6.0	6.4	5.6	1.1	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	7.6	7.6	1.6	25.5	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	5.3	5.5	4.4	0.2	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	6.6	5.1	6.5	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	5.1	5.3	10.6	0.0	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	5.5	5.9	1.9	0.2	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	6.1	6.5	1.1	1.6		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	8.1	8.1	0.3	68.8		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	6.1	6.6	1.8	2.8		0.7	0.3	0.1	3.2	2.5	1.2	0.3	0.3	0.7	0.2	0.0	0.0
LAK016	2019	6.6	7.1	2.5	4.5		2.9	0.3	0.2	2.5	6.2	2.6	0.3	0.4	0.7	0.0	0.1	0.0

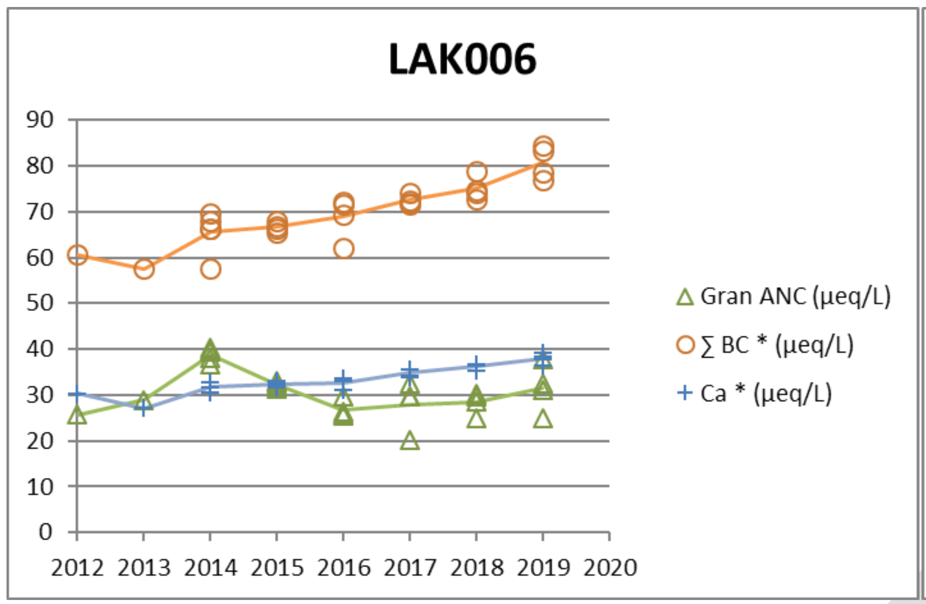
Lake	Year	pH (TU)	pH (ALS)	DOC (mg/L)	Gran Alkalinity (mg/L)	Conduct-ivity (µS/s)	SO4 (mg/L)	Cl (mg/L)	F (mg/L)	NO3 (µg/L)	NH4 (µg/L)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	Fe (mg/L)	Al (mg/L)	Mn (mg/L)
LAK022	2019	6.1	6.4	1.3	1.8		2.4	0.3	0.1	2.5	2.5	1.4	0.3	0.2	0.8	0.1	0.1	0.0
LAK023	2019	5.8	6.3	1.0	1.0		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	7.7	7.7	6.9	24.9		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	5.2	5.4	5.4	0.2		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	6.4	7.0	3.0	7.5		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	5.4	5.6	1.5	0.5		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	5.5	5.9	1.5	0.3		0.3	0.2	0.0	2.5	2.5	0.2	0.1	0.2	0.1	0.0	0.0	0.0
NC184	2013	5.7		11.6	0.8	10.0	0.4	0.9	0.0	0.0	0.0	1.0	0.3	0.2	0.8			
NC194	2013	6.6		0.7	1.4	3.9	0.2	0.3	0.0	0.0	0.0	0.5	0.1	0.2	0.3			
DCAS14A	2013	6.5		1.4	2.5	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	2015	5.5	5.6	9.8	0.9	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	6.5	6.5	0.8	1.7	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	5.8	6.2	10.6	1.4	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	6.4	6.6	1.6	1.4	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	6.6	6.8	1.5	2.9	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	5.4	6.0	13.3	0.5	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	6.4	6.4	1.0	0.6	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
DCAS14A	2017	6.6	6.7	1.5	2.6	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	6.2	6.4	7.0	2.2	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	6.5	6.7	0.3	1.3	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	6.8	6.8	1.0	3.0	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	5.7	6.1	1.1	1.2		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	6.4	6.6	0.9	1.5		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	6.6	6.8	1.4	2.9		2.0	0.3	0.0	10.3	2.5	1.7	0.2	0.5	0.4	0.0	0.0	0.0

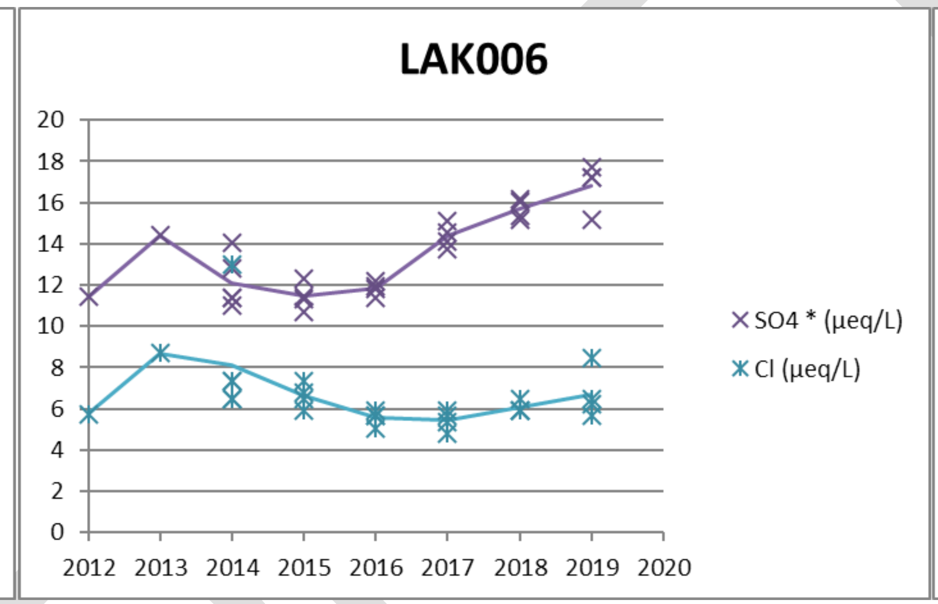
Appendix 2: Changes in Ion Concentrations from 2012 to 2017

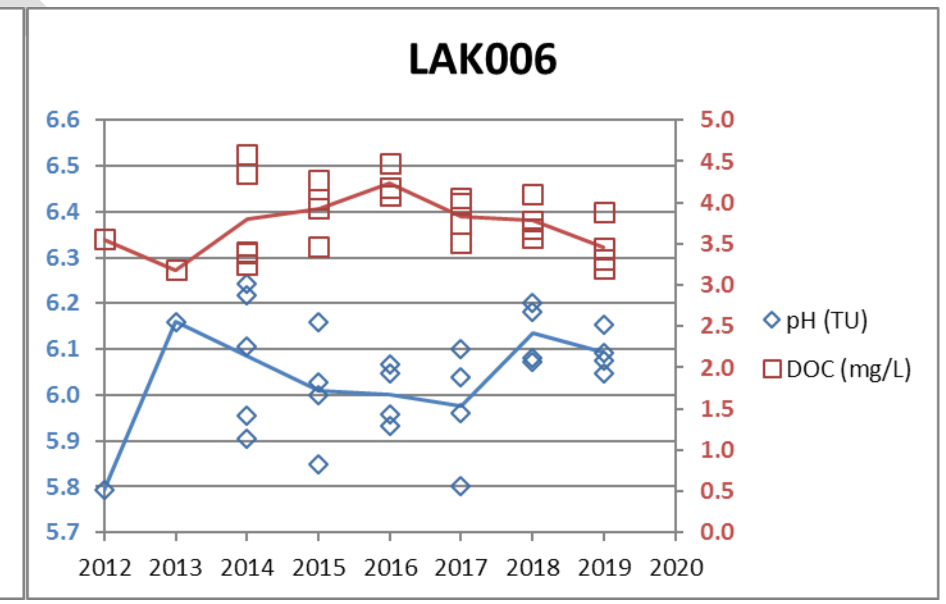
For each of the EEM lakes, the figures in this appendix show the inter-annual changes in six major water chemistry metrics from 2012 to 2019: Gran ANC, base cations and calcium (left panel), sulfate and chloride (centre panel), and pH and dissolved organic carbon (right panel). The selection of each 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.

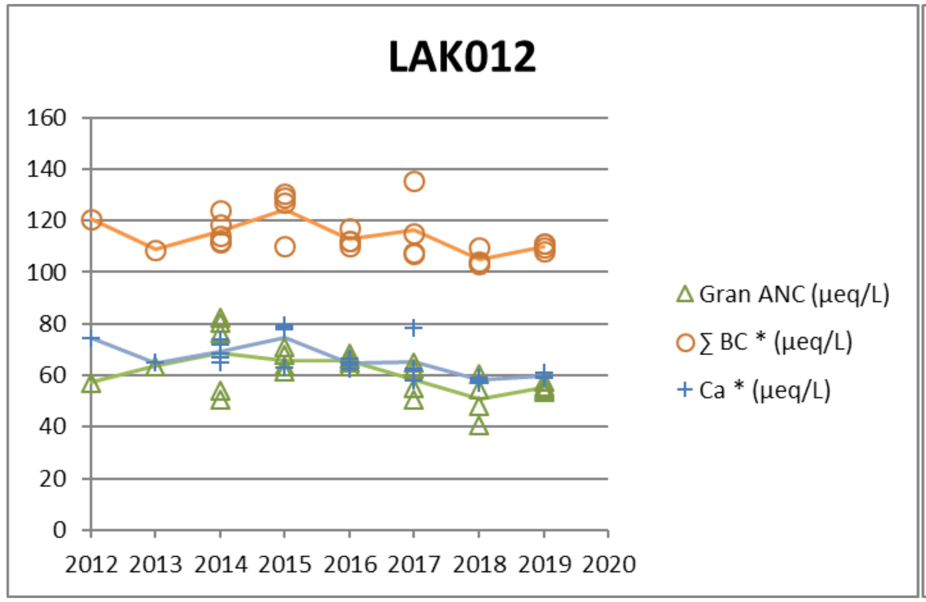
These figures show the results for all of the sampling events for each lake in each year, whether that included multiple within-season samples or only a single annual sample. The points represent the values for individual sampling events. The solid lines represent the annual trend, based on either the 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.

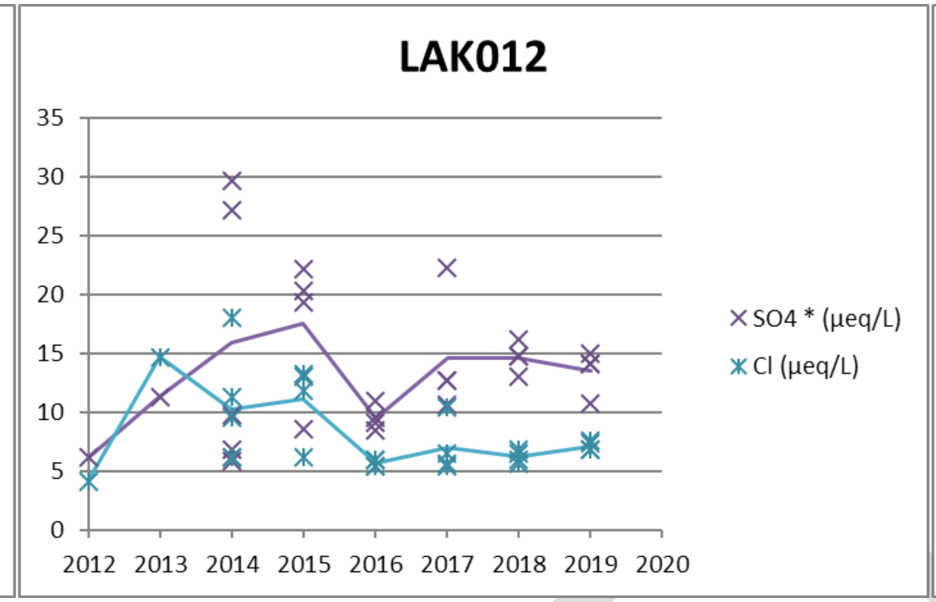
Sensitive Lakes

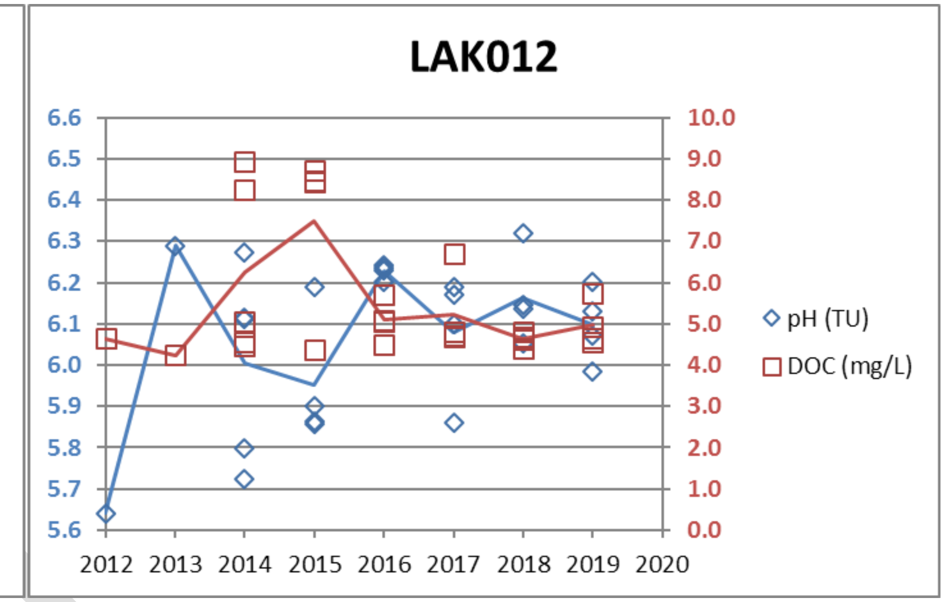


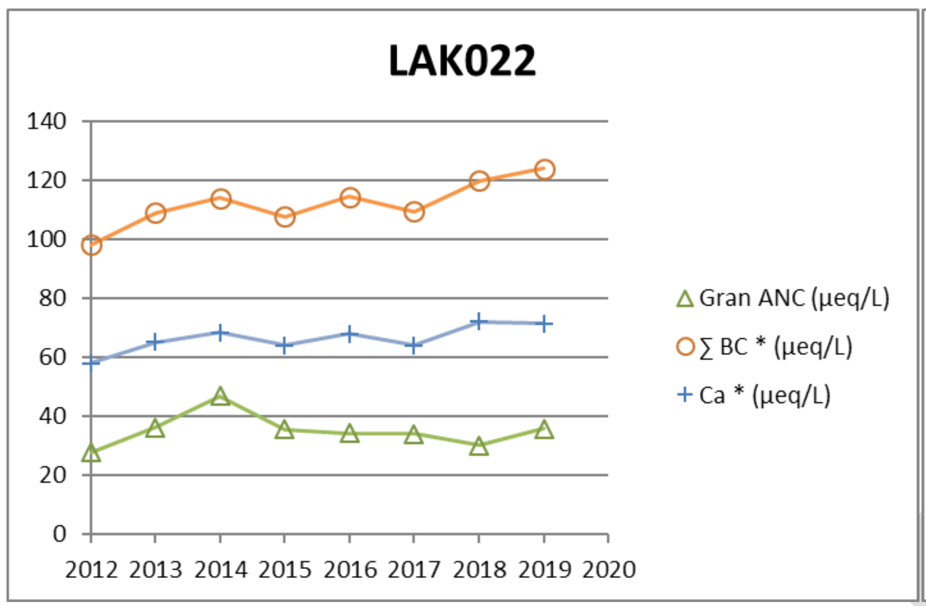


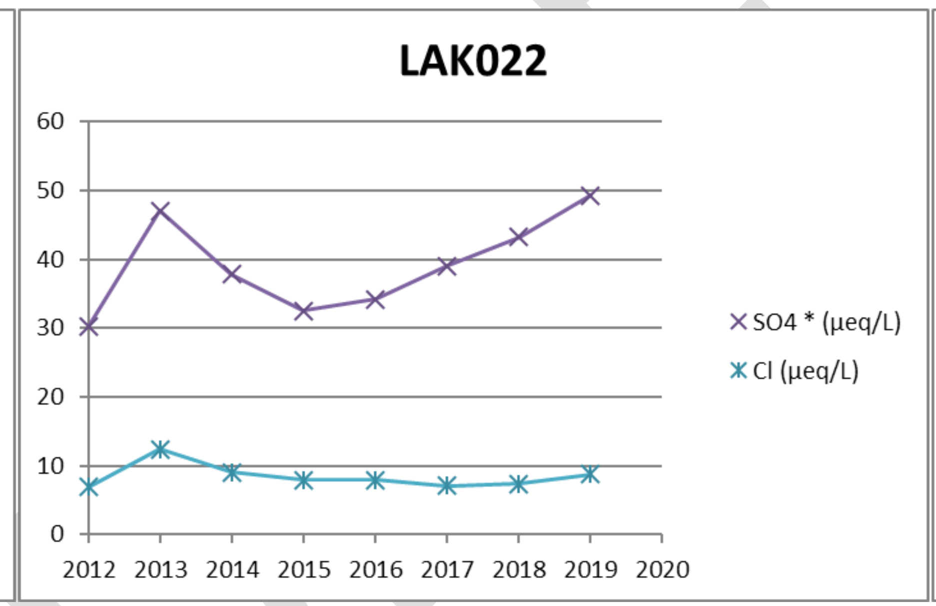


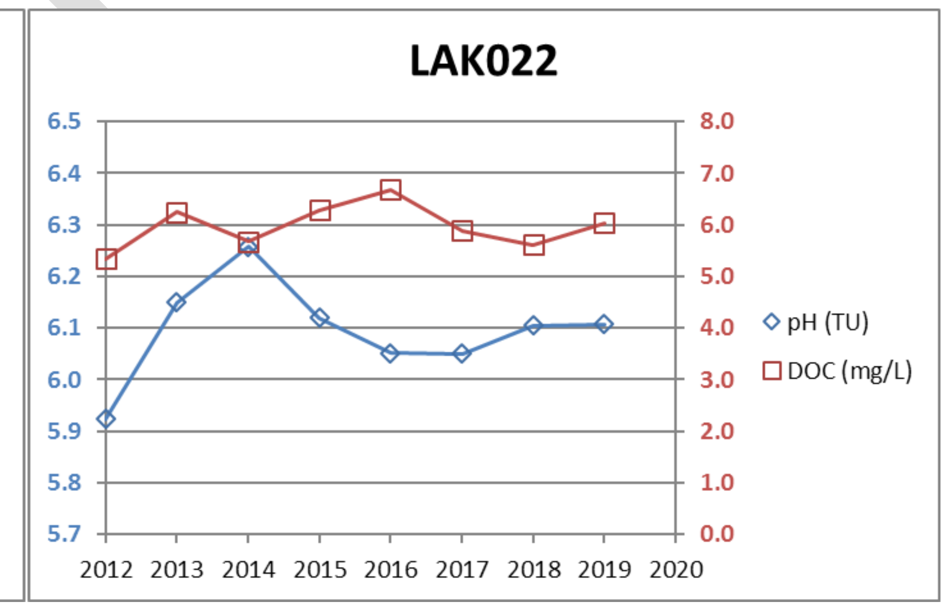

LAK012
160
140
120
100
80
60
40
20
0
2012 2013 2014 2015 2016 2017 2018 2019 2020
Gran ANC (µeq/L)
∑ BC * (µeq/L)
Ca * (µeq/L)

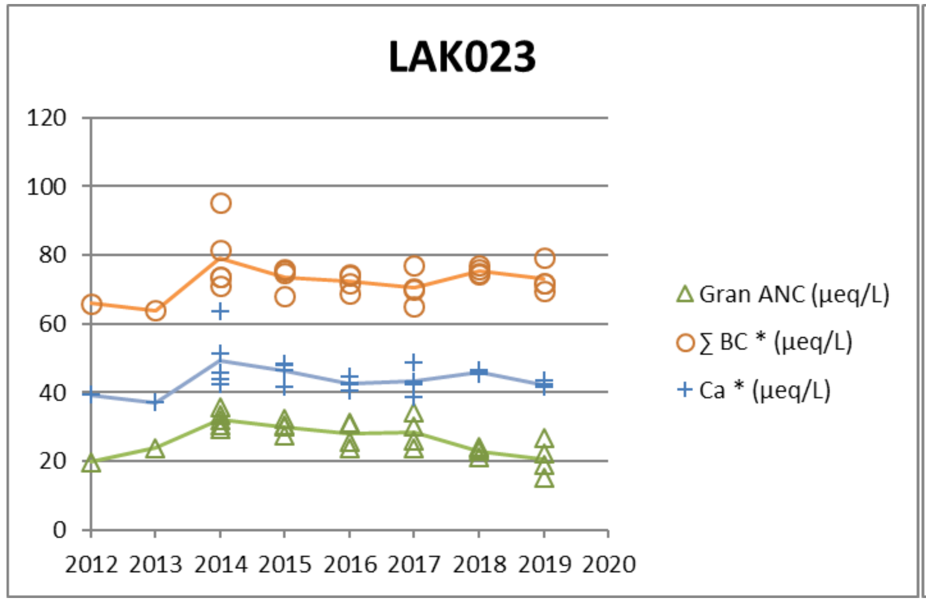

LAK012
35
30
25
20
15
10
5
0
2012 2013 2014 2015 2016 2017 2018 2019 2020
SO4 * (µeq/L)
Cl (µeq/L)

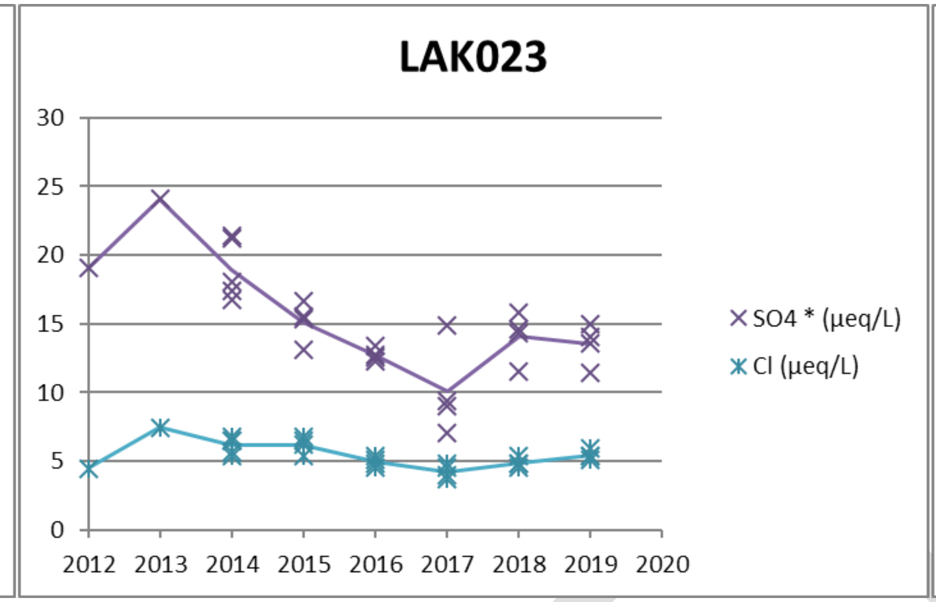

LAK012
6.6
6.5
6.4
6.3
6.2
6.1
6.0
5.9
5.8
5.7
5.6
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
2012 2013 2014 2015 2016 2017 2018 2019 2020
pH (TU)
DOC (mg/L)

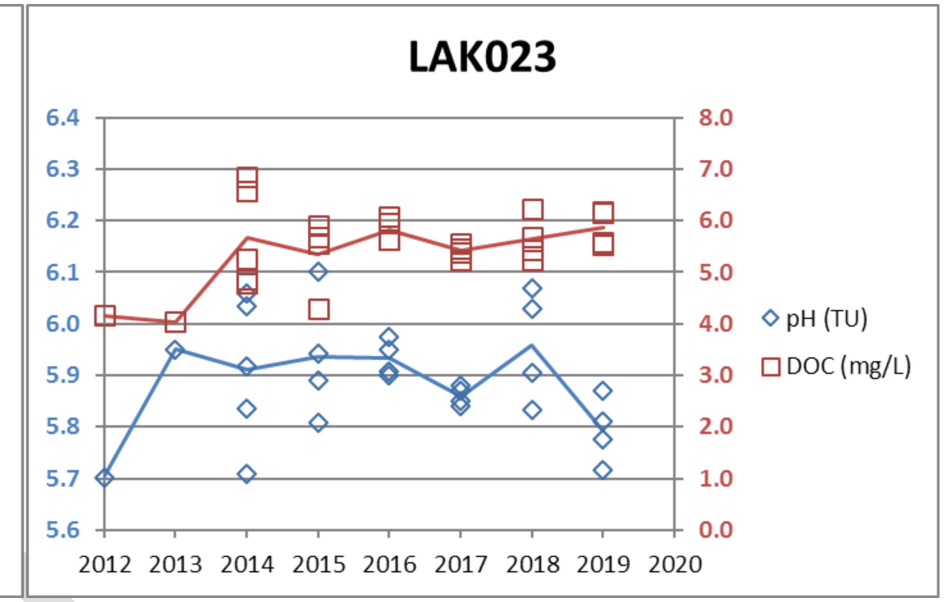

LAK022
140
120
100
80
60
40
20
0
2012 2013 2014 2015 2016 2017 2018 2019 2020
Gran ANC (µeq/L)
∑ BC * (µeq/L)
Ca * (µeq/L)

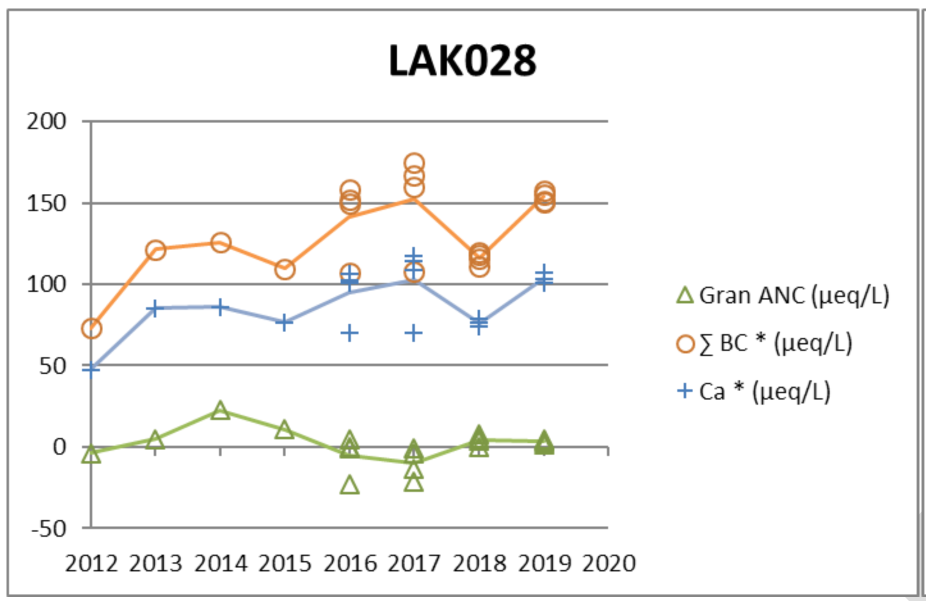

LAK022
60
50
40
30
20
10
0
2012 2013 2014 2015 2016 2017 2018 2019 2020
SO4 * (µeq/L)
Cl (µeq/L)

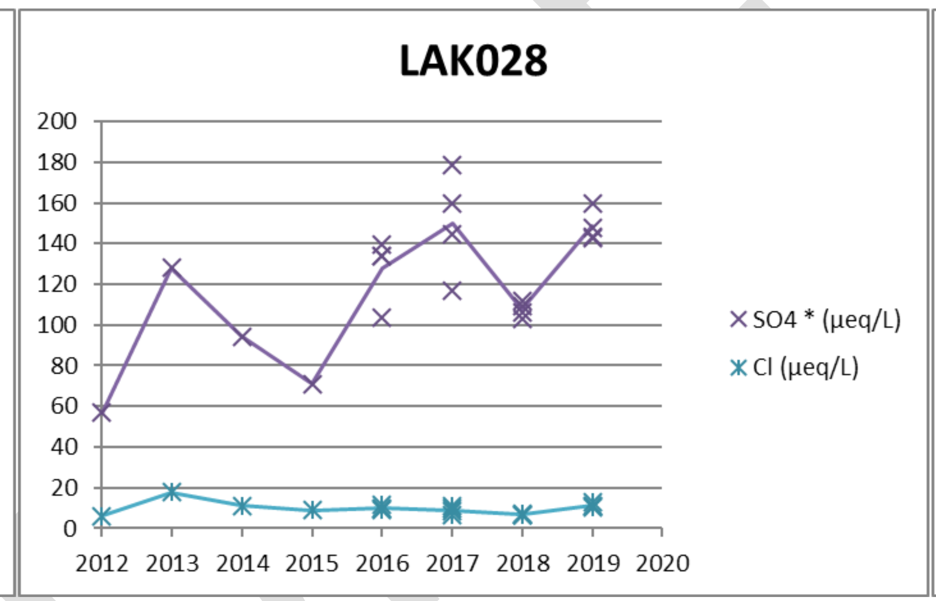

LAK022
6.5
6.4
6.3
6.2
6.1
6.0
5.9
5.8
5.7
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
2012 2013 2014 2015 2016 2017 2018 2019 2020
pH (TU)
DOC (mg/L)

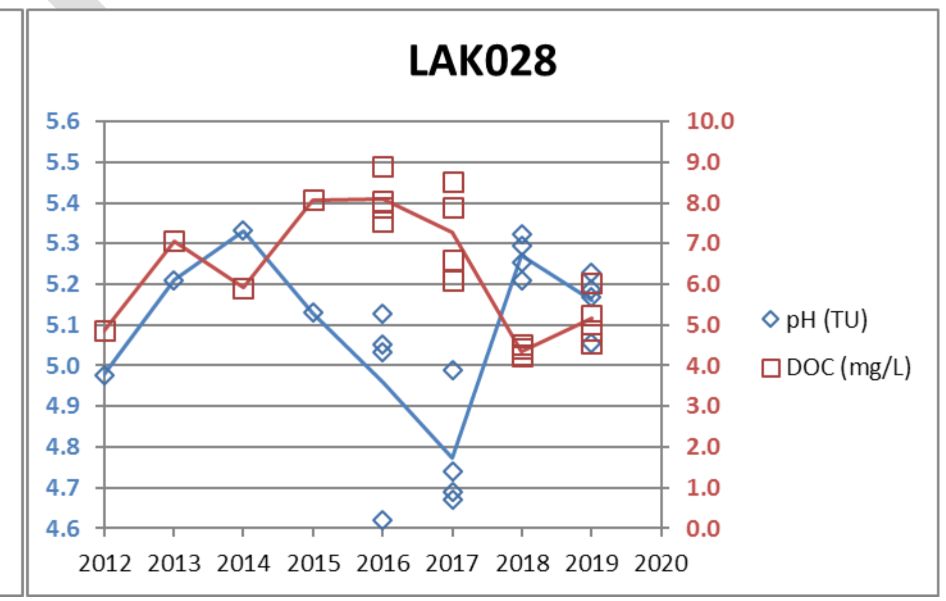

LAK023
120
100
80
60
40
20
0
2012 2013 2014 2015 2016 2017 2018 2019 2020
Gran ANC (µeq/L)
∑ BC * (µeq/L)
Ca * (µeq/L)

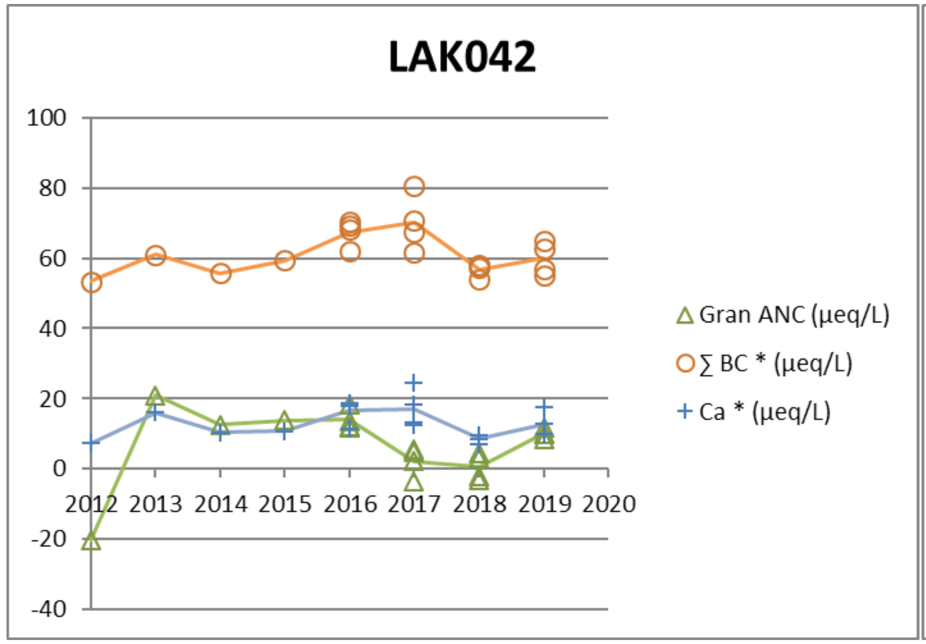

LAK023
30
25
20
15
10
5
0
2012 2013 2014 2015 2016 2017 2018 2019 2020
SO4 * (µeq/L)
Cl (µeq/L)

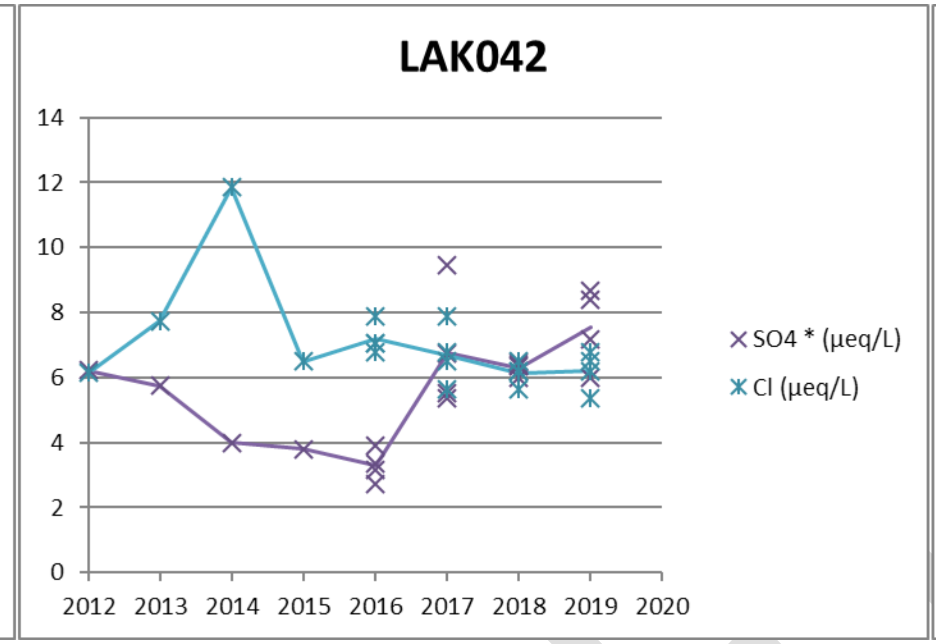

LAK023
6.4
6.3
6.2
6.1
6.0
5.9
5.8
5.7
5.6
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
2012 2013 2014 2015 2016 2017 2018 2019 2020
pH (TU)
DOC (mg/L)

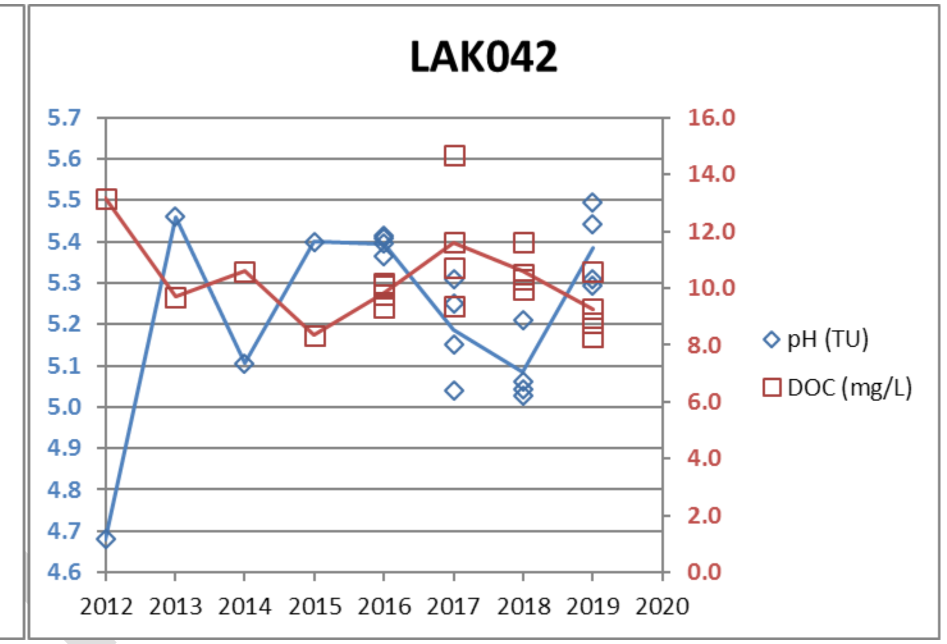

LAK028
200
150
100
50
0
-50
2012 2013 2014 2015 2016 2017 2018 2019 2020
Gran ANC (µeq/L)
∑ BC * (µeq/L)
Ca * (µeq/L)

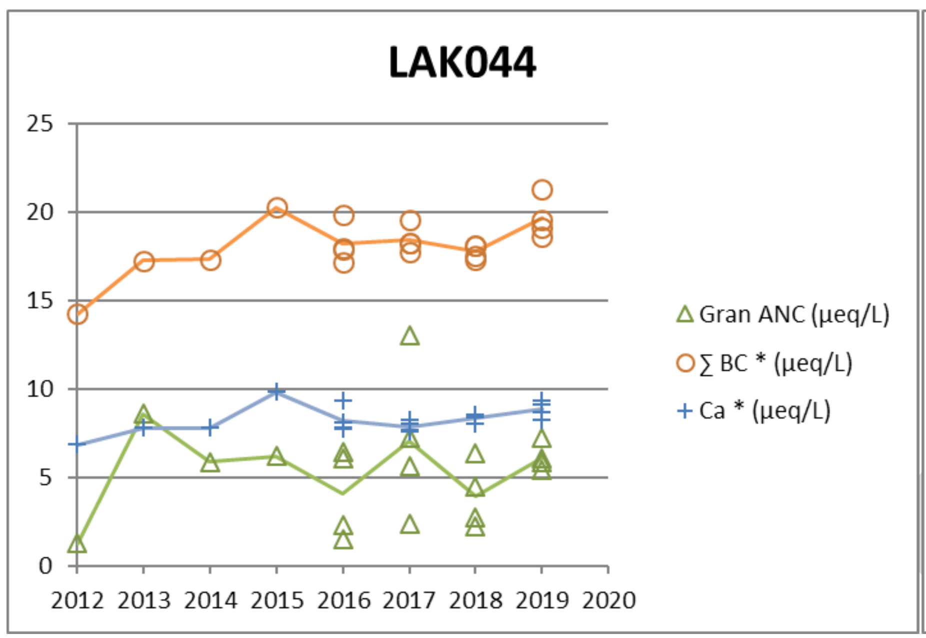

LAK028
200
180
160
140
120
100
80
60
40
20
0
2012 2013 2014 2015 2016 2017 2018 2019 2020
SO4 * (µeq/L)
Cl (µeq/L)

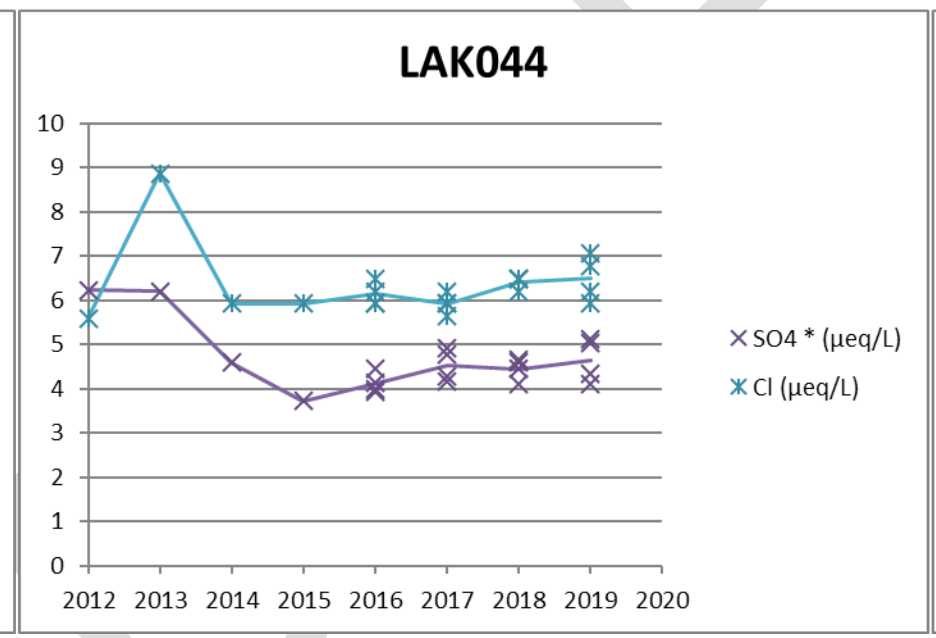

LAK028
5.6
5.5
5.4
5.3
5.2
5.1
5.0
4.9
4.8
4.7
4.6
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
2012 2013 2014 2015 2016 2017 2018 2019 2020
pH (TU)
DOC (mg/L)

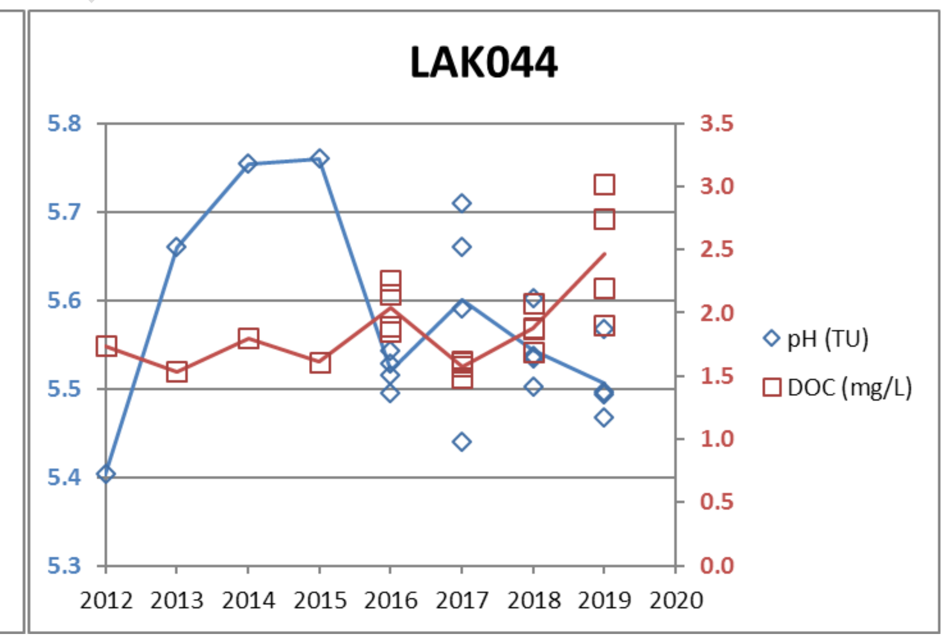

LAK042
100
80
60
40
20
0
-20
-40
2012 2013 2014 2015 2016 2017 2018 2019 2020
Gran ANC (µeq/L)
∑ BC * (µeq/L)
Ca * (µeq/L)


LAK042
14
12
10
8
6
4
2
0
2012 2013 2014 2015 2016 2017 2018 2019 2020
SO4 * (µeq/L)
Cl (µeq/L)

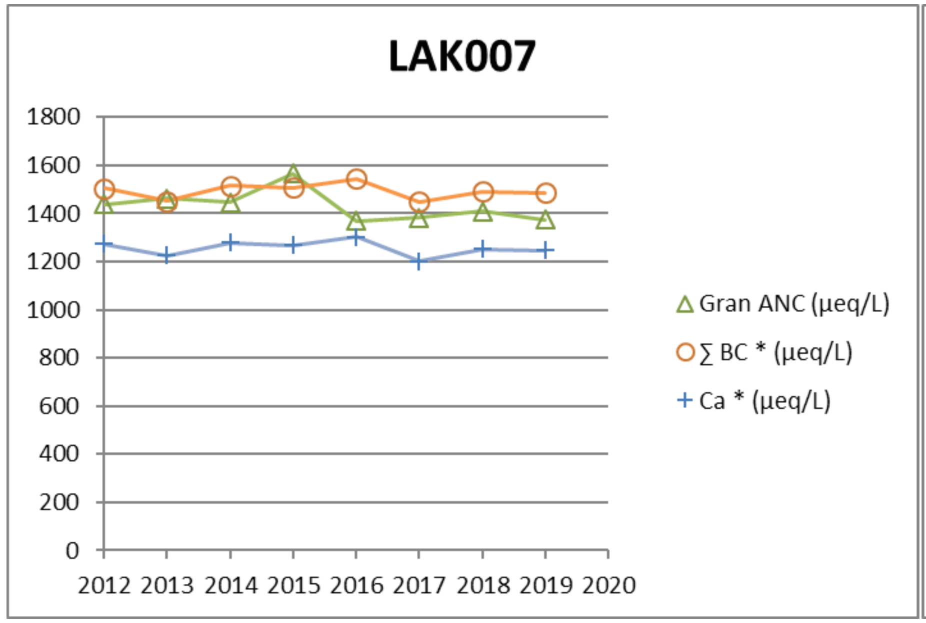

LAK042
5.7
5.6
5.5
5.4
5.3
5.2
5.1
5.0
4.9
4.8
4.7
4.6
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
2012 2013 2014 2015 2016 2017 2018 2019 2020
pH (TU)
DOC (mg/L)

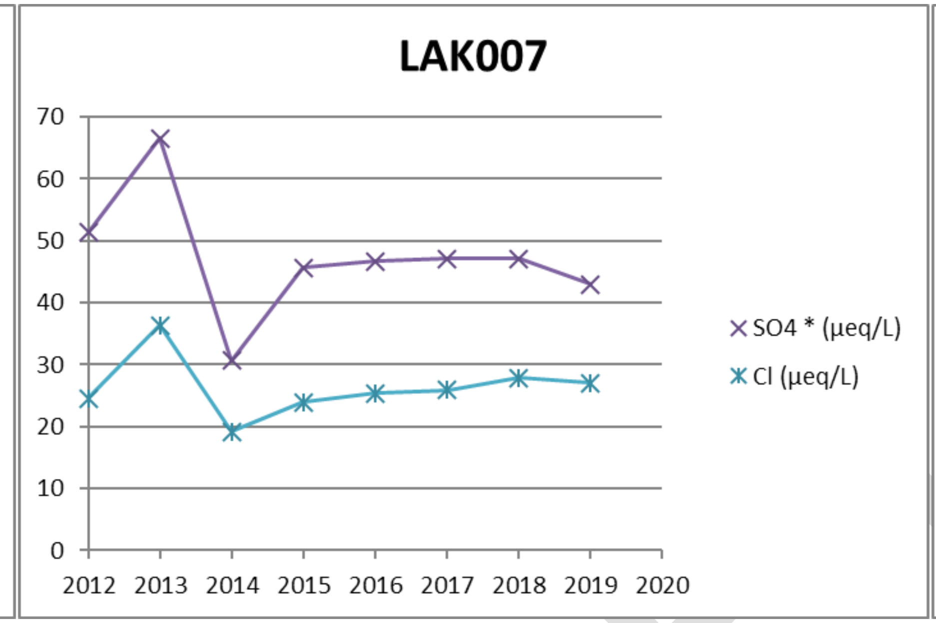

LAK044
25
20
15
10
5
0
2012 2013 2014 2015 2016 2017 2018 2019 2020
Gran ANC (µeq/L)
∑ BC * (µeq/L)
Ca * (µeq/L)

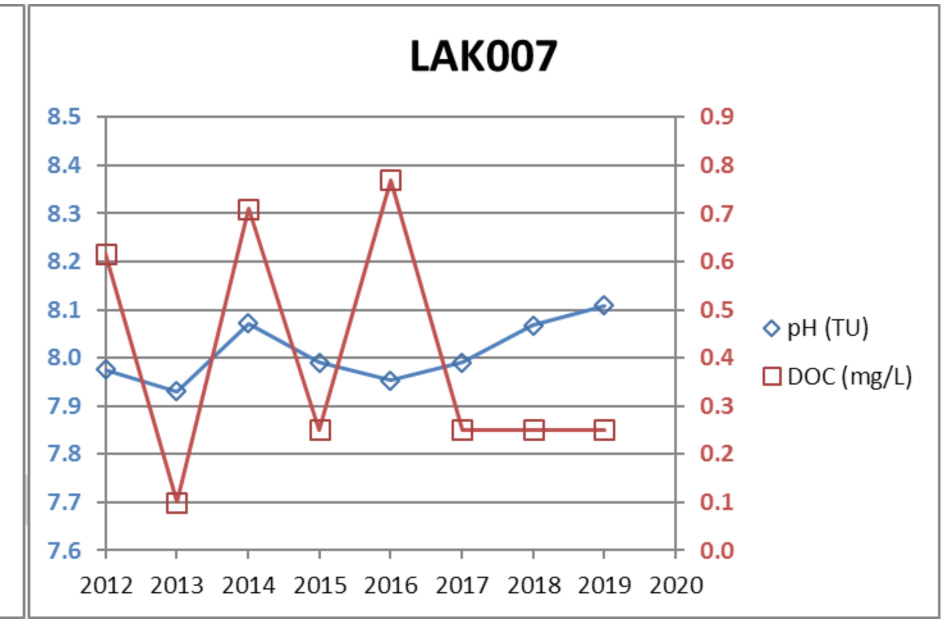

LAK044
10
9
8
7
6
5
4
3
2
1
0
2012 2013 2014 2015 2016 2017 2018 2019 2020
SO4 * (µeq/L)
Cl (µeq/L)

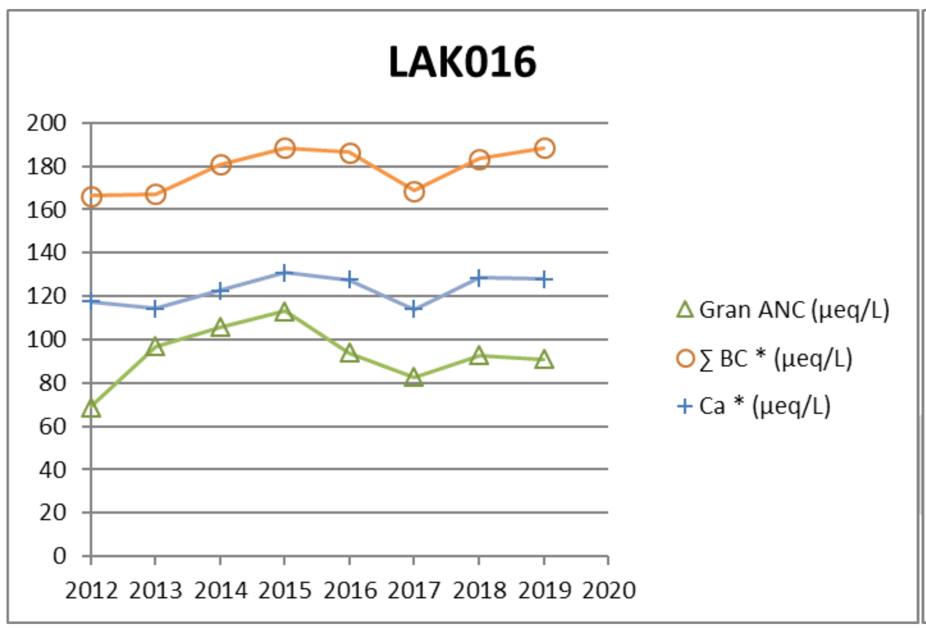

LAK044
5.8
5.7
5.6
5.5
5.4
5.3
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2012 2013 2014 2015 2016 2017 2018 2019 2020
pH (TU)
DOC (mg/L)

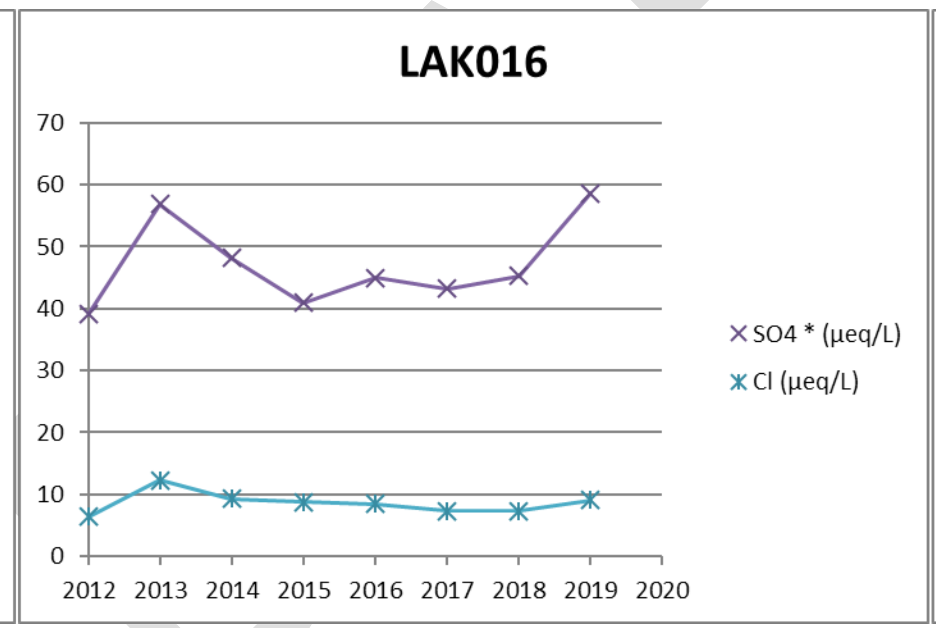
Less Sensitive Lakes

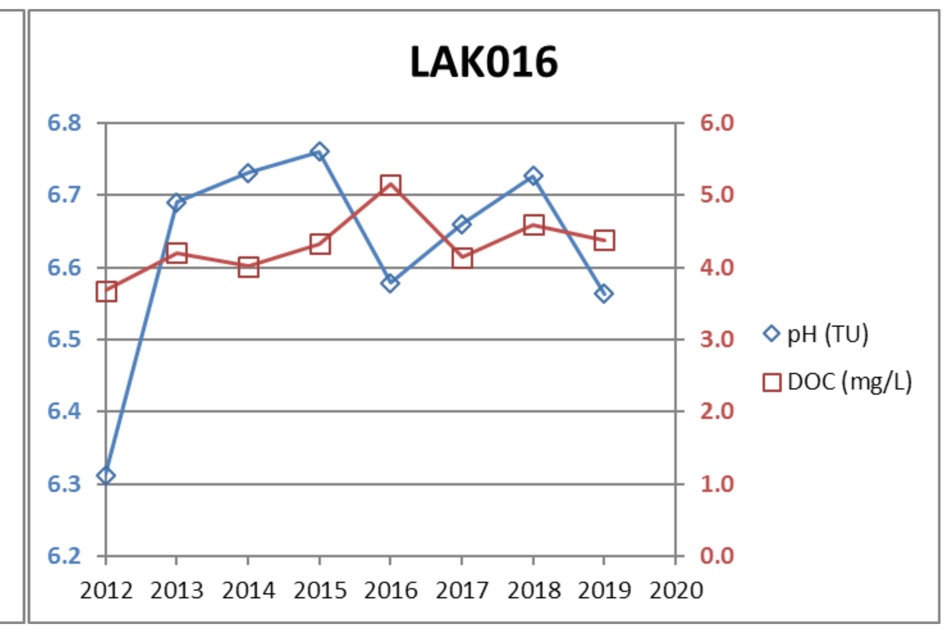


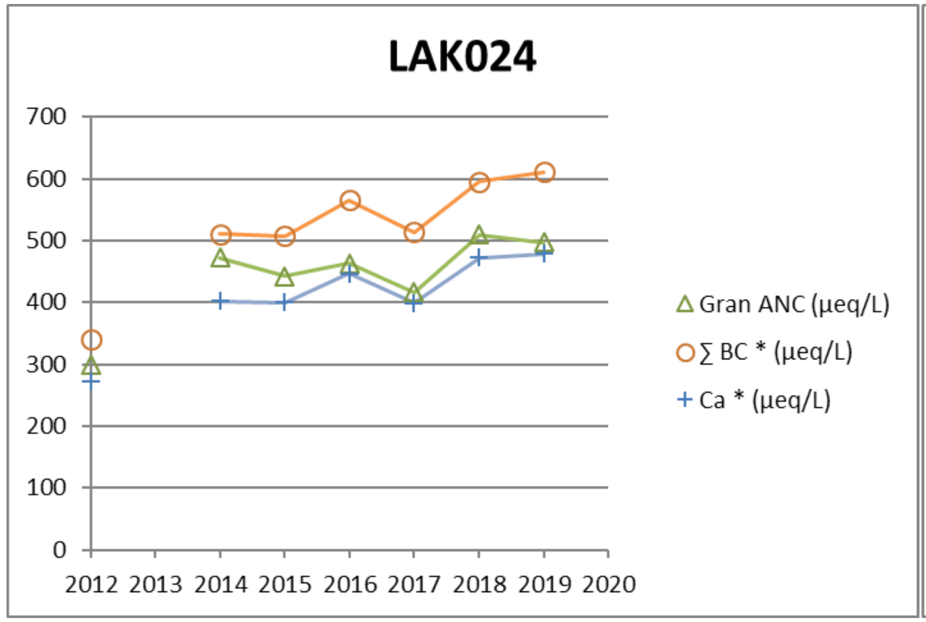


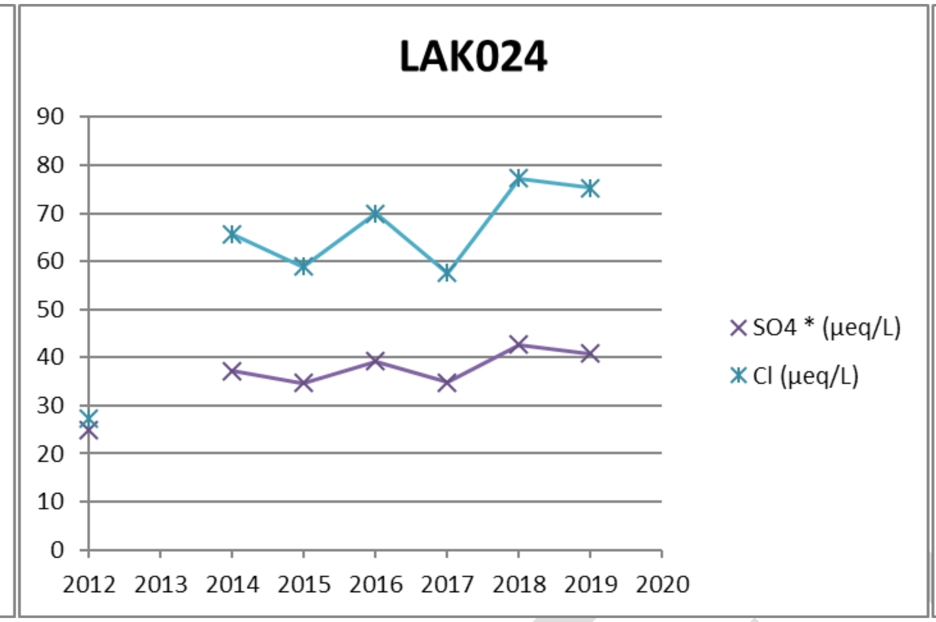


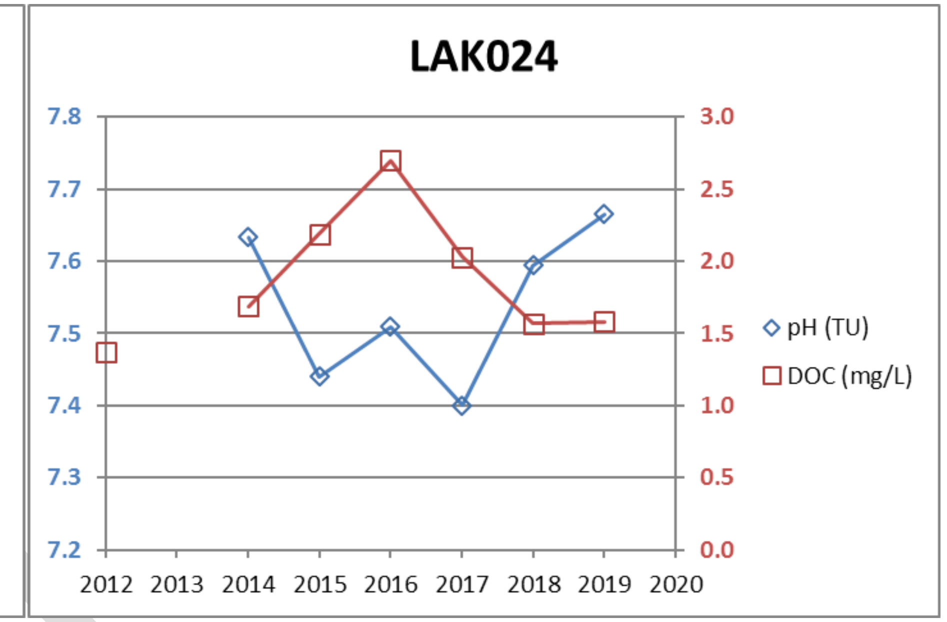


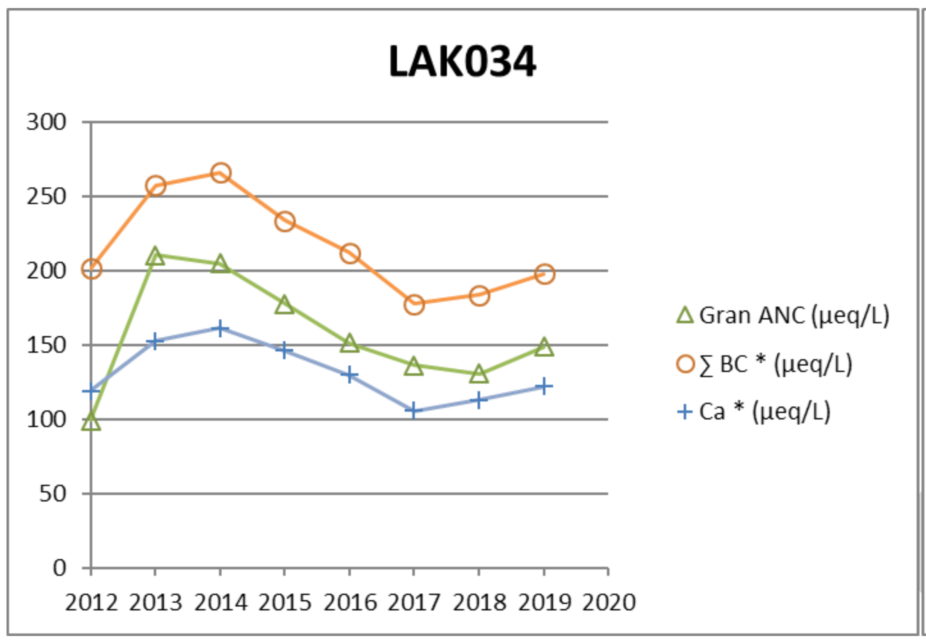


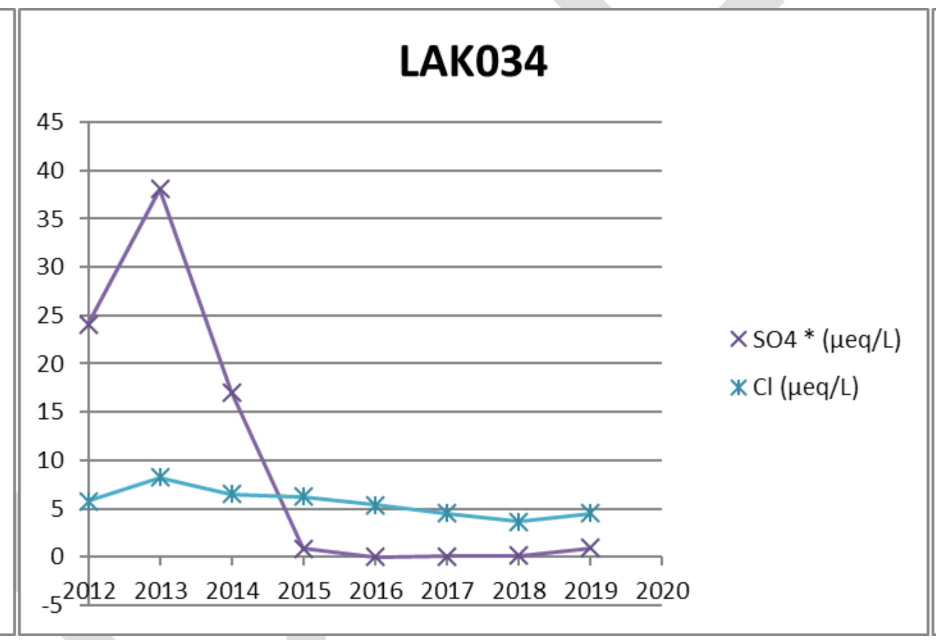


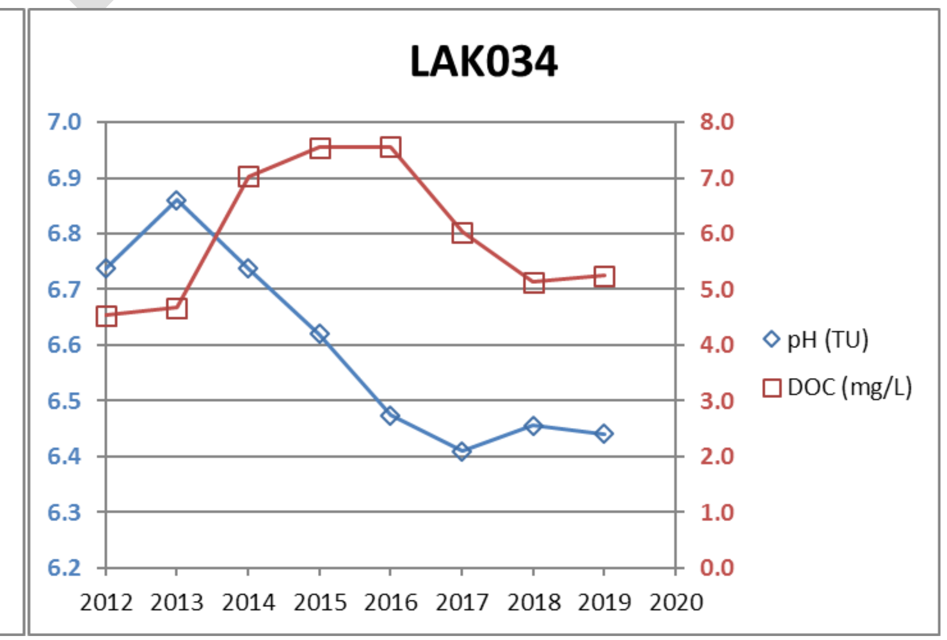

LAK024
700
600
500
400
300
200
100
0
2012 2013 2014 2015 2016 2017 2018 2019 2020
Gran ANC (µeq/L)
∑ BC * (µeq/L)
Ca * (µeq/L)


LAK024
90
80
70
60
50
40
30
20
10
0
2012 2013 2014 2015 2016 2017 2018 2019 2020
SO4 * (µeq/L)
Cl (µeq/L)

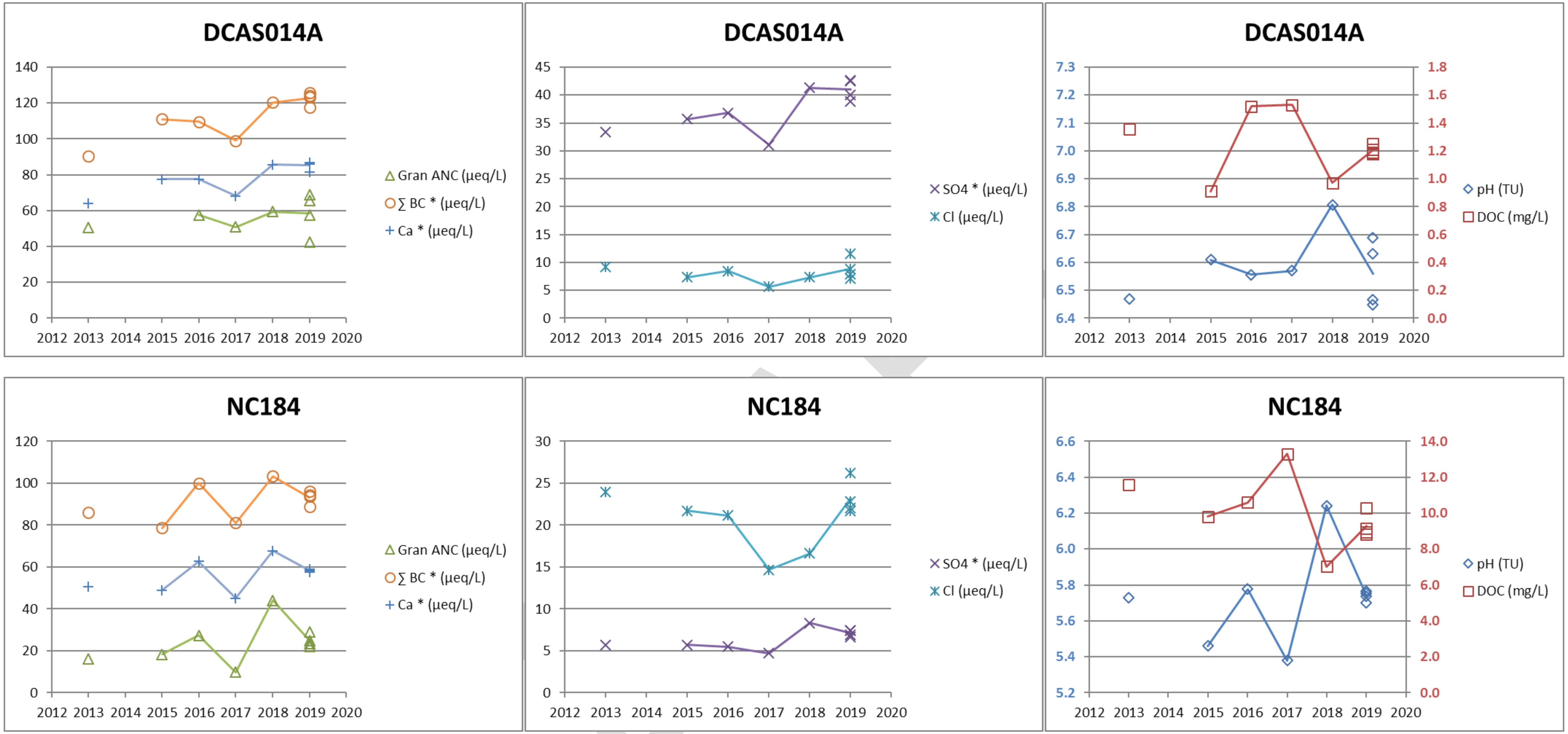

LAK024
7.8
7.7
7.6
7.5
7.4
7.3
7.2
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2012 2013 2014 2015 2016 2017 2018 2019 2020
pH (TU)
DOC (mg/L)

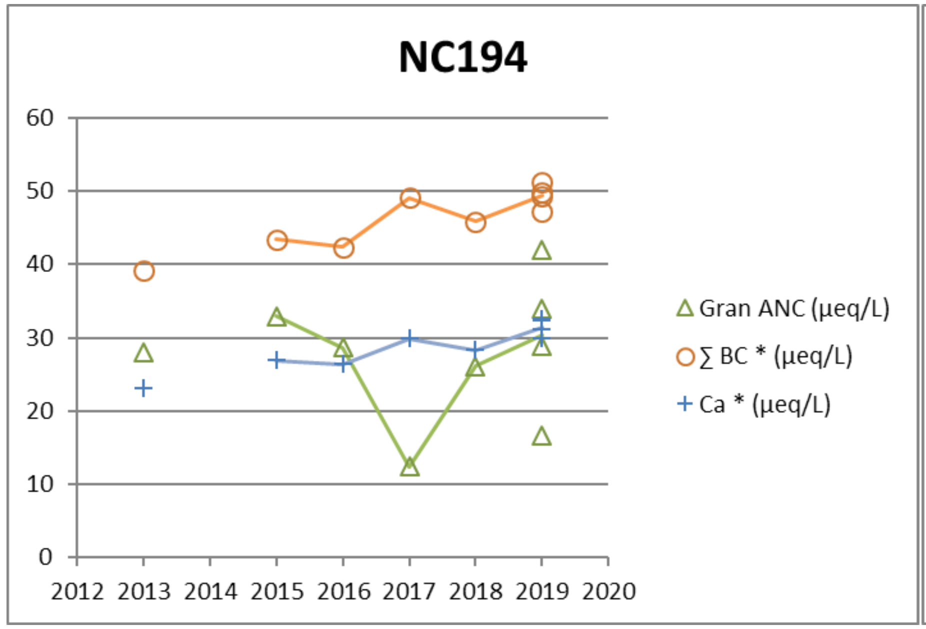

LAK034
300
250
200
150
100
50
0
2012 2013 2014 2015 2016 2017 2018 2019 2020
Gran ANC (µeq/L)
∑ BC * (µeq/L)
Ca * (µeq/L)

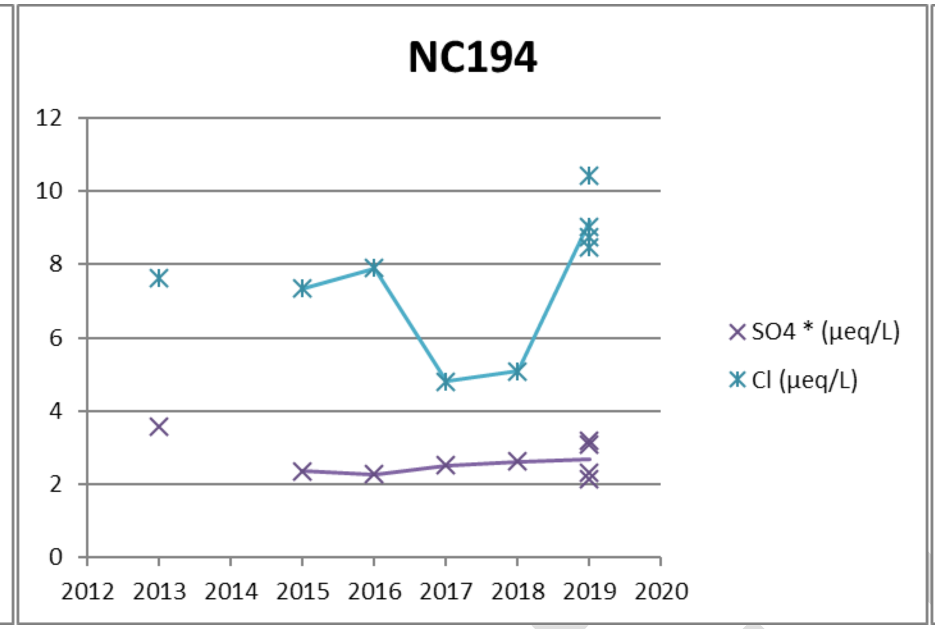

LAK034
45
40
35
30
25
20
15
10
5
0
-5
2012 2013 2014 2015 2016 2017 2018 2019 2020
SO4 * (µeq/L)
Cl (µeq/L)

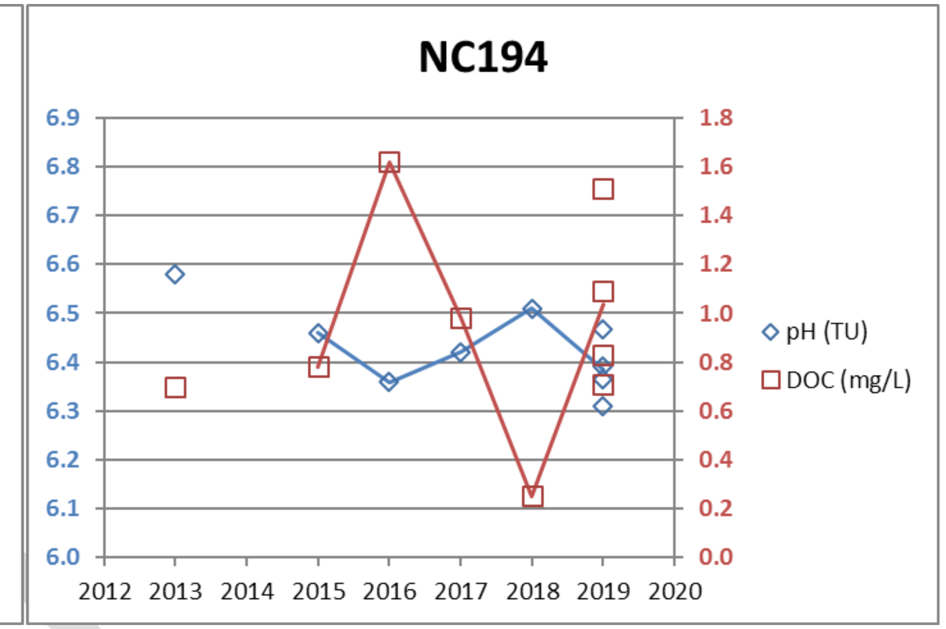

LAK034
7.0
6.9
6.8
6.7
6.6
6.5
6.4
6.3
6.2
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
2012 2013 2014 2015 2016 2017 2018 2019 2020
pH (TU)
DOC (mg/L)

Control Lakes




NC194
60
50
40
30
20
10
0
2012 2013 2014 2015 2016 2017 2018 2019 2020
Gran ANC (µeq/L)
∑ BC * (µeq/L)
Ca * (µeq/L)


NC194
12
10
8
6
4
2
0
2012 2013 2014 2015 2016 2017 2018 2019 2020
SO4 * (µeq/L)
Cl (µeq/L)


NC194
6.9
6.8
6.7
6.6
6.5
6.4
6.3
6.2
6.1
6.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2012 2013 2014 2015 2016 2017 2018 2019 2020
pH (TU)
DOC (mg/L)