B.C. Works'
Sulphur Dioxide Environmental Effects Monitoring Program

Phase III Plan for 2019 to 2025
DRAFT V.4

Prepared for:

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Version Tracking Table

No.	Date	Summary of content /changes
V.1	December 17, 2020	Draft for review by the B.C. Ministry of Environment and Climate Change Strategy (B.C. ENV)
V.2	July 18, 2021	Draft with revisions per B.C. ENV comments, for Rio Tinto review
V.3	July 13, 2022	Draft for Consultation
V.4	September 28, 2022	Revised draft addressing B.C. ENV comments

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Executive Summary

This document describes the modeling and monitoring that is planned for the Phase III Plan of the EEM Program (2019 to 2025) under the sulphur dioxide (SO_2) Environmental Effects Monitoring (EEM) Program for B.C. Works, and thresholds for increased monitoring or mitigation if warranted based on the monitoring results. Rio Tinto will implement SO_2 mitigation strategies if the outcomes of monitoring and/or modeling described in this plan show adverse impacts causally related to SO_2 cumulative emissions that are considered to be unacceptable.

The EEM Program is specific to SO_2 emissions from B.C. Works and the added SO_2 emissions from new LNG projects in Kitimat. Effects from non-SO_2 emissions from B.C. Works and other sources, and research and development of new indicators or monitoring methods are all outside of the scope of the EEM Program.

Rio Tinto is volunteering to add a section on tracking climate change to the annual SO_2 EEM reporting as the SO_2 EEM plan collects valuable data that can inform on the effects of climate change in the Kitimat valley. Climate change indicators are identified and will be further developed through a review of historical meteorological datasets. Some monitoring scopes will be enhanced for collecting data that are useful for tracking climate changes occurring in the valley.

The plan distinguishes two types of indicators: key performance indicators (KPIs) which have quantitative thresholds for increased monitoring or for mitigation, and informative indicators which provide evidence in support of key performance indicators. Exceedances of KPI thresholds for mitigation will lead to the development and implementation of mitigation action plans. The following table presents a summary of the indicators described in this Phase III Plan.

Pathways / Receptors	Key Performance Indicators	Informative Indicators
Atmospheric Pathways	None	Atmospheric SO_2 concentrations Atmospheric S (wet and dry) deposition Precipitation chemistry
Human Health	1-hour Provincial Ambient Air Quality Standard for SO_2	None
Terrestrial Ecosystems	Critical load (CL) exceedance from modelled atmospheric S deposition (estimated only if S deposition changes) Long-term soil acidification (decrease in base saturation) attributable to S deposition	Exchangeable acidity and base cations (Ca, Mg, K, Na) Modelled S deposition[1] Net base cation uptake (Ca, Mg, K) in trees Vegetation health (including potential SO_2 injury) Plant biodiversity Cyanolichen biodiversity

[1] There are no plans to revise modelled S deposition in Phase III.

Pathways / Receptors	Key Performance Indicators	Informative Indicators
Aquatic Ecosystems	Water chemistry – acidification (CBANC)	Water chemistry – acidification (pH) Water chemistry – acidification (Gran ANC, BCS) (i.e., alternate ANC metrics) Changes in SO_4 Observed changes in SO_4, ANC and pH vs. predicted changes from STAR and 2019 Comprehensive Review Predicted steady state ANC and pH versus current ANC and pH Aquatic biota: fish presence/absence per species on sensitive lakes Episodic pH change

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Glossary

acceptable impact	Not exceeding impact threshold criteria for mitigation (interchangeable with 'attainment')
acid deposition	Transfer of acids and acidifying compounds from the atmosphere to terrestrial and aquatic environments via rain, snow, sleet, hail, cloud droplets, particles, and gas exchange
acidification	The decrease of acid neutralizing capacity in water, or base saturation in soil, by natural or anthropogenic processes
acid neutralizing capacity	The equivalent capacity of a solution to neutralize strong acids; acid neutralizing capacity (ANC) and alkalinity are often used interchangeably; ANC includes alkalinity plus additional buffering from dissociated organic acids and other compounds
adaptive management	A systematic process for improving management policies and practices by learning from the outcomes of operational programs
anion	An ion with more electrons than protons, giving it a negative charge, e.g., sulphate ion (SO_4^{2-})
assess attainment	Calculate the KPI
attainment	Not exceeding impact threshold criteria for mitigation (interchangeable with 'acceptable impact')
attainment ambient air station	Any one of the three residential ambient air stations (Riverlodge, Whitesail or Kitamaat Village) that are used to assess attainment of the health KPI as set out in the 2019 B.C. Environmental Appeals Board Consent Order settling Appeals No. 2014-EMA-003, 2014-EMA-004, 2014-EMA-005
base cations	An alkali or alkaline earth metal (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+})
biodiversity	A measure of community complexity, described by the variety of all living things, the ecosystems in which they live and the ways they interact with each other
causality	Exceedance of a KPI that is caused by SO_2 emissions from B.C. Works and other SO_2 emission sources from Kitimat
critical load	A quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur, according to present knowledge[2]
dry deposition	Transfer of substances from the atmosphere to terrestrial and aquatic environments via gravitational settling of large particles and turbulent transfer of trace gases and small particles

[2] From Nilsson, J. and P. Grennfelt. 1988. Critical loads for sulphur and nitrogen. Nordic Council of Ministers. Copenhagen, Denmark. Report No. 1988:15.

environmental effects	Impacts on receptors from sulphur dioxide (SO_2) emissions from the modernized smelter
exceedance(s)	An exceedance or non-attainment of a KPI
facility-based mitigation	SO_2 emission reduction at B.C. Works
impact threshold criteria	Quantitative thresholds for a KPI that trigger additional monitoring or modelling, receptor-based mitigation, and/or facility-based mitigation
informative indicator	Indicators that will provide supporting information for key performance indicators, and may have quantitative thresholds triggering additional monitoring or modelling, but on their own will not trigger mitigation
key performance indicator	An indicator that has quantitative thresholds triggering additional monitoring or modelling, receptor-based mitigation, and/or facility-based mitigation
lichen	An organism comprising an algae or cyanobacteria and a fungus growing in symbiotic association
liming	The addition of any base materials to neutralize surface water or sediment or to increase acid neutralizing capacity
non-attainment	Exceeding impact threshold criteria for mitigation (interchangeable with ‘unacceptable impact’)
pathways	Routes of exposure or effects from atmospheric dispersion and deposition
percentile	A statistical measure for the value below which a given percentage of observations fall within a data set
pH	A measure of how acidic or basic a solution is, on a scale of 0-14; the lower the pH value, the more acidic the solution; pH 7 is neutral; a difference of 1 pH unit indicates a tenfold change in hydrogen ion activity
post-KMP	The period from 2016 forward
pre-KMP	The period of the VSS smelter operations
proportional reduction	The amount of SO_2 emissions reductions required for an exceedance of a facility based SO_2 emissions reduction threshold that is proportional to the smelter’s contribution to the KPI exceedance
receptor-based mitigation	Receptor-specific actions to reduce exposure or effects, such as liming of selected lakes
receptors	Lines of evidence assessed for potential impacts from SO_2 emissions from the modernized smelter: Human Health; Terrestrial Ecosystems; and Aquatic Ecosystems
relative abundance	Abundance of a plant species relative to other species in the community, typically measured by percent cover

richness	Number and type of species represented in a plant community
structure	Composition of the plant community (including species richness and relative abundance)
study area	The area depicted by the black hatched line in Figure 1. For the soils, the study area is the area within the modelled 7.5 kg SO_4^{2-}/ha/year deposition isopleth under the 42 tpd scenario
semi-natural uplands forest soils	Free draining mineral soils in forested (planted / second growth and natural) ecosystems
threshold	The measurement level of a KPI that triggers action to either increase monitoring or implement mitigation (receptor of facility based)
unacceptable impact	Exceeding impact threshold criteria for mitigation (interchangeable with 'non-attainment')
wet deposition	Transfer of substances from the atmosphere to terrestrial and aquatic environments via precipitation (e.g., rain, snow, sleet, hail, and cloud droplets)

Abbreviations and Symbols

Δ	delta, meaning quantitative change (e.g., ΔANC or ΔSO_2)
<	is less than what follows
>	is greater than what follows
Al	Aluminum
ANC	Acid neutralizing capacity
ANC_{OAA}	Organic acid-adjusted ANC
ARC	Annual review cycle
Bc	Base cations (Ca^{2+} + Mg^{2+} + K^+)
BC	Base cations that include Ca^{2+}, K^+, Mg^{2+} and Na^+
B.C.	British Columbia
BCS	Base cation surplus
Bcu	Base cation uptake
Ca^{2+}	Calcium ion
CAAQS	Canadian Ambient Air Quality Standards
CBANC	charge balance ANC
Cl^-	Chloride ion
CL	Critical load
DFO	Fisheries and Oceans Canada (formerly Canadian Department of Fisheries and Oceans)
EEM	SO_2 Environmental effects monitoring
B.C. ENV	British Columbia Ministry of Environment and Climate Change Strategy

Gran ANC	The capacity of a solution to neutralize strong acids, determined by titration to the inflection point of the pH-alkalinity titration curve
GTC	Gas Treatment Centre
H^+	Hydrogen ion
K^+	Potassium ion
KMP	Kitimat Modernization Project
KPAC	Kitimat Public Advisory Committee
KPI	Key performance indicator
Mg^{2+}	Magnesium ion
Na^+	Sodium ion
NA	Not applicable
NADP	National Atmospheric Deposition Program
NO_2	Nitrogen dioxide
QA/QC	Quality assurance / quality control
S	Sulphur (as in sulphur deposition)
SO_2	Sulphur dioxide
SO_4^{2-}	Sulphate ion
SO_2 EEM	Rio Tinto B.C. Works' SO_2 Environmental Effects Monitoring Program
STAR	2013 SO_2 Technical Assessment Report (for KMP)
TBD	To be determined

Measurement Units

g/m^3	grams per cubic metre
ha	hectares
m	metres
Mg/d	mega grammes per day, equivalent to metric tonnes per day
ppb	parts per billion
tpd	tonnes per day
μeq/L	microequivalents per litre

1 Introduction

1.1 Purpose and Scope of the SO_2 EEM Program and this Phase III Plan

In 2013 an SO_2 technical assessment report - STAR (ESSA et al. 2013) was completed for the Kitimat Modernization Project (KMP), to determine the potential impacts of sulphur dioxide (SO_2) emissions on Human Health, Vegetation, Terrestrial Ecosystems (soils), and Aquatic Ecosystems (lakes and streams, and aquatic biota). An EEM Plan was developed to guide the first six years of the EEM Program, from 2013 to 2018 (ESSA et al. 2014). In 2019 we undertook a Comprehensive Review of the first six years of the EEM Program (ESSA et al. 2020). Recommendations from the 2019 Comprehensive Review informed this Phase III Plan of the EEM Program. The SO_2 EEM plan is a continuing process that does not start and stop based on the phases of the plan. The new phases of the plan update and improve the plan based on the learnings gained.

The purpose of the SO_2 Environmental Effects Monitoring (EEM) Program is to monitor effects of SO_2 along the lines of evidence examined in the STAR. Results from the EEM Program will inform decisions regarding the need for changes to the scale or intensity of monitoring, as well as decisions regarding the need for mitigation. The SO_2 EEM plan also includes impact threshold criteria either for emission reduction or other mitigations that, when exceeded, would trigger emission reduction and/or other mitigation. The SO_2 EEM program is a requirement of section 4.2.5 of the P2-00001 Multimedia Waste Discharge permit (P2 Permit). The SO_2 EEM program is part of the P2 Permit and is also governed by the P2 Permit.[3]

The scope of the EEM Program encompasses B.C. Works SO_2 emissions at full production capacity, and this Phase III Plan focuses on the EEM Program from 2019 to 2025. What is learned during this period will be reviewed in 2026 and applied to improve the Program going forward.

There will be incrementally increased SO_2 emissions from the LNG projects being developed in the Kitimat Valley. The cumulative effects of SO_2 emissions from both B.C. Works and the new LNG projects are a shared responsibility. This shared responsibility has been added to the SO_2 EEM Phase III plan by adjusting the causality framework to include the cumulative SO_2 emissions effects and a proportional emission reduction framework should emissions reductions be required. Other smelter emissions and non-SO_2 emissions are outside of the scope of the SO_2 EEM program.

As the SO_2 EEM program collects data that can be used to track climate change effects in the Kitimat Valley, Rio Tinto has volunteered to add a section to the annual SO_2 EEM reports for tracking climate change. Where feasible, some additional monitoring will be added to enhance the collection of data for interpreting climate change effects in the Kitimat Valley. Details of the

[3] The P2-00001 Multimedia Waste Discharge Permit was amended on April 27, 2021 with the 2019 BC Environmental Appeals Board Consent Order where all parties of appeal numbers 2014-EMA-003, 2014-EMA-004, and EMA-005 agreed that SO_2 EEM program forms part of the P2 permit and where there are inconsistencies between P2 Permit and the SO_2 EEM, the P2 Permit will prevail.

voluntary addition of climate change monitoring will be provided in the 2021 annual SO_2 EEM report.

The study area for the Phase III Plan is shown in Figure 1.

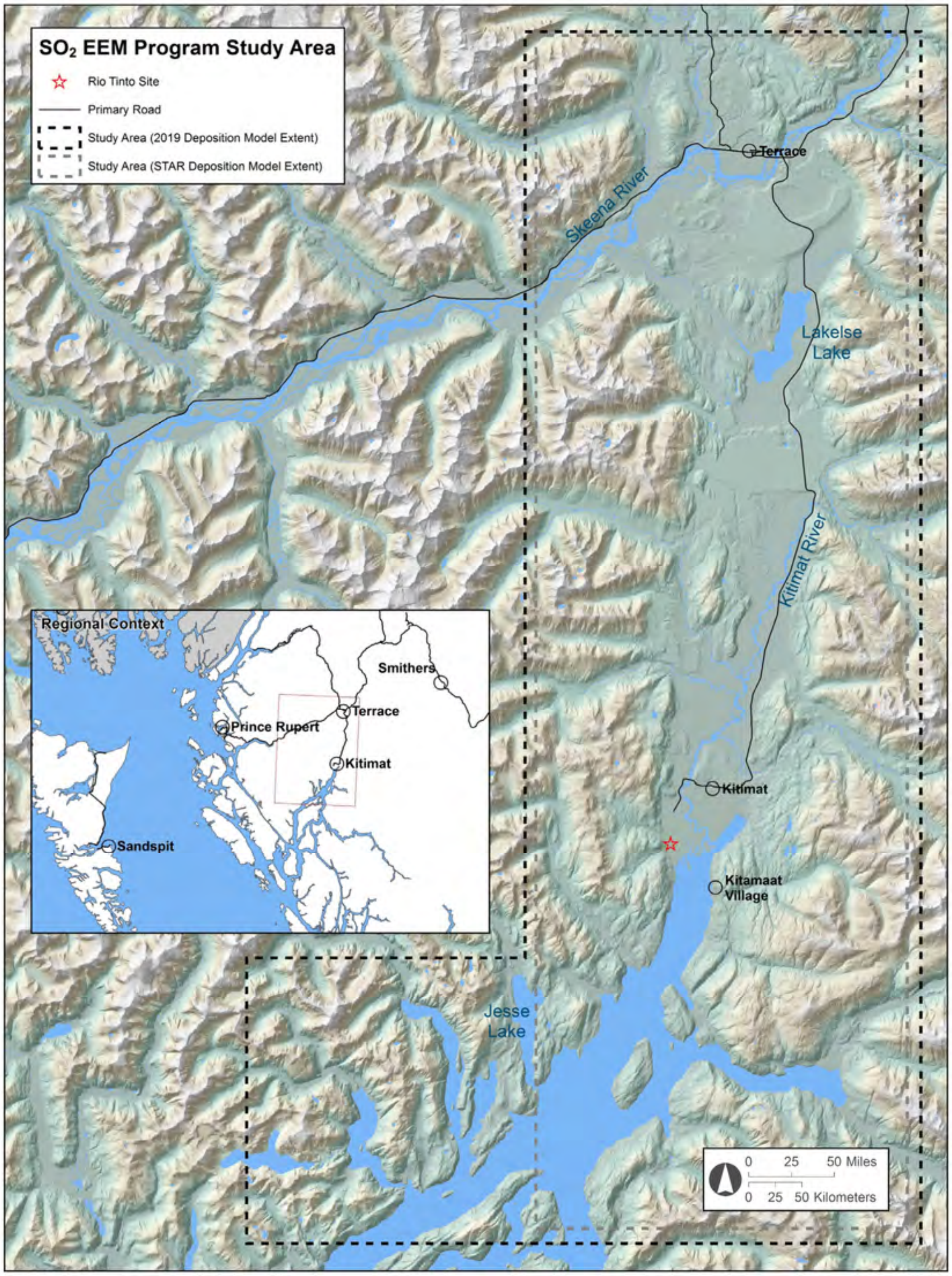

Figure 1. Map of the study area for Phase III.

This document describes the modeling and monitoring that is planned to 2025, and decision rules based on quantitative indicator thresholds for increased monitoring or mitigation if warranted based on the results. Two broad categories for mitigations are identified:

Receptor-based – mitigations that would be receptor-specific in design and application, for example adding lime to selected lakes

Facility-based – sulphur dioxide (SO_2) emission reduction at B.C. Works

The SO_2 EEM program focuses on indicators which can be causally related to SO_2 emissions. Two types of indicator are recognized:

Key performance indicator (KPI) – which will have decisions rules (quantitative thresholds) for increased monitoring and for mitigation

Informative indicator – which may have decision rules for increased monitoring, but will have no decision rules for mitigation on their own; instead they will provide evidence in support of key performance indicators

Sections 2 through 6 present indicators and methods for the pathway and receptor lines of evidence depicted in Figure 2. In this Phase III Plan the Vegetation and Terrestrial Ecosystems (Soils) receptors have been combined into one new Terrestrial Ecosystems receptor. Section 8 describes how a causal relationship to B.C. Works will be determined. Section 9 summarizes the actions that Rio Tinto will take if unacceptable impacts occur. Section 10 describes the schedule and content for SO_2 EEM reporting.

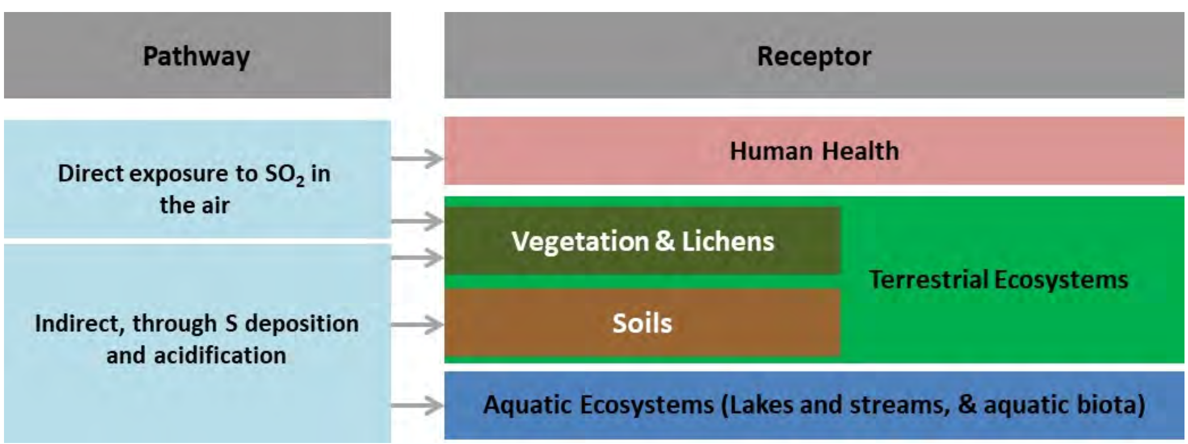

Figure 2. Organization the three lines of evidence in this Phase III Plan.

The development of this Phase III Plan has been guided by a suite of principles that are closely aligned with the principles used to guide the original development of the EEM Program in 2013:

- Safety is paramount,
- Monitor in a manner that does not harm the environment,
- Make wise use of financial and human resources,
- Ensure all information gathered is helpful for assessing risk, refining monitoring design or making decisions on mitigation,
- Measures must have sufficiently low spatial and temporal variability to provide useful information,
- Review and adjust processes based on results, and
- Regular evaluation and reporting of results.

1.2 SO_2 EEM Framework

Figure 3 illustrates the decision framework for the SO_2 EEM program. It is divided into three overall phases: pre-KMP, ramp-up and initial operation under the new smelter (2013-2018), and 2019 onward.

The first phase began before the modernization of the smelter with the SO_2 technical assessment to determine the potential impacts of SO_2 emissions from KMP. Four potential impact categories were identified, and remain relevant for interpreting monitoring results from the SO_2 EEM program (Table 1):

Table 1. Impact categories used in the SO_2 Technical Assessment Report (STAR).

Impact Category	Interpretation
Low	No impact or acceptable impact
Moderate	Acceptable impact but in need of closer scrutiny
High	Unacceptable impact; mitigation action needed
Critical	Extremely unacceptable impact; mitigation action needed

The SO_2 technical assessment predicted that impacts on vegetation would fall into the green (low) impact category, and that impacts on human health, soil, and water and aquatic biota would fall into the yellow (moderate) impact category. The SO_2 EEM program will determine whether these predictions were correct, and if EEM results indicate that actual outcomes post-KMP for any of the receptors will fall into higher impact categories than predicted, describe the decisions rules for action.

In addition, the SO_2 EEM program was set up to answer questions that arose during the technical assessment. The answers would result in one of three possible outcomes for the receptors:

- The pre-KMP assessment *over*estimated or accurately estimated the impact category. In other words, the impact category predicted in the assessment was either too high, or correct. In the framework, this situation is represented by a "thumbs up".
- The pre-KMP assessment *under*estimated the impact category. In other words, the assessment was overly optimistic – represented in the framework as one or two "thumbs down", depending on the implications of the underestimation of impacts.
- It is unclear whether the assessment underestimated or overestimated the impact risk – represented in the framework as "thumbs down" with a question mark.

The second phase occurred in 2013 to 2018, from KMP ramp-up through to the first years of full operation of the modernized smelter. It focused on learning, through regular evaluation of results designed to provide:

- Evidence that the technical assessment *under*estimated the impact category ( ) **and/or** that the impacts are (or are expected to be) high ( ) or critical ( ).
  This will require mitigation and an escalation in either the frequency or extent of monitoring, or both.
- Evidence that the assessment correctly or *over*estimated the impact category ( ), or *under*estimated the impact category ( ) **but** the impacts are (or are still expected to be) low ( ) or moderate ( ).
  This will require no mitigation, but may require modifications to monitoring.
- Unclear evidence either way due to lack of time for effects to be manifested (e.g., to observe that a lake is acidifying) ( ), and the impact category is still estimated to be no higher than moderate ( ).
  This will require no mitigation, but may require modifications to monitoring, either to increase the frequency or number of monitoring locations, or both.

Annual SO_2 EEM program reports were produced during the first 6 years to convey results as well as any mitigation that has been undertaken during the preceding year. Annual monitoring plans for the subsequent years were developed based on these results.

The third phase began in 2019, when a comprehensive review was conducted and a Comprehensive Review Report was prepared (ESSA et al. 2020) that synthesized what has been learned during the first 6 years and assessed which questions have been sufficiently answered and which remain. Based on this report decisions were made about what monitoring should continue, and the frequency of reporting. Those decisions are reflected in this Phase III Plan.

The SO_2 EEM program is expected to evolve over time according to what is learned.

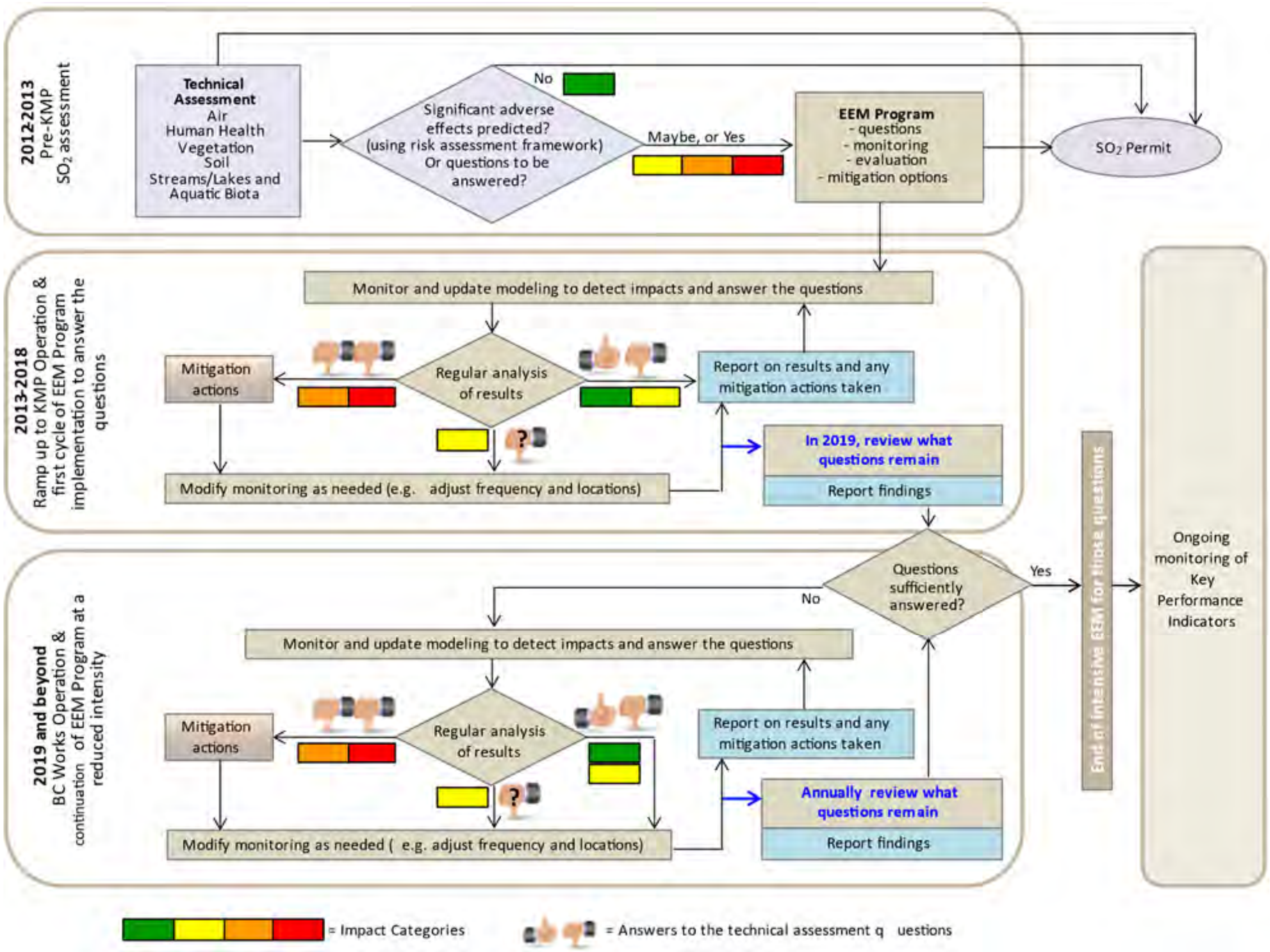

Figure 3. SO_2 EEM framework for B.C. Works.

The SO$_2$ EEM program is structured around the conceptual model shown in Figure 4. In the first phase of the EEM Program (2013-2018), vegetation and soils were separate receptors. In this Phase III Plan, these have been combined into one Terrestrial Ecosystems receptor, with indicators for both vegetation and soils components.

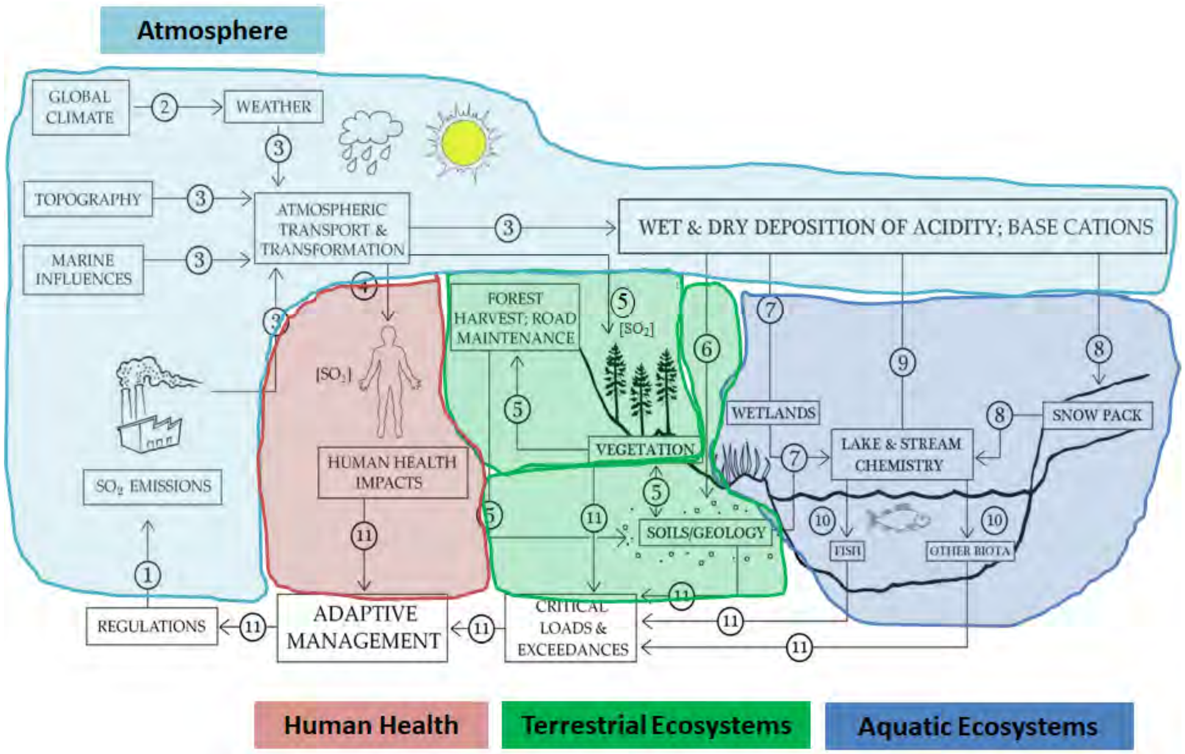

Figure 4. Conceptual (source-pathway-receptor) model of SO$_2$ emissions in the environment, showing linkages between sources and receptors. Source: Figure 1-1 from ESSA et al. 2020.

1.3 Decision Rules

The cycles within the second phase (2013-2018) and the third phase of the framework in Figure 3 involve a set of quantitative, threshold-based "decision rules" as illustrated in Figure 5. Thresholds for increased monitoring are lower than thresholds for mitigation, and thresholds for receptor-based mitigation are lower than thresholds for facility-based mitigation. If receptor-based mitigations are not feasible, or are implemented but found to be ineffective, facility-based mitigations will be implemented.

As shown in Figure 5, for each line of evidence in the SO$_2$ EEM, attainment of KPIs will be determined through assessing the individual KPI results and associated informative indicators for change and comparison to their respective thresholds for increased monitoring or mitigation. The result or change in a KPI will first be assessed through an evidentiary framework to determine if the KPI change is causally related to SO$_2$ emissions (strong statistical confidence or belief that the result is not a false positive). If a KPI is shown to have exceeded a threshold for increased monitoring or mitigation and is causally related to SO$_2$ emissions, then a pathway to mitigation would be implemented through consultation with B.C. ENV. Actions for mitigation would be developed into an action plan and implemented according to the respective KPI table and / or mitigation outlined in Section 9.

KPI attainment assessment activities and results will be reported in each annual SO_2 EEM report. Annual reports will specify which KPIs do not have attainment results to report in a given year (such as for soils), and will explain why. Annual reports will also convey when the next attainment assessment is expected for each KPI.

Results of the next comprehensive end of cycle review in 2026 will inform decisions about:

- which KPIs and informative indicators should be monitored in 2026 and beyond and at what level of intensity,
- modifications to monitoring methods,
- refinement to KPI thresholds (decision rules), and
- the timeline for the next comprehensive end of cycle review.

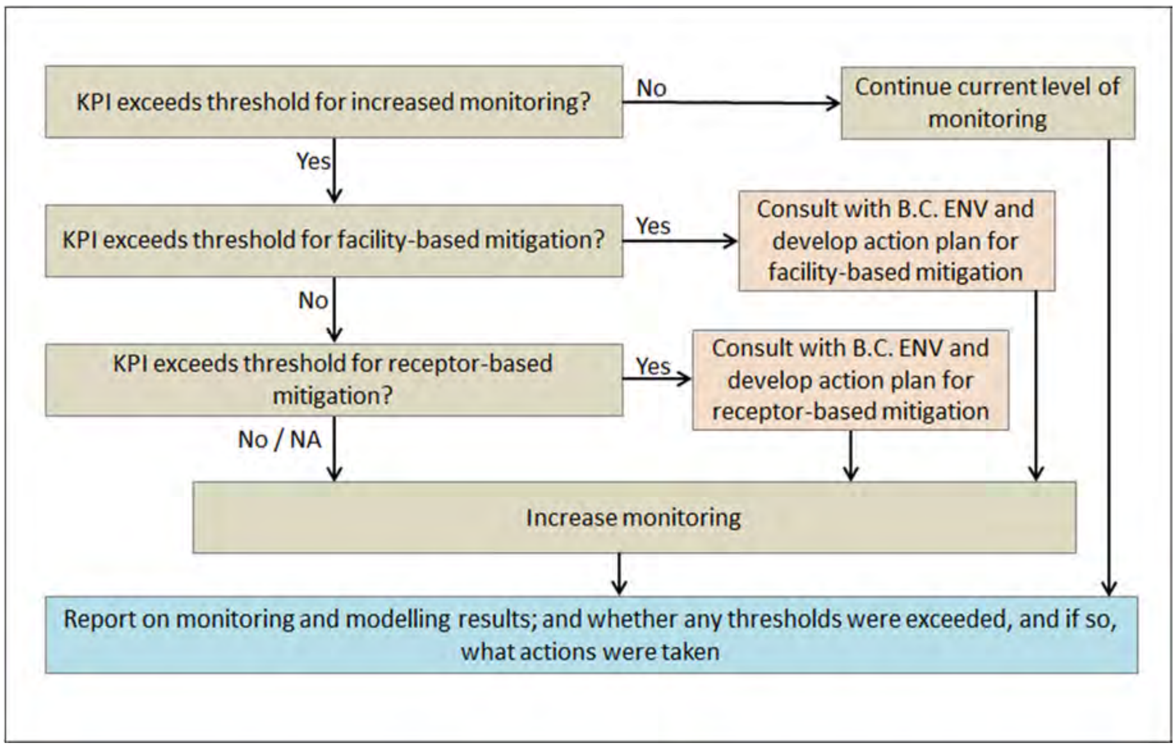

Figure 5. Decision tree for quantitative thresholds of key performance indicators and pathways to mitigation.

2 Atmospheric Pathways

2.1 Introduction

The measured SO_2 concentrations and wet S deposition provide important information. The continuous SO_2 analyzers provide real-time, accurate, and reliable direct measurements, which can be directly tied to the smelter's current SO_2 emissions. The continuous SO_2 analyzers also provide hourly and sub-hourly data that can be used to understand how concentrations change over time and how 1-hour concentrations relate to long-term average concentrations. The continuous SO_2 analyzer data combined with the 30-day passive sampling data also provide valuable information to understand the spatial distribution of the plume, and to determine dry deposition. Precipitation chemistry (wet deposition of sulphur (S), chloride (Cl), and base cations) is collected on a weekly basis. Total (wet plus dry) atmospheric S deposition is important to the assessment of risk of impacts on vegetation, terrestrial, and aquatic ecosystems.

The SO_2 concentration measurements also provide key information about the accuracy of dispersion models used for SO_2 effects assessments and to make decisions when updating the EEM. Learning whether the models over-predicted or under-predicted concentrations at various locations provides important information about whether the STAR and 2019 Comprehensive Review SO_2 effects assessments over-predicted or under-predicted risk of impacts on receptors. Understanding the model accuracy at various locations (i.e., whether the model accurately predicted the extent and position of the plume) also provides valuable information about the design of the EEM program related to the locations selected for monitoring.

2.2 Indicators

We use SO_2 atmospheric concentrations to assess the risk of direct impacts on human health and vegetation (including cyanolichens). Measured SO_2 atmospheric concentrations are used to assess health impact; modelled and measured SO_2 concentrations are used to evaluate the risk of direct injury to vegetation. We use predictions of atmospheric deposition under different emission scenarios to assess the risk of impacts on vegetation, terrestrial, and aquatic ecosystems. Since the effects of SO_2 concentrations and total S deposition on receptors are assessed in receptor-specific evaluations, there are no KPIs for atmospheric concentrations or atmospheric deposition. There are also no thresholds for increased mitigation or monitoring for this reason.

The atmospheric pathway has one atmospheric concentration informative indicator: atmospheric SO_2 concentrations, which is measured through two types of equipment: continuous SO_2 analyzers and passive SO_2 monitors. There are also two atmospheric deposition informative indicators: atmospheric S deposition and precipitation chemistry. These informative indicators are listed in Table 2 and an overview of methods for calculating them are provide in Table 3.

Table 2. Informative indicators for Atmospheric Pathways.

Informative indicators	Thresholds for increased monitoring or mitigation	Indicators to be jointly considered
Atmospheric SO$_2$ concentration	Not applicable; will support KPIs and informative indicators for the receptors	• Exceedance of SO$_2$ CAAQS • Vegetation and cyanolichen health (including potential SO$_2$ injury)
Atmospheric S (wet and dry) deposition	Not applicable; will support KPIs and informative indicators for the receptors	• Atmospheric S deposition and critical load (CL) exceedance risk • Long-term soil acidification (decrease in base saturation) attributable to S deposition • Water chemistry – acidification • Plant biodiversity – community structure (including species occurrence and abundance) of select vascular plants • Cyanolichen biodiversity (occurrence and relative abundance)
Precipitation chemistry	Not applicable; will support KPIs and informative indicators for the receptors	• Critical load (CL)

2.3 Methods

Table 3. Overview of methods for calculating informative indicators for Atmospheric Pathways.

Informative indicators	Method overview
Atmospheric SO$_2$ concentration	Continuous analyser measurements of SO$_2$ air concentrations from continuous SO$_2$ monitoring network. Passive SO$_2$ sampler measurements from network of passive samplers in the Kitimat Valley with co-deployments at continuous analyser stations.
Atmospheric S (wet and dry) deposition	NADP wet deposition monitoring stations at Lakelse Lake and Haul Road[4] Estimation of dry deposition of S (using SO$_2$ from continuous analyser at Lakelse Lake and big-leaf dry deposition model; requires ancillary meteorological monitoring)
Precipitation chemistry	Wet precipitation chemistry for major ions at Lakelse Lake

[4] As the Haul Road station's precipitation chemistry data provide little value towards understanding risk of ecological impacts and does not provide value for evaluating CALPUFF deposition modeling, a decision for discontinuing or relocating the Haul Road precipitation chemistry will be reviewed with B.C. ENV.

2.3.1 Atmospheric SO_2 concentration

The phase 2 network optimization evaluation (draft report) for SO_2 was submitted to B.C. ENV in March 2021 and recommended the number and location of continuous SO_2 analyzers.[5] Similarly, a 3-year passive monitoring program plan for the plume path network (valley network) was completed May 7, 2021 for deploying approximately mid-May or mid-June 2021 (depending on sites access) and continuing through approximately mid-October, and again from approximately mid-May or mid-June to approximately mid-October in 2022 and 2023. The passive plan includes objectives of the program and decision criteria for continuing sampling beyond 2023.

Sampling locations:

- Continuous SO_2 analyzers currently operated at Haul Road, Riverlodge, Kitamaat Village, Service Centre, and Whitesail, with additional SO_2 from Lakelse Lake (operated by Rio Tinto for dry S deposition) and Terrace-Skeena middle school (operated by ENV).
- Passive sampling locations will be consistent with the 2020-2021 passive sampling plan in general, with possible minor variation based on annual data evaluations and any siting issues identified during deployment. The 2020-2021 passive sampling plan included fifteen sites along the Kitimat Valley from V15 at Emsley Creek south of the smelter north to A04 at Lakelse Lake (co-located with the continuous SO_2 station).

Sampling timing, frequency and duration:

- Continuous SO_2 analyzers operate continuously and the network as determined from Phase 2 monitoring network evaluation will operate through the duration of Phase III (through 2025).
- Passive samplers will be deployed from approximately mid-May or mid-June to mid-October with 30-day sampling periods.

Monitoring protocols and sampling methods:

- Continue to follow the monitoring protocol for continuous analysers including maintenance, calibration, and data collection and quality review.
- Continue to follow the monitoring protocol for passive samplers including deployment site evaluation, calibration based on continuous monitors, and quality review.

How and when monitoring data will be evaluated:

- Continuous and passive sampling SO_2 monitoring data will be evaluated for quality and reported annually.
- Compare CALPUFF predictions of SO_2 (2016-2018 results from the 2019 Comprehensive Review) to continuous SO_2 monitoring data and general spatial coherence with passive SO_2 sampling data.

[5] A holistic report that combines SO_2, $PM_{2.5}$, PM_{10}, HF and PAHs ambient air quality monitoring is anticipated to be completed in 2021.

2.3.2 Atmospheric S (wet and dry) deposition

Sampling locations:

- Continue wet deposition at Lakelse Lake; review the value of the Haul Road wet deposition monitoring with B.C. ENV to determine if the monitoring should be discontinued or relocated.
- Include continuous SO_2 at Lakelse Lake in order to estimate dry S deposition.
- Continue to collect meteorological data at existing stations to estimate dry S deposition.

Sampling timing, frequency and duration:

- Continue monitoring at one NADP station providing data to evaluate sulphur, base cation, and chloride deposition in 2025.
- Precipitation chemistry samples will continue to be collected on a weekly duration from the National Atmospheric Deposition Program protocol.

Monitoring protocols and sampling methods:

- Precipitation chemistry monitoring will be carried out by the NADP following standard NADP network protocols for sample collection, handling and analysis (http://nadp.sws.uiuc.edu). The analysis of precipitation samples will include sulphur (S), nitrate (NO_3^-), ammonium (NH_4^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^+), and sodium (Na^+); as well as chloride (Cl^-). Rainfall volume is measured daily by automated (digital) rain gauge collector.

How and when monitoring data will be evaluated:

- Wet and dry deposition will be reported annually.
- Precipitation chemistry data will be regularly evaluated by the NADP for quality, and reported annually.
- CALPUFF wet deposition predictions will be compared with NADP measurements at Lakelse Lake annually.

2.3.3 Additional studies

2.3.3.1 Ambient Air Network Rationalization

- The Phase 2 SO_2 monitoring network optimization effort (including addressing comments from ENV and the community) is expected to conclude by August 2021.

2.3.3.2 Special monitoring of deposition

- Include ion-exchange resins monitoring of deposition at sites of interest for plant biodiversity program or permanent soil plots if necessary.

2.4 Summary of Atmospheric Pathways Activities Planned for 2019-2025

The schedule is for planned activities is provided in Table 4, and may be subject to change.

Table 4. Schedule of work on the Atmospheric Pathways line of evidence planned under Phase III.

Topic	2019	2020	2021	2022	2023	2024	2025
Atmospheric SO_2 Concentrations – Continuous Analysers	Maintain existing 5 continuous SO_2 analysers.	Maintain existing 6 continuous SO_2 analysers	Maintain existing 6 continuous SO_2 analysers	Maintain existing 6 continuous SO_2 analysers	Update (as applicable) continuous SO_2 analyzers as determined from phase 2 network optimization	Update (as applicable) continuous SO_2 analyzers as determined from phase 2 network optimization Maintain continuous SO_2 analysers as determined from phase 2 network optimization	Maintain continuous SO_2 analysers as determined from phase 2 network optimization
Atmospheric SO_2 Concentrations –Passive Diffusive SO_2 Monitoring	Continue spring-autumn passive monitoring program in plume path network (aka Valley network)	Continue spring-autumn passive monitoring program in plume path network (aka Valley network)	Continue spring-autumn passive monitoring program in plume path network (aka Valley network)	Continue spring-autumn passive monitoring program in plume path network (aka Valley network)	Continue spring-autumn passive monitoring program in plume path network (aka Valley network)	Evaluate whether 2024 passive sampling data are needed If yes, continue spring-autumn passive monitoring program in plume path network (aka Valley network)	Evaluate whether 2025 passive sampling data are needed If yes, continue spring-autumn passive monitoring program in plume path network (aka Valley network)
Wet S Deposition, Precipitation Chemistry (Base Cations, Chloride)	Maintain 2 rain chemistry stations (Haul Road and Lakelse Lake	Maintain 2 rain chemistry stations (Haul Road and Lakelse Lake)	Maintain 2 rain chemistry stations (Haul Road and Lakelse Lake)	Maintain 2 rain chemistry stations (Haul Road and Lakelse Lake)	Maintain 2 rain chemistry stations (Haul Road and Lakelse Lake) Review value of continuing wet deposition monitoring at the Haul Road	Pending a decision on the Haul Road station, maintain 2 rain chemistry stations (Haul Road and Lakelse Lake)	Pending a decision on the Haul Road station, maintain 2 rain chemistry stations (Haul Road and Lakelse Lake)
Dry S Deposition	Continue to estimate dry deposition at both Haul Road and Lakelse Lake stations	Continue to estimate dry deposition at both Haul Road and Lakelse Lake stations	Continue to estimate dry deposition at both Haul Road and Lakelse Lake stations	Continue to estimate dry deposition at Lakelse Lake station	Continue to estimate dry deposition at Lakelse Lake station	Continue to estimate dry deposition at Lakelse Lake station	Continue to estimate dry deposition at Lakelse Lake station
Reporting	Annual reporting	Annual reporting	Annual reporting	Annual reporting	Annual reporting	Annual reporting	Annual reporting

3 Human Health

Sections 3.1 to 3.3 of the SO_2 EEM program were amended by the 2019 B.C. Environmental Appeals Board Consent Order. All parties of appeal numbers 2014-EMA-003, 2014-EMA-004, and 2014-EMA-005 agreed to amending the human health section of the SO_2 EEM program through a mediated settlement of the appeals.

3.1 Indicators and Thresholds

The "impact threshold criteria" under clause 4.2.5 of the P2-00001 Multimedia Permit for Human Health shall be the Human Health Key Performance Indicator ("KPI") as defined by the following air quality standards:

> Until January 1, 2020, the Human Health KPI is the 1-hour Interim Provincial Ambient Air Quality Objective for SO_2. From January 1, 2020 onwards, the Human Health KPI is the 1-hour Provincial Ambient Air Quality Standard for SO_2.

3.2 Methods

The following ambient air quality monitoring stations will be used to assess attainment of the Human Health KPI: Riverlodge, Whitesail, and Kitamaat Village. [6]

3.2.1 Further monitoring stations at Service Centre

An ambient air quality monitoring station will be established by October 1, 2019 at or in close proximity to the Service Centre, subject to Ministry siting requirements and property access, and will collect SO_2 and meteorological data (the "Service Centre Station").[7]

The data collected by the Service Centre Station will be made available to the public and will be considered by the Director as part of a decision under Section 3.2.1.1.

The data collected by the Service Centre Station will not be used for determining attainment of the Human Health KPI under this permit before such a decision is made under Section 3.2.1.1.

3.2.1.1 Decision on designating the Service Centre Station to be an attainment station

Once sufficient data and information has been collected by the Service Centre Station, the Director will make a decision (as defined in section 16 of the *Environmental Management Act*) and provide reasons to the public and any potentially affected party, on whether to amend Section 3.2 so that the Service Centre Station will be used to assess attainment of the Human Health KPI, or another ambient air quality standard as determined by the Director.

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[6] Attainment of the SO_2 Human Health KPI is assessed for each of the Riverlodge, Whitesail and Kitamaat Village stations.
[7] Service Centre's data reporting started on May 12th, 2020.

In making this decision, the Director must consider: the *Environmental Management Act* and associated regulations; relevant Ministry policies; the applicable air quality standards, including the Provincial Ambient Air Quality guidelines; and relevant data and information. The Director may receive information from a variety of interested parties.

The Director shall make this decision no later than 24 months from the day that the Service Centre Station is established.

If the Director decides that Section 3.2 shall be amended to include the Service Centre Station, the Director may consider data that the Service Centre Station has gathered prior to the date of that decision in making any subsequent decision on whether there has been non-attainment.

3.3 Steps in the Event of Non-attainment of the Human Health KPI

Section 3.3 overrides Chapters 7 and 8 of the EEM Plan with respect to non-attainment of the Human Health KPI.

- If potential non-attainment of the Human Health KPI is identified, the Director will review available information and data with respect to the non-attainment as well as consider exceptional events, in order to confirm the non-attainment. Meteorological conditions are not an acceptable justification for non-attainment.
- If the Director determines that there is non-attainment of the Human Health KPI, the Permittee shall take action to bring the Human Health KPI into attainment by implementing mitigation measures to reduce SO_2 emissions.
- Within 3 months of notification by the Director for the non-attainment of the Human Health KPI, the Permittee shall submit a report to the Director outlining a mitigation action plan to reduce SO_2 emissions that will bring the Human Health KPI into attainment. This report shall include an implementation timeline not to exceed one year.
- If the Human Health KPI is not brought into attainment by the following year, the maximum allowable SO_2 emissions set out in clause 4.2.2 of the P2-00001 Multimedia Permit will be reduced by an amount the Director deems needed to bring the Human Health KPI into attainment. If there are other permitted emitters of SO_2 emissions authorized under the Environmental Management Act and located within the Kitimat airshed, the amount of SO_2 emissions reduction required under this clause shall be proportional to the percentage of the Permittee's permitted SO_2 emission limit as compared to the total SO_2 emission limit of all such permitted emitters of SO_2.
- The Director will consider the Permittee's proposed mitigation action plan schedule to determine when the reduced SO_2 emission limit will come into force and effect.
- The total SO_2 permit reduction for the Permittee under this clause will not exceed 15 Mg/day.
- The mitigation action plan will include public education and recommendations for limiting health risks. Health communications and recommendations will be developed in consultation with the B.C. Northern Health Authority.

3.3.1 Exceptional events

The Director may consider "exceptional events" in determining whether there is non-attainment of the Human Health KPI, to account for events that are outside the control of Rio Tinto and are time bound. Examples of exceptional events include, but are not limited to:

- Fire within the community that may emit SO_2;
- emergency conditions at the facilities within the Kitimat airshed (e.g., Rio Tinto Smelter upset conditions or LNG Canada emergency flare);
- vandalism or corruption of data from other point sources such as vehicle emissions in close proximity to the ambient air monitoring station; and
- temporary global events that impact SO_2 levels such as a volcano eruption.

Examples that would NOT be considered an exceptional event include, but are not limited to:

- inputs to smelting activities such as high sulphur coke;
- ongoing global SO_2 influences that are not temporary, such as industrial emissions;
- scheduled bypass of works for maintenance at facilities in the Kitimat airshed; and
- meteorological conditions.

3.4 British Columbia SO_2 Air Quality Guideline

British Columbia has adopted the Canadian Ambient Air Quality Standards (referred to by the acronym CAAQS) as the provincial air quality standard for SO_2. The CAAQS constitute a set of pollutant-specific standards that place limits on and establish goals for the levels of pollutants in the air. The CAAQS values for SO_2 were announced in October 2016 . They establish a specific SO_2 concentration limit (70 ppb) starting in 2020, and a lower limit starting in 2025 (65 ppb). A specific statistic of the observed air pollutant levels is employed to compare to the limit values ("The three-year average of the annual 99th percentile of the SO_2 daily-maximum of 1-hour-averaged concentrations."). In 2017 B.C. ENV inserted the provincial air quality objective into the SO_2 EEM program as the health KPI (Table 5). This included the interim SO_2 air quality guideline that was effective from 2017 to 2019 and the SO_2 CAAQS which are effective in 2020.

Table 5. KPI for Human Health.

Exposure Year	KPI Threshold	KPI Percentile	KPI Averaging Time	KPI
2019	75 ppb	98^{th}	3 years	The average of the 1-hour daily maximum on the 8^{th} worst day in each of 2017, 2018, 2019
CAAQS 2020-2024	70 ppb	99^{th}	3 years	The average of the 1-hour daily maximum on the 4^{th} worst day in each of three consecutive years
CAAQS 2025+	65 ppb	99^{th}	3 years	The average of the 1-hour daily maximum on the 4^{th} worst day in each of three consecutive years

The Health KPI is calculated annually using validated SO_2 hourly data. The validation is done by B.C. ENV and validated data is typically available before March 31st of the following year.

Sampling locations:

- Riverlodge, Whitesail and Kitamaat Village continuous [SO_2] monitoring stations

Sampling timing, frequency and duration:

- Hourly averaged SO_2 concentrations are available at the B.C. Air Data Archive at https://envistaweb.env.gov.bc.ca/.

Monitoring protocols and sampling methods:

- Continuous SO_2 ambient air quality monitoring will be done according to The British Columbia Field Sampling Manual, Part B Air and Air Emission Testing, 2020.
- Calculations of the 1-hour Provincial Ambient Air Quality Standard for SO_2 will done consistent with the CCME, 2020 Guidance Document on Achievement Determination For Canadian Ambient Air Quality Standards for Sulphur Dioxide, once exceptional events as defined in Section 3.3.1 are accounted for.
- Some adjustments may be made to the calculation (i.e., what day constitutes the 99th percentile) if data are missing for certain parts of the year beyond tolerable limits.

How and when monitoring data will be evaluated:

- Data for a given year are validated by June 1st of the following year.
- Calculation of the KPI will be done annually after Rio Tinto has been notified by ENV that the SO_2 hourly data have been validated ENV.

3.5 Additional Activities

- <u>Understanding air quality objectives for health protection</u>
- To increase knowledge on air quality objectives and how air quality objectives are set for health protection, either an air quality health expert will be retained to present to the KPAC or an external organization will be co-sponsored to provide a session on air quality and health.

3.6 Summary of Human Health Activities Planned for 2019-2025

The schedule is for planned activities is provided in Table 6, and may be subject to change.

Table 6. Schedule of work on the Human Health line of evidence planned under Phase III.

Topic	2019	2020	2021	2022	2023	2024	2025
Reporting	Annual reporting of KPI for the 2018 year, after data validation (normally by March 31)	Annual reporting of KPI for the 2019 year, after data validation (normally by March 31)	Annual reporting of KPI for the 2020 year, after data validation (normally by March 31)	Annual reporting of KPI for the 2021 year, after data validation (normally by March 31)	Annual reporting of KPI for the 2022 year, after data validation (normally by March 31)	Annual reporting of KPI for the 2023 year, after data validation (normally by March 31)	Annual reporting of KPI for the 2024 year, after data validation (normally by March 31)
Additional activities					Air quality objectives and health protection presentation		

4 Vegetation

The Vegetation line of evidence has been combined with the Terrestrial Ecosystems line of evidence. Please refer to Section 5, Terrestrial Ecosystems, for Vegetation indicators and methods.

5 Terrestrial Ecosystems

5.1 Introduction

We continue to monitor components of Terrestrial Ecosystems as they are known to respond to S deposition. The Terrestrial Ecosystems line of evidence integrates the former Terrestrial Ecosystems (Soils) and Vegetation receptors (Figure 6). Based on the results of the 2019 Comprehensive Review, we are shifting our emphasis to detecting mid-to-long term changes in vascular plant biodiversity as an indicator of changes in soil chemistry as affected by SO_2 emissions from the smelter and subsequent deposition. We will also evaluate changes in the biodiversity of cyanolichen species as an indicator of effects of SO_2 emissions and potential acidification of cyanolichen substrate. The addition of these plant and cyanolichen biodiversity metrics (including species richness and abundance) provides informative indicators of potential SO_2 effects by allowing the detection of shifts in community structure and composition based on species-specific responses to S deposition. We retain the periodic visual inspection in order to detect short-term changes in plant health or symptoms due to direct exposure to SO_2. The Terrestrial Ecosystems (Soils) KPIs are retained. We present an evidentiary framework based on pathways of exposure and potential resulting effects.

Figure 6 illustrates the Terrestrial Ecosystems line of evidence showing the pathways for direct effects on soils, vegetation, and cyanolichens as well as soil mediated effects on plant and cyanolichen biodiversity and health.

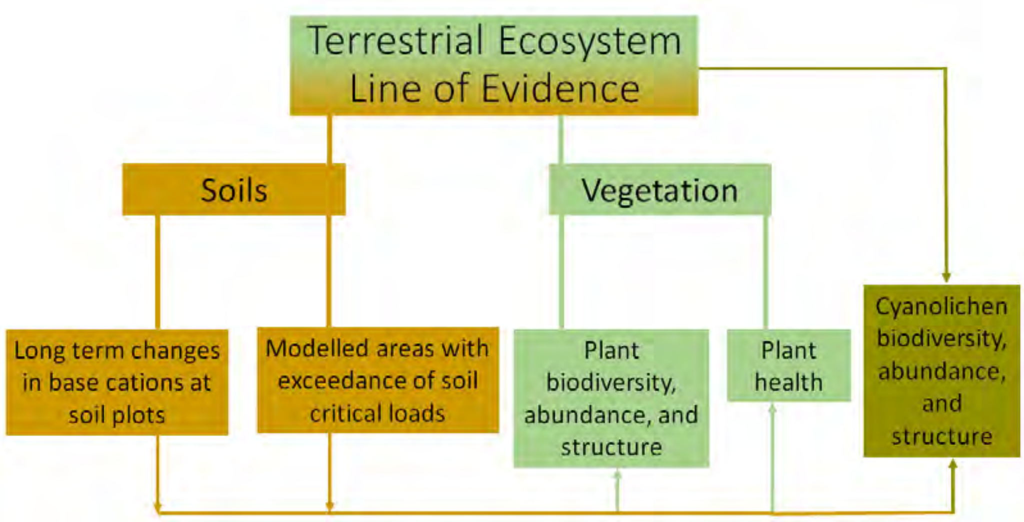

Figure 6. Effects pathways for soils and vegetation within the new Terrestrial Ecosystems line of evidence.

5.2 Indicators and Thresholds

The two soils KPI have been retained: exceedance of critical loads of acidity for forest soils from modelled S deposition, and observed change in soil base cations over time. The KPIs, their thresholds, informative indicators and other indicators to be jointly considered are presented in Table 7 and Table 8. Methods for calculating these indicators are provided in Section 5.3. The phase III comprehensive review will assess if a KPI can be established for the plant biodiversity component of the terrestrial ecosystems line of evidence.

Table 7. KPIs for Terrestrial Ecosystems.

Key performance indicators	Threshold for increased monitoring	Threshold for receptor-based mitigation	Threshold for facility-based mitigation	Indicators to be jointly considered
Critical load (CL)[8] exceedance from modelled atmospheric S deposition (estimated only if S deposition changes) **This KPI will not be assessed for attainment during Phase III.**	Modelled CL exceedance is > 5% of semi-natural upland forest soils in the study area[9] Action: an extended soil survey will be carried out to provide data for a dynamic modelling assessment of the timeline of the areal exceedance (i.e., the time for soils to reach the critical threshold)	Dynamic model assessment[10]: Modelled CL exceedance is >5% of semi-natural upland forest soils in the study area and dynamic modelling estimates the time for soils to reach the critical thresholds is less than 200 years (based on projected change in base cations) Action: Pilot application of lime/wood ash, to reduce soil acidity and increase base cation pools to pre-KMP levels, subject to B.C. ENV approval[11]	Dynamic model assessment: Modelled CL exceedance is >5% of semi-natural upland forest soils in the study area and dynamic modelling estimates the time for soils to reach the critical thresholds is less than 100 years (based on projected change in base cations) Action: reduction in SO_2 emissions	• Magnitude of exchangeable cation (Ca, Mg, K, Na) • Atmospheric S deposition

[8] Critical load exceedance mapping will be re-run in the Comprehensive Review of the Phase III Plan. However, if significant changes are observed in cyanolichen and vascular plant biodiversity that are causally related to SO_4^{2-} deposition, then the critical load exceedance mapping would also be re-run.
[9] Exceedance > 5% of forested soils (broadleaf, coniferous, mixed wood and shrub cover types in Figure 6-3 of the Comprehensive Review Report) in the effects domain (the area delineated by modelled 7.5 kg SO_4/ha/year deposition isopleth).
[10] Dynamic modelling, if needed for either receptor-based or facility-based mitigation, would begin in 2026 (i.e., after Phase III).
[11] Section 5.3.7.3 describes the development of the pilot project scope.

Key performance indicators	Threshold for increased monitoring	Threshold for receptor-based mitigation	Threshold for facility-based mitigation	Indicators to be jointly considered
Long-term soil acidification (decrease[12] in base saturation) attributable to S deposition	For one or both plots: a 40% decrease in base saturation since plot establishment, causally related to SO_2 emissions Action[13]: re-sampling of control plot and sampling of tree base cation content to confirm decrease is causally related to SO_2 emissions; if causally related then extended soil survey will be carried out to provide data for a dynamic modelling assessment of the spatial significance of base cation loss	Dynamic model assessment[14]: A predicted 40% decrease in soil base saturation in > 1% (~20 km^2) of the area of semi-natural upland forest soils, based on dynamic modelling. Action: pilot application of lime/wood ash to reduce soil acidity and increase base cation pools to pre-KMP levels, subject to B.C. ENV approval	Dynamic model assessment: A predicted decrease in base saturation of ≥ 40% in > 5% (~100 km^2) of the area of semi-natural upland forest soils, based on dynamic modelling Action: reduction in SO_2 emissions	• Atmospheric S deposition • Magnitude of exchangeable soil cations (Ca, Mg, K, Na) • Magnitude of net increase in base cations (Ca, Mg, K) in trees

Table 8. Informative indicators for Terrestrial Ecosystems.

Informative indicators	Thresholds for increased monitoring or mitigation	Indicators to be jointly considered
Exchangeable acidity and base cations (Ca, Mg, K, Na)	Not applicable; supports calculation of long-term acidification	• Atmospheric S deposition and critical load (CL) exceedance • Long-term soil acidification (decrease in base saturation) • Time to depletion of exchangeable cation pools (Ca, Mg, K, Na)
Modelled S deposition[15]	Not applicable; supports calculation of CL exceedance	• Areal exceedance of critical load (CL)

[12] The baseline for comparison is base saturation in plots sampled and measured in 2015. The intent is to resample every 5 years, with the next sampling occurring in 2025.
[13] This would be done after Phase III, as plot sampling will occur in 2025, the last year of Phase III.
[14] Dynamic modelling, if needed for either receptor-based or facility-based mitigation, would begin in 2026 (i.e., after Phase III).
[15] There are no plans to revise modelled S deposition in Phase III.

Informative indicators	Thresholds for increased monitoring or mitigation	Indicators to be jointly considered
Net base cation uptake (Ca, Mg, K) in trees	Not applicable, supports dynamic modelling if KPI thresholds are exceeded	• Magnitude of change in exchangeable soil cation (Ca, Mg, K, Na)
Vegetation Health (including potential SO_2 Injury)	More than occasional symptoms[16] of SO_2 injury outside of Rio Tinto Kitimat properties, causally related to SO_2 emissions Appearance of symptoms on vegetation of soil acidification/aluminum toxicity in areas of predicted soil CL exceedance Action: assess ambient air data, meteorological data and B.C. Works SO_2 production data to find the potential causes; and increase visual inspection frequency to annual	• Atmospheric SO_2 concentration • Atmospheric S deposition (specifically, wet deposition)
Plant Biodiversity	If there is a biologically significant differential change, causally related to SO_2 emissions, relative to reference sites in vascular plant biodiversity in the low shrub and/or herb layer outside the Comprehensive Review -modelled 7.5 kg SO_4^{2-}/ha/year the following actions will be taken: visual assessment of plant health will be expanded to include all plant biodiversity monitoring plot sites; soils will be re-sampled at the sites where the biological change is significant to determine if soils at these sites are acidic enough to potentially be causing damage; plant root simulator probes (PRS Probes) will be deployed in conjunction with soil sampling to provide an indication of changes in soil water ion concentrations [e.g. SO_4^{2-}, Ca^{2+}, Al^{3+}] and; ion exchange resin columns will be installed at the plots to determine if S deposition is greater than expected.	• Atmospheric S deposition and critical load (CL) exceedance risk • Atmospheric SO_2 concentration • Atmospheric S deposition (specifically, wet deposition)

[16] Injury, causally related to SO_2 emissions, on two or more species at two or more plant biodiversity monitoring plot sites.

Informative indicators	Thresholds for increased monitoring or mitigation	Indicators to be jointly considered
Cyanolichen Biodiversity	If there is a biologically significant differential change, causally related to SO_2 emissions, in cyanolichen biodiversity outside the Comprehensive Review -modelled 7.5 kg SO_4^{2-}/ha/year the following actions will be taken: visual assessment of cyanolichen health will be expanded to include all plant biodiversity monitoring plot sites; soils will be re-sampled at the sites where the decrease is significant to determine if levels of acidity or acidity-related ions (i.e. Al^{+3}) have changed; plant root simulator probes (PRS Probes) will be deployed in conjunction with soil sampling to provide an indication of changes in soil water ion concentrations [e.g. SO_4^{2-}, Ca^{2+}, Al^{3+}] and; ion exchange resin columns will be installed at the plots to determine if S deposition is greater than expected.	• Atmospheric S deposition and critical load (CL) exceedance risk • Atmospheric SO_2 concentration • Atmospheric S deposition (specifically, wet deposition)

5.3 Methods

Table 9 and Table 10 provide an overview of the methods for calculating the KPIs and informative indicators, respectively. More information on the methods is provided in the subsections below these two tables.

Table 9. Overview of methods for calculating the KPIs for Terrestrial Ecosystems.

Key performance indicators	Method overview and frequency of attainment assessment
Critical load (CL) exceedance risk from modelled atmospheric S deposition	Critical loads and exceedance were completed during the 2019 Comprehensive Review. CL exceedance risk will only be recalculated if modelled S deposition changes.[17] For more information, please refer to Section 5.3.1.
Long-term soil acidification (decrease in base saturation)	Soil sampling at long-term soil plots to assess the rate of change in base saturation following identical protocols as outlined in the 2019 Comprehensive Review. Soils will be sampled every 5 years along with tree diameter at breast height (DBH); the next sampling will be in 2025. Attainment will be assessed at

[17] S deposition will not be modelled during Phase III; therefore, CL exceedance will not be determined (revised) during Phase III.

Key performance indicators	Method overview and frequency of attainment assessment
attributable to S deposition	each sampling period. If soil acidification [40% decrease in base saturation] occurs, dynamic modelling will be undertaken in the next phase of the SO_2 EEM program to assess regional base cation losses. For more information, please refer to Section 5.3.2.

Table 10. Overview of methods for calculating the informative indicators for Terrestrial Ecosystems.

Informative indicators	Method overview
Exchangeable acidity and base cations (Ca, Mg, K, Na)	Measured from soil samples in long-term soil plots (and for regional soils if >5% exceedance in study area) following identical protocols to those described in the 2019 Comprehensive Review. For more information, please refer to Section 5.3.3.
Net base cation uptake (Ca, Mg, K) by trees	Measured from trees in long-term soil plots following well established field and laboratory techniques.
Vegetation Health (including potential SO_2 Injury)	Inspection at the 33 cyanolichen and vascular plant biodiversity plots. For more information, please refer to Section 5.3.4.
Plant biodiversity	A total of 33 sites will be monitored on a three-year rotating panel. These sites will be the same locations as the cyanolichen biodiversity and vegetation health plots. For more information, please refer to Section 5.3.5.
Cyanolichen biodiversity	A total of 33 sites that meet the criteria used by ENV – many of which are previously established by ENV for cyanolichen monitoring – will be monitored. For more information, please refer to Section 5.3.6.

5.3.1 Critical load (CL) exceedance risk from modelled atmospheric S deposition – KPI

Critical load and area of exceedance was assessed during the 2019 Comprehensive Review. The assessment included revised soil mapping, updated determination of weather rates, revised model parameterisation and total S deposition. The threshold for critical loads KPI was not reached, i.e., the area of critical load exceedance was < 1%. The KPI will not be re-evaluated during Phase III.

5.3.2 Long-term soil acidification (decrease in base saturation) attributable to S deposition – KPI

Sampling locations:

- Near-field and far-field plots were established at Coho Flats and Lakelse Lake, respectively, during October–December 2015, and the control plot was established at Kemano during 2016. At each location, primary and secondary (backup) plots were established within forest stands dominated by western hemlock.

Sampling timing, frequency and duration:

- Soils and tree diameter at breast height (DBH) at the primary plots at Coho Flats and Lakelse Lake will be resampled during 2025 to assess changes in soil chemistry (e.g., base saturation) and tree volume since the initial sampling during 2015. The control plot is only resampled and analysed if changes in soil chemistry exceeding the KPI threshold for decreased monitoring is detected at the Coho Flats or Lakelse Lake plots.

Monitoring protocols and sampling methods:

- Each long-term soil plot is 32 m by 30 m in size and composed of twenty 8 m by 6 m sub-plots lettered A to T. Each sub-plot is further divided into twelve 2 m by 2 m sampling grids (numbered 1 to 12); one numbered grid will be randomly sampled (without replacement) from each lettered sub-plot.
- Soil will be sampled at three depths in the mineral soil: 0–5 cm, 5–15 cm, and 15–30 cm depths (yielding a total of 60 soil samples for each plot, i.e., three soil samples by depth within each of the 20 lettered sub-plots).
- Soils (fine fraction) will be analysed for organic matter content by loss on ignition (LOI), and exchangeable base cations and exchangeable acidity. Exchangeable base cations were measured using an ammonium acetate extraction and exchangeable acidity was measured using a potassium chloride extraction. Further details are provided in the 2019 Comprehensive Review.
- The diameter at breast height (DBH) of all trees >10 cm will be measured.

How and when monitoring data will be evaluated:

- The change (decrease) in base saturation (%) will be assessed between two sampling periods (accommodating the variability in soil chemistry during both sampling events). The analysis will use soil concentrations in the top 0–30 cm.
- The minimum detectable difference will be used to evaluate the potential of an early warning change in soil base saturation using a lower level of significance and / or lower power.
- The analysis will be carried out and reported under the next comprehensive end-of-cycle review.
- Forest biomass will be estimated using baseline tree data and data collected in 2025. Combined with tree nutrient concentrations, uptake of base cations by trees can be calculated.

5.3.3 Exchangeable acidity and base cations – Informative indicator

Next steps: if there are changes at either Coho Flats or Lakelese Lake, we will carry out additional sampling in 2026 (after Phase III):

- We will sample soils at the control plots to determine if the change is causally related to B.C. Works.
- If needed based on the results, we will estimate tree biomass to evaluate the role of nutrient uptake (which may affect the control plots also).
- If there is a causal relationship, we will proceed with dynamic modelling.

5.3.4 Vegetation health (including potential SO_2 injury) – Informative indicator

Inspection locations:

- Inspection sites will be the cyanolichen and vascular plant biodiversity measurement plots. Vegetation in the areas of predicted soil CL exceedance will be inspected if safely accessible.

Sampling timing, frequency and duration:

- The inspection will be conducted in a 3-year rotating panel with one-third of the sites inspected each year.

Monitoring protocols and sampling methods:

- During the site visit, a qualified professional in the plant sciences will assess vegetation for the presence of insects and plant pathogens, any symptoms of abiotic stress such as drought, flooding, physical disturbance (natural or human), or nutrient deficiencies, or injury due to SO_2 exposure. Cyanolichen thalli will be inspected and their health will be assessed. The site measurement/inspection schedule will be such that sites located around the valley are visited each year. That will assure that we will detect changes affecting the ecosystem if and where they occur.

How and when monitoring data will be evaluated:

- Each year visual inspection and assessment results will be reported along with the activities related to measuring biodiversity. Every third year there will be an end-of-cycle report that will summarize the state of the health of vegetation in the Kitimat Valley.

5.3.5 Plant biodiversity – informative indicator

Sampling locations:

- We intend to use the ENV-established cyanolichen monitoring sites if safely accessible. If not, or if the exact site cannot be located, we will establish sites nearby within stands that meet the criteria used by ENV (stands with no history of commercial logging and at least 100 years old). Locations will be characterised by stand age, modelled critical load of acidity, and CALPUFF-modelled SO_4^{2-} deposition from the 2019 Comprehensive Review.

Sampling timing, frequency and duration:

- Plots will be visited between June 1st and August 31st. We will implement a 3-year rotating panel design with one-third of the sites visited in any given year. A full measurement cycle will be completed after year 3, 6, 9, and so on.

Monitoring protocols and sampling methods:

- When crews arrive, the boundary of a 20m x 20m permanent plot will be marked using a stringline and flagging tape, which will be removed at completion of measurements. During the initial assessment, the crew will complete the following minimum Site Information (per FS1333 form, British Columbia Ministry of Forests and Range and British Columbia Ministry of Environment 2010):
    - project name and plot #
    - date
    - surveyors
    - plot location (i.e., description of how to get there)
    - UTM and elevation
    - BGC zone/subzone/variant
    - site series
    - soil moisture and nutrient regime
    - slope and aspect
    - surface shape and mesoslope position
    - exposure type and/or site disturbance (if applicable)
    - total % cover of each vascular plant species in the low shrub and herb layers at initial measurement and each subsequent remeasurement
    - total % cover for the tree, shrub, herb and moss layers (but not individual species in the tree, tall shrub, or moss layers) at initial measurement and each subsequent remeasurement
- Photographic documentation will include, at minimum, views from plot centre to the north, east, south, west, up (canopy) and down (forest floor).
- Linear transects will then be conducted along the boundary stringlines on the west and north perimeters of the plot. For each species in the low shrub and herb layers, the drip-line length will be measured along the string line, and the start and end of each occurrence along the line will be documented. For shrubs, a plumb bob will be used to accurately record species coverage. Percent cover, by species, will be estimated from these measurements.
- Additional information for plants in the low shrub and herb layers will be collected as follows:
    - plant species present in the plot); and
    - distribution, vigor, and phenology codes.
- The presence and abundance of invasive plant species will be recorded, irrespective of their vegetation layer.
- The presence of plant species of "special interest" (as identified in Table 1 of Laurence et al. 2020) will be recorded.
- The presence of species or ecosystems of concern (per B.C. Conservation Data Centre) will be recorded, irrespective of their vegetation layer.

- General comments will be recorded, if/as applicable, regarding the vegetation and ecosystem as a whole both in and near the plot, including any disturbances or potential sources of change or impact that may be noted.
- At the time of first measurement, soil samples will be taken to determine soil pH, exchangeable cations, and exchangeable acidity. Samples will be taken in the upper 10 cm of mineral soil.
- During subsequent assessments, Site Information will be confirmed or modified, as required. During each remeasurement, we will record the following minimum information:
    - current presence and % cover of all vascular plants in the low shrub and herb layers in the 20m x 20m permanent plot;
    - current total % cover for the tree, shrub, herb and moss layers;
    - photographic documentation;
    - remeasurement of the west and north boundary linear transects for low shrub and herb layer % cover;
    - "additional information" for plants in the low shrub and herb layers (described above);
    - occurrence of plant species of special interest (e.g. cultural use; see Table 1 in Laurence et al. 2020);
    - presence and abundance of invasive plant species;
    - presence of species or ecosystems of concern within the plot (per current status provided by the B.C. Conservation Data Centre); and
- any applicable comments about the plot or activities/changes (etc.) in the immediate vicinity which may affect the plot.
- Additional details are provided in "A Plan to Monitor Components of Cyanolichen and Vascular Plant Communities in the Vicinity of Rio Tinto B.C. Works as a Component of the SO_2 Environmental Effects Monitoring Program" (Laurence et al., 2020), which is presented as Appendix D.

How and when monitoring data will be evaluated:

- Starting at the end of the first remeasurement (year 4 from program initiation), slopes of trend lines can be calculated and compared between low (reference sites), moderate, and high deposition sites. As additional remeasurement cycles are completed, our estimation of the slope and the power to detect change improves. At the end of each 3-year measurement cycle, an analysis comparing trends at moderate and high deposition sites to those at low (reference) deposition sites.
- Field monitoring methods will be reviewed after completion of a monitoring cycle. Recommendations (if any) for improving the methodology will be brought forward for updating the field method manual and work plan for the next monitoring cycle.
- For the soils samples taken at the time of first biodiversity plot measurement, laboratory methods and variables measured will be the same as those described in ESSA Technologies et al. (2020). If necessary to establish causality, soils will be re-sampled and analyzed and PRS Probes will be deployed to indicate changes in soil water ion concentrations (Watmough et al. 2013). If necessary, to establish causality, plant tissues will be analyzed to measure S, base cations, and aluminum.
- The effectiveness of the plant biodiversity monitoring program will be assessed in the end of cycle 2026 comprehensive review and completion of the 2nd monitoring cycle

(year 6). Statistical analysis of the monitoring data will be conducted to assess the effectiveness of the program and to identify adjustments to the monitoring program design.

5.3.6 Cyanolichen biodiversity – informative indicator

Sampling locations:

- We intend to use the ENV-established cyanolichen monitoring sites if safely accessible. If not, or if the exact site cannot be located, we will establish sites nearby within stands that meet the criteria used by ENV (stands with no history of commercial logging and at least 100 years old). Locations will be characterised by stand age, modelled critical load of acidity, and CALPUFF-modelled SO_4^{2-} deposition from the 2019 Comprehensive Review.

Sampling timing, frequency and duration:

- Plots will be visited between June 1st and August 31st. We will implement a 3-year rotating panel design with one-third of the sites visited in any given year. A full measurement cycle will be completed after year 3, 6, 9, and so on.

Monitoring protocols and sampling methods:

- We will conduct a 1-hour timed search for cyanolichen species and record their relative abundance (0-None; 1-Rare: 1-2 colonies per plot; 2-Occasional: 3-5 colonies per plot; 3-Common: 6 colonies to 20% cover of host trees within plot; 4-Very Common: 21-51% cover of host trees within plot; 5-Abundant: 51+% cover of host trees within plot) these lichen abundance categories were adapted in consultation with Patrick Williston (B.C. ENV) from the B.C. standards for rating arboreal lichen loading (British Columbia Ministry of Forests and Range and British Columbia Ministry of Environment 2010). The timed search will be conducted within the established 20m x 20m plot; however, if limited cyanolichen substrate is available within the established plot and the search area is exhausted prior to the one-hour time limit, the search will continue immediately outside the plot boundaries until the time limit is achieved (surveyors will record the fact that the search extended beyond plot boundaries, and results will reflect whether inside or outside the plot).
- Ion exchange resin columns (above ground) may be used at selected locations to quantify actual S deposition depending on the risk of soil acidification.
- If necessary, to establish causality, soils will be re-sampled and analyzed and PRS Probes will be deployed to indicate changes in soil water ion concentrations (Watmough et al. 2013).
- If necessary, to establish causality, cyanolichen tissues will be analyzed to measure SO_4^{2-}, base cations, and aluminum.

How and when monitoring data will be evaluated:

- Starting at the end of the first remeasurement (year 4 after program initiation), slopes of trend lines can be calculated and compared between low (reference sites), moderate, and high deposition sites. As additional remeasurement cycles are completed, our estimation of the slope and the power to detect change improves. At the end of each 3-

year measurement cycle, an analysis comparing trends at moderate and high deposition sites to those at low (reference) deposition sites.

- Field monitoring methods will be reviewed after completion of a monitoring cycle. Recommendations (if any) for improving the methodology will be brought forward for updating the field method manual and work plan for the next monitoring cycle.
- The effectiveness of the cycanolichen biodiversity monitoring program will be assessed in the end of cycle 2026 comprehensive review and completion of the 2^{nd} monitoring cycle (year 6). Statistical analysis of the monitoring data will be conducted to assess the effectiveness of the program and to identify adjustments to the monitoring program design.

5.3.7 Additional studies

5.3.7.1 Survey of wetland geochemistry

- A survey of wetlands will be carried out to determine their acid-base status, i.e., are they acid sensitive? To do this we will measure base cations, pH, and organic matter in wetlands that vary in distance from the smelter. These data will be used to verify a number of assumptions regarding wetlands included in the Comprehensive Review , The steps in this study are:
    - Review of GIS and Google earth data to locate wetland coverage
    - Select accessible sites along a gradient with distance from the smelter
    - Collect surface water (if water present at site) / wetland soil from each site during 2023 / 2024
    - Analyse samples for water chemistry and soil chemistry
    - Also potentially analyse for sulphate adsorption changes with climatic conditions

5.3.7.2 Assessment of aluminum solubility

- Acidification impacts are primarily caused by elevated concentrations of aluminium. Under the Comprehensive Review, aluminium solubility was modelled using a static relationship but the relationship can change depending on soil type. The objective of this study is to conduct experiments on Kitimat soils to better understand Al solubility and hence risk of toxic concentrations (this parameter is used within the determination of CL). The steps in this study are:
    - Review potential soil types using data from existing surveys (STAR) and surface geology maps
    - Select sites to cover a range of soil types
    - Where possible use existing archived soils from STAR and long-term plots
    - Where needed, supplement soils with new sites sampled during 2023 / 2024
    - Run laboratory experiments to extract base cations, aluminium, free aluminium, and evaluate relation between organic matter, aluminium and pH in soils

5.3.7.3 Pilot project scope for receptor-based mitigation

The scope of a pilot project to demonstrate the feasibility of receptor-based mitigation will be developed during SO_2 EEM Phase III. The purpose of the pilot project is to ensure that there is a receptor-based mitigation solution that can be feasibly implemented should the aquatics KPI exceed the threshold for receptor-based mitigation. The scope of the pilot project will include providing a review on the state of knowledge on soil liming and or other soil amendments to buffer soil acidification, different methods and technologies that have been successfully applied to treat acidified soils. Methods and technologies that are identified as potentially feasible for a pilot project will be developed into a scope of work for a pilot project that will ensure there is a mitigation method that can be successfully applied. If a solution is found that is sufficiently proven for mitigating lake acidification, the project scope will be written as the pilot project.

5.4 Summary of Terrestrial Ecosystems Activities Planned for 2019-2025

The schedule is for planned activities is provided in Table 11, and may be subject to change. The critical loads KPI will not be assessed for attainment in Phase III.

Table 11. Schedule of work on the Terrestrial Ecosystems line of evidence planned under Phase III.

Topic	2019	2020	2021	2022	2023	2024	2025
Long-term soil acidification							Sampling of primary plot at Coho Flats and Lakelse Lake[18]
Wetland geochemistry				Establish project objectives	Field survey of wetland geochemistry	Field survey of wetland geochemistry	Study results reporting
Aluminium solubility				Establish project objectives	Laboratory analysis of archived soil samples	Laboratory analysis of archived soil samples	Study results reporting
Visual inspection and assessment of plant health		Program Design	Implement first 1/3 of the plots	Implement second 1/3 of the plots	Implement third 1/3 of the plots	Re-inspect first 1/3 of the plots	Re-inspect second 1/3 of the plots
Vascular plant biodiversity		Program Design	Implement first 1/3 of the plots	Implement second 1/3 of the plots	Implement third 1/3 of the plots	Re-measure first 1/3 of the plots First calculation of slopes for the first 1/3 of the plots First comparisons of slopes for the first 1/3 of the plots First End-of-3-Year-Rotation Report	Re-measure second 1/3 of the plots First calculation of slopes for the second 1/3 of the plots First comparisons of slopes for the second 1/3 of the plots
Cyanolichen biodiversity		Program Design	Implement first 1/3 of the plots	Implement second 1/3 of the plots	Implement third 1/3 of the plots	Re-measure first 1/3 of the plots First calculation of slopes for the first 1/3 of the plots First comparisons of slopes for the first 1/3 of the plots First End-of-3-Year-Rotation Report	Re-measure second 1/3 of the plots First calculation of slopes for the second 1/3 of the plots First comparisons of slopes for the second 1/3 of the plots
S content in hemlock needles and vegetation health monitoring	Sampling from mid-August to mid-September	Sampling from mid-August to mid-September					
Reporting	Annual reporting	Annual reporting	Annual reporting	Annual reporting	Annual reporting	Annual reporting and first End-of-3-Year-Rotation Report	Annual reporting

[18] If long-term plot sampling in 2025 triggers dynamic modelling, that task will occur in 2026.

6 Aquatic Ecosystems

6.1 Introduction

Biologically relevant water chemistry provides the best early warnings of changes in lake chemistry that could be damaging to aquatic biota *in advance* of potential damage to aquatic biota and is therefore a *proactive* indicator. The Bayesian statistical methods and simple evidentiary framework described in the 2019 Comprehensive Review report provides an approach to detect if any lakes are experiencing an increase in sulphate concentrations due to the smelter, and determining if any changes in CBANC or pH are likely to exceed thresholds for biological effects.

6.1.1 EEM Lakes

The aquatic ecosystems component of the EEM Program includes 11 lakes – 7 sensitive lakes and 1 less sensitive lake, as identified in the STAR, plus 3 control lakes added in 2015 (with 2013 baseline data from the KAA) (Table 12). The EEM Program Plan for 2013-2018 included a structured, multi-factor approach for assigning relative ratings to each of the sensitive lakes, which informs how the lakes are used for evaluation of the different tiers of thresholds within the KPI. The 7 sensitive lakes (LAK006, LAK012, LAK022, LAK023, LAK028, LAK042, LAK044) are used in the assessment of KPI attainment.

Table 12. Lakes in the EEM Program.

Lake ID	Name	Acid-sensitive	EEM group	Lake Rating*	**Attainment Lakes** (i.e., used in KPI assessment)	
					Used in assessment of KPI thresholds for **increased monitoring** and **receptor-based mitigation**	Used in assessment of KPI threshold for **facility-based mitigation**
LAK006	End Lake	Yes	Sensitive	High	Yes	Yes
LAK012	Little End Lake	Yes	Sensitive	High	Yes	Yes
LAK016		Moderately	Less Sensitive	n/a	No	No
LAK022		Yes	Sensitive	Medium	Yes	Yes
LAK023	West Lake	Yes	Sensitive	Medium	Yes	Yes
LAK028		Yes	Sensitive	Low	Yes	No
LAK042		Yes	Sensitive	Low	Yes	No
LAK044		Yes	Sensitive	Low	Yes	No
DCAS14A	Alistair Lake	Yes	Control	n/a	No	No
NC184		Yes	Control	n/a	No	No
NC194		Yes	Control	n/a	No	No

* Lake ratings were developed in the EEM Program Plan for 2013-2018. Vulnerable lakes (i.e., the sensitive lakes) were assigned a relative ranking on each of seven criteria and an aggregate rating (see ESSA et al. 2014, Appendix D for full details on the methods and results). The criteria included: 1) accessibility and non-recreational use; 2) recreational values; 3) lake surface area; 4) sustainable fish species present; 5) importance for anadromous salmon habitat; 6) influence of DOC and organic acids; and 7) lake volume and residence time.

6.2 Indicators and Thresholds

6.2.1 ANC KPI and pH informative indicator

The water chemistry KPI is based on ANC. The pH KPI applied during the first phase of the EEM Program is an informative indicator. This was the most significant modification to the Aquatic Ecosystems line of evidence from the 2013-2018 EEM Program. The 2019 Comprehensive Review recommended moving to an ANC KPI because ANC better fulfills the criteria for a KPI and therefore this change strengthens the EEM. Specifically, the new ANC KPI utilizes charge balance ANC (CBANC) as the indicator metric. In summary, the rationale for the shift to CBANC are: CBANC is the most common metric applied in acidification studies, it is easily measured and calculated; the EEM Program has a continuous record of CBANC; it is not affected by changes in DOC; and we have lake-specific thresholds for changes in CBANC. (See Appendix A for further details on the rationale).

6.2.2 Two-threshold structure for acidification indicators

Both of the acidification indications (ANC and pH) use a two-threshold structure (Table 13). This structure includes two components: a *level of protection* to prevent acidification of lakes that are currently not at risk of aquatic impacts (i.e., an absolute threshold); and a *change limit* which prevents further acidification (for lakes already below the level of protection due to natural organic acids or past acidic deposition) (i.e., a relative threshold).

Table 13. Structure of thresholds for acidification indicators. See Table 17 for more information.

	ANC (KPI)[19]	pH (informative indicator)
Level of Protection (i.e., absolute threshold)	Decrease† below 20 μeq/L	Decrease† below pH=6.0
Change Limit (i.e., relative threshold)	Decrease† of greater than lake-specific thresholds (from titration analyses; see Table 14)	Decrease† of ≥ 0.30 pH units
Exceedance	**BOTH** thresholds exceeded	**BOTH** thresholds exceeded

† Change must be causally related to SO_2 emissions

6.2.3 Lake-specific thresholds for the ANC change limit

The lake-specific thresholds for the ANC change limit are the same as those applied during the 2019 Comprehensive Review. These thresholds are shown in Table 14. We developed these thresholds during the previous phase of the EEM Program, using the titration data from Trent University from the derivation of Gran ANC values, which provide measurements of the incremental change in pH in response to sample titration with sulphuric acid. For each lake, the thresholds represent the median estimate (over many samples across years) of the change in ANC that is equivalent to a decline in pH of 0.3 pH units from the 2012 baseline pH.

[19] Acid neutralizing capacity (ANC) will be used in as the key performance indicator to determine if a lake has acidified. pH will be used as supporting information for understanding changes in the ANC KPI.

Table 14. Lake-specific ANC thresholds for change limits. Values calculated from analyses of the titration data, showing the change in CBANC or Gran ANC 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	Median [mean, SE] of the lake-specific ANC threshold (μeq/L, applies to both CBANC and Gran ANC)	# titrations used to estimate medians, means, and SE
LAK006	Sensitive Lake	-10.8 [-10.8, 0.3]	19
LAK012	Sensitive Lake	-16.3 [-18.2, 1.5]	23
LAK022	Sensitive Lake	-11.5 [-11.4, 0.2]	4
LAK023	Sensitive Lake	-10.5 [-10.2, 0.3]	22
LAK028	Sensitive Lake	-13.4 [-13.9, 0.7]	13
LAK042	Sensitive Lake	-24.4 [-25.4, 1.1]	10
LAK044	Sensitive Lake	-6.2 [-6.3, 0.2]	11
LAK016	Less Sensitive Lake	-25.6 [-26.2, 1.7]	4
DCAS14A	Control Lake	-21.7 [-21.7, 3.6]	2
NC184	Control Lake	-10.8 [-10.8, n.a.]	1
NC194	Control Lake	n.a.	0

6.2.4 Key Performance Indicator

The evaluation of the KPI is based on number and rating of lakes that show an ANC exceedance under the two-threshold structure. The KPI thresholds and response actions are defined in Table 15. The lake ratings, as developed in the 2013-2018 EEM Program Plan (ESSA et al. 2014), are shown in Table 12. Section 6.3.1 provides details on the methods by which attainment of the KPI will be assessed each year.

Table 15. KPI for Aquatic Ecosystems.

Key performance indicator	Threshold for increased monitoring	Threshold for receptor-based mitigation	Threshold for facility-based mitigation	Indicators to be jointly considered
Water chemistry – acidification (CBANC)	Observed decrease in CBANC in one of the acid sensitive lakes (relative to the pre-KMP baseline) that exceeds the CBANC thresholds and is causally related to SO_2 emissions. Action: increase the frequency of fall sampling in subsequent year, to more accurately estimate mean and variability of CBANC and other informative indicators during the fall index period.	More intensive sampling confirms a decrease in CBANC (relative to the pre-KMP baseline) that exceeds the CBANC thresholds in one or more lakes and is causally related to SO_2 emissions. Action: liming to bring the lake back up to pre-KMP pH, subject to approval by B.C. ENV/DFO prior to implementation (see 2014 EEM Plan, Appendix G).	3 or more lakes rated Medium or High (based on relative lake rating) show decreases in CBANC (relative to the pre-KMP baseline) that exceed the CBANC thresholds and are causally related to SO_2 emissions. Action: reduction in SO_2 emissions	• Changes in CBANC in control lakes • Changes in alternate ANC metrics • Change in mean lake pH relative to pre-KMP baseline, and control lakes. • Changes in SO_4, to evaluate whether ΔANC and ΔpH are causally related to B.C. Works and other SO_2 emissions.

6.2.5 Informative indicators

The informative indicators for the Aquatic Ecosystems line of evidence are defined in Table 16. The informative indicators support and complement the KPI.

Table 16. Informative indicators for Aquatic Ecosystems.

Informative indicators	Threshold for increased monitoring[20]	Indicators to be jointly considered
Water chemistry – acidification (pH)	A decrease in pH relative to the pre-KMP baseline that exceeds the pH thresholds (Table 13) and is causally related to SO_2 emissions. Action: additional monitoring during the fall sampling season to determine variation in pH, ANC and SO_4^{2-} and obtain a more precise estimate of their mean values.	• All ANC metrics • SO_4 • The changes in all metrics (i.e., CBANC, Gran ANC, BCS, pH, SO_4) should be jointly considered prior to deciding to increase the intensity of monitoring, and

[20] Thresholds for mitigation are not applicable. These indicators will provide weight of evidence for assessing the magnitude, extent and causes of lake acidification.

Informative indicators	Threshold for increased monitoring[20]	Indicators to be jointly considered
		what form of increased monitoring would provide the most useful incremental information.
Water chemistry – acidification (Gran ANC, BCS) (alternate ANC metrics)	A decrease in Gran ANC or BCS relative to the pre-KMP baseline that exceeds the indicator thresholds (see Section 6.2.6) and is causally related to SO_2 emissions. Action: additional monitoring during the fall sampling season to determine variation in ANC , pH and SO_4^{2-} and obtain a more precise estimate of their mean values.	• pH • SO_4 • The changes in all metrics (i.e., CBANC, Gran ANC, BCS, pH, SO_4) should be jointly considered prior to deciding to increase the intensity of monitoring, and what form of increased monitoring would provide the most useful incremental information.
Changes in SO_4	N/A Strong evidence for an increase in SO_4 relative to the pre-KMP baseline, consistent with evidence of increased SO_2 emissions (from the smelter) and SO_4 deposition, indicates that the smelter is having an influence on the water chemistry of the lake.	• This indicator is used as input to the evidentiary framework, to inform the assessment of causality
Observed changes in SO_4, ANC and pH vs. predicted changes from STAR and 2019 Comprehensive Review	N/A	• Changes in mean lake pH, ANC and SO_4 relative to pre-KMP baseline (i.e., retrospective change)
Predicted steady state ANC and pH versus current ANC and pH	N/A	• N/A
Aquatic biota: fish presence / absence per species on sensitive lakes	Decrease in CBANC beyond lake-specific threshold Action: assess fish presence, potentially using eDNA so as to minimize impact of gillnet sampling on lake fish populations.	• Decrease in pH ≥0.30 units from pre-KMP baseline.
Episodic pH change	N/A	• None

6.2.6 Summary of thresholds for ANC and pH aquatic acidification indicators

The two thresholds (level of protection and change limit) for each of the ANC and pH aquatic acidification indicators are shown in Table 17. The suite of indicators provides complementary information. The level of protection thresholds for pH and Gran ANC are points below which acidification impacts on aquatic biota begin to occur. The level of protection threshold for BCS is the level below which concentrations of inorganic monomeric aluminum increase and there are chronic toxic effects on aquatic biota. The change limit of 0.3 pH units was derived from studies of acidification impacts on biota in Sweden (Fölster et al. 2007), which concluded that lakes should be maintained within 0.4 pH units of their original, pre-industrial pH_o; the change limit of 0.3 pH units in the EEM program is more precautionary. The lake-specific change limits for CBANC in Table 14 are consistent with a pH decline of 0.3 pH units.

Table 17. Thresholds for level of protection and change limits for aquatic acidification KPI and informative indicators.

Indicators	Type	Level of Protection (i.e., absolute threshold)	Change Limit (i.e., relative threshold)
CBANC	KPI	Decrease below 20 μeq/L	Decrease greater than lake-specific thresholds (Table 14)
pH	Informative	Decrease below 6.0 pH units	Decrease ≥0.3 pH units
Gran ANC	Informative	Decrease below 30.7 μeq/L	Decrease greater than lake-specific thresholds (Table 14)
BCS	Informative	Decrease below 0 μeq/L	Decrease greater than 13 μeq/L

6.3 Methods

The methods associated with the KPI and informative indicators for the Aquatic Ecosystems line of evidence are summarized in Table 18 and Table 19 and described in further detail in their own subsections below the two summary tables.

Table 18. Overview of methods for calculating the KPI for Aquatic Ecosystems.

Key performance indicator	Method overview and frequency of attainment assessment
Water chemistry–acidification (CBANC)	1. Analysis of level of change in CBANC **in each lake:** o Apply Bayesian analysis to determine the strength of evidence that ΔCBANC exceeds the thresholds for CBANC o Determine whether there has been an exceedance for CBANC 2. Causal linkage to smelter emissions **for each lake:** o Apply the evidentiary framework (integrating changes in SO_4, pH and ANC) o Inputs to evidentiary framework are from annual application of Bayesian analysis to determine strength of evidence that $\Delta SO_4 > 0$, ΔCBANC > KPI thresholds causing biological effects, and ΔpH > 0.3 units 3. KPI is exceeded if there is an **exceedance of both thresholds for CBANC** and those changes are **causally linked to smelter** for **one or more lakes.** Mitigation **response depends on number and rating of lakes with CBANC exceedances (see Table 15)** The assessment of KPI attainment is conducted annually. For more information, please refer to Section 6.3.1.

Table 19. Overview of methods for calculating the informative indicators for Aquatic Ecosystems.

Informative indicators	Method overview
Water chemistry–acidification (pH)	Apply Bayesian analysis to determine the strength of evidence that ΔpH is greater than thresholds. Apply the simple evidentiary framework to assess the causal linkage to smelter emissions. Evaluate the differential trends between sensitive lakes and control lakes using the BACI methods from the 2019 Comprehensive Review. For more information, please refer to Section 6.3.1.
Water chemistry – acidification (Gran ANC, BCS) (alternate ANC metrics)	Apply Bayesian analysis to determine the strength of evidence for ΔGran ANC or ΔBCS greater than thresholds. Apply the simple evidentiary framework to assess the causal linkage to smelter emissions. Evaluate the differential trends between sensitive lakes and control lakes using the BACI methods from the 2019 Comprehensive Review[21]. For more information, please refer to Section 6.3.1.
Changes in SO_4	Apply Bayesian analysis to determine the strength of evidence for an increase in SO_4.

[21] These analyses will also be conducted on the primary ANC metric (used for the KPI), but only as an informative indicator. The KPI is not based on this methodology.

Informative indicators	Method overview
	For more information, please refer to Section 6.3.1.
Observed changes in SO_4, ANC and pH vs. predicted changes from STAR and 2019 Comprehensive Review	Re-apply methods from the 2019 Comprehensive Review at time of next comprehensive review. For more information, please refer to Section 6.3.2.
Predicted steady state ANC and pH versus current ANC and pH	Re-apply methods from STAR and 2019 Comprehensive Review at time of next comprehensive report (2026). For more information, please refer to Section 6.3.3.
Aquatic biota: fish presence / absence per species on sensitive lakes	If CBANC KPI triggers are exceeded in any lake which contained fish during baseline sampling in Phase I of the EEM program, then resample this lake for fish presence. If resampling is required, explore using eDNA methods. For more information, please refer to Section 6.3.4.
Episodic pH change	To be studied in LAK006 (End Lake) and LAK028. For more information, please refer to Section 6.3.5.

6.3.1 KPI and informative indicators for changes in primary water chemistry metrics

The indicators associated with the primary water chemistry metrics (i.e., SO_4, pH and ANC) all use data that come from the same water chemistry sampling program. Therefore, the methods for the following indicators are described together in this subsection:

1. Water chemistry–acidification (CBANC) **[KPI]**
2. Water chemistry–acidification (pH) **[informative indicator]**
3. Water chemistry – acidification (Gran ANC, BCS) (alternate ANC metrics) **[informative indicator]**
4. Changes in SO_4 **[informative indicator]**

Sampling locations:

- Water chemistry samples will be taken at 7 sensitive lakes; 3 control lakes; and 1 less sensitive lake, shown in Figure 7.
- For broader context, Figure 8 (from the 2019 Comprehensive Review) shows the locations of all of the additional lake and stream sites that were sampled and analyzed as part of the STAR, the KAA, or during the EEM Program and have thus contributed to the assessment of the aquatic ecosystems receptor within the Program.
    - The lakes sampled during the STAR represent a census of all lakes greater than 1 ha within the target sampling areas (based on deposition exposure, geography, and bedrock sensitivity) that fulfill the selection criteria from the U.S. Environmental Protection Agency protocols for aquatic acidification studies (Eilers et al. 1987; Landers et al. 1987).

- The EEM Program included **all** the lakes within the defined sampling regions of the STAR for which the STAR predicted a future pH decline of >0.1 pH units under the maximum emissions. The resulting set of "EEM sensitive lakes" represents the entire population of lakes within the sampling regions that could potentially change.
- Figure 8 identifies the full set of sensitive, less sensitive and control lakes included in the 2013-2018 phase of the EEM Program. The only change to this set in Phase III is the discontinuation of three of the less sensitive lakes, as recommended in the 2019 Comprehensive Review, because true control lakes were added to the program and it has been shown that these lakes are not sensitive.

Sampling timing, frequency and duration:

- Six sensitive lakes (LAK006, LAK012, LAK023, LAK028, LAK042, LAK044) will be sampled 4 times / year in October
- One inaccessible sensitive lake (LAK022), one less sensitive lake (LAK016) and three control lakes (NC184, NC194, DCAS14A) will be sampled once annually by helicopter at the start of October
- Resampling of LAK030 (Bowbyes Lake) in 2022
- Resampling of Lakelse Lake in 2025 and including these results in the 2026 comprehensive review
- No additional lakes or stream sites need to be sampled

Monitoring protocols and sampling methods:

- Monitoring protocols and sampling methods will follow those of Phase I of the EEM, as described in Limnotek annual reports and the 2019 Comprehensive Review.
- During the helicopter lake sampling, standardized photos will be taken for each lake to document changes for both the lakes and their respective watersheds.

How and when monitoring data will be evaluated:

- Water chemistry data will be analyzed annually for the annual report
- QA/QC will be performed on all data as described in Phase I of the EEM
- ANC metrics will be calculated
- Apply Bayesian statistical analysis for changes in SO_4, pH and ANC (Bayesian Method 1 in Aquatic Appendix F of the 2019 Comprehensive Review (ESSA et al. 2020)) compared to absolute and relative thresholds specified in Section 6.2
- Apply the simple evidentiary framework to assess causal linkage to smelter emissions, as described in section 7.3.4.5 of the 2019 Comprehensive Review
- Changes in lake chemistry will be assessed against two baselines:
  - The pre-KMP baseline (2012), as was applied throughout Phase I of the EEM program. This will be the baseline utilized for the KPI evaluation.
  - The extended baseline (2012-14), as was applied in the sensitivity analyses included in Aquatic Appendix I of the 2019 Comprehensive Review. Those sensitivity analyses will be repeated every year.
- The analyses described above provide the foundation by which to assess the attainment of the KPI on an annual basis.

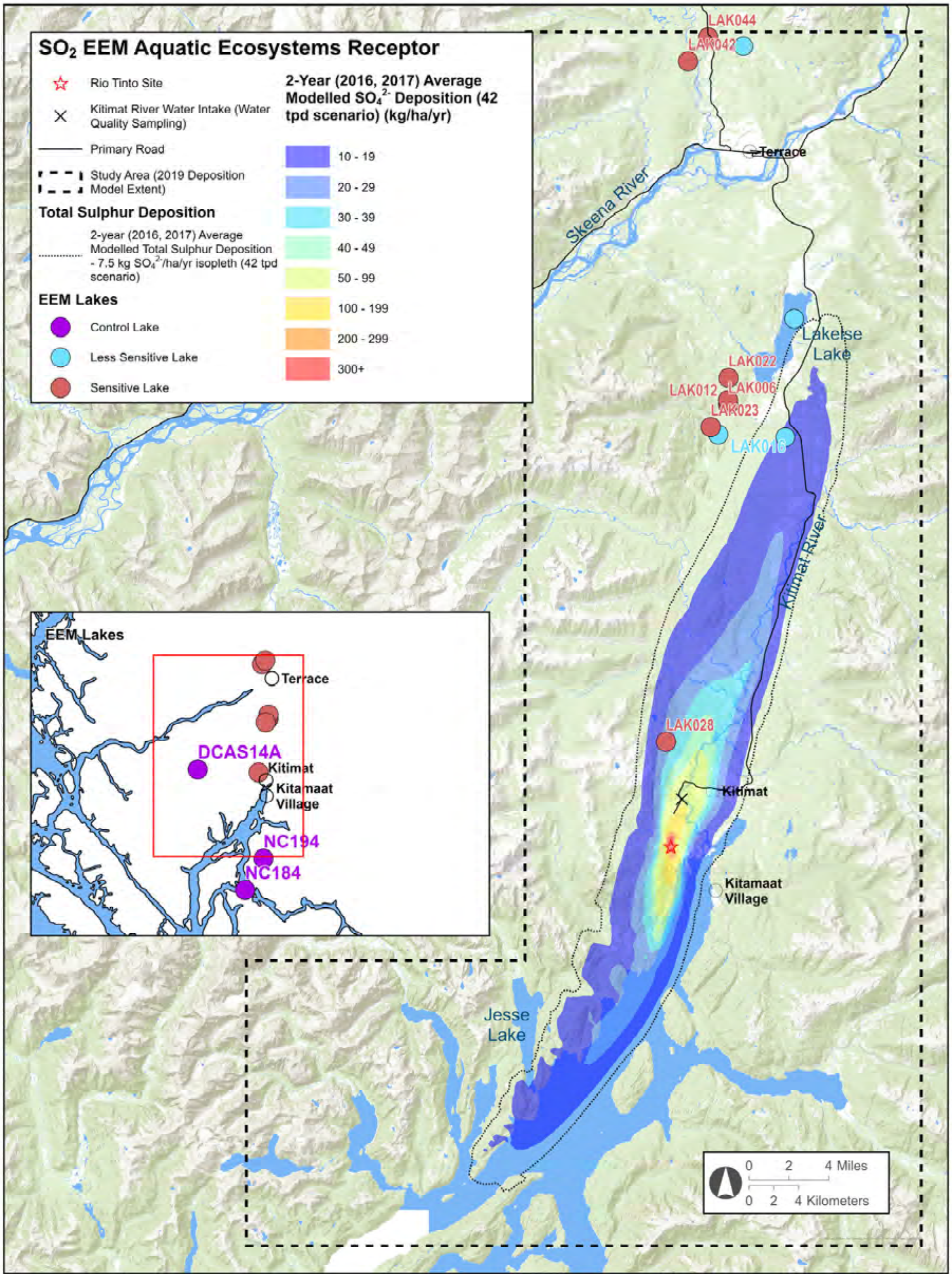

Figure 7. Lakes from which water chemistry samples will be taken.

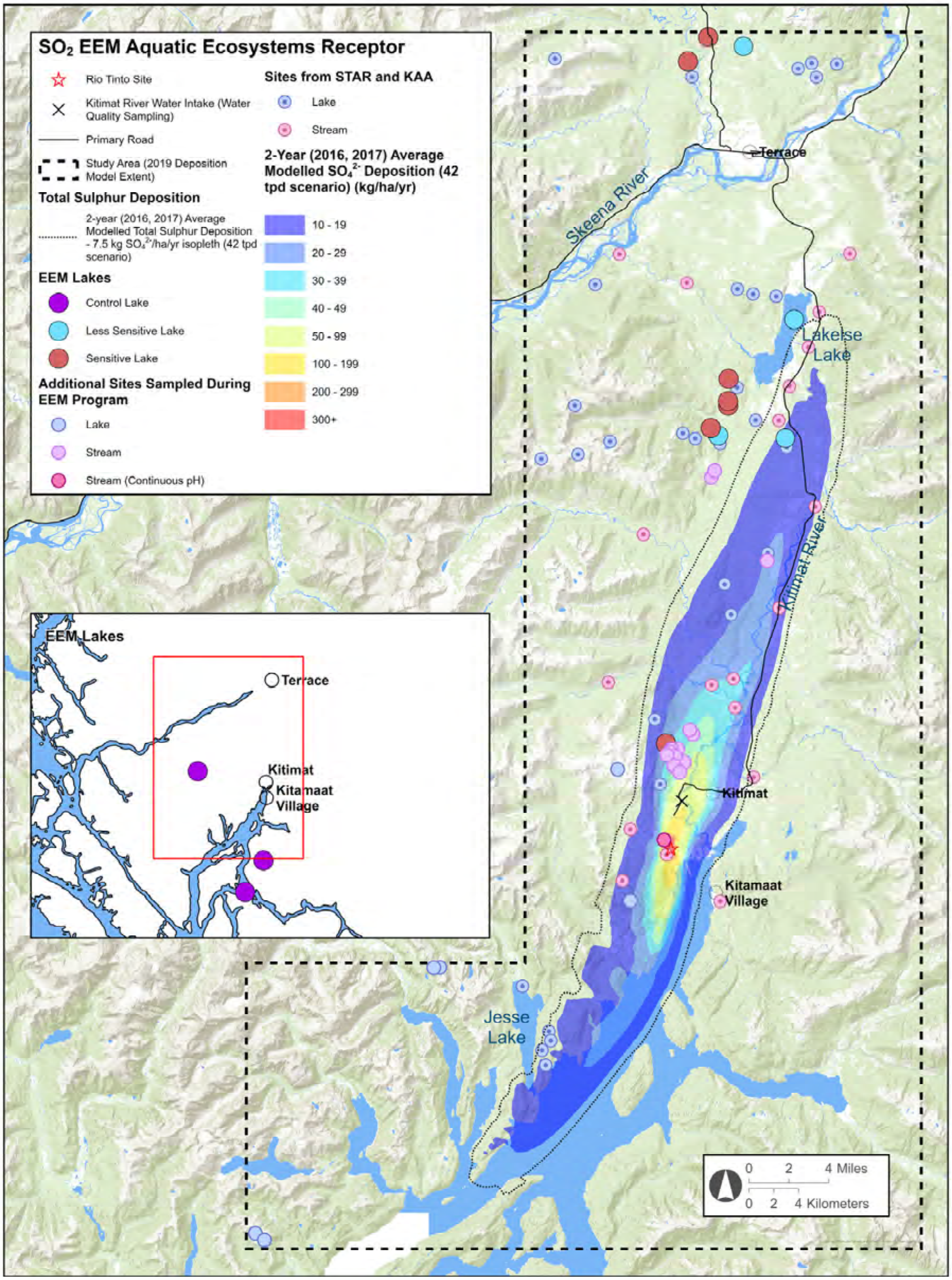

Figure 8. Locations of all lake and stream sampling locations utilized within the course of the EEM Program. (Source: Figure 7.2 in Aquatic Appendix A of the 2019 Comprehensive Review.)

6.3.2 Observed changes in SO_4, ANC and pH vs. predicted changes from STAR and 2019 Comprehensive Review – informative indicator

This indicator uses the same water chemistry data as described in Section 6.3.1 and will use the same methods to acquire these data. Therefore, the following information is identical to above: sampling locations; sampling timing, frequency and duration; and monitoring protocols and sampling methods.

How and when monitoring data will be evaluated:

- Use ESSA-DFO model results, adjusted to reflect actual emissions, similar to the methods described in the 2019 Comprehensive Review (Aquatic Appendix 7, section 7.1.3.2.4).
- These analyses will be conducted at the time of the next comprehensive review.

6.3.3 Predicted versus observed chemistry – informative indicator

This indicator uses the same water chemistry data as described in Sections 6.3.1 and 6.3.2, and will use the same methods to acquire these data.

How and when monitoring data will be evaluated:

- Apply ESSA-DFO model to estimate predicted steady-state ANC and pH under 42 tpd emissions, as described in the STAR and the 2019 Comprehensive Review.
- These analyses will be conducted at the time of the next comprehensive review.

6.3.4 Aquatic biota: fish presence/absence per species on sensitive lakes – informative indicator

This indicator is conditional on the results of the KPI (i.e., Water chemistry–acidification (CBANC).

Trigger for additional sampling:

- Resampling of individual lakes for fish presence will only be required if the triggers for CBANC are exceeded in a particular lake that contained fish during baseline sampling in Phase I of the EEM program.

Sampling locations:

- Lakes in which the conditions for resampling are met (as described above)

Sampling timing, frequency and duration:

- Completed at time of annual water sampling

Monitoring protocols and sampling methods:

- If resampling is required, the potential use of eDNA methods rather than capture-based methods for assessing fish presence will be explored.

- The rationale for exploring eDNA methods is to avoid sampling methods that involve the capture of fish because the study lakes are small enough that the act of sampling using gill nets could in itself have a negative impact on the small fish populations.
- eDNA methods would be based on methods developed by the Rocky Mountain Research Station of the US Forest Service, Bureau Veritas Labs (Guelph, Ontario) and the University of Victoria.
- If eDNA methods are not possible, then the pros and cons of resampling with original gillnet/angling methods will be assessed and discussed with ENV.
- If resampling is required, the choice of method, rationale and implementation details will be documented in the annual report.

How and when monitoring data will be evaluated:

- Presence/absence results will be compared to baseline measurements to determine if there have been any changes in species presence
- Monitoring data will be evaluated during the preparation of the annual report for the year in which the sampling occurred

6.3.5 Episodic pH change – informative indicator

Sampling locations:

- LAK006 (End Lake) and LAK028

Sampling timing, frequency and duration:

- Intensive sampling with installation of continuous pH monitor
- Record pH every half hour during the ice-free period of each year

Monitoring protocols and sampling methods:

- Onset pH monitor which accurately measures pH every half hour
- Recalibrate Onset every two weeks
- The protocols and methods are described in more detail in Limnotek (2021)

How and when monitoring data will be evaluated:

- Examine continuous data in LAK006 for sudden drops in pH
- Analyze lake level data to assess if a storm event was associated with the acidic episode
- If acidic episodes were coincident with a storm event, analyze calibration samples taken before and after the episode for full chemistry, as well as precipitation and deposition data from Lakelse Lake to assess if the acidic episode was likely driven by sulphate inputs (smelter related) as opposed to base cation dilution, or organic acid inputs (not smelter related)
- Since acidic episodes can be of very short duration, calibration samples taken every two weeks, and weekly deposition samples, may not detect episodic changes in sulphate or organic anions

6.3.6 Additional studies

6.3.6.1 Re-evaluate EEM Lakes

The EEM lakes will be re-evaluated in the 2021 annual report with respect to their inclusion in the EEM Program going forward. Some of the EEM lakes (which were all identified in the STAR as being potentially sensitive to increased acidic deposition) are now not predicted to acidify under updated modelling based on additional years of data. There are multiple lakes that are not predicted to exceed their critical loads, not predicted to decrease in pH below their 2012 baseline values, and do not show any evidence in their empirical observations of lake chemistry of patterns that are consistent with smelter-driven acidification. However, the power analyses conducted in 2014-2015 recommended that the EEM Program should not make any strong conclusions about the changes in lake chemistry that have occurred until there have been at least five years of post-KMP data collected. Therefore, the EEM program will collect an additional three years of post-KMP data for all of the originally identified sensitive lakes, for a total of six years of post-KMP data, before making any conclusions about the need for the continued inclusion of each of the lakes. If any changes are made to the set of lakes included in the EEM Program going forward, then the implications on the structure of the KPI will need to be assessed.

6.3.6.2 Pilot project scope for receptor-based mitigation

The scope of a pilot project to demonstrate the feasibility of receptor-based mitigation will be developed during SO_2 EEM Phase III. The purpose of the pilot project is to ensure that there is a receptor-based mitigation solution that can be feasibly implemented should the aquatics KPI exceed the threshold for receptor-based mitigation. The scope of the pilot project will include providing an update (from the 2014 SO_2 EEM Plan) on the state of knowledge on lake liming and different methods and technologies that have been successfully applied to treat acidified bodies of water. The review of technologies will include applications for both natural lakes and mining pit bodies of water. The feasibility of the technologies will be assessed through the lens of the acid sensitive lakes monitored in the SO_2 EEM and current provincial and federal regulations. Methods and technologies that are identified as potentially feasible for a pilot project will be developed into a scope of work for a pilot project that will ensure there is a mitigation method that can be successfully applied. If a solution is found that is sufficiently proven for mitigating lake acidification, the project scope will be written as the pilot project.

6.4 Summary of Aquatic Ecosystems Activities Planned for 2019-2025

The schedule is for planned activities is provided in Table 20, and may be subject to change.

Table 20. Schedule of work on the Aquatic Ecosystems line of evidence planned under Phase III.

Topic	2019	2020	2021	2022	2023	2024	2025
Water chemistry sampling	Annual water sampling and laboratory analysis (subject to re-evaluation in 2022)	Annual water sampling and laboratory analysis (subject to re-evaluation in 2022)	Annual water sampling and laboratory analysis (subject to re-evaluation in 2022)	Annual water sampling and laboratory analysis (subject to re-evaluation in 2022)	Annual water sampling and laboratory analysis (subject to re-evaluation in 2022)	Annual water sampling and laboratory analysis (subject to re-evaluation in 2022)	Annual water sampling and laboratory analysis (subject to re-evaluation in 2022)
Developing ANC KPI			Exploratory analyses on different ANC metrics; select metric; finalize and apply new KPI				
Fish presence / absence sampling	Resample if lake pH change reaches threshold	Resample if lake pH change reaches threshold	Resample if lake ANC change reaches threshold	Resample if lake ANC change reaches threshold	Resample if lake ANC change reaches threshold	Resample if lake ANC change reaches threshold	Resample if lake ANC change reaches threshold
Re-evaluation of EEM lakes monitoring program				Re-evaluate EEM lakes with respect to their inclusion in the EEM program			
Receptor-based Mitigation							Pilot project scope for lake liming
KPI attainment assessment	Annual assessment	Annual assessment	Annual assessment	Annual assessment	Annual assessment	Annual assessment	Annual assessment
Reporting	Annual reporting	Annual reporting	Annual reporting	Annual reporting	Annual reporting	Annual reporting	Annual reporting

7 Climate Change

7.1 Introduction

The SO_2 EEM program collects data that are of value for understanding and tracking the effects of climate change in the Kitimat Valley. Rio Tinto has volunteered to add the tracking of climate change indicators using some of the data currently collected by the SO_2 EEM program and some additional new monitoring data.

The purpose of this chapter is to synthesize the SO_2 EEM collected monitoring data through the lens of climate change into indicators for tracking the changes in climate and the physical effects of the climatic change over time. The intent of adding climate change to the SO_2 EEM program is to be able to provide an understanding of how the climate and environment are changing in the Kitimat valley using the SO_2 EEM monitoring data. This chapter is not intended to look beyond the beneficial data collected by the pathways and receptor based monitoring programs of SO_2 EEM plan, but reasonably accessible data of interest may be added by Rio Tinto.

7.2 Climate Change Indicators

Indicators for climate change (Table 21) are divided into two categories. First category of indicators are the Meteorological Indicators that are derived from data collected in the atmospheric pathways monitoring programs. These indicators will provide direct meteorological measurements that can be interpreted to understand how the clime in the Kitimat valley has changed over time. The second category of indicators are the Effects Monitoring Indicators; these indicators will measure the physical response of the environment in the Kitimat valley to the changing climate.

Table 21. Climate Change Indicators.

Meteorological Indicators	Measurement Locations	Reporting Frequency
Precipitation annual average against historical normal	Haul Road and Lakelse Lake	Annual
Precipitation patterns (cumulative and storm depths)	Haul Road and Lakelse Lake	Annual
Precipitation pH (weekly and annual average)	Haul Road and Lakelse Lake	
Air temperature against historical normals (seasonal, extremes and annual averages)	Yacht Club	Annual
Still air days (days with low windspeed)	Yacht Club	Annual
Solar irradiance (to be added at Lakelse Lake)	Lakelse Lake	Annual

Effects monitoring Indicators	Measurement Locations	Reporting Frequency
SO_4 deposition rates and ratios of wet vs. dry deposition (seasonal and annual averages)	Haul Road and Lakelse Lake	Annual
Soil moisture (to be added at Lakelse Lake soil plots)	Lakelse Lake	Annual
Vascular plant biodiversity (specifics of the indicator are to be developed)	Kitimat and Kemano Valleys	Every 3rd year
Lake chemistry	Control Lakes DCAS14A, NC194 and NC184	Annual
Water temperature and water levels	Lak006 and Lak028	Annual

7.3 Methods

A review of available data will be conducted in 2022 and the first quarter of 2023 for both the Meteorological and Effects Monitoring indicators. The review will determine the best quality data set to use for establishing the historical normal (baseline) of the meteorological indicators. Data sets from Rio Tinto, Environment and Climate Change Canada, and B.C. ENV will be included in the review. Specific statistics to set the baseline and evaluate change will be identified for each of the indicators data sets in addition, the graphical plots of the data showing trends will also be determined. Future changes to both the statistical analysis and displays of the analyzed data may made based on learnings.

Annual averages, seasonal averages and other statistics for the indicators will be calculated from data collected by the SO_2 EEM from 2012 to 2021. On an ongoing, annual basis, subsequent years of data will be added to the analysis and trend plots.

7.4 Reporting of Climate Change Trends

Trend plots of the climate change indicators will be provided in the SO_2 EEM annual report in a separate chapter on climate change. This chapter will present indicators but will not provide an interpretation or analysis of the indicators. The interpretation of the climate change indicators will be done in the update of the Comprehensive Review (for the Phase III plan). This chapter will not interpret the effects of annual weather variation on the monitoring data as the influence of weather variation on the KPIs and associated indicators is assessed in the relevant chapters for the pathways and receptors.

7.5 Additional Studies

A project will be sponsored under SO_2 EEM Phase III that will review and summarize the available predictions and literature for climate change in the Kitimat Valley and develop predictions for environmental responses. The intent of this project is to develop an understanding of the predicted climate changes that may occur in the Kitimat Valley and to develop an understanding of the potential effects of the changes. This project will be completed between 2023 to 2025.

8 Determination of Causal Relationship to B.C. Works

The KPI thresholds presented in Sections 2 through 6 include the condition that threshold exceedances are causally related to cumulative SO_2 emissions from B.C. Works and LNG projects in the Kitimat Valley. The process for determining causality is summarized below, by line of evidence. These steps would be undertaken for a given KPI if the thresholds for increased monitoring or mitigation are reached.

Human Health

- Investigate each 1-hour exceedance of the numerical component of the 1-hour health KPI (e.g.: 70 ppb) by assessing meteorological conditions, and estimates of B.C. Works' SO_2 emissions.
- Update the CALPUFF SO_2 dispersion model from the 2019 Comprehensive Review with meteorology and SO_2 source emission data from all industrial sources.

Terrestrial Ecosystems

- Soils ,vegetation and lichens will be evaluated along a S deposition gradient. Estimates of total S deposition will be obtained from CALPUFF using emissions from B.C. Works and LNG source emissions.
- For long-term soil plot monitoring results, causal relationship to B.C. Works and LNG SO_2 emission sources will be determined by comparison with changes (or lack thereof) at the background (control) plot.
- Vascular plant and cyanolichen biodiversity: If there are differential changes in trends in plant or cyanolichen biodiversity (high or moderate deposition sites compared to low deposition sites) chemical analysis of foliage, fine roots, and/or thalli will be done to determine if indicators of acidification are present (e.g., elevated levels of S concentration in tissues; changes in the concentration and availability of base cations in soil; an increase in the concentration of Al+3 on soil; increased concentrations of Al in plant tissues or lichen thalli; morphologic or cellular aberrations in plant tissues or lichen thalli). If so, a determination will be made whether the affected area has expanded beyond that historically affected (pre-KMP)22 as determined by initial measurements. The evidentiary framework is presented in
- Figure 9.

Aquatic Ecosystems

- Apply the simple evidentiary framework each year shown in Figure 10 (from Figure 7-3 in the 2019 Comprehensive Review).
- Apply the more detailed evidentiary framework in 2026 (Table 7-12 in the 2019 Comprehensive Review).

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[22] For sulphur, pre-KMP S levels in vegetation were within background levels reported in literature. Historical impact area of the old smelter was determined using the fluoride measurements in western hemlock. From 2010 on, there were no sulphur concentrations that exceeded the background levels identified in literature. Sites are within and outside the area historically affected by fluoride.
current scientific literature shows that at levels less than 7.5 kg SO_4^{2-}/ha/year effects on plants and lichens are not observed.

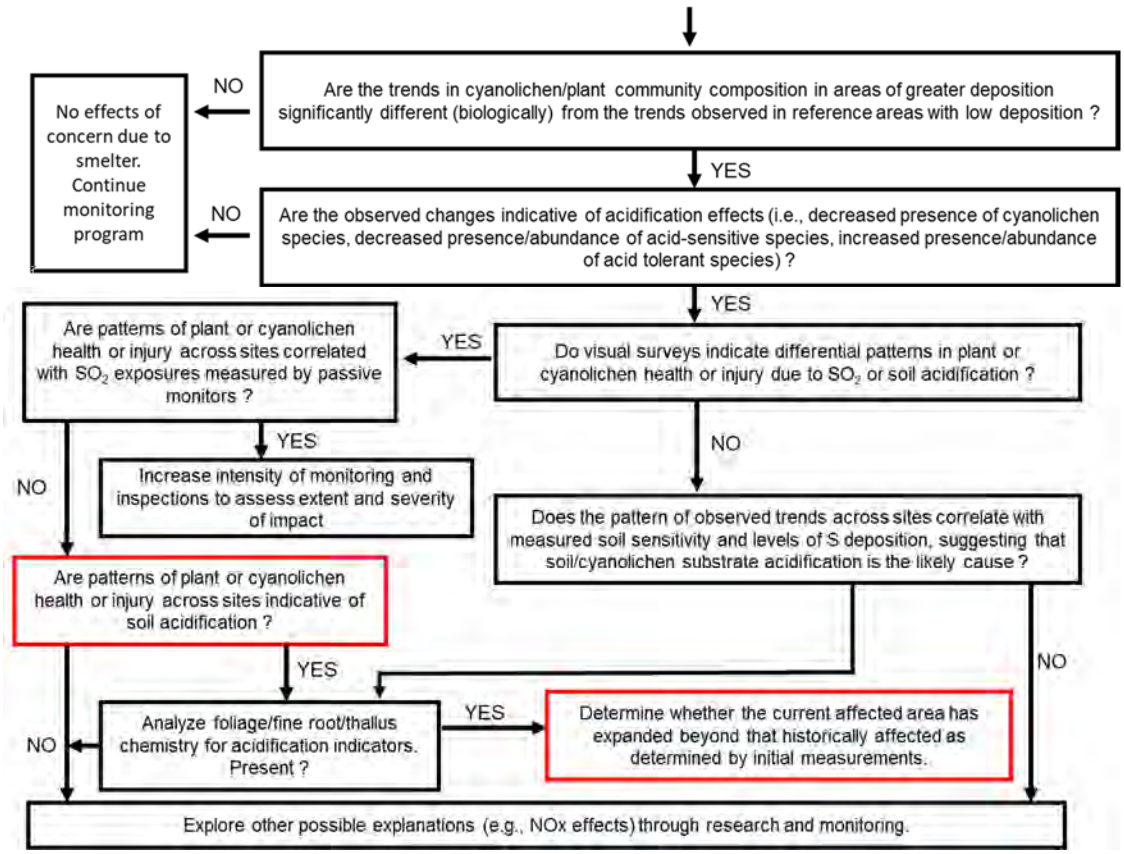

Figure 9. Evidentiary framework for determining a causal relationship between changes in trends in plant biodiversity and SO_2 emissions from B.C. Works and other sources. Red boxes show where causality to the smelter's SO_2 emissions is established.

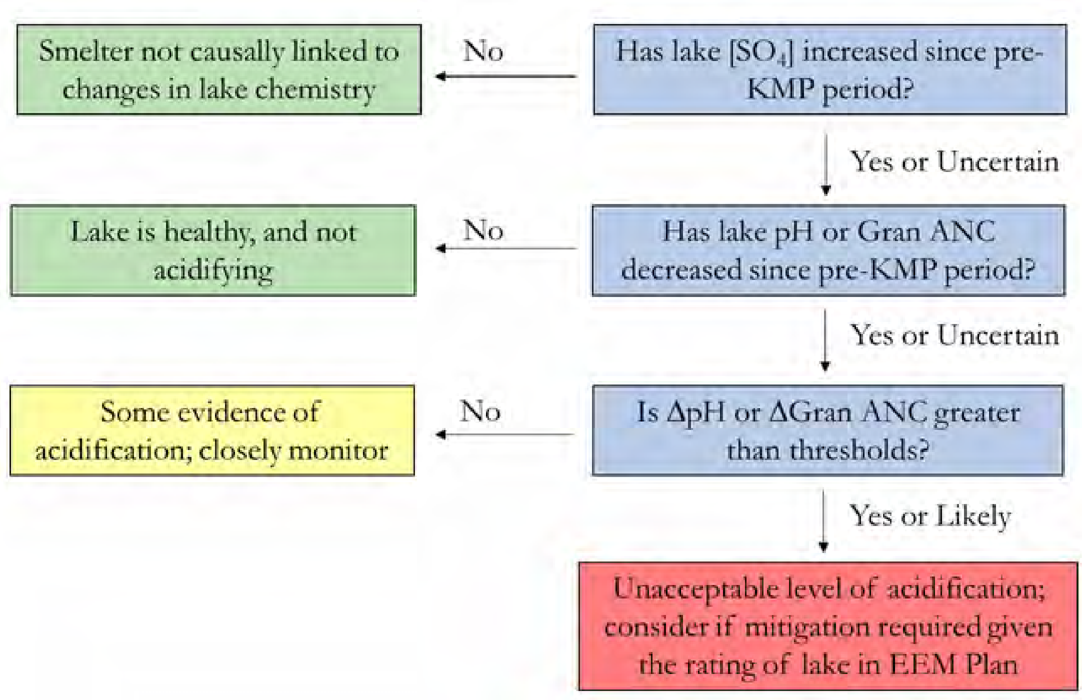

Figure 10. Simplified evidentiary framework for determining whether lakes have experienced acidification that is causally related to SO_2 emissions.

9 Pathways to Mitigation

Rio Tinto will implement SO_2 mitigation strategies if the outcomes of monitoring and modeling under the SO_2 EEM program show adverse impacts related to Rio Tinto emissions of SO_2 that have contributed to an exceedance of a KPI threshold for mitigation. The SO_2 EEM program distinguishes two types of mitigations: receptor-based mitigations and facility-based mitigations. Mitigation for episodic events in either the Terrestrial or Aquatics ecosystems will be restricted to specific well-defined situations where it is very clear that the likelihood of reoccurrence is very low and temporary mitigations might be appropriate because the impact is short-term and reversable.

Pathway to mitigation:

- If potential non-attainment of the either the Terrestrial or Aquatics ecosystems KPIs are identified, the Director will review available information and data with respect to the non-attainment as well as consider exceptional events, in order to confirm the non-attainment. Meteorological conditions are not an acceptable justification for non-attainment.
- If the Director determines that there is non-attainment of either the Terrestrial or Aquatics ecosystems KPIs the Director will provide notification to Rio Tinto of the determination of non-attainment of a KPI threshold for mitigation.
- Within 6 months of notification by the Director for the non-attainment of either the Terrestrial or Aquatics ecosystems KPIs, Rio Tinto will submit a report to the Director outlining an action plan to determine the amount of SO_2 emissions required to bring the KPI back into attainment and the proportionality of Rio Tinto's SO_2 emission reduction. The action plan will detail the proposed mitigation option and both the short and long term actions to implement the mitigation. The action plan will also contain steps for monitoring the success of the implemented mitigation. The development of the action plan will be done in consultation with B.C. ENV.

The following paragraphs describe examples of each type of mitigation.

9.1 Receptor-based Mitigation

If a terrestrial ecosystems KPI threshold for receptor-based mitigation (detailed in Sections 5.2 and 5.3) is exceeded, the application of lime and wood ash are options for reducing soil acidity in very localized applications, increasing calcium concentrations in trees, and potentially improving tree growth. Given the wide range of effectiveness of these treatments (summarized in Appendix F in the EEM Plan for 2013-2018 (ESSA et al. 2014)), small scale pilot applications would be required as a proof of concept prior to large scale application. The 200 year horizon allows ample time for a liming/wood ash pilot, and consideration of a shift to facility-based mitigation if the pilot is unsuccessful. Most studies show a response in the soil within 5-10 years.

If ANC in a valued[23] lake declines by more than its lake-specific threshold, and the most likely explanation of this ANC decline is increased SO_2 emissions from B.C. Works, then if liming is logistically feasible, Rio Tinto could develop and implement a process to restore the lake pH back to its level in 2012, and reverse the acidification caused by B.C. Works SO_2 emissions. The options for treating a lake will be developed in the pilot project scope of work (Section 6.3.6.2). One of the options used to mitigate acidic conditions in surface water is the addition of alkaline materials like limestone (calcium carbonate). Depending on lake access, safety and other environmental considerations, liming could be done on the whole lake, its running water or on its watershed using a boat, truck or helicopter (Olem 1990). A summary of the state of knowledge regarding liming of lakes is provided in Appendix G of the 2014 SO_2 EEM Plan. Liming would only be applied for up to two lakes; if 3 or more lakes show pH declines greater than 0.30 units and related to B.C. Works, Rio Tinto would implement facility-based mitigation[24].

If cumulative SO_2 emissions have caused the exceedance of a receptor-based mitigation threshold, Rio Tinto may work with B.C. ENV on a proportional model for implementing the mitigation.

9.2 Facility-based Mitigation

9.2.1 SO_2 Emission reductions and options

Sections 3.1, 5.2 and 6.2 describe (respectively) the human health, terrestrial ecosystems and aquatic ecosystems thresholds for facility-based mitigation. Facility-based mitigation will be a response to demonstrated exceedances of KPI threshold for SO_2 emission reductions. Facility-based mitigation will proportionally reduce SO_2 emissions from the smelting operation, and may be episodic or permanent depending on the persistence of the threshold exceedance. The implemented reduction options will be sufficient to meet the proportional emissions reduction level identified.[25] The methodology for reducing SO_2 emissions will be a Rio Tinto business-based decision that will factor in consideration of the nature of the impacts, feasibility and sustainability of alternative mitigation methods, and marketplace conditions.

Rio Tinto will consult with B.C. ENV on the specifics the selected mitigation options. This consultation may include a review of the specific option selected by Rio Tinto in the context of B.C. ENV's policy on best available technology (BAT), if a scrubbing option is selected by Rio Tinto.[26] However, the specifics of the mitigation option will be based on the total SO_2 emission load reduction that is required to mitigate the exceedance of the facility based mitigation threshold.

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[23] Refer to Appendix D the EEM Plan for 2013-2018 (ESSA et al. 2014) for information on the method and results for rating the vulnerable lakes.
[24] Refer to Section 6.2 for the thresholds for receptor-based mitigation.
[25] Reducing SO_2 emissions beyond the identified proportional emissions reduction requirement will be a Rio Tinto business decision.
[26] A best available technologies (BAT) review on SO_2 scrubbing options for the modernized smelter was completed as part of the 2013 SO_2 Technical Assessment Report for the 2013 amendment of the P2-00001 Multimedia Waste Discharge Permit.

Some examples of options that Rio Tinto will consider for reducing SO_2 emissions are briefly described below, followed by Table 22 which presents the range of SO_2 reduction in t/day that could be achieved, and the implementation timeline.

a) Procuring lower sulphur content coke
The coke blend used for anode manufacturing can be adjusted to lower the overall sulphur content in the anode. The magnitude of the sulphur content reductions will be determined based on marketplace conditions and accessibility to anode grade cokes with lower sulphur content.

b) Reducing the amount of calcined coke produced on site
Increased quantities of calcined coke can be procured to reduce or stop coke calcining onsite. The feasibility of this option will be based on marketplace conditions for anode grade calcined coke.

c) Importing anodes
Baked anodes can be imported to Kitimat to either reduce or stop coke calcining or anode baking operations. This option would be reviewed for feasibility based on marketplace access to baked anodes and transportation costs.

d) Scrubber on Coke Calciner
Implementing a scrubber on the coke calciner is possible. A decision to implement scrubbing on the coke calciner will be based on a business review of the carbon products and scrubbing options. The assessment will also consider the environmental impacts and lifecycle assessment of the mitigation measure selected, including waste generation, energy consumption, GHG emissions, the operating risks of the scrubber and the acceptability to stakeholders of the selected type of feasible scrubbing.

e) Scrubbing on one or both gas treatment centres
The option of implementing scrubbing on one or both gas treatment centres will be based on a business case review of the options to reduce SO_2 emissions from the Kitimat smelter. The review will consider the construction and operating costs of the scrubber in comparison to the feasibility assessment of the other options to reduce SO_2 loadings from smelting operations. The assessment will also consider the environmental impacts and lifecycle assessment of the mitigation measure selected, including waste generation, water release, energy consumption, GHG emissions, the operating risks of the scrubber and the acceptability to stakeholders of the selected type of feasible scrubbing.

f) New Technologies
New technologies (that are in development or may be developed in the future) that reduce or eliminate SO_2 emission sources may be considered by Rio Tinto. The selection of new technologies will depend on degree of readiness and cost efficiency of the technology.

Table 22. Examples of SO_2 reduction options and potential implementation timelines[27].

Reduction option	Potential range of reduction		Implementation timeline
	Lower t/day	Upper t/day	
Procuring lower sulphur content coke	1	15	> 12 months
Reducing the amount of calcined coke produced on site	1	8	Short-term curtailment: 2 weeks Long-term curtailment: > 16 months
Importing anodes with lower sulfur content	1	20	6 to 18 months
Scrubber on Coke Calciner	7	NA	5 - 6 years : a) Feasibility study: 1 year b) Permitting: 1 years c) Engineering, Procurement, Construction: 2 - 3 Years d) Commissioning: 1 years
Scrubber on 1 GTC	14	NA	7-8 years : a) Feasibility study: 1 years b) Permitting: 2-3 years c) Engineering, Procurement, Construction: 3 years d) Commissioning: 1 years
Scrubbers on 2 GTC	29	NA	
New technologies	TBD	TBD	TBD

9.2.2 Proportional Emissions Reductions for Terrestrial and Aquatic Ecosystems

The SO_2 effects pathway for both the terrestrial and aquatic ecosystems are through acidic, sulphate (SO_4) deposition.

If SO_2 effects from SO_2 emissions (from Rio Tinto or cumulative from LNG facilities in the Kitimat Valley) are measured through an exceedance of a KPI's threshold for facility-based mitigation and that it is demonstrated through applying the relevant evidentiary framework in the SO_2 EEM plan (with strong statistical confidence or belief to be actual (not a false positive)) then Rio Tinto will proportionally reduce SO_2 emissions.

[27] One or more of these reduction options would only be implemented if:

- there is a confirmed environmental impact causally related to SO_2 emissions, and
- an SO_2 EEM KPI facility-based mitigation threshold has been exceeded.

These options are not binding, as the efficacy and availability of some options may vary with time and other options may become available in the future. The specific proportional reduction levels required will determine the level of either the efficiency or reduction level required.

The total amount of SO_2 emissions reduction required to bring the KPI back into attainment will be determined through estimating the SO_4 deposition level that caused the exceedance. The specific contribution of each SO_2 emitter to the SO_4 deposition level that caused the exceedance will be estimated through modeling and/or measurements as identified below. The percentage of Rio Tinto's contribution to the total SO_4 deposition that caused the exceedance will be the proportion of Rio Tinto's SO_2 emissions reduction.

Tools used to determine the proportion of SO_2 emissions reduction will be:

- 2019 SO_2 EEM Comprehensive Review's CALPUFF SO_2 dispersion model (updated with new meteorology and the SO_2 emission inventory from all SO_2 emitters),
- SO_2 EEM's deposition model (to both validate the SO_4 deposition levels that caused the KPI exceedance and refine the CALPUFF deposition model results to improve the agreement with observations), and
- Updated relevant Aquatic and Terrestrial Ecosystems models from the 2019 SO_2 EEM Comprehensive Review.

Further emissions reductions to address a future KPI exceedance will only be made after all other SO_2 emitters have proportionally reduced their SO_2 emissions to in response to the first KPI exceedance.

The combined total amount of facility-based SO_2 emissions for Rio Tinto will not exceed 15 Mg/d and the 2013 unamended P2-00001 Multimedia Permit limit of 27 Mg/d.

10 Reporting, Consultations and Comprehensive Review

10.1 Reporting and Consultation Schedule

SO_2 EEM reporting and consultation will occur on an annual basis in accordance with Table 23. Additional requirements (terms of reference) related to the deliverables in Table 23 are outlined in Appendix B, and work plans in Appendix C.

Table 23. Reporting and consultation requirements under the SO_2 EEM plan.

Deliverable	Due Date (current year) [1]
Annual Review Cycle[2]	
Review of interim draft results and QP recommended adjustments to work plans	March 15th to April 20th [3]
Draft work plans[4]	April 30th
Final annual work plans (for current year)	May 31st
Draft documents[5] (Annual SO_2 EEM Report for previous year)	May 31st
Implementation of work plans	In accordance with finalized work plans[6]
Consultation process (on draft documents) [7]	To be completed by June 30th
Consultation report (for draft documents)	September 15th
Final Annual SO_2 EEM Report with finalized technical memoranda (for previous year)	October 31st
Comprehensive Review (2026)	
Terms of reference and schedule for completing the comprehensive review	December 31st, 2025

[1] Rio Tinto may submit requests to B.C. ENV to extend due dates.
[2] The annual review cycle for the phase III program will commence in 2022, following B.C. ENV approval of the program.
[3] A meeting(s) will be held with Rio Tinto, select QPs and B.C. ENV to review interim draft results and recommended adjustments to the work plans.
[4] Draft work plans will be issued concurrently to B.C. ENV, KPAC, and KAG (atmospheric pathways and human health at a minimum). The KPAC for a 14 day commenting period on the changes made to the work plans. The commenting period will start on the day after the work plans are issued.
[5] Draft documents (Annual SO_2 EEM Report with technical reports/memoranda that are relevant to the reporting year) are intended to be complete drafts according to the respective terms of reference and using data that are available up to April 30th of the year that the draft report is written.
[6] If B.C. ENV has not commented or acknowledged the finalized annual work plans within 10 days of the submissions the field monitoring work will commence according to the most recent submitted versions of the annual work plans.
[7] A 30-day consultation period on the draft annual SO_2 EEM report with technical memoranda will be conducted according to Section 10.4.

10.2 Annual Work Plans

Five-year work plans have been prepared for atmospheric pathways and each line of evidence. These work plans are presented in Appendix C. On an annual basis, the five-year work plans will be updated based on (if any) learnings from the previous year. The work plans will be updated and issued in draft to B.C. ENV for review and approval based on the schedule outlined in Table 23. Monitoring work for the SO_2 EEM program will be conducted according to the approved work plans.[28]

10.3 Annual Reporting

The Annual SO_2 EEM Report will be prepared according to both the schedule in Table 23 and the terms of reference presented in Appendix B. The purpose of the Annual SO_2 EEM Report is to provide a summary of the knowledge gained, an evaluation of the KPIs and recommendations for adjusting the work plans for the following year. Technical reports and/or memoranda that are completed as sub-components for the atmospheric pathways and the lines of evidence will be completed according to the terms of reference in Appendix B. The technical reports and/or memoranda will be appended to the annual SO_2 EEM report.

10.4 Annual SO_2 EEM Consultations

10.4.1 Consulted Parties

Consulted parties will include the following:

- Haisla Nation and other First Nations as identified by the Director,
- B.C. Works' Kitimat Public Advisory Committee (KPAC),
- Kitimat Airshed Group (KAG) for the atmospheric pathways and human health at a minimum, and
- Other groups as specified by the Director.

If parties who are listed in Section 10.4.1 as consulted parties or designated as a consulted party at a later date by the Director join the KPAC, consultations with those parties may be done through the KPAC consultation session. B.C. ENV will be provided the opportunity to be included in the consultation events.

10.4.2 Consultation Process

At a minimum, the consultation process will consist of:

- Referral of the draft Annual SO_2 EEM report (with technical memoranda) to the consulted parties on or before May 31st of the current year. Documents will either be sent to the consulted parties as attachments by email or an email will be issued to the consulted parties inviting them to download the files from a public-facing website. The draft Annual SO_2 EEM report will be made available at least one week in advance of meeting.

- Hosting of a consultation event made available to all consulted parties according to Section 10.4.1. Notice of the event will be issued a minimum of 2 months prior to the consultation event.

[28] If the work plans have not been approved by the director according to Section 10, the most recent version of the work plan submitted to B.C. ENV will be applied for initiating the monitoring work.

- The consultation event will consist of a single session, where all consulted parties (according to Section 10.4.1) will be invited to participate, discuss the consultation materials and provide input for consideration. Presentations of the draft Annual SO_2 EEM report (and supporting technical memoranda) will be given at the session, with content tailored for a non-technical audience.
- A consultation session will be offered to the Kitimat Airshed Group according to the scope of Section 10.4.1.
- Consulted parties will be given 30 days to provide written comments on the draft Annual SO_2 EEM report. Received written comments and verbal comments received during the consultation session will be consolidated into a tracking table.
- Responses to comments received will be provided in the consultation tracking table. This tracking table will be posted to a public-facing website and the consulted parties will be issued an email inviting them to download the tracking table and provide follow-up comments within 10 days. Received comments that are within scope of the draft Annual SO_2 EEM report will be taken into consideration. Revisions to the draft Annual SO_2 EEM Report will be considered for material comments that are in scope of the consultation documents.

10.4.3 Consultation Report

A concisely written consultation report will be prepared that summarizes the consultation process, comments received and responses. The consultation report will be a short and concisely written document (according to the terms of reference provided in Appendix B) that includes the summary of the consultation process, meeting minutes, presentations and completed tracking table.

10.5 Comprehensive Review in 2026

A compressive review of the monitoring conducted during the Phase III SO_2 EEM program will be undertaken in 2026. A draft report synthesizing the results of this review will be prepared by December 31, 2026, which will:

- Build on the knowledge gained in the 2019 SO_2 EEM Comprehensive Review,
- Summarize what has been learned, and what question have been answered,
- Describe which if any of the KPI thresholds have been exceeded, and if so, what actions were taken,
- Describe any modifications to KPIs, methods or thresholds that have been made based on annual results to date, and why,
- Summarize the effects of climate change based on an assessment of the climate change indicators,
- Look across the data for of the three lines of evidence to develop a holistic understanding of B.C. Works aluminium smelter's SO_2 effects on the environment and human health, and
- Recommend changes if/as needed to: the suite of KPIs to be continued post-2025, their measurement methods, and/or their thresholds – along with the rationale for these recommended changes.

Terms of reference for the 2026 Comprehensive Review (including an approved dispersion model protocol) will be prepared by December 31st, 2025. The terms of reference will be developed according to Table 24. The schedule will target completion of the terms of reference by October 31st, 2025 but will allow 2 months of contingency time. The finalized terms of reference will be the scope of work for the 2026 Comprehensive Review.

Table 24. 2026 Comprehensive Review Terms of Reference development.

Deliverable	Due Date
Terms of Reference	
Scoping Workshop (one to two days)[1]	January - February 2025
Tracking table[2]	Two weeks following the scoping workshop
B.C. ENV Scoping comments stemming from Scoping workshop via tracking table[3]	30 days following the receipt of the tracking table from Rio Tinto
Rio Tinto response to B.C. ENV Scoping Comments via tracking table[4]	45 days following the receipt of scoping comments from B.C. ENV
Draft terms of reference[5]	June 15th, 2025
B.C. ENV review of draft terms of reference via tracking table	July 30th, 2025
Rio Tinto response to B.C. ENV comments on draft terms of reference via tracking table	September 30th, 2025
Final terms of reference[6]	December 31st, 2025
Dispersion Model Protocol	
Draft Dispersion Model Protocol[7]	May 30th, 2025
B.C. ENV review (and comments) of draft dispersion model protocol	June 30th, 2025
Rio Tinto Response to B.C. ENV comments on draft dispersion model protocol via tracking table	July 31st, 2025
Final Dispersion Model Protocol	July 31st, 2025
B.C. ENV approval of dispersion model protocol	August 31st, 2025

[1] Rio Tinto will host a scoping workshop with QPs (who are available to attend) and B.C. ENV. The scoping workshop will be held over 1 to 2 days and may be either an in-person or virtual (remote) attended workshop.

[2] Rio Tinto will prepare a tracking table based on the scope of the 2026 Comprehensive Review developed in the workshop. The tracking table will be provided in a spreadsheet format that is editable.

[3] B.C. ENV will be invited to provide follow-up comments to the scope agreed to at the scoping workshop. Comments will be entered in the tracking table provided by Rio Tinto.

[4] Rio Tinto with the input from the QPs will provide responses to the received comments from B.C. ENV. The responses will be used to prepare the draft terms of reference.

[5] The draft terms of reference will contain at a minimum: table of contents, section and sub-section headings, and summary bullets of the scope for each section and sub-section.

[6] Rio Tinto will submit the finalized draft terms of reference to B.C. ENV for review and approval. Two months of contingency time (Nov and Dec) is provided to allow for further iterations of the terms of reference (if required).

[7] Dispersion modelling is a long lead process that is relied on for the analysis the lines of evidence in the Comprehensive Review. The dispersion model protocol will be developed from B.C. ENV's template for dispersion model protocols. Approval of the dispersion model protocol will be required before September 1st in order for the development of the dispersion model to begin in 2025 and completion of the model runs to be done in the first quarter of 2026.

10.6 Mid-stream Adjustments

Mid-stream adjustments to the KPIs may be made if there is demonstrable evidence to support adjustments to the KPIs and associated thresholds for the Terrestrial Ecosystems and Aquatic Ecosystems lines of evidence. If Rio Tinto seeks mid-stream adjustments, a request for mid-stream adjustments to the KPIs will need to be made to B.C. ENV.

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Appendix A: Changes in the EEM Program and the Rationale

This appendix summarizes the key changes to the SO_2 EEM program in this Phase III Plan, and provides the rationale for the changes.

Atmospheric Pathways

- Establishment of a continuous SO_2 monitoring station within the Service Centre commercial area to provide information on model performance in this area (2019 Comprehensive Review, Atmospheric Pathways recommendation 2).
- Monitoring data evaluation will not include a monitoring data study or a CALPUFF model refinement because this was conducted in the first phase of the EEM Program and reported in the 2019 Comprehensive Review.
- Review of passive sampling network sites (2020 and 2021 Kitimat Passive Monitoring Plan for Sulphur Dioxide, prepared by Trinity Consultants, September 2020). The details of the passive sampling program were formalized in the passive sampling plan currently under review.
- Discontinuation of the Haul Road wet deposition monitor, as the monitoring of wet deposition at Haul Road provides no ecological value (i.e., for the assessment of impacts) owing to its fence line location, and it provides limited value for model (CALPUFF) evaluation (2019 Comprehensive Review, Atmospheric Pathways recommendation 5).
- Change of the third informative indicator from base cation deposition to precipitation chemistry, from the Lakelse Lake NADP station. This reflects the importance of chloride (CL-) as a tracer for sea-salts, in addition to the use of base cations for CL exceedance should CLs need to be recalculated.

Human Health

- Shifting of the KPI for the EEM Program toward alignment with the CAAQS for SO_2 (2019 Comprehensive Review recommendation for human health).
- 2019 settlement of the SO_2 EEM appeal.
- Mitigation action plan to include public health messages and recommendations.

Terrestrial Ecosystems

- Combining of the Vegetation and Terrestrial Ecosystems (Soils) lines of evidence into a new Terrestrial Ecosystems line of evidence (2019 Comprehensive Review, Vegetation recommendation 1).
- Discontinuation of sampling and chemical analysis of western hemlock foliage in favour of maintaining a valley passive sampler network (2019 Comprehensive Review, Vegetation recommendation 3).
- Change of the visible injury KPI to an informative indicator to support the Terrestrial Ecosystems line of evidence (2019 Comprehensive Review, Vegetation recommendation 1).

- Change of the focus of vegetation monitoring to detect mid to long-term effects on Terrestrial Ecosystems (2019 Comprehensive Review, Vegetation recommendation 3) by:
  - Implementing a 3-year rotating panel of 33 plots for monitoring the biodiversity (species richness and abundance) of cyanolichens and of vascular plants in the low shrub and herb layers, and
  - Assessing the health of the vegetation at the biodiversity plots during the annual measurement cycle.
- Revision of the assessment of changes in exchangeable base cation at the long-term soil plots (2019 Comprehensive Review, Soils recommendation 3) to:
  - Use soil concentrations in the top 0–30 cm (rather than 0–5cm or 0–15 cm) of mineral soil rather than pools to assess changes in soil chemistry,
  - Use a change (decrease) in base saturation (%) to calculate KPI (rather than a change in exchangeable base cation pools),
  - Further analyse the minimum detectable difference to evaluate the potential of an early warning change in soil base saturation using a lower level of significance and / or lower power, and
  - Carry out the next sampling of long-term plots during 2025 (to return to a five-year period) and measure trees (DBH) at time of soil sampling. If the KPI is triggered, measure tree chemistry to estimate Bcu [base cation uptake] by trees and its contribution to soil chemistry changes.
- Pilot project scope development for receptor based mitigation.

Aquatic Ecosystems

- Change of the KPI calculation from pH to ANC (rationale provided in 2019 Comprehensive Review, Aquatic Ecosystems recommendations 10, 11, 12, 13 and 14).
- Rationale for using CBANC as the indicator metric:
  - CBANC is the most common ANC metric applied in acidification studies
  - It is easily measured/calculated (doesn't require special lab equipment like Gran ANC)
  - The EEM Program has a continuous record of the constituent data needed to calculate CBANC with single analytical laboratory (whereas there was an unavoidable change in analytical laboratories for pH and Gran ANC, with overlap in 2019)
  - CBANC does not change in response to changes in DOC and organic acids and therefore can be interpreted as a more direct indicator of anthropogenic acidification (though acidification can sometimes cause a decline in DOC so it is still useful to also have Gran ANC and BCS)
  - We have lake-specific thresholds for change limits directly obtainable from the record of Gran ANC titrations
- Rationale for the CBANC level of protection threshold (i.e., 20 μeq/L)
- Based on ANC Literature Review (Aquatic Appendix B of the 2019 EEM Comprehensive Review Report) shift of the role of pH from KPI to informative indicator (rationale provided in 2019 Comprehensive Review, Aquatic Ecosystems recommendation 10).

- Change of the number of lakes being sampled annually, from 14 to 11 (rationale provided in 2019 Comprehensive Review, Aquatic Ecosystems recommendations 1, 2, 3, 5 and 9).
- Change of the number of lakes being monitored intensively from 3 to 1 (rationale provided in 2019 Comprehensive Review, Aquatic Ecosystems recommendations 6 and 7).
- No further CL modeling or predictions of steady state pH unless emissions change substantially from 42 tpd scenario (rationale provided in 2019 Comprehensive Review, Aquatic Ecosystems recommendations 15, 16 and 17).
- Pilot project scope development for receptor based mitigation.

Climate Change

- Addition of new chapter on climate change that will develop climate change indicators (meteorological and effects monitoring).
- Indicators will be reported in the annual SO2 EEM report.
- Support of a study to review and summarize available climate change predictions for the Kitimat Valley.

Determination of Causal Relationships to B.C. Works

- Addition of vegetation and lichens to Terrestrial Ecosystems

Pathways to Mitigation

- Chapter name changed from "Rio Tinto Alcan Mitigation Response for Unacceptable Impacts" to "Pathways to Mitigation".
- Description of process with BC ENV for determining a KPI non-attainment and development of a mitigation action plan.
- Addition of cumulative SO_2 effects from BC Works' smelter and two LNG projects in Kitimat.
- Addition of proportional SO_2 emissions reductions on facility-based emissions reduction thresholds. Exceedances.
- Addition of "New technologies" to the examples of facility-based mitigation options.

Reporting, Consultations and Comprehensive Review

- Chapter name changed from "Annual Reporting and Comprehensive Review in 2019" to "Reporting, Consultations and Comprehensive Review"
- Addition of a work cycle that idenitifies the key tasks and dates for conducting work and consultations
- Addition of annual work plans that are based on five year work plans that are updated annually.
- Addition of annual report and technical memoranda terms of references.
- Addition of an expanded consultation process.
- Description of the 2026 comprehensive review process,

Appendix B: Terms of Reference for Reporting and Consultation Deliverables Required under the SO_2 EEM Plan

This appendix is packaged as a separate document: **SO_2 Environmental Effects Monitoring Program Phase III Plan for 2019-2025. Appendix B, Terms of Reference for Reporting and Consultation Deliverables Required under the SO_2 EEM Plan**, and is provided on the following pages in PDF format.

It contains Terms of Reference for the following technical reports that are expected to be prepared on a routine basis:

- SO_2 EEM Annual Report
- SO_2 Passive Sampling Program Technical Memo
- Human Health KPI Technical Memo
- Vascular Plant and Cyanolichen Biodiversity Monitoring Program Annual Report
- Vascular Plant and Cyanolichen Biodiversity Monitoring Program End-of-Cycle Report of Activities
- SO_2 Aquatic Sampling Annual Technical Report
- SO_2 Aquatic Ecosystems Actions and Analyses Technical Memo
- SO_2 EEM Annual Consultation Report

It will be provided on the following pages in the final version of the Phase III Plan.

Appendix C. Annual Sampling and Monitoring Program Workplans.

This appendix is packaged as a separate file: **SO_2 Environmental Effects Monitoring Program Phase III Plan for 2019-2025. Appendix C, Annual Sampling and Monitoring Program Workplans**, and is provided on the following pages in PDF format.

The appendix contains a workplan for each line of evidence to the year 2025. Workplans are structured according to activities within five common topics. Each line of evidence has one or more Gantt charts with the planned annual activity schedule in half-month increments, as well as a table describing each of the planned activities.

It will be provided on the following pages in the final version of the Phase III Plan.

Appendix D. A Plan to Monitor Components of Cyanolichen and Vascular Plant Communities in the Vicinity of Rio Tinto B.C. Works as a Component of the SO_2 Environmental Effects Monitoring Program

This appendix is the complete version of the Amanita Coosemans and John Laurence September 19th, 2022 document, *Field Manual – Vascular Plant Biodiversity and Cyanolichen Monitoring Program – Rio Tinto B.C. Works*.

It will be provided on the following pages in its original PDF format in the final version of the Phase III Plan.