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.

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

Phase III Plan for 2019 to 2025

Appendix B: Terms of Reference for Reporting and Consultation Deliverables
DRAFT V.4

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Version Tracking Table

No.	Date	Summary of content /changes
V.1	July 2, 2021	Draft for review by the B.C. Ministry of Environment and Climate Change Strategy
V.2	July 18, 2021	Draft with revisions per ENV comments, for Rio Tinto review
V.3	July 30, 2021	Revised draft for ENV review
V.4	September 28, 2022	Revised draft addressing comments

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SO_2 EEM Annual Report

Executive Summary

- Summarize key results by line of evidence
- Tabulate the attainment results for each KPI

Introduction

- Summarize the purpose and scope of the EEM Program
- Convey the purpose and scope of the annual report
- Specify the reporting year

Figures:

- Source-pathway-receptor model, updated for Phase III
- Pathway and receptor framework for reporting on EEM activities, updated for Phase III

Facility Emissions

- Note whether the average of the SO_2 emissions for the reporting year is higher or lower than the average in the previous year
- Note whether the SO_2 emissions remained below the 42 tpd permitted limit

Figure:

- Annual SO_2 emissions from the smelter, from 2013 to the reporting year, showing the average each year and the maximum permitted level

EEM Activities

Atmospheric Pathways

SO_2 Concentrations – Continuous Monitoring

- List the continuous monitoring station sites used for the reporting year
- Note any changes from the sites used in the previous year
- Note any changes from the workplan for the reporting year, and the reason
- Specify which passed ENV's audits, and convey the % data capture for the reporting year
- Convey monthly average SO_2 concentrations at the continuous monitoring stations, starting from 2013, compared with monthly SO_2 emissions over the same period; convey any notable patterns or changes
- Convey the relative frequency of hourly averaged concentrations of SO_2 the analyzers
- Compare the monitoring data from the continuous monitoring stations to the modelling results prepared for the EEM 2019 Comprehensive Review

Figures:

- Map of continuous monitoring station locations
- Graph of monthly SO_2 emissions, and monthly average ambient SO_2 concentrations at the continuous monitoring stations; zoom in on low concentrations
- Graph of relative frequency of hourly averaged concentrations at SO_2 the continuous monitoring stations
- Graphs of the comparison between monitored concentrations in the reporting year and the predicted SO_2 concentrations from the 2019 Comprehensive Review

Table:

- Table comparing monitored annual average SO_2 concentrations to modelled concentrations at each monitoring station site

SO_2 Concentrations – Passive Sampling

- Describe the passive sampler network deployment for the year – number of samplers, and their locations, including co-location with continuous monitoring stations
- Note any changes from the sites used in the previous year
- Note any changes from the workplan for the reporting year, and the reason
- Specify the deployment dates in the reporting year
- Specify the total number of sample exposures across the network in the reporting year
- Direct the reader to the Passive Sampling Technical Memo for results from co-located continuous and passive samplers, and for the updated calibration equation

Figure:

- Map of passive sampler locations and average SO_2 concentrations at each station for the reporting year

Tables:

- Table of monthly SO_2 concentrations at each station from the plume path network

Precipitation Chemistry

- Identify the precipitation chemistry monitoring station locations for the reporting year
- Note any changes from the sites used in the previous year
- Note any changes from the workplan for the reporting year, and the reason
- Convey the annual and weekly precipitation volume at each location for the reporting year, and characterize how the volume and chemistry data at these sites compare to each other in the reporting year, and to prior years

Figure:

- Graph of annual precipitation volume starting in 2019 at the precipitation chemistry monitoring station(s)
- Graphs of weekly rainfall volume, rainfall sulphate, and pH at the precipitation chemistry monitoring station(s)

Sulphur: Dry and Wet Deposition

- Identify the model used by the EEM Program to estimate dry deposition
- Summarize how dry deposition was estimated for the reporting year
- Convey estimated dry deposition and wet deposition for the reporting year
- Note patterns and/or any changes in dry deposition from prior years

Figure:

- Graph of dry and wet deposition of sulphur

Human Health

- Explain the KPI calculation method (CAAQS, D1HM percentile, ppb threshold for the 3-year average) for the reporting year
- Convey the KPI calculation and results, and specify whether the locations were in attainment or not in attainment for the reporting year
- Refer the reader to the Health KPI Technical Memo for more details

Table:

- Calculation method and results for the reporting year, including when the data were validated by ENV and when the data were extracted from the Envista database

Terrestrial Ecosystems

Soils

- In 2022, summarize work on the wetland geochemistry project and the aluminum solubility project; refer the reader to the Technical Memo for the reporting year
- In 2025, summarize the work done under the long-term acidification soils monitoring program (analyses and results and results will be reported in 2026)
- Note any changes from the workplan for these projects for the reporting year, and the reason

Plant Biodiversity and Plant Health

- Summarize the status of the Vascular Plant and Cyanolichen Biodiversity Monitoring Program
- Summarize activities conducted during the reporting year
- Note any changes from the workplan for the reporting year, and the reason
- Summarize the results
- Refer the reader to the Technical Report for the reporting year for more details
- Note when the next 3-year biodiversity rotation end of rotation report will be prepared

Aquatic Ecosystems

Major Actions in the reporting year

- Identify which lakes were sampled in the reporting year
- Note any changes in sampling from the previous year
- Note any changes from the workplan for the reporting year, and the reason
- Refer the reader to the Technical Report on lake sampling for the reporting year
- Summarize how changes in water chemistry were examined and analyzed; refer the reader to the Aquatic Ecosystems Technical Memo for the reporting year

Knowledge Gained from Actions in the reporting year

- Summarize the empirical changes in water chemistry
- Summarize the results of the statistical analyses of changes in water chemistry
- Refer the reader to the Aquatic Ecosystems Technical Memo for the reporting year
- Specify whether any KPI thresholds have been reached, and state whether the KPI is in attainment or not in attainment for the reporting year
- Summarize the application of the simplified evidentiary framework and whether any lakes have moved their location in the framework since the 2019 Comprehensive Review

Figure:

- Map of lake locations and spatial distribution of % belief in the chemical change in the reporting year
- Classification of EEM lakes according to the simplified evidentiary framework

Tables:

- Empirical changes (increases and decreases) in lake chemistry, by lake
- Summary of findings of the statistical analysis of changes in lake chemistry across all lakes in the EEM Program

Climate Change

- Summary of any reviews of datasets to identify historical normal or adjust the baseline
- Summary of any changes or additions to the climate change indicators
- Graphs of the meteorological indicators
- Graphs of the effects monitoring indicators

List of Cited Reports

- References for reports cited in the sections above

List of Cited EEM Technical Memos

- References for Technical Memos cited in the sections above

SO_2 Passive Sampling Program Technical Memo

Introduction

- Scope and purpose of the SO_2 passive sampling program

Overview

- Note the sampling period for the reporting year (day, month started; day, month ended; total duration)
- Note the number of samplers deployed
- Summarize any changes in sampler deployment from that planned, e.g.:
    - if any samplers were discontinued during the sampling period, and the shorter number of sampling days at those locations
    - if any sampling periods were substantially different than 30 days and why
- Summarize the overall performance of passive samplers for the reporting year

Study Design

- Note if monitoring employed the same procedures as the previous year and summarize changes if applicable
- Identify any new sites added to or decommissioned from the network; direct the reader to the appropriate figures/tables
- Identify anything else that changed from the previous year's deployment
- Note the number of monitoring sites with valid sample exposures across the network, and the % of time duplicate samplers were deployed

Results

- Note when [month or months] and where the observed data showed elevated/high atmospheric sulphur dioxide (SO_2) along the plume path; cite the appropriate figures/tables
- Note whether average SO_2 concentrations during the reporting year increased or decreased from the previous year, and by how much (%) – cite the previous year's Passive Sampling Program Technical Memo and/or SO_2 EEM report
- Note where monthly exposures were consistently low or high; cite appropriate figure(s)
- Note the % variation between the duplicate passive sampler exposures; cite appropriate Appendix table; explain what these results indicate
- Compare results to those of the co-located continuous SO_2 monitors (degree of correspondence; difference), cite appropriate figure; explain what these results indicate; update calibration equation(s) as appropriate

Figures:

- Figure 1, map(s) of passive sampler locations in the reporting year, colour-coded to convey average atmospheric sulphur dioxide (SO_2) concentration during the sampling period
- Figure 2, scatter plot comparing passive sampler results to continuous SO_2 measurements where the passive samplers are co-located with the continuous monitors

Conclusion

- Explain how the results for the reporting year compared with those in the previous year based on raw data; note any changes from the same monitoring period in the previous year
- Convey whether the results from the network in the reporting year continue to support the use of passive samplers to provide empirical observations of atmospheric SO_2 concentrations to (a) assess spatial and temporal changes, (b) evaluate modelled concentration fields, and (c) estimate dry deposition of SO_2
- Recommendations for adjustments in the passive monitoring program, should changes be warranted
- In 2023, recommend whether to continue or cease deployment in 2024 and 2025

Literature Cited

- Previous year's Technical Memo
- Previous year's SO2 EEM report
- Comprehensive Review Report
- Any other cited references

Appendix A

Tables:

- Table A1, Location of passive sampler monitoring network sites established and deployed during the reporting year
- Table A2, SO_2 concentrations (ppb) at passive sampler monitoring network sites established and deployed during the reporting year
- Table A3, Analysis of replicate passive sampler deployments

Figures:

- Figure A1, Map of average atmospheric SO_2 concentration (ppb) at each sampling site during the reporting year in the passive sampling network [only needed if the map will not duplicate the map(s) in Section 3]
- Figure A2, Site locations and IDs for the Kitimat urban and ambient passive diffusive sampler network

Human Health KPI Technical Memo

Introduction

- Summarize the purpose of the Technical Memo
- Specify the reporting year

Health KPI

- Explain the purpose of the Health KPI in the EEM Program measured at the Riverlodge, Whitesail and Kitamaat Village ambient air quality monitoring stations
- Describe what the KPI is for the reporting year, and when the KPI shifts from 70 ppb to 65 ppb

Exceptional Events

- Identify exceptional event conditions that have occurred during the year from[1]:
  - 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
- Describe how the exceptional event has affect the ambient SO_2 concentrations measured at the stations
- Describe the materiality of the exceptional event in relation to the determination of the health KPI

Calculation Method

- List the monitoring stations (Riverlodge, Whitesail and Kitamaat Village) which have sufficient data collected for the reporting year
- Convey when the data were validated for the reporting year and in the two prior years for data also used in the calculation
- Specify when hourly measurements for the reporting year and the two prior years were downloaded from the Envista database

[1] 2019 B.C. Environmental Appeals Board Consent Order between Elisabeth Stannus, Emily Toews, UNIFOR Local 2301 and Delegate of the Director, Environmental Management Act, and Rio Tinto Alcan Inc.

- Identify data that has been affected by exceptional events and remove the impacted data from the health KPI calculation
- List the steps used to process the data, and cite the Guidance[2] followed in doing so, and convey completeness results (Table 1, Attachment 1)
- List the steps used to calculate the KPI, and state whether each monitor station is considered in attainment or non-attainment status for this human health KPI (Table 2)

Tables:

- Table 1: quarterly and annual data completeness results by monitoring station
- Table 2: convey the KPI results and health KPI attainment status, by monitoring station

AQHI plus SO_2 Data Review

- List the dates, times and monitoring station locations at which hourly $S0_2$ measurements triggered additional guidance beyond the standard AQHI messages (at 36 ppb and 185 ppb)

Attachment A

Tables:

- Table A1: Provide the daily 1-hour maximum concentrations and completeness summary
- Table A2: Exceptional events details and summary of daily 1-hour maximum concentrations affected by the exceptional events

[2] CCME, 2020. Guidance document on achievement determination for Canadian ambient air quality standards for sulphur dioxide

Vascular Plant and Cyanolichen Biodiversity Monitoring Program Annual Report

Introduction

- Background
- Current status of the Vascular Plant and Cyanolichen Biodiversity Monitoring Program (PCMP)

Activities Conducted During the Reporting Period

- Schedule of measurements
  - Vascular plant biodiversity
  - Cyanolichen biodiversity
  - Plant health assessment
  - Soil sampling (including soil and atmospheric ion exchange resin columns [IER] if used)
- Variance from planned activities
  - Plots lost
  - Plots added
  - Plots that couldn't be accessed
- Adjustments to the PCMP
  - Plots lost
  - Plots added
  - Variables added and measured
  - Variables not measured or dropped

Results

- Vascular plant biodiversity measurements
  - Species richness
  - Percent cover
  - Calculation of slope (beginning with the first plot re-measurement)
  - Trends acid sensitive and culturally important species

- Cyanolichen biodiversity measurements
  - Species richness
  - Relative abundance
  - Calculation of slope (beginning with the first plot re-measurement)
- Plant health assessment
  - Biotic factors
  - Abiotic factors including natural or human disturbance

  - Patterns observed
    - Related to emissions
    - Unrelated to emissions
- Soil and IER (if used) analysis
- RT BC Works Data
  - SO_2 emissions
  - Metal production
  - Annual average ambient SO_2 concentration (continuous monitoring sites)
  - Annual wet and dry deposition (NADP sites)

Discussion and Interpretation

- Logistics (sites lost, changes to the program, etc.)
- Vascular plant biodiversity
  - High deposition sites
  - Moderate deposition sites
  - Low deposition sites
  - Comparison of variability and trends (beginning with the first plot re-measurement and continuing after that)
- Cyanolichen biodiversity
  - High deposition sites
  - Moderate deposition sites
  - Low deposition sites
  - Comparison of variability and trends (beginning with the first plot re-measurement and continuing after that)
- Plant health assessment
  - High deposition sites
  - Moderate deposition sites
  - Low deposition sites
  - Comparison of variability and trends (beginning with the first plot re-measurement and continuing after that)
    - Related to emissions
    - Unrelated to emissions
- Soil analysis and risk of acidification

Conclusions and Recommendations

Appendix

- Data spreadsheets
- Photo archive

Vascular Plant and Cyanolichen Biodiversity Monitoring Program End of Cycle Report of Activities

Introduction

- Background
- 3-year status of the Vascular Plant and Cyanolichen Biodiversity Monitoring Program (PCMP)

Activities Conducted During the 3-year Cycle

- Schedule of measurements
  - Vascular plant biodiversity
  - Cyanolichen biodiversity
  - Plant health assessment
  - Soil sampling (including soil and atmospheric ion exchange resin columns [IER] if used)
- Variance from planned activities
  - Plots lost
  - Plots added
  - Plots that couldn't be accessed
- Adjustments to the PCMP
  - Plots lost
  - Plots added
  - Variables added and measured
  - Variables not measured or dropped

Results

- Vascular plant biodiversity measurements
  - Species richness
  - Percent cover
  - Calculation of slopes and comparison of trends between high, moderate, and low deposition sites
- Cyanolichen biodiversity measurements
  - Species richness
  - Relative abundance
  - Calculation of slopes and comparison of trends between high, moderate, and low deposition sites
- Plant health assessment

    - Biotic factors
    - Abiotic factors including natural or human disturbance
    - Patterns observed
        - Related to emissions
        - Unrelated to emissions
- Soil and IER (if used) analysis
- RT BC Works Data
    - SO_2 emissions
    - Metal production
    - 3-year Annual average ambient SO_2 concentration (continuous monitoring)
    - 3-year Annual average wet and dry deposition (NADP sites)

Discussion and Interpretation

- Logistics (sites lost, changes to the program, etc.)
- Trends in vascular plant biodiversity
    - Related to emissions
    - Unrelated to emissions
- Trends in cyanolichen biodiversity
    - Related to emissions
    - Unrelated to emissions
- Plant health assessment
    - Related to emissions
    - Unrelated to emissions
- Soil analysis and risk of acidification
- Analysis of results vis a vis the Evidentiary Framework

Conclusions and Recommendations

Appendix

- Data spreadsheets
- Photo archive

SO_2 Aquatic Sampling Annual Technical Report

Executive Summary

Introduction

- Brief introduction
- Summary of main tasks

Methods

- Sampling sites
    - Names and locations of sampling sites
    - Basic identification/location characteristics presented in table
- Annual lake water sampling
    - Description of methods and procedures
    - Sample collection description, step by step
- Frequent lake water sampling
    - Overview
    - LAK028
    - LAK006 (End Lake), LAK012 (Little End Lake), and LAK023 (West Lake)
    - LAK042 and LAK044
- Quality of chemical data
    - Blanks and duplicates
    - Precision
    - Accuracy
- Instrument effects on pH measurement
    - Onset pH sensor drift
    - Time to stable pH reading
    - EEM lakes sampled
    - Time course pH in End Lake, Little End Lake, West Lake, and LAK028
- Water surface elevation in End Lake, Little End Lake, West Lake, and LAK028

Results

- Overview
- Quality of chemical data
- Instrument effects on pH measurement
- Water surface elevation in End Lake, Little End Lake, West Lake, and LAK028
- LAK028

Discussion and Recommendations

- Data compilation
- Quality of chemical data
- Instrument effects on pH measurement
- LAK028

List of References

Appendix A: Standard Field Sheet for Rio Tinto Water Sampling

Appendix B: Gran-ANC Lab Methods

Appendix C: pH Over Time in Lakes with Continuous Monitoring

SO_2 Aquatic Ecosystems Actions and Analyses Technical Memo

Grey shaded text is boilerplate and expected to be the same each year, with the exception of small portions **bolded and underlined** which will be updated for the reporting year.

Introduction

This Technical Memo provides additional information on the data and analyses in support of the 202**x** requirements for the Aquatic Ecosystems component of the B.C. Works SO_2 Environmental Effects Monitoring (EEM) program (**citation**). These data and analyses thus provide the foundation for Section **x.x** in the 202**x** Annual Report (**citation**).

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

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

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

Methods

Water Chemistry Sampling

EEM Lakes

In 202**x**, [**water sampling technical consultant**] sampled **xx** lakes as part of the EEM long-term sampling plan. These lakes included the seven sensitive lakes and **xx** less sensitive lakes identified in the EEM Plan, and three additional control lakes added to the EEM in 2015. The three control lakes (NC184, NC194 and DCAS14A) are all located outside of the B.C. Works-influenced airshed and have baseline data for 2013 from sampling as part of the KAA (ESSA et al. 2014a). The sampling methodology is described in detail in [**water sampling technical consultant**]'s technical report on the water quality monitoring (**citation**). Table summarizes all of the EEM sites sampled during 2012-202**x**. Figure shows a map of the lakes sampled in 202**x**.

Tables and figures:

- Table (optional) – Summary of sites sampled within the EEM Program (site name, rationale, years sampled)
- Table (optional) – Summary of lake sampling in current year (site name, location, and sampling dates).
- Figure – Location of the lakes that were sampled.

Sampling frequency

- Note any *differences* in sampling frequency from the Plan

Continuous monitoring

xx lakes (**list**) had continuous monitoring of surface water pH, temperature and lake levels. LAK028 also had a similar instrument installed at depth. This work was planned, implemented and documented by [**water sampling technical consultant**]. The methods and results for 202**x** are reported in [**citation**].

Water chemistry data

- Note any *differences* in sampling compared to the Plan and/or previous years

Empirical Changes in Water Chemistry

The methods applied for examining empirical changes are the same as described in the last several years.

- Note any *differences* in sampling compared to the Plan and/or previous years

Statistical Analyses of Changes in Water Chemistry

The 2019 comprehensive review performed an extensive series of statistical analyses of changes in water chemistry and concluded that the results from the Bayesian statistical analyses provided the greatest ability to assess the level of support for different hypotheses of chemical change. The 2019 comprehensive review further recommended that these analyses be re-run on an annual basis to assess status and detect any anomalous patterns. This annual report represents the **xx** iteration of re-running those analyses, with **xx** additional years of monitoring data. These methods are described in detail in the Appendix F of the 2019 Comprehensive Review Report (see Bayesian Method 1 especially).

Environmental Data

- Identify and describe supplementary environmental observations/data utilized in the interpretation of the water chemistry results (as discussed in Section 4.3)
- For example, data could include:
  - Monthly precipitation over multiple years (as indicator of wetter/drier years or periods within the sampling year)
  - Lake level data (as local-scale indicator of seasonal precipitation patterns and timing of major precipitation events)
  - Anomalous atmospheric events such as forest fires or persistent inversions

Results

Water Chemistry Sampling Results

Appendix 1 reports the results of the water chemistry sampling for the EEM lakes and control lakes from the sampling conducted in 202**x** (with the data from 2012-20**xx** included for reference), for major water chemistry metrics (pH, DOC, Gran ANC, base cations, and major anions).

Empirical Changes in Water Chemistry

- Tabular and graphical results of the empirical changes in ANC, pH, SO_4^{2-}, DOC, sum of base cations, chloride, and calcium
  - Changes are reported in terms of the difference between the post-KMP average (2016-202**x**) and the pre-KMP baseline (2012 for the sensitive and less sensitive lakes; 2013 for the control lakes).
  - The sensitive EEM lakes and less sensitive EEM lakes are presented separately within each of the tables.
  - The inter-annual changes presented in this report use the mean annual values whenever multiple within-season samples were taken for a given lake in a given year.
- The annual changes between individual years ***will not*** be reported and analyzed.
  - As already stated in previous years (e.g., ESSA 2018), year-to-year changes should be interpreted cautiously: "… annual changes should be interpreted with substantial caution due to the combination of large natural variation (both within and between years) and limitations on measurement precision… multiple years of observations are required to reliably detect changes in mean pH, Gran ANC and SO4; it is risky to draw conclusions based only on annual changes".
  - Furthermore, in the December 2018 workshop on the terms of reference for the EEM comprehensive review, the ENV external acidification expert recommended that we stop reporting annual changes because inter-annual variability in lake chemistry is too variable to make any meaningful interpretation of the changes between two years.

Tables and figures:

- Table – Empirical changes in pH, ANC, SO_4^{2-}, DOC, base cations, chloride, and calcium for EEM lakes, 2012-2019.
- Figure – Changes in water chemistry metrics and pH across sensitive EEM lakes, across period of record.
- Figure – Changes in water chemistry metrics and pH across less sensitive EEM lakes, across period of record.
- Figure – Map of observed changes in SO_4^{2-}, ANC and pH, across all lakes, across period of record.

Appendix 2 provides a detailed set of figures showing the inter-annual changes in major water chemistry metrics (Gran ANC, base cations, calcium, SO_4^{2-}, chloride, pH and DOC) for each of the EEM lakes across the **xx** years of annual monitoring (2012-202**x**). Similar figures are also included for the three control lakes based on their **xx** years of annual monitoring (2013 and 2015-202**x**).

Statistical Analysis of Changes in Water Chemistry

- Statistical analyses in support of the simple evidentiary framework will apply Bayesian Method 1, described in Appendix F of the 2019 Comprehensive Review Report.
- Sensitivity analyses using the extended, transition period baseline (2012-2014)

Tables and figures:

- Table – Summary of results of statistical across all lakes.
- Figure – Map of results of statistical analyses across all lakes.

Discussion

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

- Discussion or statements with respect to:
  - Whether there have been any exceedances of the KPIs
  - Observed decreases in the metrics associated with the KPI and informative indicators
  - Whether the empirical data indicate that any of the lakes have exceeded:
    - the ANC thresholds associated with the KPI
    - the pH thresholds associated with the informative indicator

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

Statistical Analysis of Changes in Lake Chemistry

- Discussion or statements with respect to:
  - Comparison of the results with the 2019 comprehensive review, highlighting differences and magnitude of changes (for all three primary metrics)
  - How many lakes show a moderate percent belief (>20%) or high percent belief (>80%) in a change in any of the primary metrics

Tables and figures:

- Table – Comparison of the results of the statistical analyses to the results presented in the 2019 Comprehensive Review (CR).
  - Changes in SO_4 – % belief in SO4 increase
  - Changes in ANC – % belief that ANC threshold exceeded
  - Changes in pH – % belief that pH threshold exceeded
  - Following the 2019 Comprehensive Review, values of % belief < 20% are coloured green, 20-80% yellow, and >80% red.

Separating Natural and Anthropogenic Factors: the Environmental Context

- Description of significant patterns, trends or anomalies in environmental conditions that could potentially influence the observed patterns in lake chemistry

- Discussion of the impact of relevant environmental conditions on the interpretation of lake chemistry results
- Discussion, if applicable, of whether any potential influence of environmental conditions on lake chemistry warrants considering changes to the field program (e.g., adaptations to lake sampling approach and/or other supplementary environmental monitoring)

Additional Context:

The STAR and EEM program were designed to track potential pathways of effects, as illustrated in the Source-Pathway-Receptor (SPR) conceptual model (Figure 1-1 in the 2019 Comprehensive Review Report). Link 3 of the SPR conceptual model illustrates how weather patterns (e.g., sunlight, winds, precipitation) can affect the transport and transformation of emissions, and subsequent links in the conceptual model (i.e., concentrations of SO_2, the relative amounts of dry and wet deposition, the accumulated snowpack, annual changes in lake chemistry). The objective of the aquatic component of the EEM is to determine if smelter emissions are having medium to long term effects on lake chemistry and aquatic ecosystems. The primary approach to fulfilling this objective is via application of the simple evidentiary framework (Figures 7-3 and 7-10 in the 2019 Comprehensive Review Report), which focuses on statistical analyses of multi-year changes in lake [SO_4], ANC and pH.

As illustrated in the SPR conceptual model, natural and anthropogenic forces combine to determine changes in lake chemistry. Understanding medium to long term changes in lake chemistry therefore may require examination of the causes or effects of natural forces, in addition to the effects of the smelter. For example, major changes in the magnitude of precipitation in the two months prior to fall sampling can affect the concentrations of base cations or organic anions, with resultant effects on acid-base chemistry. These effects may vary across the EEM lakes due to regional differences in precipitation patterns, the topographic characteristics of watersheds, or the water residence time of lakes. Where required to logically explain observed patterns of change in lake chemistry over multiple years and multiple lakes, the annual report may examine changes in regional patterns of wet deposition, dry deposition, and precipitation, and may explore the potential effects of variation in watershed and lake attributes.

The EEM is not designed to explain the causes of changes in lake chemistry that are unrelated to the smelter (section 7.1.4 of the 2019 Comprehensive Review Report). However, if a lake shows significant changes in pH or ANC unrelated to the smelter (i.e., with no concurrent changes in lake [SO_4]), it is prudent to explore what environmental factors and lake attributes might be responsible, as these factors may have also contributed to observed changes in other lakes which have shown changes in lake [SO_4].

Application of the Simplified Evidentiary Framework

We have applied the simplified evidentiary framework, as described in the 2019 Comprehensive Review Report, using the updated results of the statistical analyses. The results are shown in Figure. The underlying results are compiled in Table. The updated application of the simplified evidentiary framework show that:

a) **xx** sensitive lakes, **xx** less sensitive lakes, and all 3 control lakes[3] land within the first box, "smelter not causally linked to changes in lake chemistry";
b) **xx** sensitive lakes and **xx** less sensitive lakes all land within the second box, "lake is healthy, and not acidifying";
c) **xx** [**sensitive/less sensitive**] lakes (**list lakes**) land within "some evidence of acidification"; and
d) **xx** [**sensitive/less sensitive**] lakes (**list lakes**) land within "unacceptable level of acidification".

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

- Describe the underlying percent belief values for any lakes falling in the yellow box ("some evidence of acidification") or red box ("unacceptable level of acidification")
- Describe whether these results have changed from previous years:
  - How have any changes in the underlying percent believe values changed (or not changed) the results within the framework

Tables and figures:

- Figure – Classification of EEM lakes according to the simplified evidentiary framework.
- Table – Results used in the application of the simplified evidentiary framework (as described above).
  - Changes in SO_4 – % belief in SO_4 increase
  - Changes in ANC – % belief that ANC threshold exceeded
  - Changes in pH – % belief that pH threshold exceeded
  - Changes in ANC (no threshold) – % belief that ANC decreased
  - Changes in pH (no threshold) – % belief that pH decreased

Recommendations

- Recommendations based on results from this year:
  - Recommendations for adjustments to next year's program (as appropriate)
  - Recommendations for broader program (as appropriate)

References Cited

- Referenced cited in document

Appendix 1: Water Chemistry Data from Annual Sampling, 2012-202x

The two tables below shows the sample results for each of the EEM lakes and control lakes from annual monitoring conducted from 2012 to 202**x**, including pH, dissolved organic carbon (DOC), Gran ANC, and the concentration of major anions and cations, as well as the sum of all base cations (BC). In 2013-202**x**, the pH of the water samples was measured by two different laboratories (Trent University and ALS).

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

Mean Annual Values

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

Lake	Year	pH TU	*SE*[1]	pH ALS	*SE*	DOC mg/L	*SE*	ANC µeq/L	*SE*	SO4* µeq/L	*SE*	Cl µeq/L	*SE*	F µeq/L	*SE*	Ca* µeq/L	*SE*	Mg* µeq/L	*SE*	K* µeq/L	*SE*	Na* µeq/L	*SE*	∑ BC* µeq/L
LAK006																								
LAK007																								
LAK012																								
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…

[1] SE = standard deviation

Sampling Data in "Raw" Units

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

Lake	Year	pH (TU)	pH (ALS)	DOC (mg/L)	Gran Alkalinity (mg/L)	Conduct-ivity (µS/s)	SO4 (mg/L)	Cl (mg/L)	F (mg/L)	NO3 (µg/L)	NH4 (µg/L)	Ca (mg/L)	Mg (mg/L)	K (mg/L)	Na (mg/L)	Fe (mg/L)	Al (mg/L)	Mn (mg/L)
Lak006																		
Lak007																		
LAK012																		
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…

Appendix 2: Changes in Ion Concentrations from 2012 to 202x

For each of the EEM lakes, the figures in this appendix show the inter-annual changes in six major water chemistry metrics from 2012 to 202**x**: ANC, base cations and calcium (left panel), sulfate and chloride (centre panel), and pH and dissolved organic carbon (right panel). The selection of each pair of metrics is solely based on optimizing graphical representation across all metrics and lakes (i.e., metrics with somewhat similar numeric ranges are shown together). The right panel has two Y-axes. The axis for pH does not start at zero – be aware that this can make relatively minor changes appear to be much more substantial than they are. Due to large variation among the lakes for some of the metrics, the Y-axis is not consistent across the lakes, therefore extra caution is required for making comparisons among lakes with respect to the magnitude of changes. However, these graphs are especially useful for looking at the patterns of changes for individual lakes across the sampling record and determining whether similar patterns are observed across lakes and/or metrics.

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

Sensitive Lakes

- 3-panel figures for each lake (as described in text)

Less Sensitive Lakes

- 3-panel figures for each lake (as described in text)

Control Lakes

- 3-panel figures for each lake (as described in text)

SO_2 EEM Annual Consultation Report

Introduction

- Introduces consultation report
- Purpose of consultation report
- Summary of consultation requirements from section 9 of the SO_2 EEM Phase III plan

Consulted Parties

- Table of the consulted parties and scope of consultations according to section 9 of the SO_2 EEM Phase III plan.
- Summary of consulted parties added by the Director and the agreed consultation scope.

Consultation documents

- Table listing the consultation documents, date issued and transmittal method.

Consultation Results

KPAC and First Nations Consultation Session

Annual SO_2 EEM Report

- Summary of consultation results for the annual SO_2 EEM report.

Work plans

- Summary of consultation results for the work plans for atmospheric pathways, Human Health, Terrestrial Ecosystems and Aquatic Ecosystems

KAG Consultation Session

Annual SO_2 EEM Report

- Summary of consultation results for the atmospheric pathways and human health line of evidence sections of the SO_2 EEM Annual Report.

Work plans

- Summary of consultation results for the atmospheric pathways work plan and human health work plan.

Other Parties Added by the Director

If not included in the KPAC & First Nations Consultation session, summarize the consultation results according to the scope agreed to with the Director.

Consultation beyond requirements of the SO2 EEM Phase III Plan

- Summary of consultation activities that are beyond the requirements specified in the SO_2 EEM Phase III plan (if any were done for a given reporting year).
- Summary of consultation results from activities that are beyond the requirements specified in the SO_2 EEM Phase III plan (if any were done for a given reporting year).

Finalization of the SO_2 EEM Annual Report and Work Plans

SO_2 EEM Annual Report Finalization

- Summary of in-scope material comments received related to the SO_2 EEM Annual Report during the consultation process and revisions made to the SO_2 EEM annual report to resolve the comments.

Work Plan Finalization

- Summary of in-scope material comments received related to the work plans for the reporting year during the consultation process and revisions made to the work plans to resolve the comments.

Appendix A – Document transmittals and invitations to consultation sessions

- Contains:
  - emails advising consulted parties to download the consultation documents from a publicly facing website.
  - emails with attached consultation documents (if any documents were issued to consulted parties by email.
  - Invitations to the consulted parties to attend the consultation sessions

Appendix B – Presentation materials used for the Consultation sessions

- Contains the presentations used at the consultation sessions.

Appendix C – Consultation Tracking table

- Contains the tracking table that documents the comments received from the consulted parties and responses to comments received.
- Tracking table will contain at a minimum:
  - Consulted party name and organization.
  - Date of comment received from the consulted party.
  - Response to comment received from the consulted party.
  - Follow-up comment from the consulted party (if any received).

Appendix D – Comment Correspondence

- Contains the written correspondence with comments on the consultation documents received from stakeholders and responses to the written comments provided on the tracking table.

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.

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

Phase III Plan for 2019 to 2025

Appendix C: Annual Workplans
DRAFT V.4

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September 28, 2022

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 comments

Please cite this report as follows:

ESSA Technologies, J. Laurence, Balanced Ecological Management, Risk Sciences International, Trent University, and Trinity Consultants. 2021. B.C. Works' Sulphur Dioxide Environmental Effects Monitoring Program – Phase III Plan for 2019 to 2025. Appendix C: Annual Workplans, Draft V.4. Prepared for Rio Tinto, B.C. Works, 22 pp.

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1 Atmospheric Pathways

Section 2.4 in the draft Phase III Plan provides an overview of work activities for the Atmospheric Pathways line of evidence over the period from 2019 to 2025. The targeted timing of EEM work plan activities to be completed in each year of the period from 2021 to 2025 are shown in Table 1. The specifics of each activity are described in Table 3. Timing of activities may be adjusted depending on circumstances. For detailed methods, see the B.C. Field Sampling Manual, Part B, Air and Air Emission Testing[1] and the National Atmospheric Deposition Program (NADP) site operations field manual[2].

[1] BC Field Sampling Manual, Part B, Air and Air Emission Testing, 2020. https://www2.gov.bc.ca/assets/gov/environment/research-monitoring-and-reporting/monitoring/emre/bc_field_sampling_manual_part_b.pdf

[2] http://nadp.slh.wisc.edu/lib/manuals/NTN_Operations_Manual_v_2-3.pdf

Table 1. Timing of work plan activities to be completed in 2021 for the Atmospheric Pathways line of evidence

Topic	#	Activity	Half-month periods in 2021					
			1-Jan	15-Jan	1-Feb	14-Feb	1-Mar	15-Ma
Planning	1.1	Preparation & coordination; update workplan if needed (passive sampling)						
Planning	1.2	Field operation planning (passive sampling only)						
Field Work	2.1a	Continuous SO_2 monitoring and weekly precip. chemistry sampling						
Field Work	2.1b	Check / install field equipment - Passive samping						
Field Work	2.2a	Collect field samples and field data						
Field Work	2.2b	Collect field samples and field data - Passive sampling						
Lab Work	3.1	Analyze field samples in lab						
Lab Work	3.2	Archive samples and lab data						
Data Analysis	4.1	Data QA						
Data Analysis	4.1	Data compilation *	For prior year's data					
Reporting	4.2	Data analysis and modelling			For prior year's data			
Reporting	5.1	Prepare draft and final technical report on field program	NA; no separate reports on atmospheric monitori					
Reporting	5.2	Prepare draft and final technical memos on atmospheric results						
Reporting	5.3	Prepare draft and final annual report for previous year				Annual EEM Report		
Reporting	5.4	KPAC consultation on current year's field program						
Reporting	5.5	Reviews of draft report for previous year by Rio Tinto						
Reporting	5.6	Reviews of draft report for previous year by ENV						
Reporting	5.7	Presentation of previous year's results to KPAC						

Table 2. Timing of work plan activities to be completed in 2021 for the Atmospheric Pathways line of evidence

Topic	#	Activity	Half-month periods in 2022-2025					
			1-Jan	15-Jan	1-Feb	14-Feb	1-Mar	15-M
Planning	1.1	Preparation & coordination; update workplan if needed (passive sampling)						
Planning	1.2	Field operation planning (passive sampling only)						
Field Work	2.1a	Continuous SO_2 monitoring and weekly precip. chemistry sampling						
Field Work	2.1b	Check / install field equipment - Passive samping						
Field Work	2.2a	Collect field samples and field data						
Field Work	2.2b	Collect field samples and field data - Passive sampling						
Lab Work	3.1	Analyze field samples in lab						
Lab Work	3.2	Archive samples and lab data						
Data Analysis	4.1	Data QA						
Data Analysis	4.1	Data compilation *	For prior year's data					
Reporting	4.2	Data analysis and modelling			For prior year's data			
Reporting	5.1	Prepare draft and final technical report on field program	NA; no separate reports on atmospheric monitori					
Reporting	5.2	Prepare draft and final technical memos on atmospheric results						
Reporting	5.3	Prepare draft and final annual report for previous year				Annual EEM Report		
Reporting	5.4	KPAC consultation on current year's field program						
Reporting	5.5	Reviews of draft report for previous year by Rio Tinto						
Reporting	5.6	Reviews of draft report for previous year by ENV						
Reporting	5.7	Presentation of previous year's results to KPAC						

Legend: C = Consultation with KPAC R = Review by Rio Tinto R = Review by ENV D = Delivery of final to ENV A = Ac

* NADP data compilation will be up to the data released by the NADP on March 1st of each year. Data that are released p will be included in the following year's SO_2 EEM reporting cycle.

Table 3. Annual work plan activities for the Atmospheric Pathways line of evidence.

Topic	#	Activity	Activity Description
Planning	1.1	Preparation and coordination	Continuous SO_2 monitoring: In 2022, identify what changes are necessary (if any) from the results of the phase 2 network optimization. (Changes identified in 2022 would take place in 2023-2025). Passive SO_2 sampling: In 2021-2023, prepare for any changes needed to the SO_2 Passive Sampling Program for the year (e.g., minor variations to the passive sampling if needed based on the previous year's deployment and data analysis), and prepare to establish any new passive sampling sites to be added to the Program. If new passive sampling sites are needed, determine where the new sites should be located using the site selection procedure for Phase 2, and finalize the list of sites. In 2024-2025, no action required if the passive sampling data are not needed. If passive sampling data are needed in 2024-2025, prepare as for 2021-2023. • Locations will be in areas that can help define the plume path. These sites are referred to as the "plume path network." In general, sites are accessible from May or June through October depending on weather. Starting in 2021 the passive monitoring season will run mid-May/mid-June through mid-October, weather and access allowing. • Duplicate samplers will be co-located with continuous active samplers (Haul Road, Riverlodge, Service Centre, and Lakelse Lake) to understanding the accuracy and precision of the SO_2 data collected. In addition, at least 20% of sites will have duplicate samplers. The one to three other duplicate samplers will rotate among several sites. Update the work plan for the year if changes are required based on the past year's results. ENV to review and approve the updated work plan.
	1.2	Field operations planning	Continuous SO_2 monitoring: In 2021-2022, if siting changes are needed, determine where new sites should be located, and where existing sites should be discontinued if applicable. Passive sampling: Evaluate locations at a finer scale to identify/avoid site selection issues during site installation; re-establish (or re-install) samplers at prior sites and any new sites if needed.
Field Work	2.1	Check / install field equipment	Continuous SO_2 monitoring: Contractor performs routine zero span and multi-point checks of continuous SO_2 analyzers at Haul Road, Riverlodge, Kitamaat Village, Service Centre, Whitesail, Lakelse Lake, and ENV checks the analyzer Terrace-Skeena middle school (operated by ENV). In 2023-2025, add, remove, or move analyzers as needed from the phase 2 network optimization. Passive sampling: Local contractor (and potentially QP) sets up the SO_2 passive sampler shelters in May - June and deploys the first set of samplers for the season (and replaces monthly). Precipitation chemistry sampling: Local contractor checks that the samplers are operating properly.
	2.2	Collect field samples and field data	Continuous SO_2 monitoring: Monitoring occurs year-round. Passive sampling: Deploy passive samplers from approximately mid-May or mid-June to mid-October, with approximately 30 days per exposure to allow for a lower detection limit concentration of 0.1 $\mu g/m^3$ (0.04 ppb). Local contactor collects samples every 30 days, and sends them to the laboratory, for analysis. Precipitation chemistry sampling: In 2021-2025, local contractor collects field samples weekly from the operating rain chemistry stations.
Lab Work	3.1	Analyze field samples in the laboratory	Continuous SO_2 monitoring: Field analyzer data are checked and calibrated by contractor. Passive sampling: Field samples are processed by the laboratory. Precipitation chemistry sampling: Field samples are processed by NADP.
	3.2	Archive laboratory data	Continuous SO_2 monitoring: ENV and contractor archive the data. Passive sampling: Rio Tinto and QPs archive the data. Precipitation chemistry sampling: NADP archives the data.
Data Analysis	4.1	Compile data and do QA	Continuous SO_2 monitoring: Contractor conducts routine QA checks. ENV performs audits and annual data validation. Passive sampling: QA and data validation are done by the laboratory. Precipitation chemistry: QA and data validation are done by NADP.
	4.2	Data analysis and modelling	Continuous SO_2 monitoring: QPs analyze the monitoring data for the year after ENV performs annual data validation. QPs compare CALPUFF predictions of SO_2 (2016-2018 results from the 2019 Comprehensive Review) to continuous SO_2 monitoring data. Passive sampling: QPs analyze the monitoring data for the year and compare general spatial pattern to previous years' pattern. QPs evaluate the need for changes to the network of passive samplers; review field notes and exclude invalidated data; and compare replicates. QPs compare results from co-located continuous and passive samplers, and update calibration equation. S deposition: QPs analyze the wet S deposition and precipitation chemistry data (data from NADP that is available at the time of analysis) and estimate dry deposition (using continuous SO_2 monitoring data) at sampling locations for the year.
Reporting	5.1	Prepare report on field program	No specific field reporting; see activities 5.2 and 5.3.
	5.2	Prepare technical reports and memos on atmospheric program	Continuous SO_2 monitoring: QPs prepare SO_2 optimization report in March 2021. In 2022-2023 if siting changes are needed, report on where new sites should be located, and where existing sites should be discontinued if applicable. Passive sampling: QPs prepare a technical memo summarizing passive sampling actions, analyses and results, and specify any changes proposed for the sampling program, following the format of EEM Technical Memo P05 (Trent University 2018). See the Terms of Reference for the Technical Memo in Appendix B.
	5.3	Prepare Atmospheric Pathways chapter of annual report	QPs prepare the Atmospheric Pathways chapter of the annual report, according to the Terms of Reference for the Annual Report in Appendix B.
	5.4	KPAC meeting	Rio Tinto and QPs consult with the KPAC on the intended plan for the monitoring program in the current year, and revise if required.
	5.5	RT review	Rio Tinto reviews the technical memos and annual report; Atmospheric Pathways QPs make revisions as required.
	5.6	ENV review	ENV reviews the technical memos and annual report; Atmospheric Pathways QPs make revisions as required.
	5.7	Present results to KPAC	Results from the previous year's SO_2 EEM report are presented to the KPAC.

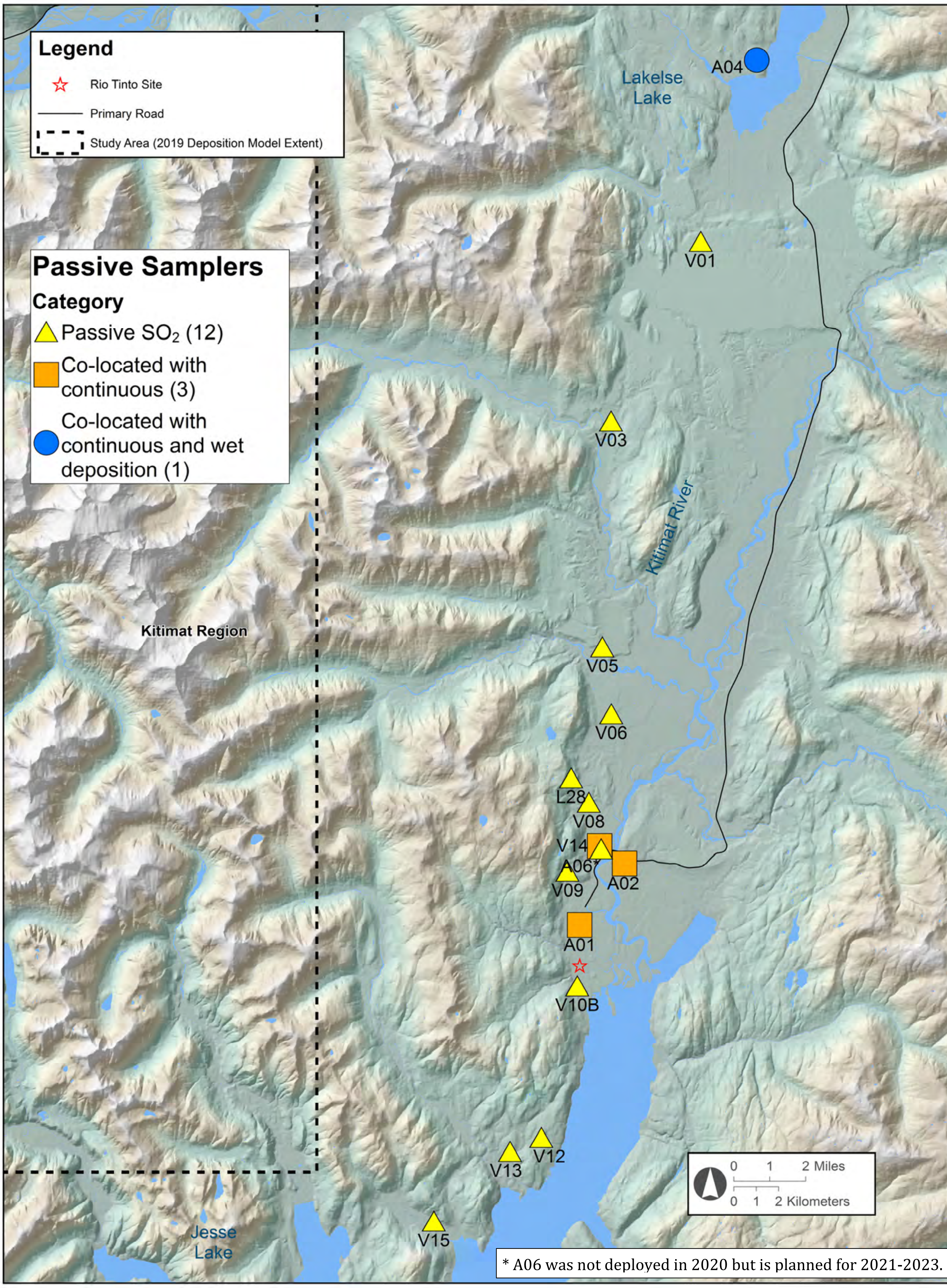

Figure 1. Map showing SO_2 passive sampling locations. Passive monitoring stations may be adjusted each year depending on safe access, learnings from the previous year and questions raised for investigating the plume path.

Table 4. SO_2 passive sampling locations.[a]

ID	Site Name	Reason for Selection [b]	Location Description
A01	Haul Road Station	Continuous site = good siting; co-location with SO2 monitor.	Ambient monitoring station; sampler on roof.
A02	Riverlodge Station	Continuous site = good siting; co-location with SO2 monitor.	Ambient monitoring station; sampler on roof.
A04	Lakelse Lake NADP Station	Continuous site = good siting; farther valley location with year-round access; wet deposition and veg [c] site co-location.	Sampler on roof of NADP wet deposition monitoring station.
A06	Industrial Ave Station	Continuous site = good siting; location of interest.	Future.[d] On roof of continuous monitoring station
V01	Onion Lake Ski Trail North	Far distance but good exposure and good history.	North on Wedeene Road after Onion Lake Ski Trail. Samplers on lone tree in open area.
V03	Mound TKTP92	Good for SO2 plume path; will be moved slightly to improve siting.	Sampler on tree on the right side of road going south. Mound has location marker on top TKTP#92, before km 17 and bridge.
V05	LNG Muster Station	Moderate SO2 levels; OK siting criteria but will be moved to stake to improve siting.	Road opens to LNG muster location, as you enter muster area take road on left opposite gravel / sand hill with ATV tracks and follow to forest edge.
V06	Sand Pit	Good for SO2 plume path; will be moved slightly to improve siting.	Sampler on tree on right side of road going south, before the sand pit with ATV tracks on the right side of road.
V08	Claque Mountain Trail at Powerline	Measured higher SO2, good plume exposure; good candidate for future co-located veg site.[c]	Sampler on powerline post on left side of road going uphill on the Claque mountain trail.
V09	Sand Hill at Powerline	Measured higher SO2; OK siting criteria; may be moved slightly to stake to improve siting.	Sampler on wooden stake on the left side of the road going uphill (at top) across the road from the powerline.
V10B	Rifle Range	Co-located with veg site; [b] OK siting criteria; may be moved slightly to stake to improve siting.	Sampler on wooden stake on gravel mound beside gun club (left of salt / road grit storage units).
V12	Bish Road Pullout 4	Good for SO2 plume path; backup candidate for veg site.[c]	Sampler on tree on the right side of the road going south, across from Pullout 4.
V13	Bish Road at Chevron LNG	Best exposure south of smelter; good candidate for future co-located veg site.[b]	Sampler on wooden stake (on bolder outcrop) on left side of road going south just before Chevron LNG.
V14 /U12	Industrial area Kitimat Hotel	Good for SO_2 plume path and siting	Located on a telegraph pole in the industrial (service) centre across from Kitimat Hotel.
V15	Emsley Creek	Additional southern site in more open location accessible by road	Second clearing after road U turns from heading southeast to heading northwest.
L28 [e]	Lake 28	Higher measured SO_2, good siting, will support defining bounds of plume.	Floating raft in lake.

[a] Passive monitoring stations may be adjusted on an annual basis depending on safe access, learnings from the previous monitoring year and questions being investigated in the current year.
[b] All sites will be evaluated for siting criteria conditions at the time of deployment and will only be included in the program if they meet all siting criteria. This table shows sites as-deployed for 2020. The 2021 plan will use 2020 sites as a starting basis and evaluate siting criteria and need for new sites or changes; 2022 will use 2021 sites as a starting basis; etc.
[c] Passive sampling data at historic vegetation sites initially thought to add value to vegetation program, but data are not actively used for vegetation program. Therefore, V08, V10B, and V13 will continue based on value for defining plume path.
[d] The 2020-2021 passive sampling plan included A06 for a passive sampler co-located at the Industrial Avenue SO2 monitoring station. The location was not established in 2020, but it is planned for 2021-2023.
[e] Lake 28 was deployed in 2020 even though not in the submitted 2020-2021 passive sampling plan. Continued monitoring at the site will consider value in understanding Lake 28 specifically as well as value for defining the plume path.

2 Human Health

Section 3.5 in the draft Phase III Plan provides an overview of work activities for the Human Health line of evidence over the period from 2019 to 2025. The timing of EEM work plan activities for Human Health to be completed in 2021-2025 are illustrated in Table 5. Activities to be completed each year are shown in Table 6.

Table 5. Timing of annual work plan activities to be completed in 2021-2025 for the Human Health line of evidence.

Topic	#	Activity	Half-month periods in 2021 - 2025																							
			1-Jan	15-Jan	1-Feb	14-Feb	1-Mar	15-Mar	1-Apr	15-Apr	1-May	15-May	1-Jun	15-Jun	1-Jul	15-Jul	1-Aug	15-Aug	1-Sep	15-Sep	1-Oct	15-Oct	1-Nov	15-Nov	1-Dec	15-Dec
Data Analysis	4.2	Calculate the KPI																								
Reporting	5.1	Prepare Health KPI Technical Memo																								
Reporting	5.3	Reviews of draft tech. memo for previous year by Rio Tinto					R							R												
Reporting	5.4	Reviews of draft tech. memo for previous year by ENV						D/R	R	R	R	R	R	R												
Reporting	5.5	Presentation of previous year's Technical Memo to KPAC								C	C	C														

Legend: C = Consultation with KPAC; R = Review by Rio Tinto; R = Review by ENV; D = Delivery of final to ENV; A = Acceptance by ENV

Table 6. Annual work plan activities for the Human Health line of evidence.

Topic	#	Activity	Activity Description
Planning	1.1	Preparation and coordination	Please refer to the continuous SO_2 sampling activities for Atmospheric Pathways.
Field Work	2.1	Collect field samples and field data	Please refer to the continuous SO_2 sampling activities for Atmospheric Pathways. Continuous SO_2 sampling locations: Riverlodge, Whitesail, Kitamaat Village (Figure 2).
Lab Work	3.1	NA	NA
Data Analysis	4.1	Compile data and do QA	Please refer to the continuous SO_2 sampling activities for the Atmospheric Pathways line of evidence. Document exceptional events.
	4.2	Analyze the data	Calculate the KPI as described in Section 3.4 of the draft Phase III Plan. The schedule for calculating the health KPI is dependent on the date when ENV completes the validation of Kitimat's SO_2 air quality data.
Reporting	5.1	Prepare the health KPI technical memo and human health chapter of the annual report	Prepare the Human Health chapter of the annual report, according to the Terms of Reference for the Annual Report in Appendix B of the draft Phase III Plan. Prepare the Health KPI Technical Memo according to the Terms of Reference in Appendix B of the draft Phase III Plan. Completion of the SO_2 Health KPI technical memo will be done according to the schedule if the Kitimat SO_2 air quality data is validated by March 31st. Otherwise, the technical memo will be completed using the unvalidated data and a disclaimer will be included in the report identifying the data as being unvalidated.
	5.2	NA	NA
	5.3	Rio Tinto review	Rio Tinto reviews the annual report
	5.4	ENV review	ENV reviews the annual report; Rio Tinto makes revisions as required.
	5.5	Present results to KPAC	Present the results from the previous year's SO_2 EEM report.

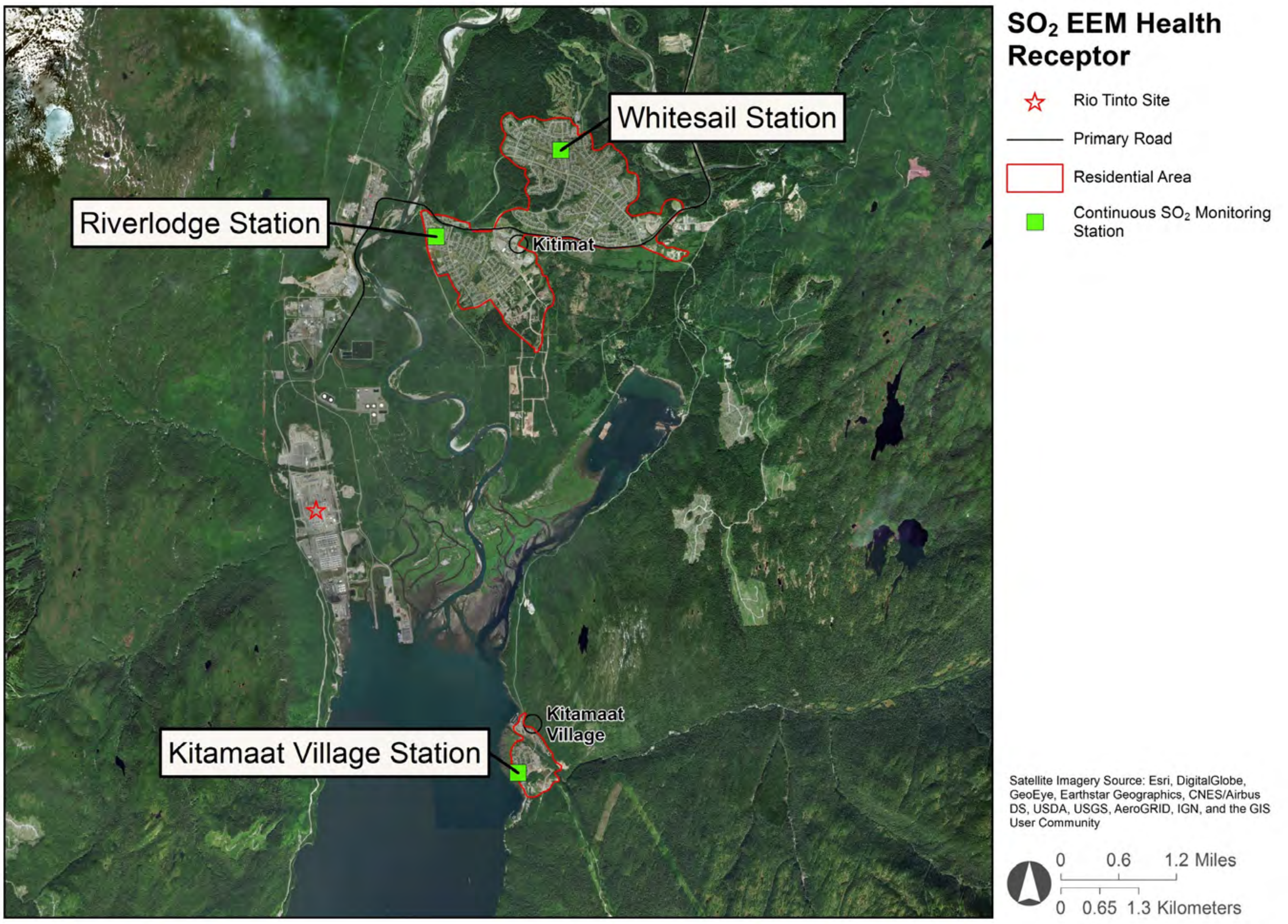

Figure 2. Map showing SO_2 sampling locations used to calculate the Human Health KPI.

3 Terrestrial Ecosystems

Section 5.4 of the draft Phase III Plan provides an overview of work activities for the Terrestrial Ecosystems line of evidence over the period from 2019 to 2025.

The timing of EEM work plan activities for the Plant Biodiversity Monitoring component to be completed in 2021-2025 are illustrated in Table 7 and Table 8. Activities to be completed each year are shown in Table 9.

The target timing of EEM work plan activities for the Soil and Critical Loads Monitoring components to be completed in 2021-2025 are illustrated in Table 11 and Table 12. Activities to be completed each year are shown in Table 13. Timing of activities may be adjusted depending on circumstances.

3.1 Cyanolichen and Vascular Plant Monitoring (Plant Biodiversity Monitoring)

Table 7. Timing of work plan activities to be completed in 2021 for the plant biodiversity monitoring component of the Terrestrial Ecosystems line of evidence (plant biodiversity monitoring component).

Table 8. Schedule of work plan activities to be completed in 2022-2025 for the plant biodiversity monitoring component of the Terrestrial Ecosystems line of evidence.

			Half-month periods in 2022-2025																							
Topic	**#**	**Activity**	1-Jan	15-Jan	1-Feb	14-Feb	1-Mar	15-Mar	1-Apr	15-Apr	1-May	15-May	1-Jun	15-Jun	1-Jul	15-Jul	1-Aug	15-Aug	1-Sep	15-Sep	1-Oct	15-Oct	1-Nov	15-Nov	1-Dec	15-Dec
Planning	1.1	Initial preparation & coordination; update workplan if needed								R	R	R / A														
Planning	1.2	Field operations							Planning				Coordinating													
Planning	1.3	Coordinate any adjustments to the work plan																								
Planning	1.4	Field crew training																								
Planning	1.5	Pre-field review																								
Field Work	2.1	Check / install field supplies, materials and/or equipment																								
Field Work	2.2	Collect field samples and field data																								
Lab Work	3.1	Analyze field samples																								
Lab Work	3.2	Archival of field samples and lab data																								
Data Analysis	4.1	Data compilation and QA																								
Data Analysis	4.2	Data analysis and modelling	Every 3rd year ---------------->																Annual analyses and summaries ----------->						Every 3rd year	
Reporting	5.1	Prepare draft and final technical report on field program	NA; no separate reports on biodiversity monitoring field programs																							
Reporting	5.2	Prepare draft and final technical memo on terrestrial results	End-of-Cycle Report ----------------------->																				Annual Report --------------->			
Reporting	5.3	Prepare draft and final annual report for previous year				Annual EEM Report																				
Reporting	5.4	KPAC consultation on current year's field program								C																
Reporting	5.5	Reviews of draft report for previous year by Rio Tinto								R																
Reporting	5.6	Reviews of draft report for previous year by ENV								R	R	R	R	R												
Reporting	5.7	Presentation of previous year's results to KPAC								C	C	C								D						

Legend: C = Consultation with KPAC; R = Review by Rio Tinto; R = Review by ENV; D = Delivery of final to ENV; A = Acceptance by ENV

Table 9. Annual work plan activities for the plant biodiversity monitoring component of the Terrestrial Ecosystems line of evidence.

Topic	#	Component	Activity Description
Planning	1.1	Initial preparation and coordination	Prepare and coordinate logistics for the annual field monitoring program based on this work plan. Update the work plan if there are any changes required based on the past year's results. Identify risks to the annual project plan and develop strategies to address potential risks. ENV to review and approve the updated work plan.
	1.2	Field operations	**Biodiversity Monitoring** Select and/or confirm field crew. Liaise with Rio Tinto, QPs and field crew throughout the field season, confirming that the work plan is being followed and making any required adjustments due to unexpected events. Identify sites for the current year – 11 total sites to be assessed, plus 3 alternates identified (1 in each deposition type) for a total of 9 alternate sites across all three cycle years. Scope out alternate plot locations during/following the field season to ensure replacement sites are available as needed. Details on plot selection are provided in the Monitoring Plan.
	1.3	Coordinate any work plan adjustments	**Biodiversity Monitoring** Coordinate among field technicians and the QPs regarding any required adjustments to the field programs, and the implications of these adjustments.
	1.4	Training and preparation of field crew	**Biodiversity Monitoring** Train (or retrain) field crews each year, as appropriate, on plant and lichen monitoring methods and soil sampling (soil sampling only occurs during initial plot assessment). Field crews review protocols and procedures in the Field Manual. Conduct planning meeting field crew and Rio Tinto to review: a) site selection, health, safety & environment protocols, and b) decision/communication protocol for field crew selection of alternate site(s). Some (re-)training of field crew will also occur in the field (e.g., lichen identification).
	1.5	Pre-field review	**Biodiversity Monitoring** Update lists of Plants & Ecosystems at Risk (B.C. Conservation Data Centre) and high priority Invasive Plant Species (Invasive Species Council of BC).
Field Work	2.1	Check/install field supplies, materials and/or equipment	**Biodiversity Monitoring** <u>Vegetation</u>: Confirm that all required supplies and materials are available and ready for field visits (as specified in the Field Manual). Confirm GPS, emergency communications and safety equipment is in proper working order. The soil sampling requires bulk density sampling kits or fixed volume sampling kits. There is no additional specialized field equipment for the vegetation sampling. Monument plots on the first sampling visit for long-term monitoring, with permanent stakes placed at plot centre and at each of the four corners. Check/re-establish plot staking in future years.
	2.2	Collect field samples and field data	**Biodiversity Monitoring** <u>Vegetation</u>: Conduct vegetation assessments at 11 plots each year according to the schedule in Table 10. Plot locations are shown in Figure 3. Further details on plot measurements and methods are provided in the Monitoring Plan and Field Manual. Plots will be visited and sampled between June 1 and August 31. Sites are accessed via road (backroad or highway) followed by a walk in. Conduct reconnaissance for plots that need to be established for monitoring in the proceeding years of the 3 year monitoring cycle. *Visual assessment* - When plots are measured to determine biodiversity, a visual inspection and assessment will be conducted to record the condition of vascular plants (including plants in the tree and tall shrub layer), the presence of insects or diseases, or symptoms due to environmental factors (e.g., nutrient deficiencies, SO_2 injury, physical disturbance, drought, flooding, and other abiotic factors). The inspection and assessment will be conducted by a qualified professional (QP) in the plant sciences, as detailed in the Field Manual. Conduct initial internal QA/QC of site data. Physical samples will rarely be taken (e.g., if it is necessary to clarify species identification). <u>Soil chemistry</u>: At the time of first plot measurements, soil samples will be taken to determine soil pH, exchangeable cations, and exchangeable acidity. At each plot, soil samples will be collected outside the plot corners. Samples will be taken at a depth of 0-10 cm. Forest floor material will not be included in the sample. Samples from the four positions will be composited for analysis. Once all samples are collected, ship to laboratory for analysis.
Laboratory Work	3.1	Analyze field samples in laboratory	**Biodiversity Monitoring** <u>Soil chemistry</u>: Following collection, the samples will be analyzed using methods common to the SO_2 EEM (Trent University, 2018) to determine pH, exchangeable cations, and exchangeable acidity. Methods are specified in Field Manual.
	3.2	Archive laboratory and/or field data	**Biodiversity Monitoring** <u>Vegetation</u>: Final field data (and photos) will be archived with Rio Tinto subsequent to the annual processes of compiling, summarizing, and analyzing the data and preparing final reports. Conduct third and final data QA/QC as part of the process of archiving the data. <u>Soil chemistry</u>: The analytical laboratory will record all measurements, note any equipment problems associated with particular analyses, and archive data reports. Once all laboratory and data analyses are complete and finalized, the soil samples are shipped to Rio Tinto for storage in the existing archive of soil samples.
Data Analysis	4.1	Compile data and do QA	**Biodiversity Monitoring** <u>Vegetation</u>: All field observations and field measurements from annual monitoring efforts are entered into a VPro database and Excel spreadsheet. Prepare data summaries and tables. Conduct further QA/QC during process of compiling and summarizing. <u>Soil chemistry</u>: The analytical laboratory will follow standard QA/QC methods and compile the data for analyses.

Topic	#	Component	Activity Description
	4.2	Data analysis and modelling	**Biodiversity Monitoring** Annual Reports. Simple summary statistics (e.g., means and standard deviations of the cover values by deposition class) and simple summary graphics will be developed to present the data for the annual reports. Anomalous data will be identified and, if in error, will be corrected as soon as possible. Beginning in year 4 with the first remeasurements of one-third of the plots, slopes of the trend lines will be calculated. End-of-Cycle Reports. In the first end-of-cycle report (3 years), all of the sites will have a single measurement. Simple analyses of the variability in the observation data across all of the sites and spatial distribution of values relative to levels of deposition will be conducted. At the end of year 6, all plots will have been re-measured, and trends at high and moderate deposition sites will be compared to those at reference sites. The analyses of comparative trends will be repeated every 3 years. We will apply a number of different analytical methods to these data. Apply general linear models in a Before-After-Control-Impact type design to test if S deposition and soil chemistry are significant explanatory variables in explaining differential temporal trends at higher deposition sites (i.e., different from the trends at reference sites), after accounting for common year effects affecting all sites (e.g., due to year to year variation in climate) and other site factors that might influence plant response (e.g., aspect, elevation, available light). Further details on the statistical analyses are provided in the Field Manual.
Reporting	5.1	Prepare report on field program	**Biodiversity Monitoring** Included in 5.2
	5.2	Prepare technical memo on terrestrial program	Prepare a technical memo summarizing terrestrial ecosystem actions, analyses, and results as per the Terms of Reference in Appendix B. **Biodiversity Monitoring** An annual report of activities (5.1) will be submitted by December 31st of the current year except at the end of a 3-year measurement cycle when the annual report will be merged with the End-of-Cycle report. An End-of-Cycle report will be prepared at the end of each 3-year cycle and will be submitted by March 31st of the following year to allow sufficient time to conduct the data analysis and interpret the results. The annual report will describe the methods and results of the field program, as per the terms of reference in Appendix B. The annual summaries of the field program will include implementation (including issues and adjustments, if applicable), data collected, and recommendations for following year's field program. The field program summaries will be integrated into the annual technical reports, as appropriate. The annual reports will also present a summary of each year's field results and recommendations. The first End-of-Cycle report (Year 3) will describe patterns in the observation data across all sites based on the first measurements. From year 4 and onwards, the annual reports will also include the calculated slopes of trend lines for each plot that has had repeat sampling. The results and discussion of the statistical analyses of comparative trends will be included in End-of-Cycle reports starting in year 6. The terms of reference for the annual report are detailed in Appendix B. **Soils Monitoring and Critical Loads Monitoring** *[addressed separately in Table 13]*
	5.3	Prepare chapter for annual report	Prepare the terrestrial chapter of the annual report, according to the Terms of Reference for the Annual Report in Appendix B.
	5.4	KPAC meeting	Consult with the KPAC on the intended plan for the field program(s) in the current year, and revise if required.
	5.5	RT review	Rio Tinto reviews the tech memos and annual report; QPs makes revisions as required.
	5.6	ENV review	ENV reviews the tech memos and annual report; QPs makes revisions as required.
	5.7	Present results to KPAC	Present the results from the previous year's SO_2 EEM report. In 2021, task 5.7 is delayed due to work on finalizing the Phase III Plan.

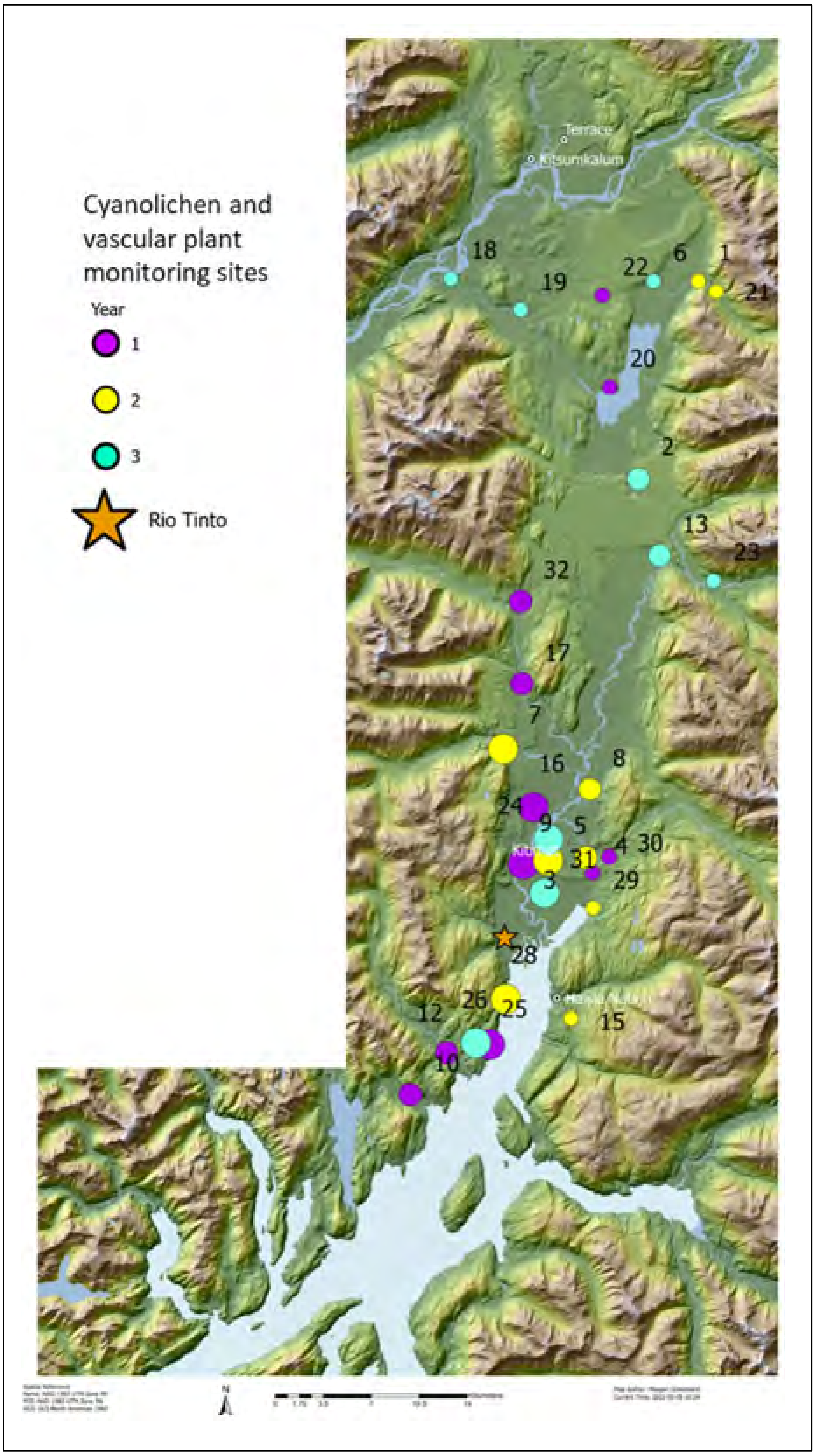

Figure 3. Location of cyanolichen and vascular plant monitoring sites. The plots are colour-coded by cohort (i.e., the year of initial assessment). The size of the dots represents whether the site is located within a high, medium or low deposition zone, as per Table 10.

Table 10. Three year monitoring cycle of cyanolichen and vascular plant monitoring plots

Plot #	Easting	Northing	BEC Subzone and Variant		Deposition Zone	Year
30	527179	5990884	CWH	vm1	L	1
22	526676	6031777	CWH	ws1	L	1
4	525944	5989784	CWH	vm1	L	1
20	527222	6025103	CWH	ws1	L	1
32	520702	6009460	CWH	ws1	M	1
10	512679	5973563	CWH	vm1	M	1
12	515291	5976609	CWH	vm1	M	1
17	520801	6003473	CWH	ws1	M	1
26	518455	5977210	CWH	vm1	H	1
16	521631	5994495	CWH	vm1	H	1
9	520895	5990386	CWH	vm1	H	1
15	524377	5979097	CWH	vm1	L	2
21	535012	6032054	CWH	ws1	L	2
1	533706	6032830	CWH	ws1	L	2
29	525991	5987150	CWH	vm1	L	2
3	525490	5990827	CWH	vm1	M	2
8	525764	5995821	CWH	vm1	M	2
TBD*			CWH			2
TBD*			CWH			2
28	519623	5980517	CWH	vm1	H	2
7	519432	5998784	CWH	vm1	H	2
5	522709	5990667	CWH	vm1	H	2
18	515594	6033009	CWH	ws1	L	3
23	534806	6010948	CWH	ws1	L	3
19	520698	6030688	CWH	ws1	L	3
6	530418	6032820	CWH	ws1	L	3
13	530863	6012801	CWH	ws1	M	3
2	529321	6018428	CWH	ws1	M	3
TBD*			CWH			3
TBD*			CWH			3
31	522437	5988257	CWH	vm1	H	3
25	517436	5977325	CWH	vm1	H	3
24	522742	5992140	CWH	vm1	H	3

*Reconnaissance for the additional four required sites (in years 2 and 3) will be undertaken in 2021.

3.2 Soil and Critical Loads Monitoring Components

Table 11. Timing of work plan activities to be completed in 2021 for the soils and critical loads component of the Terrestrial Ecosystems line of evidence. (C=consultation; R=review; D=delivery of final)

			Half-month periods in 2021																							
Topic	**#**	**Activity**	1-Jan	15-Jan	1-Feb	14-Feb	1-Mar	15-Mar	1-Apr	15-Apr	1-May	15-May	1-Jun	15-Jun	1-Jul	15-Jul	1-Aug	15-Aug	1-Sep	15-Sep	1-Oct	15-Oct	1-Nov	15-Nov	1-Dec	15-Dec
Planning	1.1	Initial preparation & coordination; update workplan if needed																								
Planning	1.2	Field operations																								
Planning	1.3	Coordinate any adjustments to the work plan																								
Planning	1.4	Field crew training																								
Field Work	1.5	Check / install field supplies, materials and/or equipment											Check permanent plots													
Field Work	2.1	Collect field samples and field data											Tag Kemano trees in 2022 or 2023													
Lab Work	2.2	Analyze field samples																								
Lab Work	3.1	Archival of field samples and lab data																								
Data Analysis	3.2	Data compilation and QA																								
Data Analysis	4.1	Data analysis and modelling																								
Reporting	4.2	Prepare draft and final technical report on field program																								
Reporting	5.1	Prepare draft and final technical memo on terrestrial results																								
Reporting	5.2	Prepare draft and final annual report for previous year									2020 Annual EEM Report															
Reporting	5.3	Prepare draft and final annual report for previous year									2020 Annual EEM Report															
Reporting	5.4	KPAC consultation on current year's field program								C																
Reporting	5.5	Reviews of draft report for previous year by Rio Tinto																		R		R				
Reporting	5.6	Reviews of draft report for previous year by ENV																			R		D			
Reporting	5.7	Presentation of previous year's results to KPAC								C											C	C				

Table 12. Schedule of work plan activities to be completed in 2022-2025 for the soils and critical loads component of the Terrestrial Ecosystems line of evidence. (C=consultation; R=review; D=delivery of final)

			Half-month periods in 2022-2025						(2025 only unless noted)																	
Topic	**#**	**Activity**	1-Jan	15-Jan	1-Feb	14-Feb	1-Mar	15-Mar	1-Apr	15-Apr	1-May	15-May	1-Jun	15-Jun	1-Jul	15-Jul	1-Aug	15-Aug	1-Sep	15-Sep	1-Oct	15-Oct	1-Nov	15-Nov	1-Dec	15-Dec
Planning	1.1	Initial preparation & coordination; update workplan if needed								R	R	R/ A														
Planning	1.2	Field operations							Planning				Coordinating													
Planning	1.3	Coordinate any adjustments to the work plan																								
Planning	1.4	Field crew training																								
Field Work	1.5	Check / install field supplies, materials and/or equipment												<---- Annual check of plots ---->												
Field Work	2.1	Collect field samples and field data																								
Lab Work	2.2	Analyze field samples																								
Lab Work	3.1	Archival of field samples and lab data																							Occurs after CR --->	
Data Analysis	3.2	Data compilation and QA																								
Data Analysis	4.1	Data analysis and modelling																							During 2026 CR ---->	
Reporting	4.2	Prepare draft and final technical report on field program																				Part of the 2026 Comprehensive Review --->				
Reporting	5.1	Prepare draft and final technical memo on terrestrial results																				Part of the 2026 Comprehensive Review --->				
Reporting	5.2	Prepare draft and final annual report for previous year				Annual EEM Report																				
Reporting	5.3	Prepare draft and final annual report for previous year				Annual EEM Report																				
Reporting	5.4	KPAC consultation on current year's field program								C																
Reporting	5.5	Reviews of draft report for previous year by Rio Tinto								R																
Reporting	5.6	Reviews of draft report for previous year by ENV								R	R	R	R	R												
Reporting	5.7	Presentation of previous year's results to KPAC								C	C	C														

Legend: C = Consultation with KPAC; R = Review by Rio Tinto; R = Review by ENV; D = Delivery of final to ENV; A = Acceptance by ENV

Table 13. Annual work plan activities for the soils and critical loads component of the Terrestrial Ecosystems line of evidence.

Topic	#	Component	Activity Description
Planning	1.1	Initial preparation and coordination	**Soils Monitoring** Long-term acidification: In 2025 only, prepare and coordinate logistics for field monitoring program. Unless otherwise specified, all tasks in this work plan associated with the long-term acidification element apply *only to 2025*. **Critical Loads Monitoring** Wetland geochemistry: In 2021, establish project objectives, develop and document approach, and revise this work plan as appropriate for this additional study, as described in Section 5.3.7.1 (i.e., details not in current work plan). Aluminum solubility: In 2021, establish project objectives, develop and document approach, and revise this work plan as appropriate for this additional study, as described in Section 5.3.7.2 (i.e., details not in current work plan).
	1.2	Field operations	**Soils Monitoring** Long-term acidification: Select and/or confirm field crew. Liaise with Rio Tinto, field technicians, analytical laboratories, and QPs, as appropriate, throughout the field season, confirming that the work plan is being followed and making any required adjustments due to unexpected events. Locations within each subplot in each future sampling year are already identified.
	1.3	Coordinate any work plan adjustments	**Soils Monitoring** Long-term acidification: Coordinate between field technicians and the Terrestrial QPs regarding any required adjustments to the field program, and the implications of these adjustments.
	1.4	Field crew training	**Soils Monitoring** Long-term acidification: Field crew and/or students supporting the QPs will be trained on field protocols and soil sampling methodology as appropriate.
Field Work	2.1	Check / install field equipment	**Soils Monitoring** Long-term acidification: Starting in 2021, inspect plot staking (i.e., corner posts and centre stakes) for permanent plots annually, with expectation of requiring some replacements of posts/stakes every couple of years. In 2025 only, confirm that all required supplies and materials are available and ready for field visits, including checking that GPS, emergency communications and safety equipment are in proper working order. Confirm that all field equipment is functioning properly. Approximately 2 days are required per plot to start up work, collect the soil samples and measure the trees.
	2.3	Collect field samples and field data	**Soils Monitoring** Long-term acidification: In 2022 or 2023, tag and remeasure/reidentify trees in the Kemano plot, as done for the plots at Lakelse Lake and Coho Flats. In 2025 only, resample the primary permanent soil plots at Coho Flats and Lakelse Lake. Collect 20 soil samples at 3 depths at each plot (120 total soil samples), following established methodology (see Section 5.3.2). Continue monitoring of trees on the plots – record the species/locations of trees and measure DBH (diameter at breast height) for all trees with DBH >10 cm. The plots will be resampled during summer 2025. Plot locations are shown in Figure 4.
Lab Work	3.1	Analyze field samples in laboratory	**Soils Monitoring** Long-term acidification: Conduct laboratory analyses on collected samples to assess organic matter content, exchangeable base cations, exchangeable acidity, and pH.
	3.2	Archive laboratory data	**Soils Monitoring** Long-term acidification: The analytical laboratory will record all measurements, note any equipment problems associated with particular analyses, and archive data reports. Once all laboratory and data analyses are complete and finalized, the soil samples are shipped to Rio Tinto for storage in the existing archive of soil samples.
Data Analysis	4.1	Compile data and do QA	**Soils Monitoring** Long-term acidification (2025 only): All field observations, field measurements and laboratory analyses from annual sampling efforts are entered into a spreadsheet that includes past years' data. The analytical laboratory will follow standard QA/QC methods and compile the data for analyses.
	4.2	Data analysis and modelling	**Soils Monitoring** Long-term acidification: Conduct analyses of the changes in base saturation (see Section 5.3.2) as part of the 2026 Comprehensive Review including changes in base saturation, minimum detectable difference). Further details on the specific methods are provided in the 2019 Comprehensive Review. Calculate basal area increment for the trees measured.
Reporting	5.1	Prepare report on field program	**Soils Monitoring** In any year with field work prior to 2025, a basic summary of the field program – methods, implementation (including issues and adjustments, if applicable), data collected, and recommendations for following year's field program – will be developed and integrated into the Annual Report.

Topic	#	Component	Activity Description
	5.2	Prepare technical memo on terrestrial program	Prepare a technical memo summarizing terrestrial ecosystem actions, analyses, and results as per the Terms of Reference in Appendix B. **Biodiversity Monitoring** *[addressed separately in Table 9]* **Soils Monitoring** Long-term acidification: Summary of field and laboratory actions, results of laboratory analyses and data analyses, and discussion of the results will be included in the 2026 Comprehensive Review. **Critical Loads Monitoring** Wetland geochemistry: Summary of field actions, laboratory actions and resultant data in the 2022 and 2023 Annual Reports. Analyses of the data from this study, discussion of the results and recommendations will be included in the 2024 Annual Report. Aluminum solubility: Summary of laboratory actions and resultant data in the 2022 and 2023 Annual Reports. Analyses of the data from this study, discussion of the results and recommendations will be included in the 2024 Annual Report.
	5.3	Prepare chapter of annual report	Prepare the terrestrial chapter of the annual report, according to the Terms of Reference for the Annual Report in Appendix B.
	5.4	KPAC meeting	Consult with the KPAC on the intended plan for the field program in the current year, and revise if required.
	5.5	RT review	Rio Tinto reviews the tech memos and annual report; Terrestrial QPs makes revisions as required.
	5.6	ENV review	ENV reviews the tech memos and annual report; Terrestrial QPs makes revisions as required.
	5.7	Present results to KPAC	Present the results from the previous year's SO_2 EEM report. In 2021, task 5.7 is delayed due to work on finalizing the Phase III Plan.

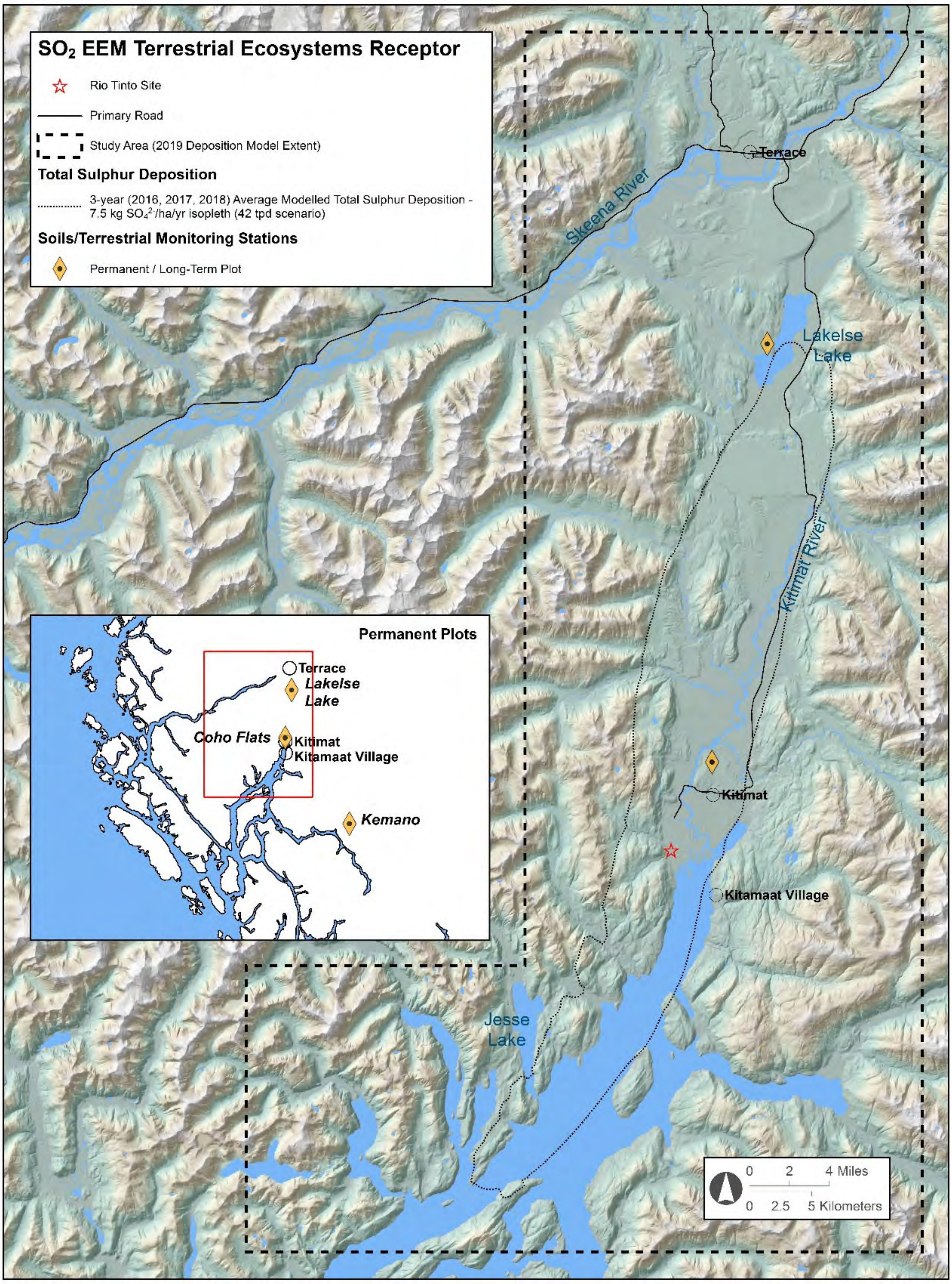

Figure 4. Location of the long-term monitoring plots (n = 3). The three long-term soil plots are at Coho Flats (latitude: 54.07660, longitude: –128.65117), Lakelse Lake (latitude: 54.37827, longitude: –128.57990) and Kemano (latitude: 53.53032, longitude: –127.97384). Background deposition of 3.6 kg SO_4^{2-}/ha/yr is not included in the isopleth.

4 Aquatic Ecosystems

Section 6.4 in the draft Phase III Plan provides an overview of work activities for the Aquatic Ecosystems line of evidence over the period from 2019 to 2025. The target timing of EEM work plan activities to be completed in 2021 are illustrated in Table 14. The year 2021 includes some special activities which are not required in subsequent years. Activities to be completed over each year of the period from 2022 to 2025 are shown in Table 15. Timing of activities may be adjusted depending on circumstances. The specifics of each activity are described in Table 16. For detailed methods, see Limnotek (2020).

Table 14. Timing of work plan activities to be completed in 2021 for the Aquatic Ecosystems line of evidence. (C=consultation; R=review; D=delivery of final)

Topic	#	Activity	Half-month periods in 2021																							
			1-Jan	15-Jan	1-Feb	14-Feb	1-Mar	15-Mar	1-Apr	15-Apr	1-May	15-May	1-Jun	15-Jun	1-Jul	15-Jul	1-Aug	15-Aug	1-Sep	15-Sep	1-Oct	15-Oct	1-Nov	15-Nov	1-Dec	15-Dec
Planning	1.1	Initial preparation & coordination; update workplan if needed								R	R	R/A														
Planning	1.2	Direct field operations, liaise w Rio Tinto & labs																								
Planning	1.3	Coordinate any adjustments to the work plan per activity 1.2																								
Field Work	2.1	Install, inspect and/or prepare field equipment								LAK006, LAK028									Annual sampling							
Field Work	2.2	Calibrate field equipment										LAK006 & LAK028 in each window May-Aug									All lakes					
Field Work	2.3	Collect field samples and field data										LAK006 & LAK028 in each window May-Aug									All lakes					
Lab Work	3.1	Analyze field samples for water chemistry																								
Lab Work	3.2	Archival of field samples and lab data																								
Data Analysis	4.1	Data compilation and QA																								
Data Analysis	4.2	Data analysis and modelling																								
Reporting	5.1	Prepare draft and final technical report on field program	Technical report on 2020 field pgm																							
Reporting	5.2	Prepare draft and final technical memo on aquatics results									2020 EEM Technical Memos															
Reporting	5.3	Prepare draft and final annual report for previous year									2020 Annual EEM Report															
Reporting	5.4	KPAC consultation on current year's field program								C																
Reporting	5.5	Reviews of draft report for previous year by Rio Tinto																		R		R				
Reporting	5.6	Reviews of draft report for previous year by ENV																			R		D			
Reporting	5.7	Presentation of previous year's results to KPAC								C											C	C				

Table 15. Schedule of work plan activities to be completed in 2022-2025 for the Aquatic Ecosystems line of evidence. (C=consultation; R=review; D=delivery of final)

Topic	#	Activity	Half-month periods in 2022-2025																							
			1-Jan	15-Jan	1-Feb	14-Feb	1-Mar	15-Mar	1-Apr	15-Apr	1-May	15-May	1-Jun	15-Jun	1-Jul	15-Jul	1-Aug	15-Aug	1-Sep	15-Sep	1-Oct	15-Oct	1-Nov	15-Nov	1-Dec	15-Dec
Planning	1.1	Initial preparation & coordination; update workplan if needed							R	R	R / A															
Planning	1.2	Direct field operations, liaise w Rio Tinto & labs																								
Planning	1.3	Coordinate any adjustments to the work plan per activity 1.2																								
Field Work	2.1	Install, inspect and/or prepare field equipment								LAK006, LAK028									Annual sampling							
Field Work	2.2	Calibrate field equipment										LAK006 & LAK028 in each window May-Aug									All lakes					
Field Work	2.3	Collect field samples and field data										LAK006 & LAK028 in each window May-Aug									All lakes					
Lab Work	3.1	Analyze field samples for water chemistry																								
Lab Work	3.2	Archival of field samples and lab data																								
Data Analysis	4.1	Data compilation and QA																								
Data Analysis	4.2	Data analysis and modelling																								
Reporting	5.1	Prepare draft and final technical report on field program	Technical report on last year's field program																							
Reporting	5.2	Prepare draft and final technical memo on aquatics results				EEM Technical Memos																				
Reporting	5.3	Prepare draft and final annual report for previous year				Annual EEM Report																				
Reporting	5.4	KPAC consultation on current year's field program								C																
Reporting	5.5	Reviews of draft report for previous year by Rio Tinto								R																
Reporting	5.6	Reviews of draft report for previous year by ENV								R	R	R	R	R												
Reporting	5.7	Presentation of previous year's results to KPAC								C	C	C									D					

Legend: C = Consultation with KPAC; R = Review by Rio Tinto; R = Review by ENV; D = Delivery of final to ENV; A = Acceptance by ENV

Table 16. Annual work plan activities for the Aquatic Ecosystems line of evidence.

Topic	#	Activity	Activity Description
Planning	1.1	Initial preparation and coordination	Prepare and coordinate logistics for the annual field monitoring program based on this work plan. Update the work plan if there are any changes required based on the past year's results. ENV to review and approve the updated work plan.
	1.2	Field operations	Liaise with Rio Tinto, the helicopter company, field technicians in Terrace, and analytical laboratories including Biogeochemical Analytical Services Laboratory (BASL; U. Alberta, Edmonton) throughout the field season, confirming that the work plan is being followed and making any required adjustments due to unexpected events.
	1.3	Coordinate any work plan adjustments	Coordinate between field technicians and the Aquatic QP regarding any required adjustments to the field program, and the implications of these adjustments.
Field Work	2.1	Check / install field equipment	Confirm that all field equipment is working properly, including Onset pH and temperature loggers, water level and barometric pressure loggers (LAK006 and LAK028); WTW pH meter (all lakes); boats, vehicles, GPS, emergency communications and safety equipment. Install intensive monitoring stations in LAK006 and LAK028. Install/maintain temperature mooring in LAK028, which consists of a vertical line with 10 Onset temperature loggers at various depths from the lake surface to the bottom, continuously logging all four seasons. The temperature mooring in LAK028 is left in place year-round and the battery life is checked on each download visit. Two days are taken to start up work at each of LAK006 and LAK028 (one day for equipment set up and one day for first sampling). It has been standard practice to visit the lakes two weeks after the installation date to make sure the loggers are working properly.
	2.2	Calibrate field equipment	<u>LAK006 and LAK028 intensive monitoring</u>: Once monthly visits to calibrate Onset pH meters. Replace Onset pH sensors every month. In October, the pH meters are calibrated approximately weekly, during each sampling visit. The temperature loggers do not require calibration. <u>Annual sampling in October</u>: Calibrate WTW pH meter prior to each sampling day.
	2.3	Collect field samples and field data	<u>LAK006 and LAK028 intensive monitoring</u>: Monitor pH every half-hour and lake water levels according to methods described in section 6.3 of the Phase III Plan. While calibrating Onset pH meter every month, download past data and collect surface water (and bottom water, for LAK028 only) samples for WTW (field), and analytical laboratories (including BASL for Gran ANC). See description in section 6.3 of the Phase III Plan and Limnotek (2020). Field and laboratory pH probes should be kept in the water sample for at least 10 minutes to ensure a stable reading. Conduct CTD casts (i.e., water column sampling) during monthly visits to LAK006 and LAK028. <u>LAK028 temperature profile monitoring:</u> Download temperature data in May, August and October. <u>Annual sampling</u>: Collect samples in October from 7 sensitive lakes (LAK006, LAK012, LAK022, LAK023, LAK028, LAK042, LAK044); 3 control lakes (NC184, NC194, DCAS14A); and 1 less sensitive lake (LAK016) (see map in Figure 5), description in section 6.3 of the Phase III Plan, and sampling methods in Limnotek (2020). Lake access for sampling is as follows: • All 11 lakes will be sampled once annually by helicopter at the end of September or the start of October • Six sensitive lakes (LAK006, LAK012, LAK023, LAK028, LAK042, LAK044) will be sampled 3 additional times / year in October through road access and hiking with an inflatable boat, except for LAK028 (where a boat is permanently stored) Samples should be shipped to the appropriate laboratories on the day after the day of sampling. When possible, the crew needs to avoid sampling late in the week because there is risk of samples being left in a warehouse or truck for an extended period over a weekend or holidays. Conduct photo-documentation of each lake during sampling visits.
Lab Work	3.1	Analyze field samples in laboratory	Laboratory analyses include pH, alkalinity and Gran ANC at BASL and a full scan of other analytes at an appropriate analytical laboratory (i.e., NH_4-N, NO_3-N, TN, TP, TDP, SRP, Cl, F, SO_4, DIC, DOC, specific conductance, TDS, dissolved Al, total Al, inorganic monomeric Al, and an ICP scan for total and dissolved cations). Laboratories also analyze blank, duplicate and spiked samples (see Limnotek 2020). The lab pH measurements will always exceed hold times, which emphasizes the importance of including a section in the aquatic data report on method effects on pH measurement.
	3.2	Archive laboratory data	BASL will archive the data from the Mantech PC automatic titrator to provide ancillary information for confirming ANC thresholds. BASL and/or other analytical laboratories will record all measurements, note any equipment problems associated with particular analyses, and archive data reports. Samples are discarded from the labs one month after analysis.
Data Analysis	4.1	Compile data and do QA	All field observations, field measurements and laboratory analyses from annual sampling efforts are entered into a spreadsheet that includes past years' data. Data from LAK006 and LAK028 (i.e., continuous pH, temperature, lake levels) are entered into separate worksheets. Multiple pH measurements using different equipment are compared (e.g., Limnotek 2020) to assess if there is an instrument effect, and to check the Onset pH sensor for drift. Analyses of blank samples are analyzed to determine if any exceed the detection limit (positive blanks), replicate samples are analyzed to determine laboratory precision, and spiked samples are analyzed to determine laboratory accuracy (Limnotek 2020).
	4.2	Data analysis and modelling	Conduct data analyses and modelling as outlined in section 6.3. Examine empirical changes in water chemistry. Apply Bayesian analysis to determine strength of evidence that changes in primary water chemistry metrics are greater than the thresholds associated with the KPI and informative indicators. Apply the simple evidentiary framework to assess the causal linkage of any observed changes in water chemistry to smelter emissions. Evaluate the differential trends between sensitive lakes and control lakes using the Bayesian BACI methods from the 2019 Comprehensive Review. Further details on the specific methods are provided in the 2019 Comprehensive Review, the 2019 Annual Report and previous Annual Reports.
Reporting	5.1	Prepare report on field program	Describe the methods and results of the field program, following the format of the terms of reference in Appendix B for the components described above.
	5.2	Prepare technical memo on aquatic program	Prepare a technical memo summarizing aquatic ecosystem actions, analyses, and results as per the Terms of Reference in Appendix B. In 2022 (for the 2021 Annual Report), the technical memo will include analyses of ANC metrics, and a re-evaluation of each lake for inclusion in future sampling.
	5.3	Prepare Aquatic Ecosystems chapter of annual report	Prepare the aquatic chapter of the annual report, according to the Terms of Reference for the Annual Report in Appendix B.
	5.4	KPAC meeting	Consult with the KPAC on the intended plan for the field program in the current year, and revise if required.
	5.5	RT review	Rio Tinto reviews the tech memos and annual report; Aquatic QP makes revisions as required.
	5.6	ENV review	ENV reviews the tech memos and annual report; Aquatic QP makes revisions as required.
	5.7	Present results to KPAC	Present the results from the previous year's SO_2 EEM report. In 2021, task 5.7 is delayed due to work on finalizing the Phase III Plan.

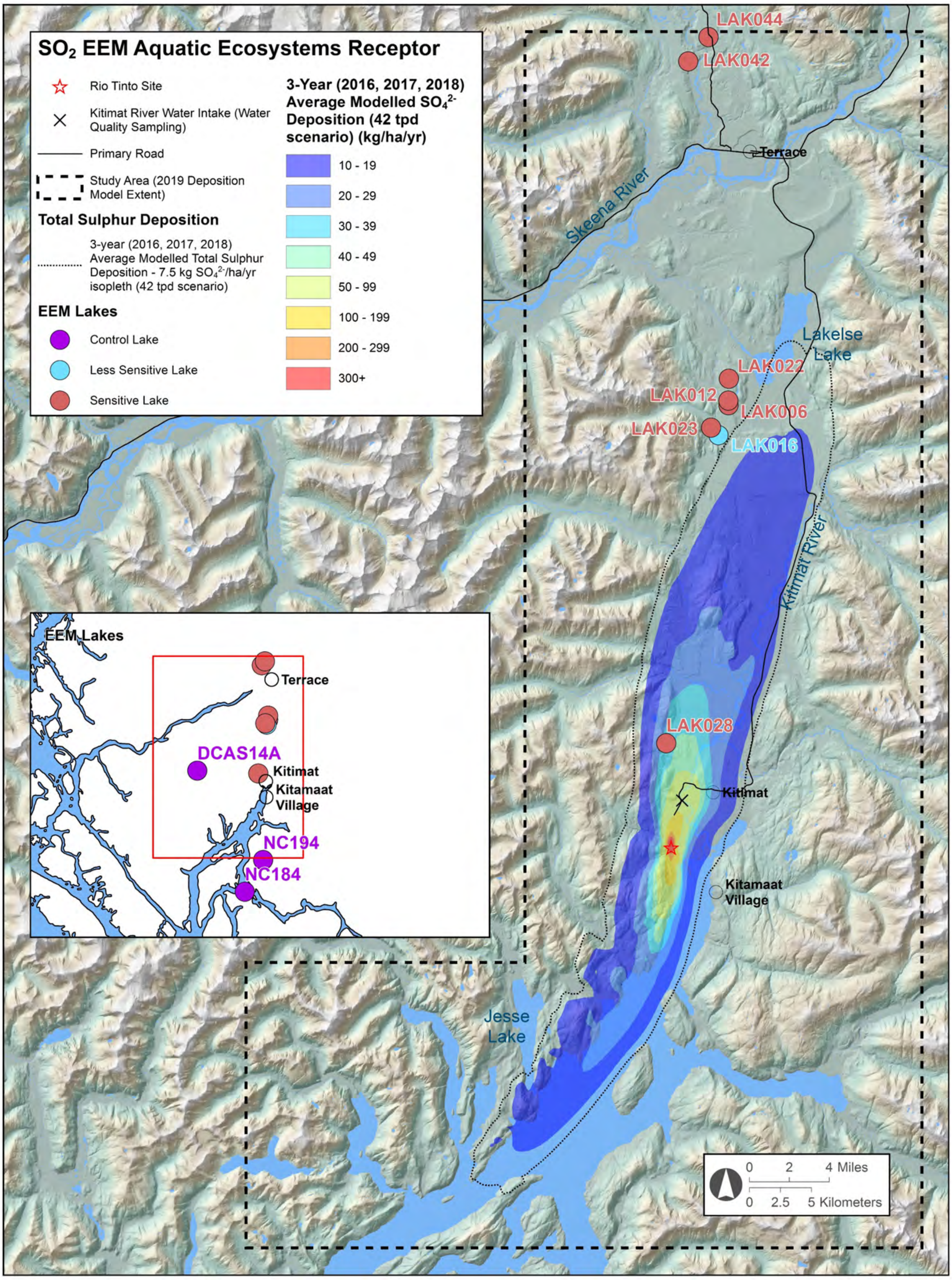

Figure 5. Lakes from which water chemistry samples will be taken (Activity #2.3).

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.

Field Manual
Vascular Plant Biodiversity and Cyanolichen Monitoring Program
Rio Tinto B.C. Works

Prepared by Amanita Coosemans and John Laurence
29 April 2021

Version 2.1, September 19th, 2022

Suggested citation: Coosemans, A., and J. Laurence. Field manual, Vascular Plant Biodiversity and Cyanolichen Monitoring Program; Version 2.1: September 19th, 2022. Prepared for Rio Tinto B.C. Works, 45pp.

Document Revision History		
Version	***Date***	***Comments***
Revision	May 26th, 2021	Internal review.
Revision	June 4th, 2021	Adjustments in response to ENV comments.
Version 2.0	July 28th, 2022	Added Document Revision History table and removed references to counts of individual plants within plots.
Version 2.1	September 19th, 2022	Replaced field form Page 1 with updated version that has additional fields for data collection (e.g. additional photos and soil sample depths). Minor formatting and wording improvements throughout document to improve clarity.

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Attachment 1_Example sample size_power analysis from Vaccinium cover.pdf

Introduction

The Vascular Plant and Cyanolichen Monitoring Program (PCMP / the Program) is designed to detect potential changes in the biodiversity (species richness and abundance) of vascular plants in the low shrub and forb layers and of cyanolichens in forest ecosystems of the Kitimat Valley and Lakelse Watersheds. The Program focuses on detecting mid-to-long-term effects on plants and cyanolichens due to acidification of soils or lichen substrates due to emissions of SO_2 from the Rio Tinto BC Works (RTBC) south of Kitimat. The details of the Program are found in Laurence *et al.* (2020).

This field manual establishes the methods and protocols that will be used in the PCMP.

Pre-Field Planning Activities and Methods

Annual Pre-Field Planning Meeting

Once the field crew is selected each year, a pre-field planning meeting will be undertaken with the crew and Rio Tinto program staff. During the annual pre-field meeting, expectations will be set with respect to all aspects of the field Program, at minimum including the following:

- health and safety briefing, planning, and documentation;
- review of previous season's Program results, issues encountered, lessons, etc.;
- confirmation of site selection for the season, including an updated plan for potentially inaccessible sites, addition of replacement sites, or other issues that may affect plot assessment during the field Program;
- identification of forms, documents, and materials required;
- scheduling (training, field session, etc.).

Training

Prior to commencing fieldwork, field team members must be trained and knowledgeable in the health, safety and environmental stewardship expectations; the field methods identified in this manual; and in vascular plant & cyanolichen identification. Training will include a mix of independent learning and group sessions and will encompass both office- and field- based learning.

A reference collection of cyanolichens has been provided by Patrick Williston of the British Columbia Ministry of Environment and Climate Change Strategy (BC ENV) and will be maintained and further developed as needed during the Program. No reference collection is currently planned for vascular plants, as their identification is not expected to be problematic and many resources are available for the species anticipated to occur at the plots.

Review of relevant updated information sources

Plants and Ecosystems at Risk

Prior to undertaking field sessions each year, the BC Conservation Data Centre (CDC) must be consulted to determine what plants and ecosystems are identified as "at risk," including provincially identified species or ecosystems, and federally identified species (through COSEWIC and/or SARA Schedule 1). Currently, the BC CDC offers the BC Species & Ecosystems Explorer to facilitate the search (available at https://a100.gov.bc.ca/pub/eswp/). Search criteria must include the following:

- BC List (Red: Extirpated, Endangered or Threatened; and Blue: Special Concern);
- COSEWIC Status (Endangered; Threatened; and Special Concern);
- Legal Designation (Federal Species at Risk Act (SARA); Provincial Forest and Range Practices Act (FRPA) – Previously Identified Wildlife; Provincial Wildlife Act; and Land Use Objectives (LUO)).

In addition, an Area (e.g. ecoregions) or Biogeoclimatic Unit (e.g. CWH zone) and/or Habitat Type (e.g. Forest—*for species only, not ecosystems) may be selected in order to reduce and refine the list. These spatial options should be selected with caution, recognizing that not all species information is spatially complete; results should be cross-checked with a non- area-based search of the CDC database prior to finalizing the list of potential plants and ecosystems at risk in the study area.

Invasive Plants

Prior to undertaking field sessions each year, the BC Invasive Species Council (ISC) should be consulted for a list of high priority species. Ideally, field crews will have the Report Invasives BC application downloaded and updated on their devices and can use it both to look up suspected weed species and report them to the ISC—particularly if any high priority species are observed.

Biogeoclimatic Ecosystem Classification (BEC)

Although unlikely to change from year to year, the Province updates BEC from time to time; plot classification should be reviewed whenever a BEC update is released.

Field Methods

Health, Safety & Environmental Stewardship

Field teams must ensure they approach fieldwork in line with RTBC safety and environmental standards and following best practices for environmental stewardship.

Health and Safety Protocols

Health and Safety are paramount to the Program. All field activities will conform to RTBC standards using their risk assessment and mitigation methodology. Safety plans will be developed annually in collaboration with the RTBC project manager and reviewed during the Annual Pre-Field Planning Meeting. The plans will be reviewed and approved by RTBC before field activities commence for the year.

Environmental Stewardship Protocols

Invasive species management

Plots are located in rare and sensitive forest environments and are sometimes located adjacent to highly sensitive wetland or riparian ecosystems: The introduction of invasive species is a particular concern for this project.

Ideally, fieldwork will be undertaken prior to seed set for most weed species present in the study area (generally beginning in August and peaking in early September). Prior to starting the journey to any plot, ensure that clothing, boots and vehicle are free of excess dirt, and that no seeds are present. If necessary, wash the vehicle, including the undercarriage and tires. When arriving at a site, avoid parking in weed-infested areas—particularly if weeds are setting seed. Avoid walking through weedy areas, and check clothing and footwear prior to entering uninfested areas—particularly older forests and wetlands—removing and securing any seeds found to ensure they do not spread to new areas. If the risk of introducing weed seeds is high, communicate this information to the project manager. Substitute the plot with another and ensure timing of fieldwork at the plot the following year will avoid the seeding period.

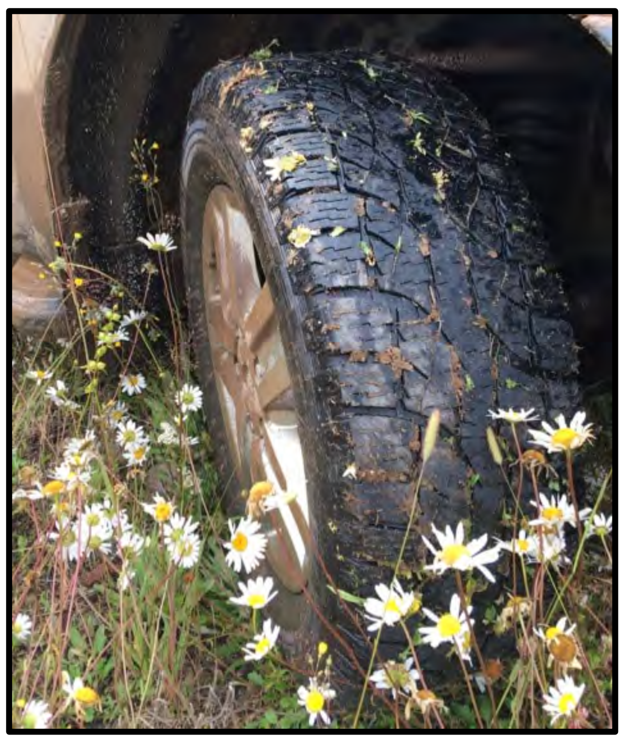

Photo 1: Tire showing potential transport of weed seeds (oxeye daisy and hawkweed) from infested area.

Avoiding Damage to Sensitive Areas, Wildlife, or Wildlife Habitat

In addition to managing the spread of invasive weeds, crews must be aware of other potential for disrupting habitat or wildlife.

All waterways, riparian areas and wetlands are sensitive areas, and field crews must conduct themselves in a manner that will not cause damage. For instance, it is not acceptable to drive through or park in sensitive areas, including small streams or seasonally wet meadows.

Most direct, human-caused wildlife mortality is associated with roads. Crews will drive at an appropriate speed to avoid collisions with wildlife and will avoid driving at dawn and dusk—when wildlife activity peaks and visibility is poor. If a wildlife migration is in progress across an access route (e.g. migration of juvenile western toads), the site(s) should not be visited unless or until access can be attained without harm to wildlife.

Human-wildlife conflicts represent another major—largely preventable—source of mortality for wildlife. Crews will follow established RTBC protocols to protect themselves and wildlife from dangerous encounters, including keeping food and waste secure (in trucks), and carrying bear spray.

Plot Establishment

A total of 33 plots will be assessed in a three-year rotating panel, with 11 plots measured in each given year. Plots have been classified into one of three deposition zone classes—Low, Medium, and High—based on the CALPUFF-modelled 42 TPD emissions scenario. (See Table 1).

In the fall of 2020, the 32 cyanolichen plots originally established by Patrick Williston (ENV; Williston and Perkins 2019) were assessed for potential use in this Program. At that time, a total of 29 plots at or near the original ENV locations were considered feasible (ENV-designated plot #s have been retained and are identified with these numbers in Table 1): All but one of these plots was marked at that time with temporary wire flags at the corners and flagging around a center tree (one plot was not physically marked as it was located in Haisla territory). Plot locations and any previously gathered data for these plots will be provided during the initial pre-field planning meeting, and will be updated during subsequent annual meetings.

Plots will be established as 20m x 20m, and (wherever practical) will be oriented along the cardinal directions.

Table 1: Schedule for Plot Establishment (with location and deposition zone, where known)[1].

Plot #	Easting	Northing	BEC Subzone and Variant		Deposition Zone	Sulphur Deposition at Nearest Receptor (42 TPD scenario; kg SO4/ha/yr)	Year
30	527179	5990884	CWH	vm1	L	4.6	1
22	526676	6031777	CWH	ws1	L	4.6	1
4	525944	5989784	CWH	vm1	L	6.0	1
20	527222	6025103	CWH	ws1	L	7.0	1
32	520702	6009460	CWH	ws1	M	8.3	1
10	512679	5973563	CWH	vm1	M	8.6	1
12	515291	5976609	CWH	vm1	M	13.2	1
17	520801	6003473	CWH	ws1	M	17.0	1
26	518455	5977210	CWH	vm1	H	34.8	1
16	521631	5994495	CWH	vm1	H	39.0	1
9	520895	5990386	CWH	vm1	H	53.2	1
15	524377	5979097	CWH	vm1	L	3.4	2
21	535012	6032054	CWH	ws1	L	4.2	2
1	533706	6032830	CWH	ws1	L	4.6	2
29	525991	5987150	CWH	vm1	L	5.0	2
3	525490	5990827	CWH	vm1	M	7.7	2
8	525764	5995821	CWH	vm1	M	11.8	2
28	519623	5980517	CWH	vm1	H	55.6	2
7	519432	5998784	CWH	vm1	H	20.8	2
5	522709	5990667	CWH	vm1	H	34.4	2
TBD*			CWH				2
TBD*			CWH				2
18	515594	6033009	CWH	ws1	L	1.9	3
23	534806	6010948	CWH	ws1	L	2.2	3
19	520698	6030688	CWH	ws1	L	2.6	3
6	530418	6032820	CWH	ws1	L	5.4	3
13	530863	6012801	CWH	ws1	M	8.7	3
2	529321	6018428	CWH	ws1	M	10.1	3
31	522437	5988257	CWH	vm1	H	31.3	3
25	517436	5977325	CWH	vm1	H	27.2	3
24	522742	5992140	CWH	vm1	H	33.2	3
TBD*			CWH				3
TBD*			CWH				3

[1] This table has not been updated; refer to annual reports for updated plot establishment.
*Reconnaissance for additional required sites TBD.

Permanent Plot [Re-]Monumenting

Plots will be permanently monumented to enable long-term re-measurements (see Figure 1). Metal rods will be used to mark the four corners, as well as plot centre; additional wooden stakes may be used to mark the midpoints of plot boundaries, and may also be added to the corners to increase visibility. Stakes will be marked with the plot's unique identifier. Metal rods will have safety caps installed to reduce risk of injury, and caps will be labelled with the plot's unique identifier and corner/center location. In most cases, rods and stakes will be flagged for visibility, and the most central tree in each plot will also be flagged and marked with the plot identifier; however, flagging may not be used in locations where there are concerns around visual sensitivity. Monuments will be repaired or replaced as needed on an ongoing basis during the course of the PCMP study.

Temporary plot demarcations

When arriving at the plot, the field team will locate plot center and the four corners of the plot (located ~14.1m northeast, southeast, southwest and northwest of center; Figure 1; note that idealized plot distances assume a planar surface, thus actual ground distances will vary slightly). The team may hang temporary flagging at intervals along the outer plot boundary to provide a visual indication of plot edges. Further demarcation (e.g. marking the four quadrants of the plot) could be flagged with a different colour, and would assist in visual cover estimates of vegetation in more complex or diverse plots.

The crew may find it efficient to also place the measuring tape for the linear transects along the north and east plot boundaries at this time.

Prior to leaving the plot, all temporary flagging/demarcations will be removed.

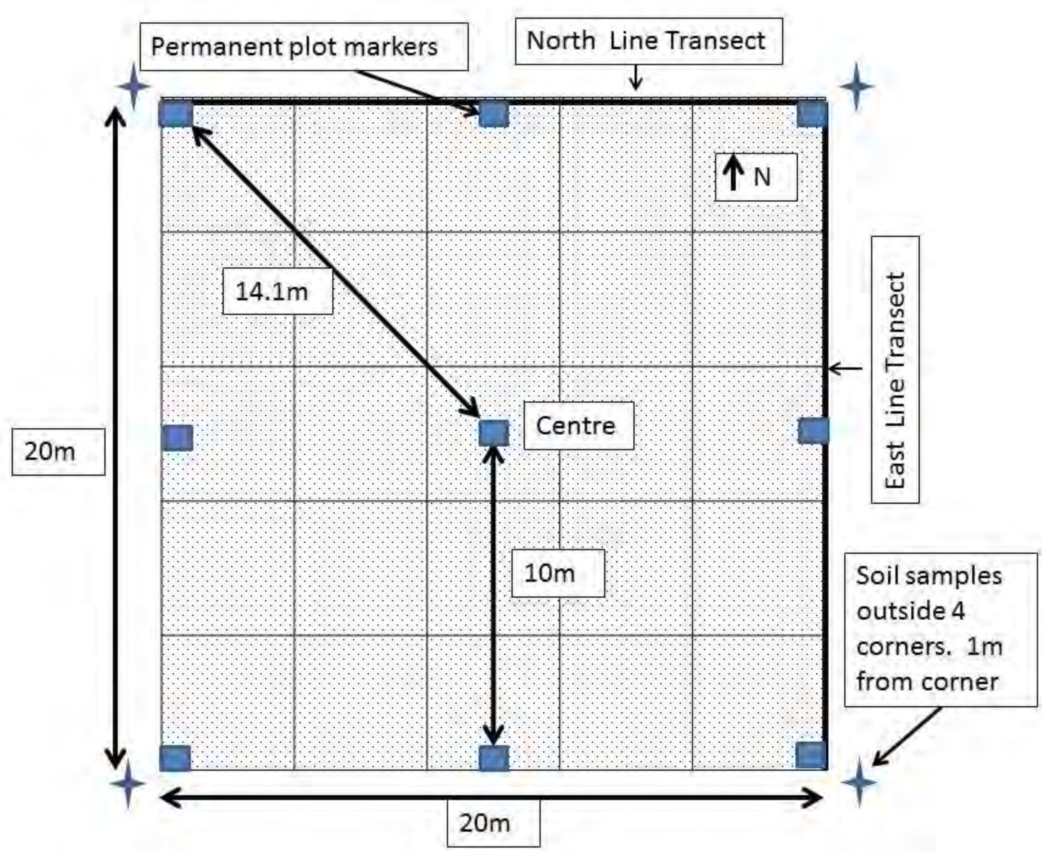

Figure 1: Plot design and orientation.

Plot Site Data

Basic ecological site data will be collected at each plot location during the initial assessment, and will reviewed, amended and updated (as needed) during subsequent visits. The ecological site data will provide essential information to understand—and allow comparisons between—plots.

A sample *Plot Site Data* form (a slightly modified version of the Province of BC's 2010 FS1333 form) is presented in Appendix A. The field crew will complete (or verify) all fields on the Plot Site Data form as per detailed direction in *Appendix B: Detailed Field Guide* (which in turn is based largely and directly on the methodology provided by the Province of BC in their guidance document, *Field Manual for Describing Terrestrial Ecosystems—2nd Edition* (2010)).

Vascular Plant Biodiversity

Vascular plant biodiversity will be assessed through measures of species richness and abundance described below.

All relevant data forms are presented in Appendix A, including the *Plot Site Data* form (which includes fields for the total percent cover of each vegetation layer), *Plot Vegetation Data* form, and *Line Transect Vegetation Data* form.

Species Richness

Species Richness refers to the number of distinct species present in a given area. Alone or in combination with a measure of species abundance, richness provides a measure of species diversity.

Low Shrub and Herb Layers

Crews will methodically search the plot for all vascular species assigned to the low shrub (B2) and herb (C) layers, recording each on the Plot Vegetation Data form, thus providing the metrics for each plot's Species Richness for those vegetation layers.

Additional Species of Importance

Regardless of the vegetation layer in which they occur, certain additional groups of species will be recorded if they occur in the plots, namely species listed by the BC CDC as "at risk," species known to be of cultural significance, and species classified by the BC ISC as "priority" weeds.

Naming/species coding

Species will be coded according to BC's most current version of the *BC Flora Checklist* (a 7-8 character code for all vegetation layers) and the *BC Tree Code List* (a 2-3 letter code for tree species) available through the Ministry of Forests and Range's Biogeoclimatic Ecosystem Classification Program website (last accessed

March 2021). As of the writing of this document, the most current version is Version 10 (2016).

Species Abundance

In combination with species richness, abundance data provide measures of plant and structural diversity. For the vegetation portion of the PCMP, abundance is measured primarily as percent cover.

Percent Cover

For the species described in Species Richness, above (*low shrubs, herbs* and *additional species of importance*), percent cover will be estimated during each plot assessment using two methods outlined below:

1. *Throughout plot*—Visual estimates of percent cover by species will be provided for the full 400m^2 area of each plot, using the methodology described in detail in Appendix A (based on Province of BC 2010).
2. *Linear (line) transect*—Using a measuring tape and plumb bob (as needed), crews will record precise (up to +/- 0.5cm) measurements of the species that intersect the north and east boundary lines of each plot. These measures can then be used for an alternate percent cover measure of abundance at the plots, with the advantage of being directly [re]measurable and comparable between assessments.

Distribution, vigour and phenology coding

To better understand vegetation structure and potential change over time, distribution, vigour and phenology codes will be recorded for each species that is accounted for in vegetation richness and abundance data collection. Use of these codes is described in Appendix B and is based directly on Province of BC (2010).

Cyanolichen Biodiversity

Species Richness

Species Richness refers to the number of distinct species present in a given area. Alone or in combination with a measure of species abundance, richness provides a measure of species diversity. This lichen monitoring portion of the PCMP focuses on cyanolichens that use conifer trees as hosts, and species richness data will be collected only for this group of lichens. To ensure repeatable, comparable results, a one-hour timed search will be used. If present, dead (but not downed) tree hosts will be included in the search.

Host species group

For cyanolichens—species that often have specific host substrates—species richness is, in part, a function of host diversity. When collecting species richness data for cyanolichens, host species will be recorded .

Relative Abundance

In combination with species richness, abundance data provide measures of cyanolichen diversity. For the cyanolichen portion of the PCMP, relative abundance is recorded, according to the following categories for arboreal lichen loading (Province of BC 2010):

0 None
1 Rare: 1 or 2 colonies per [host] tree
2 Occasional: 3-5 colonies per [host] tree
3 Common: 6 colonies to 20% cover per [host] tree
4 Very Common: 21-50% cover per [host] tree
5 Abundant: 51+% cover per [host] tree

Visual Inspection and Assessment

Vascular Plants

When plots are measured to determine biodiversity, a visual inspection and assessment will be conducted to record the general condition of vascular plants (including any notable conditions for plants in the tree, tall shrub, moss/seedling and epiphyte layers), the presence of insects or diseases, or symptoms due to environmental factors (e.g., nutrient deficiencies, physical disturbance, drought, flooding, and other abiotic factors). The inspection and assessment will be conducted by a qualified professional (QP) in the plant sciences (e.g., plant ecologist, plant pathologist, forester, etc.).

General Site Conditions—At each plot an assessment of general conditions will be made. This assessment includes the general appearance of the site (e.g., green, healthy vegetation; droughty conditions; insect infestation; dusty; industrial activity such as logging, transmission line maintenance, construction, etc.). The prescribed photos taken at each site will support the description, and additional site photos will be taken if needed to better describe general site conditions with respect to the Visual Inspection and Assessment.

Survey of Signs and Symptoms—A survey of vegetation in the sampling plot is made. This survey notes the presence of symptoms or signs of pests, pathogens, and other stressors on any vegetation at the site. Symptoms are noted on the field data sheets (Appendix A). If symptoms are present, the affected area of individual leaves and the percentage of the plant that is affected are visually estimated for calculation of an injury or disease index (Laurence 2010). Standardized diagrams of affected leaf area (e.g. Duarte *et al*. 2013) are helpful for training the observer.

It is important to pay particular attention to species that are common to a large number of plots (e.g., western hemlock, western redcedar, Sitka spruce, elderberry, red-osier dogwood, balsam poplar, thimble berry, salmon berry, and others) as widely distributed species will help determine the spatial pattern of any potential insect outbreak or disease epidemic.

Digital Images—Digital images are used to document the general conditions and any signs or symptoms of stressors such as insects, pathogens, air pollutants, physical injury, or other environmental stressors. Digital images should be geo-referenced, and date/time stamped to assure accurate site location information.

A digital image archive is maintained along with the report of the inspection by RTBC (see Data Archiving section, below).

Cyanolichens

At the time of plot measurement, observations will be made to document the health and condition of cyanolichens. Cyanolichens are affected directly by both wet and dry deposition. Symptoms to note include a general "off-color", bleaching of tissues, and reduced growth, and will be recorded on the field data sheets (Appendix A).

Soil and Atmospheric Chemistry

At the time of plot establishment, soil samples will be taken and analyzed to help determine the potential acid sensitivity. Methods will be the same as used in the SO_2 Environmental Effects Monitoring program (SO_2 EEM). The purpose of this sampling is to assess the sensitivity of the soils to acidification, not to measure and detect differential changes in soil chemistry over time.

Soil Chemistry

At each plot, soil samples will be collected outside (minimum 1m from) the four plot corners. Mineral soil samples will be taken at a depth of 0-10 cm and 10-20 cm, where practical. Forest floor/organic material will not be included in the sample and will be removed prior to sampling. Samples from the four positions will be composited for analysis.

Following collection, the samples will be analyzed using methods common to the SO_2 EEM (Trent University 2018) to determine pH, exchangeable cations, and exchangeable acidity:

. Soil pH is measured by mixing 5 g of soil with 20 mL of water and analyzed using a pH probe.

. Exchangeable acidity is measured using a potassium chloride (KCl) extraction; 5g of soil is mixed with 25 ml of KCl, the solution is extracted via vacuum filtration. The sample then receives five additional washes of 25 ml KCl. The extractant (135 ml) is titrated with sodium hydroxide (NaOH) to determine exchange acidity ($H^+ + Al^{3+}$). The extractant (15 ml) is also analyzed by ICP–OES to determine exchangeable aluminum (Al^{3+}).

. Exchangeable base cations are measured using an ammonium acetate (NH_4OAC) extraction; 5 g of mineral soil is mixed with 25 ml of NH_4OAC, the solution is extracted via vacuum filtration. The sample receives two additional washes of 10 ml NH_4OAC, and the extractant is analyzed by *Inductively Coupled Plasma - Optical Emission Spectrometry* (ICP–OES) for exchangeable cations (Ca^{2+}, Mg^{2+}, K^+, Fe^{3+} and Mn^{2+}).

Ion Exchange Resin Columns

Throughfall ion exchange resin columns may be used above ground at selected locations to quantify actual sulphur (S) deposition depending on the risk of soil acidification. These measurements will help characterize that risk. Although not currently scheduled, ion exchange resin columns will be planted vertically in the soil to measure SO_4^{2-}, base cations, and aluminum, *if necessary* to establish causality. Methods for ion exchange resin columns and their analysis will be those described by Blanchard (2019). Similarly, if needed to establish causality, Plant Root Simulator probes (PRS probes) may be installed to determine soil water concentrations of base cations and Al^{3+}. If they are installed, the methodology of Watmough *et al*. (2013) will be used.

Data Management and Analysis

Data Collection

Emissions and Air Monitoring Data

Emissions, metal production, and air monitoring data will be provided by RTBC for use in data analysis. These data will be the same as those provided for the annual and summary SO_2 EEM Program reports.

Data Archiving

All data collected, analyses performed, images collected, and reports in the PCMP will be archived by RTBC and made available on the RTBC internet.

Data Analysis

Monitoring Design.

The monitoring design is a type of rotating panel-design where plots are measured on a rotating schedule repeatedly over time. By measuring the same plot repeatedly over time, each plot keeps other confounding factors (e.g. aspect) constant over time, which should reduce the amount of extraneous variation seen in the response.

An example of a rotation panel design is seen in Figure 2, showing a set of plots measured in a three-year rotation. For the purpose of this example, plots are classified into *high* and *reference* deposition classes.

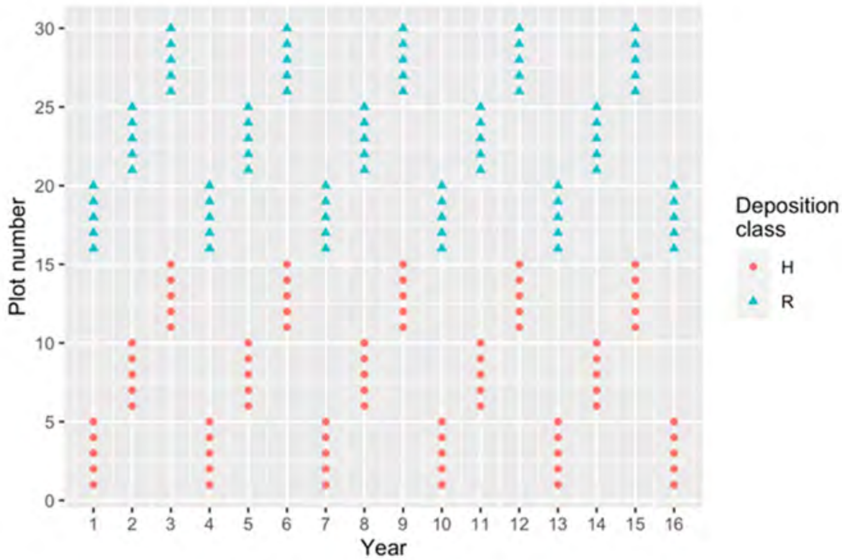

Figure 2. An illustration of a rotating panel design. Each plot is measured every 3 years on a rotating schedule. Plots are classified as being in a high deposition (H) or reference deposition (R) class.

While Figure 2 shows a nicely balanced design, this rotating panel design is very flexible, for example allowing for plot measurements on differing rotating schedules, if a change is the existing plan is desired or required for any reason (e.g. some plots could be measured every 2 years or even every year). If a plot becomes damaged or permanently inaccessible (e.g., land clearing, forest fire, landslide), it is simply "replaced" by a new plot whose first measurement takes place when the new plot is rotated in[1]. If a plot is removed, the data prior to being removed are still included in the analysis.

Sample sizes in the deposition classes do not have to be equal, but power is highest to detect differential changes over time if the sample sizes in all deposition classes are equal, *and* power is also increased if contrast (i.e., between deposition classes) is maximized. The number of deposition classes is also not theoretically restricted, but if too fine a classification is used (i.e., a large number of deposition classes), then the number of plots within each deposition class may be too small to have any power to detect differential trends.

At the outset of this Project, we have 29 sites previously selected (ENV locations), and an additional four sites that will be selected in order to bring the total number of sample sites to 33 (Table 1). The additional sites will be preferentially selected to maximize statistical power (i.e., to achieve roughly equal numbers of plots in all deposition classes and to maximize contrast); however, field constraints (e.g., safety,

[1] While the new plot "replaces" the old plot, it should not use the same plot number and the two sets of measurements should be kept separate from each other.

access, and availability of suitable sites) may limit ability to achieve the "ideal" plot composition. As well, additional locations will be assessed for their feasibility for use as alternate plot sites, in the event that a plot needs to be replaced.

As shown in Table 1, plots will be undertaken in each of the deposition classes annually.

Measurements

Proposed response measurements will be the percent cover by species, or by species groupings (e.g. pooling all *Vaccinium* sp.).

Ideally, measurements will be available for every plot in every year that it is measured, but the methods below provide a framework to deal with missing data. It is assumed that missing data are Missing Completely at Random (MCAR); that is , the missingness is unrelated to plot characteristics or to the response value. For example, if a plot measurement was unavailable because the crew misplaced the raw data sheets, then the missingness is unlikely to be related to plot characteristics or to the response value. However, if measurement could not be taken because the plot was so overgrown with vegetation that it would take too long to measure cover, then the missingness is related to the response value, and cannot be treated as MCAR.

Notice that if a species does not exist on the plot, the recorded value for cover/relative abundance for that species in that year should be 0 and not missing. In general, values for cover should be recorded for each plot in each year it is measured for *all* species of interest (e.g. all cyanolichens, low shrubs and herbs). Some care will be needed to deal with species that are new to plots: Assuming that crews could have recognized the species in earlier visits, values of 0 for cover/relative abundance of a new species will have to be imputed for past years. Similarly, if a species disappears from a plot, value of 0 will have to be imputed for future years when the species is no longer present. If a species never appears in a plot for all years it is measured, that plot will not be included in the analysis of cover for that species, as there is no information available on changes in cover if a species never appears in a plot. In practice, during plot measurements, crews will not include values of 0 for species that are not present, but a zero value will be inferred during data analysis. Care will be taken, however, to ensure every species present is recorded, with extra efforts made to confirm absence (0) if a species previously recorded at a plot is not found during a subsequent assessment of that plot.

An example of what the data could look like is shown in Figure 3.

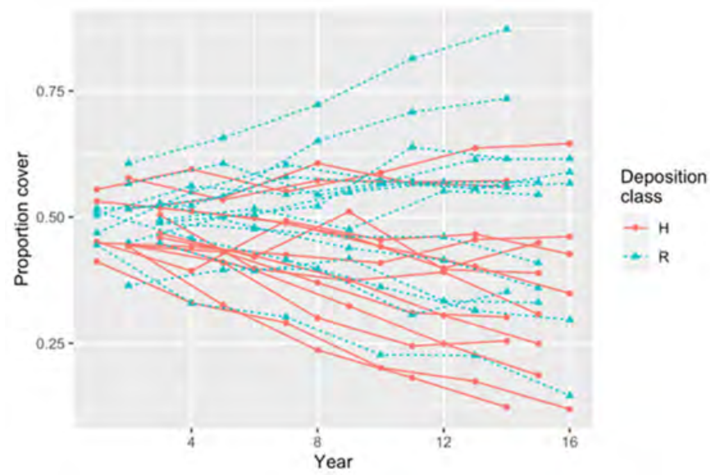

Figure 3. Hypothetical example of data collected from a rotating panel monitoring design. Plots are classified as being in a high deposition (H) or reference deposition (R) class.

Data Analysis.

Annual Reports.

As data are accumulated over time, they will be examined on a yearly basis to correct any data recording errors, etc. For all plots examined in the current year, simple summary statistics (e.g. means and standard deviations of the cover values by deposition class) and—when sufficient data are available—simple plots (e.g. similar to Figure 3) and the calculated trend line slopes will be presented in annual reports.

Prior to completion of the annual reports, these summaries will also be used as a secondary quality assurance, to help identify values that are anomalous, and if in error, correct them as soon as possible. Imputation of 0's for past years may be needed. Notice that not all anomalous values are necessarily erroneous—i.e., anomalous values do occur, but data should be examined carefully each year.

End-of-3-Year-Cycle Reports.

End-of-Cycle reports examining the impact of different deposition levels will occur at intervals due to the slow changes in the cover that may occur in response to deposition. In the first end-of-cycle report (3 years), all of the sites will have a single measurement. Simple analyses of the variability in the observation data across all of the sites and spatial distribution of values relative to levels of deposition will be conducted. At the end of Year 6, all plots will have been re-measured, and trends at high and medium deposition sites will be compared to those at low/reference sites. The analyses of comparative trends will be repeated every 3 years.

There may be changes over time in the absence of effects of deposition, for example owing to climate change. Consequently, the analysis must account for these "natural" changes and look for differential changes in the trends between the deposition classes.

The statistical model to analyze this design will be a random slope and intercept model where evidence of impact would a difference in the mean trend among the deposition classes. In reference to Figure 3, the model will fit a separate line for each plot, and then a comparison is made of the mean trend line among the deposition classes.

More formally, using a compact modelling notation used by many statistical packages, the statistical model is a linear mixed model:

$$Y \sim Year + DC + Year{:}DC + YearC(R) + Plot(R) + Year{:}Plot(R)$$

where:

. *Y* is the response value;
. *Year* is the common trend over time for all deposition classes;
. *DC* is the effect of deposition class on the initial mean response at the start of the study;
. *Year:DC* is the differential mean trend over time among the deposition classes;
. *Plot(R)* is a random effect associated with every individual plot;
. *YearC(R)* is a random effect associated with each (categorical) value of year reflecting year specific effects on cover (e.g., a particular year may be warmer than normal which could simultaneously affect the cover in all plots in that year in a similar fashion).
. *Year:Plot(R)* are random slopes around the respective mean trend for each deposition class for each plot.
. The *Year:DC* term represents the impact of deposition on the trend, i.e., the differential trend over time among the deposition classes and is the key term in the model to examine. An example of the model fitted to the hypothetical data is shown in Figure 4.

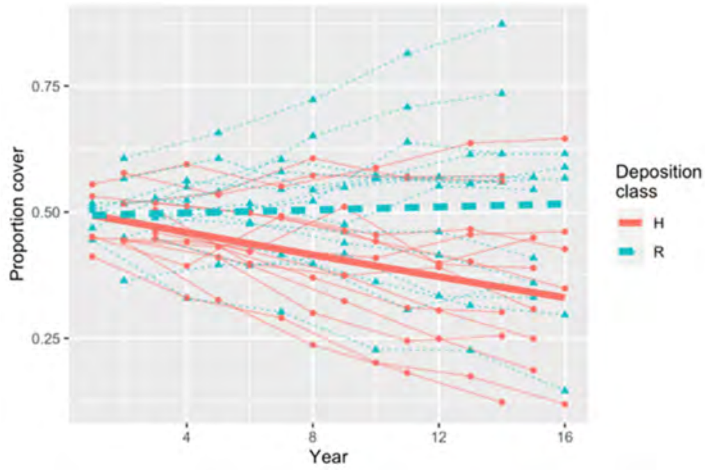

Figure 4. Example of fitted model to the hypothetical data. P lots are classified as being in a high deposition (H) or reference deposition (R) class. The thicker lines are the mean trends over times for each deposition class.

This model is flexible enough that it can accommodate missing values (not zero, but actually missing), different numbers of plots within deposition classes, plots that are rolled out because of damage, or plots that are rolled in as replacements—without any required changes to the model. If a plot is removed due to damage or access issues, data for the plot until the time of removal are kept in the model. It is likely best to wait until all plots have been measured at least twice before running this model.

The response value could be the raw cover value for a plot, but Warton and Hui (2011) also suggest that the empirical logit transformation of the cover values (i.e., $\theta = \log(p/(1-p))$ where p is the cover value and log() is the natural logarithmic transformation may be more suitable for data that are proportions). This transformation would avoid the trend lines taking values below 0 or above 1. As noted previously, values of 0 for the cover may be present for species that are absent, in which case the logit() transformation is undefined, but Warton and Hui suggest bounding low cover values from 0 using a small value (e.g., .001) rather than the raw value of 0. Some care will be needed to express the differential change in appropriate units (e.g., differential changes in log(odds)).

A standard hypothesis-testing framework can be used to examine if there is evidence of an effect for the *Year:DC* term. It is not necessary and not of interest to examine the other terms in the model. Estimates of effect sizes (e.g., the individual mean slopes for each deposition class and the difference in mean slopes among pairs of deposition classes) should also be computed.

The model can be extended through the use of plot-level covariates (i.e., covariates that are constant for a plot over time such as elevation), year-level covariates (i.e., covariates that affect all plots simultaneously in a year such as values representing the Pacific Decadal Oscillations), or plot-year covariates (i.e., covariates that vary by plot and year, such as actual rainfall in a plot in year), assuming that all covariates can be measured in each plot, year, or plot-year as needed.

An example of an analysis conducted using the *R* (R Core Team, 2020) statistical package is found in Attachment 1. The model could be fit using other statistical packages such as SAS or could be implemented in a Bayesian framework. The advantage of a Bayesian framework lies in the natural way the posterior beliefs about effects can be stated, for example, there is a 72% posterior belief that the differential slope is less than 1%/year. A Bayesian implementation is straightforward.

Quality Assurance

Quality assurance (QA) will be undertaken at several different stages, both for data collection and data archiving. QA for the planning process is presumed to be complete through the internal and external (ENV) reviews and ultimate acceptance of the PCMP proposal document (Laurence *et al.* 2020).

Data Collection

Data collection QA will be a layered, internal process, beginning with pre-field training and checklists to ensure the correct data will be collected, and continuing through end-of-day field data reviews, data entry data review and correction, and final QA when summarizing and reporting data.

Where taxonomically difficult or unusual plant/lichen species or damage agents have been tentatively identified during fieldwork, physical and/or photographic specimens will be retained until a qualified professional can verify them in the lab/office.

Laboratory specimens will be subjected to standard laboratory QA procedures.

All reporting will be subjected to an internal Project team review prior to distribution.

Data Archiving

Data, once entered, summarized, and presented in report form, will be given a final QA and will be archived in RTBC's internal servers.

Reporting

Annual Reporting

An annual report of activities in the PCMP will be submitted by December 31st of the current year except at the end of a 3-year measurement cycle when the annual report will be merged with the End-of-Cycle report. The terms of reference for the annual report are detailed in the 2021 Environmental Effects Monitoring (EEM) Phase III Plan (ESSA Technologies *et al*.), and will include implementation (including issues and adjustments, if applicable), summaries of all data collected, and recommendations for following year's field program.

End-of-Cycle Reporting

An End-of-Cycle report will be prepared at the end of each 3-year cycle of the PCMP will be submitted by March 31st of the following year to allow sufficient time to conduct the data analysis and interpret the results. The terms of reference for the annual report are detailed in the 2021 Environmental Effects Monitoring (EEM) Phase III Plan (ESSA Technologies *et al*.).

Literature Cited

Banner, A., W. MacKenzie, S. Haeussler, S. Thomson, J. Pojar, and R. Trowbridge. 1993. *A field guide to site identification and interpretation for the Prince Rupert Forest Region*. Land Management Handbook No. 26. BC Ministry of Forests, Victoria, BC.

Blanchard, D. 2019. Observation-based assessment of atmospheric sulphur surrounding a major aluminum smelter in British Columbia, Canada. (2019). https://digitalcollections.trentu.ca/objects/etd-756

Duarte, H. S. S., Zambolim, L., Capucho, A. S., Júnior, A. F. N., Rosado, A. W. C., Cardoso, C. R., … Mizubuti, E. S. G. 2013. Development and validation of a set of standard area diagrams to estimate severity of potato early blight. *European Journal of Plant Pathology*, *137*(2), 249–257. https://doi.org/10.1007/s10658-013-0234-3

ESSA Technologies, J. Laurence, Risk Sciences International, Trent University, and Trinity Consultants. 2021. Sulphur Dioxide Environmental Effects Monitoring Program for the Kitimat Modernization Project – Phase III Plan for 2019 to 2025, Draft V.2. Prepared for Rio Tinto, B.C. Works.

Laurence, J. A. 2010. A Review of the Vegetation Monitoring and Assessment Program in the Vicinity of the Rio Tinto Alcan British Columbia Operations at Kitimat, British Columbia. Submitted to Rio Tinto Alcan British Columbia Operations, May 16, 2010. 92 p. and appendices 49 p.

Laurence, J., A. Coosemans, J. Aherne, M. Grossmann, A. Hall, D. Marmorek, C. Schwarz, S. Watmough, and S. Zettler. 2020. *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 SO2 Environmental Effects Monitoring Program*. Report submitted to B.C. Ministry of Environment and Climate Change Strategy. 20p.

Luttmerding, H.A., D.A. Demarchi, E.C. Lea, D.V. Meidinger, and T. Vold (editors). 1990. *Describing ecosystems in the Field, 2nd ed*. BC Ministry of Environment, Lands and Parks and BC Ministry of Forests, MOE Manual 11. Victoria, BC.

Ministry of Forests and Range. 2021. Biogeoclimatic Ecosystem Classification Program: BC Flora Checklist (2016) and BC Tree Code List (2016). Available at https://www.for.gov.bc.ca/hre/becweb/resources/codes-standards/standards-species.html (last accessed 10 March 2021).

Province of BC. 2010. *Field manual for describing terrestrial ecosystems, 2nd ed*. Land Management Handbook No. 25. Research Branch, BC Ministry of Forests and Range, and Resources Inventory Branch, BC Ministry of Environment. Victoria, BC. (Reprint with updates 2015).

Province of BC. 2018. *Vegetation Resources Inventory—British Columbia: Ground Sampling Procedures, March 2018, Version 5.5.* Prepared by the Forest Analysis and Inventory Branch, BC Ministry of Forests, Lands and Natural Resource Operations, for the Resources Information Standards Committee. Victoria, BC. 214p.

R Core Team. 2020. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Trent University. 2018. Long-term Soil Monitoring Plots. Laboratory Analysis. KMP SO_2 EEM Program – Technical Memo S07. June, 2018. 9p.

U.S. Department of Agriculture, Forest Service. 2011. Section 21. Lichen Communities. In *Field Methods for Forest Health (Phase 3) Measurements*; Forest Inventory and Analysis National Program: Washington, DC, USA. p. 19.

Warton, David I., and Francis K. C. Hui. 2011. "The Arcsine Is Asinine: The Analysis of Proportions in Ecology." *Ecology* 92 (1): 3–10. https://doi.org/10.1890/10-0340.1.

Watmough, S. A., Koseva, I., & Landre, A. 2013. A comparison of tension and zero-tension lysimeter and PRS™ probes for measuring soil water chemistry in sandy boreal soils in the Athabasca oil Sands Region, Canada. *Water, Air, and Soil Pollution, 224*(9). https://doi.org/10.1007/s11270-013-1663-5

Williston, P., and G. Perkins. 2019. Cyanolichens on conifers as indicators of air quality in the Kitimat Valley, March 2019 DRAFT. Unpublished report prepared for BC Ministry of Environment, Environmental Protection Division, Regional Operations Branch. 23p.

Appendix A: Data Collection Templates

Page 1: Plot Site Data Form

Plot Site Data

1	Project ID	RT_EEM_PCMP	Plot No.		Date		Surveyors		Deposition Category	L / M / H
2	Plot Location								Elevation	m
3	FS Region/District	RNI.DKM	UTM Zone	9U	Easting		Northing		GPS Accur.	± m
4	Plot Representing								Listed ecosystem?	Y / N
5	BGC (circle)	CWHws1 / CWHvm1	Site Series		SMR		SNR		Surface shape	ST / CC / CV
6	Slope	%	Aspect	°	Mesosl. Pos.		Exposure Type		Site Disturbance	
7	Canopy Composition			Densio. Cnt.	____/____/____/____		Struc. Stg.		Successional Status	
8	Total % Cover by Layer:	Tree (A)	%	Shrub (B)	%	Herb (C)	%		Moss/Lichen/Seedling (D)	%
9	Visual Inspection of veg. health (circle)	green healthy / drought / saturation (flood) / physical damage / insect infestation / disease / dust / nutrient deficiency / industrial activity / other (describe below)								
10	General Site Conditions (veg. health)	Inside plot / Near plot							Additional Survey Form?	Y / N
11	Photos	ID / N / E / S / W / Up	NE / SE / SW / NW		From corner to center:	NE / SE / SW / NW			Ph. Loc.	
	Other photos (describe):									
12	General site comments/notes								Sample Event (e.g. 1st, 2nd, etc.)	
13	Soil Samples Collected?	NE 0-10 ; 10-20 / SE 0-10 ; 10-20 / SW 0-10 ; 10-20 / NW 0-10 ; 10-20 / None / Other (comment)								
14	on Exchange Resin Column(s)	Y / N	Soil/IER comment							

Page 2: Plot Vegetation Data Form

Plot Vegetation Data

1	Layer (circle)	Species Code	% Cover (plot)	# Individuals (if countable)	Listed sp.?	Table 1 sp.?	ID Conf. Req'd?	Photo ?	Distrib Code (1-9)	Vigour Code (0-4)	Phenology Code* - Vegetative	Phenology Code* - Generative	
2	B2 / C				☐	☐	☐	☐					
3	B2 / C				☐	☐	☐	☐					
4	B2 / C				☐	☐	☐	☐					
5	B2 / C				☐	☐	☐	☐					
6	B2 / C				☐	☐	☐	☐					
7	B2 / C				☐	☐	☐	☐					
8	B2 / C				☐	☐	☐	☐					
9	B2 / C				☐	☐	☐	☐					
10	B2 / C				☐	☐	☐	☐					
11	B2 / C				☐	☐	☐	☐					
12	B2 / C				☐	☐	☐	☐					
13	B2 / C				☐	☐	☐	☐					
14	B2 / C				☐	☐	☐	☐					
15	B2 / C				☐	☐	☐	☐					
16	B2 / C				☐	☐	☐	☐					
17	B2 / C				☐	☐	☐	☐					
18	B2 / C				☐	☐	☐	☐					
19	B2 / C				☐	☐	☐	☐					
20	B2 / C				☐	☐	☐	☐					
21	B2 / C				☐	☐	☐	☐					
22	B2 / C				☐	☐	☐	☐					
23	B2 / C				☐	☐	☐	☐					
24	B2 / C				☐	☐	☐	☐					
25	B2 / C				☐	☐	☐	☐					
26	B2 / C				☐	☐	☐	☐					
27	B2 / C				☐	☐	☐	☐					
28	B2 / C				☐	☐	☐	☐					
29	B2 / C				☐	☐	☐	☐					
30	B2 / C				☐	☐	☐	☐					
31	Additional Species of Importance (other layers)												At Risk (R) / Cultural (C) / Weed (W)
32	A / B1 / D / E				☐	☐	☐	☐					R / C / W
33	A / B1 / D / E				☐	☐	☐	☐					R / C / W
34	A / B1 / D / E				☐	☐	☐	☐					R / C / W
35	A / B1 / D / E				☐	☐	☐	☐					R / C / W
36	A / B1 / D / E				☐	☐	☐	☐					R / C / W
37	A / B1 / D / E				☐	☐	☐	☐					R / C / W

Distrib. Code	Description	# plants/400m2
1	Rare individual, single occurrence	1
2	A few sporadiclly occurring individuals	2-5
3	A single patch or clump of a species	1 patch (<25% of plot)
4	Several sporadically occurring individuals	≥6
5	A few patches or clumps of a species	2-5 patches, each <25% of plot
6	Several well-spaced patches or clumps	≥6 patches, each <25% of plot
7	Continuous uniform occurrence of well-spaced individuals	many
8	Continuous occurrence of a species with a few gaps in the distribution	many
9	Continuous dense occurrence of a species	many

Vigour Coding:		Decription
0	Species dead	All leaves dry, shriveled and/or necrotic.
1	Vigour poor	Severe necrosis or wilting.
2	Vigour fair	Some reduced vigour, possible browning of leaf tips, wilting, chlorosis or necrosis. Damage or disease agents may be impacting this species.
3	Vigour good	Relatively healthy, but growth not vigourous, plants are green but not deep green and lush. Damage or disease symptoms may be evident, but minor.
4	Vigour excellent	Deep green leaves, lush growth, and no chlorosis, wilting, or evidence of ongoing damage or disease.

* see Province of BC (2010) for Phenology Codes

Page 3: Line Transect Vegetation Data Form

Line Transect Vetatation Data

Segment 1: 20m	**N-bdry /other: __________**	**Segment 2: 20m**	**E-bdry /other: ________**
POC:	**__________cm**	**POC:**	**__________cm**
Distance	**Species Code**	**Distance**	**Species Code**
cm - cm		cm - cm	
cm - cm		cm - cm	
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cm - cm		cm - cm	
cm - cm		cm - cm	
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cm - cm		cm - cm	
cm - cm		cm - cm	
cm - cm		cm - cm	
cm - cm		cm - cm	
cm - cm		cm - cm	
cm - cm		cm - cm	
POT:	**__________cm**	**POT:**	**__________cm**

Page 4: Plot Cyanolichen Data Form

Plot Cyanolichen Data

1-Hour Timed Search Start		h	End time	h	(use 24-hour clock; e.g. 13h15)					
Did lichen search extend outside plot boundary?				Y / N				If yes, at what time did search begin outside plot?		h
Species Code	**Presence Inside Plot**	**Tally (individuals or colonies) Inside Plot**	**Abundance Rating***	**Presence in Search Area Outside Plot**	**Conifer Host Tree Spp. (circle all host spp.)**	**Listed sp.?**	**ID Conf. Req'd ?**	**Photo ?**	**Health: Normal (N), Injured (I) or Stressed (S)?**	**Comment**
	□			□ / n/a	Ba/Cw/Hw/Pl/Sx/Yc/__	□	□	□	N / I / S	
	□			□ / n/a	Ba/Cw/Hw/Pl/Sx/Yc/__	□	□	□	N / I / S	
	□			□ / n/a	Ba/Cw/Hw/Pl/Sx/Yc/__	□	□	□	N / I / S	
	□			□ / n/a	Ba/Cw/Hw/Pl/Sx/Yc/__	□	□	□	N / I / S	
	□			□ / n/a	Ba/Cw/Hw/Pl/Sx/Yc/__	□	□	□	N / I / S	
	□			□ / n/a	Ba/Cw/Hw/Pl/Sx/Yc/__	□	□	□	N / I / S	
	□			□ / n/a	Ba/Cw/Hw/Pl/Sx/Yc/__	□	□	□	N / I / S	
	□			□ / n/a	Ba/Cw/Hw/Pl/Sx/Yc/__	□	□	□	N / I / S	
	□			□ / n/a	Ba/Cw/Hw/Pl/Sx/Yc/__	□	□	□	N / I / S	
	□			□ / n/a	Ba/Cw/Hw/Pl/Sx/Yc/__	□	□	□	N / I / S	
	□			□ / n/a	Ba/Cw/Hw/Pl/Sx/Yc/__	□	□	□	N / I / S	
	□			□ / n/a	Ba/Cw/Hw/Pl/Sx/Yc/__	□	□	□	N / I / S	
	□			□ / n/a	Ba/Cw/Hw/Pl/Sx/Yc/__	□	□	□	N / I / S	

Overall comments on cyanolichen presence, abundance, or substrate/host(s)
Visual Inspection and Assessment of Cyanolichen Health (e.g. any symptoms such as "off-colour," bleaching of tissues, or notably reduced growth?):

***Abundance Rating Guide (Prov. of BC 2010)**		
	Rating	**Criteria**
0	None (N)	Not present
1	Rare (R)	1 or 2 colonies per [host] tree
2	Occasional (O)	3-5 colonies per [host] tree
3	Common (C)	6 colonies to 20% cover per [host] tree
4	Very Common (VC)	21-51% cover per [host] tree
5	Abundant (A)	51+% cover per [host] tree

Page 5: Additional Vegetation Health Data Form

Additional Vegetation Health Data

Species Code	Symptom	Proportion of Affected Individuals in Plot	Average % of Leaf Area Affected	Average % of Plant Affected	Cause	Comments	Photo(s)?
							☐
							☐
							☐
							☐
							☐
							☐
							☐
							☐
Other comments:							

Appendix B: Detailed Field Guide

Field Equipment Checklist

Truck Gear:

- ☐ All Rio Tinto required truck-based safety gear (e.g., radio communication, wheel chocks)—to be established during pre-field planning meeting, annually
- ☐ First aid kit (Level 1)—include hard candy (e.g. tic-tacs), antihistamine, and extra medication (if needed)—and blanket
- ☐ Charging cables for tablets and other devices
- ☐ Saw and tow-rope (carry in truck for emergency use only)

Personal Safety Gear:

- ☐ All Rio Tinto required PPE (e.g., hard hat, safety boots, hi-viz vest, gloves, safety glasses)—to be established during pre-field planning meeting, annually
- ☐ inReach or other satellite communication system (for check-ins or emergencies in sites without cellular service)
- ☐ Handheld radios with local frequencies
- ☐ Contractor-grade garbage bag or emergency blanket (carry in field vest/bag for emergency cover/shelter)
- ☐ First aid kit (personal to carry; Level 1 in truck)—include hard candy (e.g. tic-tacs), antihistamine, and extra medication (if needed)
- ☐ Headlamp/flashlight

Suggested Minimum Personal Gear:

- ☐ Food/drink, including extra water and a hot drink for cold days
- ☐ Personal medication (if needed)
- ☐ Hip or chest waders (optional, for access to wetter sites)
- ☐ Rain gear
- ☐ Extra clothes in case you become wet or cold (e.g., spare layers, toque, mitts)

Special equipment for biodiversity plots:

- ☐ Metal rods (5-per plot), wooden stakes (up to 9-per plot) & rubber mallet (to install)
- ☐ Flagging tape (2 colours) and/or pin flags to delineate boundaries & quadrants (optional)
- ☐ Measuring tapes (metric; minimum 25m)
- ☐ Measuring stick or ruler (ideally a folding 1m+ ruler)
- ☐ Stringline (optional)
- ☐ Plum-bob
- ☐ Tablet loaded with mapping program, Theodolite photo application, Field Form (if using digital), reference documents (e.g., this guide, DEIF, plant/lichen guides, etc.)
- ☐ Timer (timed search for cyanolichens)
- ☐ GPS (optional if using tablet)
- ☐ Extra batteries for everything (consider a battery pack that can charge all devices)
- ☐ Compass

- ☐ Clinometer
- ☐ Hand lens (10x)
- ☐ Sample bags
- ☐ Clippers
- ☐ Waterproof markers
- ☐ Densiometer (convex)
- ☐ Diameter (DBH) tape (optional)
- ☐ Set of forms for each plot, plus extras
- ☐ Clipboard or notebook to house forms
- ☐ Ducksback or Write-in-the-Rain paper for additional notes

Special Equipment for Soil Sampling:

- ☐ Rubbing alcohol to sanitize soil sampling equipment
- ☐ Nitrile gloves
- ☐ Spade, trowel
- ☐ Soil sample bags
- ☐ Permanent marker
- ☐ Soil auger

Suggested Minimum Reference Material:

- ☐ Previous plot information (if available)
- ☐ Annual instructions for field work (e.g., site list, alternate sites, sampling requirements, etc.)
- ☐ Laminated and/or digital copy of this Detailed Field Guidance document
- ☐ Copy of relevant sections of DEIF Manual (Province of BC 2010)
- ☐ Plant guide(s) (e.g., *Plants of Northern BC*, *Plants of Coastal BC*)
- ☐ Lichen guide(s) (e.g. *Macrolichens of the Pacific Northwest*)
- ☐ Invasive plant guide and/or Report Invasives BC application

Plot Site Data Card

The fields on the *Plot Site Data* card are described below; the numbers associated with the descriptions below correlate to line numbers on the data card. Many of the fields on this card are also described in Province of BC's (2010) *Field Manual for Describing Terrestrial Ecosystems*: Where this is the case, only a brief description is provided here, and the reader is directed to collect the data by referring to—and in accordance with—this essential reference.

For quick reference, boxed instructions detail whether/how these fields will be used between locations and years (assessments), and include the following coding: **I**=Record data at initial assessment and confirm during subsequent visits; **Δ**=Record when changed from initial assessment; **A**=Record data annually (during each assessment).

1. **Project ID, Plot No., Date, and Surveyors**

   Project ID: this will remain the same during each year of the PCMP, and will be recorded at each plot as **RT_EEM_PCMP** or as directed during the pre-field meeting.

A Pre-fill this provided ID (**RT_EEM_PCMP**) on your Site Data Card for each assessment.

   Plot number: this number will be unique for every assessment of every plot.

   Because plots will be visited over multiple years, *Plot Number* will be a unique *Plot Location Identifier* combined with a unique site visit code. *Plot Location Identifiers* identify a spatial site/location where plots will be located, and will be provided annually to the field team. For *Plot Number*, field teams will enter the *Plot Location Identifier*, followed by a two-letter crew-lead initials, and a two-digit year (e.g. L32AC21).

A Each assessment at each location will be given a unique Plot No.; these will be predetermined and confirmed at each annual pre-field planning meeting.

   Date: record the date in YY_MM_DD format.

A Record during each assessment.

   Surveyors: Record the first initial and last name of each member of the field team who is contributing to data collection. If teams are consistent, this could be reduced to initials on the field form, but should be expanded at the data entry phase.

A Record during each assessment.

Deposition Category: this will remain the same during each year of the PCMP. The category will be provided to field teams for each plot prior to assessment, and will be recorded as Low, Moderate or High.

I/Δ Record during initial assessment; confirm during subsequent assessments.

2. Plot Location and Elevation

Plot Location: a description of where the site is located at both regional and local scales. Reference features such as waterbodies, as well as roads (e.g. name and kilometer board), when describing how the site is accessed.

I/Δ Record during initial assessment; confirm or amend during subsequent assessments.

Elevation: Enter the elevation provided by your GPS device.

I/Δ Record during initial assessment; confirm or amend during subsequent assessments.

3. FS Region/District, UTM, and GPS Accuracy

***FS Region/District*:** This field is the Forest Region & District, and will be included in order to facilitate potential data-sharing in the future (at Rio Tinto's sole discretion). The study area lies entirely within the Northern Interior Forest Region and Kalum District, and will be recorded at each plot as **RNI.DKM**.

A Pre-fill this field with **RNI.DKM** on your Site Data Card for each assessment.

UTM Zone, Easting & Northing: Enter the precise location of plot center using UTM coordinates. Entire Project Area is located in Zone 9U. Plot UTM will remain the same from year-to-year, unless a correction is required.
*UTM is preferred to the Latitude/Longitude system for this Project; if Lat./Long. are collected, they should be converted to UTM during data entry.

I/Δ Record during initial assessment; confirm during subsequent assessments, and amend only if you believe you have more accurate location information.

GPS Accuracy: If determining the UTM of the plot for the first time or as a correction to a less accurate UTM collected previously, enter the GPS accuracy. If using UTM coordinates provided from previous plot visits to this location, leave this field blank.

Record during initial assessment; in subsequent assessments, only include if you have provided new UTM coordinates.

4. **Plot Representing, and Listed Ecosystems**

Plot Representing: Provide a description of the plot. If a description has been provided during a previous plot visit to this location, this field may be left blank—unless an adjustment is required owing to a change in plot dynamics or composition.

This field should include the dominant species present in each vegetation layer (A, B, C, and D), as well as a short description of vegetation stage and/or any special disturbance/edaphic/terrain or other prominent site features.

I/Δ Record during initial assessment; confirm or amend (if required) during subsequent assessments.

Listed Ecosystem: Circle yes (Y) if this Site Series (described in number 5, below) is currently a listed ecosystem per the BC Conservation Data Centre.

A Record during each assessment, per current BC CDC listing.

5. **BGC, Site Series, SMR, SNR and Surface Shape**

BGC: Record the BioGeoClimatic (BGC) Ecosystem Classification (BEC) by circling the zone/subzone/variant in which the plot occurs. Digital BEC mapping is available through BC's Data Catalogue, Data BC: https://catalogue.data.gov.bc.ca/dataset/bec-map.

I/Δ Record during initial assessment; confirm or amend during subsequent assessments. The BGC is unlikely to change, although the information is periodically reviewed and could be amended.

Site Series: Determine the Site Series using *A Field Guide to Site Identification and Interpretation for the Prince Rupert Forest Region (Part 1)*(Banner et al. 1993). If the site series has been determined during a previous plot at this location, leave this field blank.

I/Δ Record during initial assessment; confirm or amend during subsequent assessments.

SMR: Using the keys provided in Province of BC (2010), determine Soil Moisture Regime during initial soil sample collection. Enter the code (0-8). If SMR has been identified during a previous plot at this location, confirm SMR.

I/Δ Record during initial assessment; confirm or amend during subsequent assessments.

SNR: Using the keys provided in Province of BC (2010), determine Soil Nutrient Regime during soil sample collection. Enter the code (A-F). If SNR has been identified during a previous plot at this location, confirm SNR.

I/Δ Record during initial assessment; confirm or amend during subsequent assessments.

Surface Shape: Circle whether the overall surface of the plot is generally straight (ST), concave (CC) or convex (CV).

I/Δ Record during initial assessment; confirm or amend during subsequent assessments.

6. **Slope, Aspect, Mesoslope Position, Exposure Type, and Site Disturbance**

Slope: Using your clinometer, record the % slope (not degrees!). Remember, you are trying to give a good estimate of the average slope where your plot is located, not the slope of the small features inside the plot.

I/Δ Record during initial assessment; confirm or amend during subsequent assessments.

Aspect: Using a compass that has the correct declination, record aspect (in degrees). If your site doesn't face any particular direction (i.e. it's level), write "999".

I/Δ Record during initial assessment; confirm or amend during subsequent assessments.

Mesoslope Position: describes where your plot lies in a more local context (i.e. what you can see). Mesoslope position influences a suite of ecological information, helping us guess at moisture and nutrient inputs, what species likely grow here, and how wildlife may use the site. Refer to Province of BC (2010) to determine mesoslope position.

I/Δ Record during initial assessment; confirm or amend during subsequent assessments.

Exposure Type: If applicable, and using the codes presented in Province of BC (2010), crews should note "significant localized atmospheric and climate-related factors that are reflected in atypical soil and/or vegetation features" (e.g. Atmospheric Toxicity).

I/Δ Record during initial assessment; confirm or amend during subsequent assessments.

Site Disturbance: If applicable, and using the codes presented in Province of BC (2010), crews should "note events that have caused vegetation and soil characteristics to differ from those expected at climax for the site" (e.g., Wind, Forest Harvesting, etc.).

I/Δ Record during initial assessment; confirm or amend during subsequent assessments.

7. **Canopy Composition, Densiometer Counts, Structural Stage, and Successional Status**

   Canopy Composition: Record the composition of the tree canopy using the 2-3 letter tree species codes separated by single digits representing decile proportion canopy closure (adding to 10 to make 100%), e.g.: Hw7 Act2 Cw1.

   Densiometer Counts: Providing a metric similar to total % cover of the tree layer (see 8, below), desiometers provide an objective measure of overstorey cover; however, densiometer cover includes all cover above the height the densiometer is held, including the tall shrub layer and any topographic features that may overhang a site, as the instrument—unlike the human eye—cannot discern between layers or features.

   Collect four densiometer counts in the cardinal directions at plot center during each assessment. (These will be converted into a % overhead cover metric by subtracting the average from 96, and multiplying the result by 1.04).

A Record during each assessment.

   Structural Stage: Describes the stand using the characteristic life form (e.g. trees) and a number of physical attributes. Refer to Province of BC (2010) for Structural Stage codes and descriptions.

   In the case of forests, structural stage infers a developmental trajectory from immediately post-disturbance towards an old-growth community, and describes the "typical" sequential steps of structural development. Keep in mind that human interference (e.g. stand management activities such as thinning or selective/partial cutting) can directly impact structural stage, sometimes circumventing or speeding up development the typical trajectory.

   Successional Status: Describes the stand using species-related attributes. Refer to Province of BC (2010) for Successional Status codes and descriptions.

   Even more than structural stage, successional status assumes a predictable, temporal development from "seral" to "climax." While structural stage focuses on the physical structure of species and the community, successional status describes species shifts over time (e.g., changing species composition, stature, dominance, relative age, and vigour).

A Record during each assessment.

8. **Total % Cover By Layer**

For each of the four major vegetation layers (A, B, C and D), estimate the total percent cover in the plot, using comparison charts for visual estimation (such as that provided in Province of BC 2010). Record whole numbers (no decimals) for these fields. (* 2m x 2m is 1% in our 400m^2 plots).
Note that if part of an individual shrub or small tree extends in height beyond the layer cutoff (e.g. 10m), the entire individual is assigned to the higher class.

A Record during each assessment.

9. Visual Inspection of Vegetation Health

Circle the condition(s) you observe for the site as a whole. (Circle all that apply).

A Record during each assessment.

10. General Site Conditions (Vegetation Health)

Comment on general site conditions with respect to vegetation health. For example,

- How does it look? Green and lush or dry and brown?
- If green and lush, does that apply to all plants?
- If dry and brown, is everything dry and brown?

If there is no damage to vegetation, OR if the damage is "universal" across species (e.g. dust covering all shrubs), OR if damage is "simple" (e.g. all cedar trees exhibiting columnar growth), no additional form is required—simply a description of such. However, if signs of vegetation damage are present, complete the *Additional Vegetation Health Data* form.

A Record during each assessment.

11. Photos Taken, and Photo Location

Photos Taken: Crews will aim to take a minimum total of ten specific photographs during each assessment at each location. Photos will be taken consistently at each plot, in the same order. Ideally, an application such as Theodolite is used to take the photos, recording location and direction on each photograph.
As a marker, the first photograph in each sequence will include a Plot ID—ideally a photo of the first page of the completed field form. Remaining photos to be taken from plot center: North, east, south, west, up (canopy), and four "down" (oblique, showing ground) photographs to NE, SE, SW and NW plot corners (and, from 2022, from each corner toward plot center). On the Field Card, circle all photos that have been taken.

Other photos should be taken as needed to document site conditions, vegetation health, disturbance, for specimen identification, etc. If other photos are taken, include a brief description.

A Record during each assessment.

Photo Location: Record what camera/device the photos are stored in.

A Record during each assessment.

12. General Site Comments/Notes, and Sample Year

General Site Comments/Notes: Record any site notes you feel may be relevant.

A Record during each assessment.

Sample Year: Record whether this is a location's initial (1st) assessment, or a subsequent assessment (2nd, 3rd, etc.) for the PCMP.

A Record during each assessment; the Sample Year will increase by one for each new assessment.

13. Soil Samples

Soil Samples Collected: Circle all locations at which soils samples were collected (~1m outside of plot corners—without disturbing vegetation at plot boundary), or circle "None" if none taken from the site during the current assessment. Samples will be taken at a depth of 0-10 cm & 10-20 cm, when practical. Humus or other organic layers will not be included in the sample. Samples will be collected using sterilized equipment (including gloves), and will be placed in sample bags labeled with the date, time, plot, location, crew and Project ID. Samples will be stored and shipped following the directions provided annually (based on laboratory recommendations). Samples from the four positions will be composited for analysis.

Soil samples to be collected during initial year, and then again only as directed. Comment as required (e.g. samples taken at different location in/near plot).

A Record during each assessment (but sample soil only during initial year and as directed).

14. Ion Exchange Resin Columns (IERC)

Are IERCs installed at the plot? Comment if/as needed (and only if "yes").

A Record during each assessment (but install only as directed).

Plot Vegetation Data Card

This data card will be completed in full during each plot [re-]assessment. Each row on this form represents a species (in some cases, related species that cannot be reliably distinguished in the field may be combined). For each new species, complete each of the fields, as described below:

Layer: Circle the appropriate vegetation layer for the species. Vegetation layers are as described in detail in Province of BC (2010), and are summarized as follows:

- A—Tree Layer—Includes all woody plants >10m tall.
- B1—Tall Shrub Layer—All woody plants 2-10m tall.
- **B2—Low Shrub Layer—All woody plants <2m tall, except low or trailing species (see Province of BC's (2010) *List of low woody species and species of uncertain life form assigned to the herb layer*).**
- **C—Herb Layer—All herbaceous species and low woody species described above**
- D—Moss, Lichen, Liverwort and Seedling Layer—All bryophytes, terrestrial lichens and liverworts, and tree seedlings less than 2 years old, occurring on mineral soil and humus. Subcategory "Dr" includes such species occurring on rock, and "Dw" occurring on wood.
- E—Epiphyte Layer—All species which grow on other living plants.

***Categories A, B1, D and E will only be included if identified as an "Additional Species of Importance" (i.e. it is at risk, a weed, or of cultural importance).**

% Cover (plot): Estimated as the percentage of the ground surface covered when the crowns are projected vertically: Follow the outside perimeter of the projected crown (small gaps in the canopy that are not fully covered can be ignored). If a plant is only partially in the plot (example the stem is outside but part of the plant vertically projects on the inside of the plot), include the % cover that occurs inside the plot boundaries.

Some tips for ensuring cover estimates are reliable:

- Walk around and view all areas of the plot from above—viewing obliquely can cause you to overestimate.
- For species with high cover values, mentally move the plants to a corner of the plot to estimate if they represent one-quarter, one-third, or one-half, or more of the plot.
- For species that almost cover the plot, mentally move them together and estimate how much of the area is not covered by the plants.

- For species with low cover, break the plot into subsections and add up the cover in the subsections.
- Work semi-independently with a partner and see if your estimates agree.
- Most importantly, use a ruler, and re-calibrate yourself with it at each plot. Equating percent cover with equivalent dimensions relative to plot area can be very helpful. These sample dimensions are applicable in our $400m^2$ plots:

Dimensions	Area (m^2)	% Cover
10m x 10m	100.0	25.0
5m x 8m	40.0	10.0
5m x 5m	25.0	6.25
4m x 4m	16.0	4.0
2m x 2m	4.0	1.0
1m x 1m	1.0	0.25
63cm x 63cm	0.4	0.1
20cm x 20cm	0.04	0.01 ("1H")
6.3cm x 6.3cm	0.004	0.001 ("1T")

Record to the number of decimals you feel confident about, to a maximum of thousandths (you may record these as "xT," for example 3 thousandths would be recorded as "3T"; hundredths similarly may be recorded as "xH").

Individuals: [This metric has been removed]

Listed sp.?: Check the box if the species is identified as at risk (current BC CDC listing, provided annually during pre-field planning). If unsure, circle the box to flag it for follow-up.

Table 1 sp.?: Check the box if the species is a *Table 1* species (provided annually during pre-field planning). If unsure, circle the box to flag it for follow-up.

ID Conf. Req'd?: Check the box if you are not certain about correct identification of this plant (i.e. confirmation is required). Photograph the species. Do not collect a specimen from inside the plot, but do collect a specimen if you can find one nearby—and be sure to label it with species (can be "unknown 1," etc.), Plot ID, Date, and any other pertinent information.

Photo?: Take photo(s) and check the box IF the species identification is uncertain, or if you have specially taken additional photographs of this species (for any reason).

Distrib Code (1-9): Use the Distribution Codes (Province of BC 2010) to describe the spatial distribution pattern in the plot of individuals of each species.

Vigour Code (0-4): Use the Vigour Codes (Province of BC 2010) to describe individual species' vigour within the plot. As the coding does not elaborate on how to differentiate between the codes, the following is meant to provide guidance and clarity:

- ☐ 0—Dead—All leaves dry, shriveled and/or necrotic.
- ☐ 1—Poor—Severe necrosis or wilting.
- ☐ 2—Fair—Some reduced vigour, possible browning of leaf tips, wilting, chlorosis or necrosis. Damage or disease agents may be impacting this species.
- ☐ 3—Good—Relatively healthy, but growth not vigourous, plants are green but not deep green and lush. Damage or disease symptoms may be evident, but minor.
- ☐ 4—Excellent—Deep green leaves, lush growth, and no chlorosis, wilting, or evidence of ongoing damage or disease.

Phenology Codes (Vegetative/Generative): Use the appropriate Phenology Codes (Province of BC 2010) to describe the Vegetative (non-reproductive) AND Generative Stages in the plot for each species. Note that different species groups have different codes.

At Risk/Cultural/Weed: For Additional Species of Importance, indicate the reason this species was included by circling the appropriate category.

Line Transect Vegetation Data Card

The methods for the Line Transect Vegetation Data collected for the PCMP are adapted (to include herbs) from the Province of BC's (2018) *Vegetation Resource Inventory Ground Sampling Procedures'* Line-Intersect Method for Shrubs.

The object of this exercise is to quickly and reliably estimate cover by vertically projecting the "canopy" of low shrubs (B2) and herbs (C) onto a "two-dimensional" horizontal line, measuring the length of the line that intersects with the canopy.

Two connected ~20m transects will be established: One along the northern plot boundary, and the other along the eastern plot boundary (wherever practical; however, field crews may choose a different boundary if it is justified, but must then highlight this on the form and ensure a note is attached to the plot information for future re-assessments).

1) Stretch a measuring tape at a consistent, reasonable height (e.g. 30cm) along the transect lines (one at a time), attaching the tape tightly to the corner at either end.
2) Record the starting (POC) distance as read on the strung measuring tape (it does not need to begin at 0—simply read the centimeter mark off the tape where the transect begins (the corner)).
3) Identify and record the distances covered for each B2 and C layer species whose "vertical projection" intercepts the sampling line (see Figure 5*):
    a. Record distance along transect to the nearest 1cm.
    b. Ignore any gaps less than 5cm in an individual plant's "canopy" cover.
    c. Especially on slopes, remember to measure the horizontal distance: Use the plumb bob to help accuracy (i.e. project the canopy vertically, using gravity!).
    d. If the canopies of different species overlap, record the plants separately (including any area of overlap)
    e. If the canopies of the same species overlap, record them as one occurrence.
    f. It doesn't matter how you organize the data on the form (by species or by distance) so long as the distances are correctly recorded.
4) Use an additional page if you require more space to record data.
5) Record the ending (POT) distance as read on the strung measuring tape (it does not need to be at 20m—simply read the meter & centimeter marks off the tape where the transect ends (the corner)).
   It does not matter if the transect is slightly longer or shorter than 20m—given topography and other field conditions, plot corners will rarely (if ever) be precisely 20m apart.

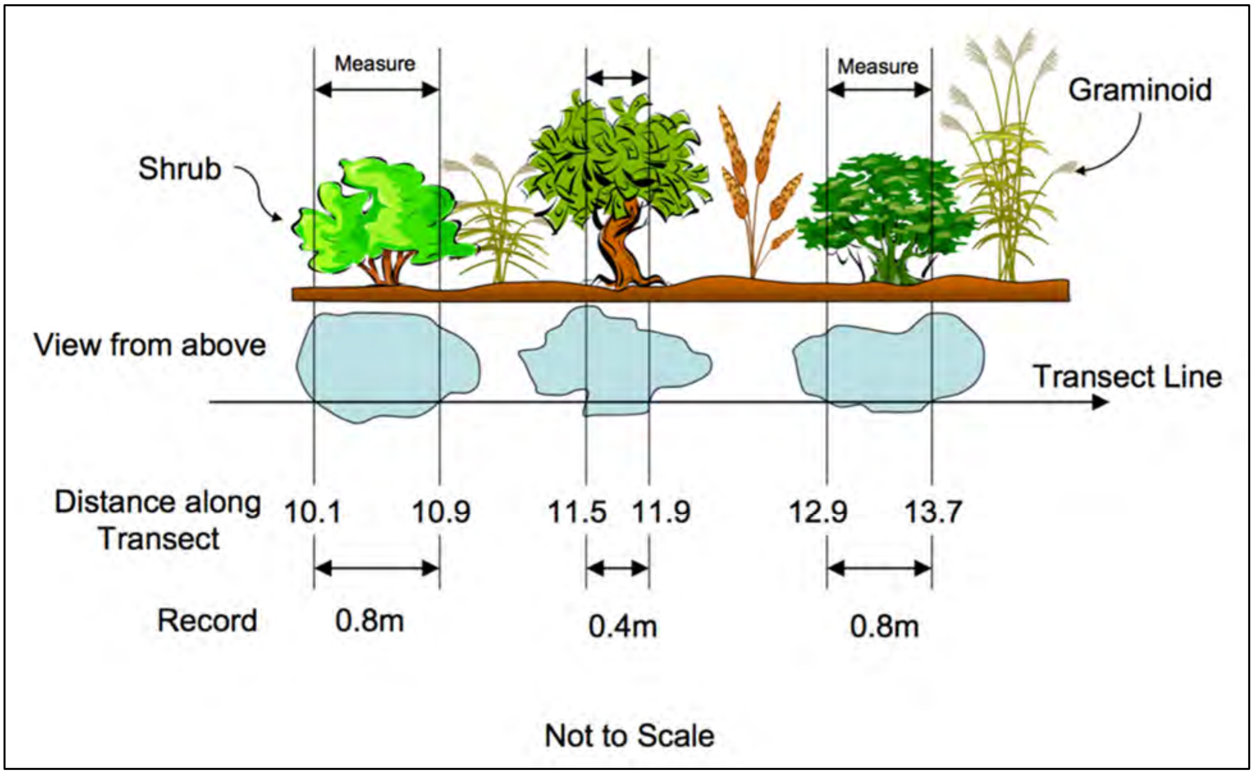

Figure 5: Line-intercept method for shrubs, taken from Province of BC (2018).

*Figure 5 shows the use of the method for shrubs only, excluding herbaceous species; however, for this project, all shrubs and herbs in the B2 and C layer will be included and measured as per the shrub cover shown in Figure 5.

Plot Cyanolichen Data Card

A one-hour timed search for cyanolichens is to be undertaken at each plot, during each assessment. A timer with an alarm should be used for this activity.

Using the 24-hour clock, record the start time for the search, and, when complete, the end time. If the search extends beyond the plot boundary (i.e. because the plot search area has been fully exploited), record the start time for this activity and continue searching until the one-hour total time limit is complete.

For each cyanolichen species encountered on a coniferous host tree (living, or dead but standing), record the following:

- Species code.
- Tick the box if it was encountered inside the plot boundaries.
- Tally the number of individuals/colonies that occur <u>inside</u> the plot **to a maximum of 15 (indicate more with a "+"),** and assign a corresponding abundance rating based on the tally within the plot when the timed search is completed.
- If the timed search continued <u>outside</u> the plot boundaries, tick the box if the species was encountered outside the plot during the timed search. Circle "n/a" only if the timed search did not continue beyond the plot boundaries.
- For each lichen species, record all coniferous host species observed during the timed search.
- Tick the box if the species is listed (at risk).
- Tick the box if identification of this species requires confirmation. If this is the case, do not take a physical sample (unless one can be obtained from outside the plot), but do take a set of good quality photographs of upper and lower surfaces.
- Tick the box if photos were taken of this species.
- For Health, circle Normal, Injured, or Stressed.
- Record a comment (optional).

Do not include cyanolichens found on downed trees or deciduous hosts in the table: Instead, provide this information in comments section.

When the timed search is complete, record any overall comments (e.g., presence, abundance, substrate, host species, etc.). It is helpful to add comments about distribution: e.g. is there one specific tree that is host to all/most of a species' occurrences?

Provide a comment on Cyanolichen Health (e.g., are there any symptoms of poor health in plot cyanolichen community? Describe. If yes, is it affecting all members, or are the effects differentiated between locations, species, etc.?

Additional Vegetation Health Data Card

This is an optional data form, to be filled in only at plots when the vegetation and/or cyanolichen inspection and assessment indicate its necessity.

For each species with symptom(s), be sure to take photographs, and ensure they are labeled with date, location and species information.

- record the symptom(s) (i.e. what you see that suggests health is being negatively affected);
- record the proportion of individuals of this species present in the plot that show the symptom(s);
- for individual leaves that are affected, record the average percentage of affected leaf area;
- for individual plants that are affected, record the average percent of plant affected;
- record the suspected cause of symptom(s), and provide a comment; and
- note whether photographs have been taken.