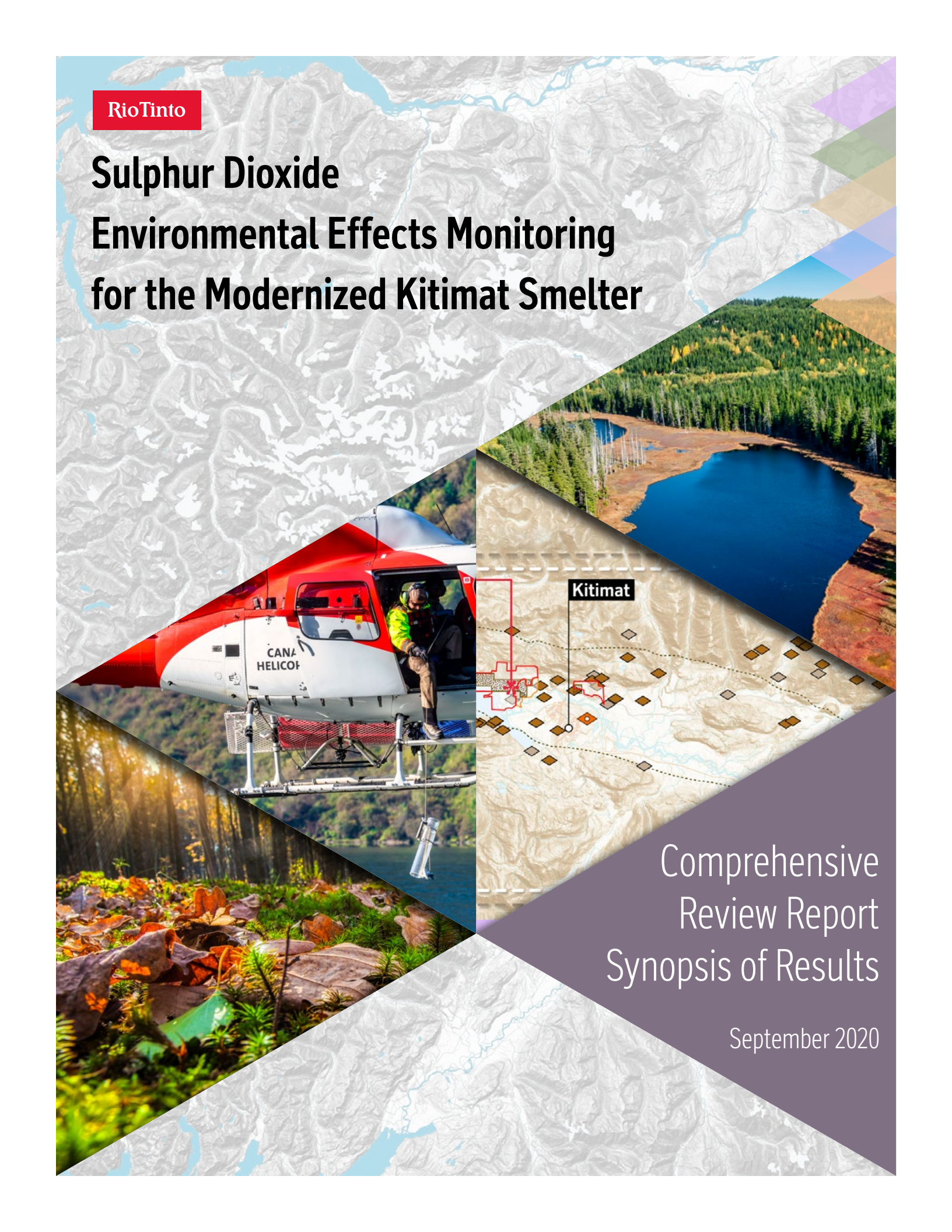


The cover features a collage of images: a topographic map of a mountainous region with a river, a red and white helicopter with 'CANA HELICOPT' on its side, a person in a yellow safety vest in the helicopter, a large blue lake surrounded by a forest, and a close-up of autumn leaves. A purple banner is in the top right corner.

RioTinto

Sulphur Dioxide Environmental Effects Monitoring for the Modernized Kitimat Smelter

Comprehensive
Review Report
Synopsis of Results

September 2020

Sulphur Dioxide Environmental Effects Monitoring for the Modernized Kitimat Smelter

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Abbreviations and Key Terms

CAAQS: Canadian Ambient Air Quality Standards. A set of standards for specific substances developed by the Canadian Council of Ministers of the Environment (CCME) in support of federal and provincial air quality management programs. A standard for SO₂ was adopted by the CCME in 2016, to take effect in 2020. More information can be found at: <https://www.ccme.ca/en/resources/air/air/sulphur-dioxide.html>

CR: Comprehensive Review. A large review of the studies conducted from 2013 to 2018 under the SO₂ Environmental Effects Monitoring (SO₂ EEM) Program, as required under the provincial P2 permit for the modernized smelter.

Critical load: A level of a pollutant that an ecosystem can tolerate before harmful effects may occur.

KPI: Key performance indicator. A measurable factor related to the effects of sulphur defined for each receptor. KPI's are associated with thresholds that trigger additional monitoring or mitigation measures.

P2: P2-00001 Multimedia Waste Discharge Permit issued to the Kitimat Smelter under the BC Environmental Management Act in 1999.

Particulate sulphate: Sulphate (a compound of sulphuric acid) occurring in particulate form, or microscopic matter suspended in the air.

QPs: Qualified Professionals; the subject-matter experts who conduct the SO₂ EEM Program studies and interpret the results. The QPs authored the Comprehensive Review Report.

S: Sulphur. A natural chemical element, found in most plant and animal sources, including fossil fuels.

SO₂: Sulphur dioxide. A gas emitted from the burning of fossil fuels, in combination with oxygen. SO₂ is emitted from the smelter from the combustion of petroleum coke in the smelting process.

S deposition: The transfer of sulphur compounds from the atmosphere to land or water surfaces.

STAR: SO₂ Technical Assessment Report. The initial assessment of the effects of SO₂ from the modernized smelter, 2013.

Tpd: Tonnes per day. The measurement unit used to record and report the amount of SO₂ that is emitted from the smelter.

Wet deposition: Sulphur dioxide that has transformed into sulphuric acid through contact with moisture, and is deposited as acidic precipitation.

Comprehensive Review: Results Summary

The 2020 Comprehensive Review (CR) presents the findings of the first six years of the Sulphur Dioxide Environmental Effects Monitoring (SO₂ EEM) Program. The team of seven Qualified Professionals (QPs) and the British Columbia Ministry of Environment have evaluated the data gathered through the modelling and monitoring activities on concentrations of SO₂ in the Kitimat Valley and effects on humans, vegetation, soils and aquatic ecosystems. Following extensive review of these data, the QPs report that they observe no evidence of harm from the smelter emissions to the four receptor types.

The key performance indicators (KPIs) in the SO₂ EEM Program were chosen to provide early warning of potential impacts on the receptors. None of the thresholds associated with the KPIs have been reached, including the thresholds for increased monitoring. No prediction-based KPI threshold exceedances are projected.

Air concentrations of SO₂ at residential monitoring stations are well below the human health KPI threshold as well as the new CAAQS level (70 ppb). Air concentrations of SO₂ in the valley are well below concentrations that would cause visible injury to **vegetation**. No **soil** plots show evidence of acidification, and less than 1% of the study area close to the smelter is predicted

to receive sulphur deposition in excess of the critical load under 42 tonnes per day. Prediction-based KPIs for soils and lakes are not expected to reach mitigation thresholds even under SO₂ emissions at 42 tpd.

Of the 14 **lakes** in the SO₂ EEM Program, 12 lakes show no evidence of acidification caused by the Kitimat smelter. Only two lakes show evidence of any acidifying change: one small fishless lake close to the smelter shows signs of acidification, and had before construction of the new smelter; the other shows signs of some acidification but the evidence relating this to the smelter is inconsistent, and no KPIs have been exceeded. Rio Tinto voluntarily increased the amount of lake monitoring at nine lakes to better track changes in lake chemistry that could be due to the smelter.

Looking across these lines of evidence the QPs do not see signs of harm in the valley based on the six years of monitoring work. Through all of the analyses, discussions, and results of the comprehensive review they are confident in these conclusions and recommend going forward with a more consolidated, efficient environmental effects monitoring program, including some adjustments to the KPIs for vegetation, soils and surface waters.



SO₂ Emissions from the Modernized Smelter

SO₂ emissions have increased with the modernization of the smelter due to higher production levels (50% increase) and higher levels of sulphur in petroleum coke.

They have not reached the permit maximum of 42 tpd, and are expected to remain between 33 and 36 tpd. See Figure 1 below.

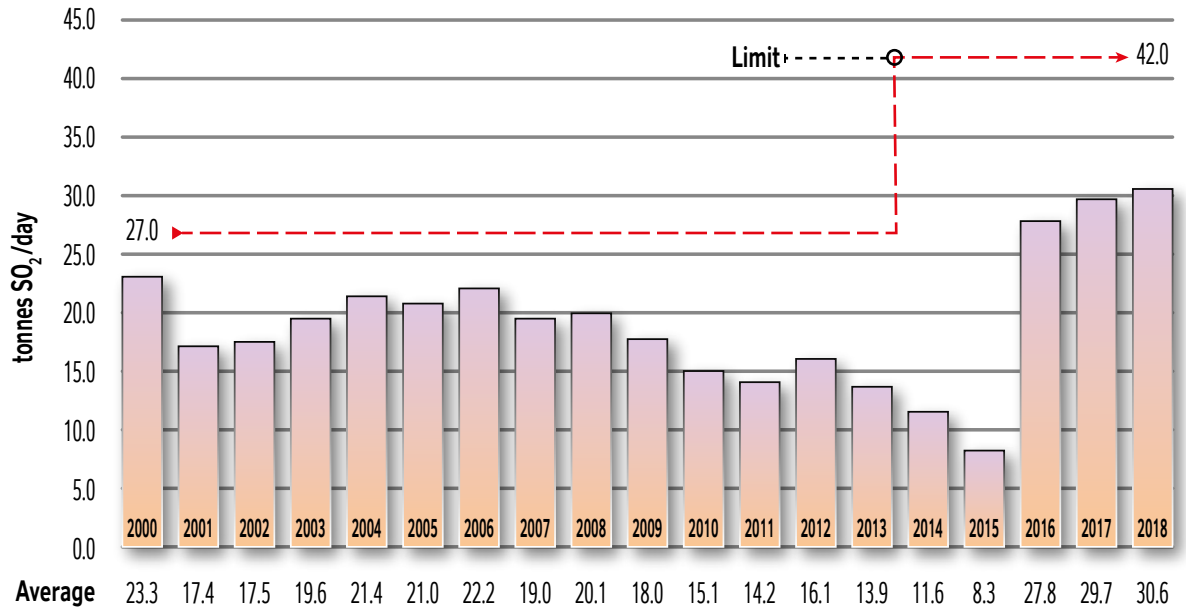


Figure 1. **Average annual SO₂ emissions from the Kitimat smelter, 2000-2018.** The red line represents the SO₂ emissions permit limit set by the province, which rose to 42 tpd in 2014 (the low emissions in 2015 were due to the shutdown of the old smelter for the Kitimat Modernization Project).



The Comprehensive Review Process

The 2020 Comprehensive Review (CR) Report describes the methods and results of the Sulphur Dioxide Environmental Effects Monitoring (SO₂ EEM) Program from 2013 to 2018.¹

The SO₂ EEM Program was developed to monitor and evaluate the potential effects of SO₂ emissions from the modernized smelter in Kitimat. The provincial P2 permit for the project allowed an increase of SO₂ emissions of up to a maximum of 42 tonnes per day (tpd), but required a scientific study to monitor the effects of the SO₂ on four receptors: human health, vegetation, terrestrial ecosystems (soils) and aquatic ecosystems (lakes, streams and aquatic biota).

The initial assessment of the effects of SO₂ from the modernized smelter, including modelled predictions of SO₂ and sulphur (S) deposition amounts in the study area, was presented in the SO₂ Technical Assessment Report (STAR, 2013).²

The CR reports on the methods and results of studies that have been done under the SO₂ EEM plan from 2013 to 2018. It was guided by a Terms of Reference document,³ which explains the types of information that would be gathered by comprehensive review monitoring activities, the analyses that would be carried out and the terms in which the information would be described in the full CR Report. A draft CR report was submitted to the BC Ministry of Environment on October 31, 2019.

Key Participants

The scientific studies reported in the STAR and for the ongoing SO₂ EEM Program are carried out by independent Qualified Professionals (QPs) and interpreted through a consistent analytical framework. The QPs have been working on the Kitimat SO₂ permitting and EEM program for nine years, and on the comprehensive review for almost two years.



The QPs include seven experts in the fields of air dispersion monitoring, health risk standards for SO₂, and the effects of SO₂ and acidic deposition on vegetation, soils, and aquatic ecosystems. The experts represent internationally known science and environmental consulting firms and universities, and together have more than 240 years of combined experience.

Complementing the QPs' studies on the receptor programs has been the contribution of the Kitimat Public Advisory Committee (KPAC), which provides input on community interests related to the smelter operation in Kitimat, particularly on environmental and regulatory matters. The KPAC is the main consultative body for the P2 permit for the project under the British Columbia Environmental Management Act.

KPAC members have been very active in the permitting process, providing feedback on reports and developments. Consultations with the KPAC on the CR process have been conducted, including seven webinars presenting the results of the CR.

KPAC

KPAC members represent 17 jurisdictional and community organizations.

BC Ministry of Environment

District of Kitimat (staff and council)

Douglas Channel Watch

Former Mayor of Kitimat

Haisla Nation

Kitimat Health Advocacy Group

Kitimat Rod and Gun Association

Kitimat Valley Naturalists

Kitimat Understanding the Environment (KUTE)

Lakelse Lake Society

Northern Health Authority

Northwest Regional Hospital District

UNIFOR

Kitimat First United Church

Steelhead Society

School District 82

Rio Tinto

Kitimat Chamber of Commerce

1 A copy of the CR Report is available by request, at bcworksinfo@riotinto.com
2 STAR: <https://www.riotinto.com/en/operations/canada/bc-works>
3 TOR: <https://www.riotinto.com/en/operations/canada/bc-works>



Comprehensive Review Results: Discussion

Air concentrations of SO₂ and S deposition rates in the Kitimat area are low.

Results of the atmospheric pathways program, which includes measuring and predicting levels of SO₂ in air in support of the receptor monitoring programs, show that concentrations of SO₂ in the air in most locations are substantially lower than those predicted in the STAR. Monitoring has confirmed that the Kitimat residential areas have low SO₂ concentrations relative to the human health KPI, and that only a fraction of atmospheric sulphur is particulate sulphate.

Deposition rates of sulphur from the smelter are well below levels that can potentially affect soils, vegeta-

tion, lakes and streams. The SO₂ that is emitted from the smelter travels widely through the air and disperses significantly before reaching ground level (Figure 3 on page 10). Only about 8% of the SO₂ that is emitted from the smelter is deposited through wet or dry deposition within the 3653.5 km² study area.

No KPI thresholds have been exceeded through the SO₂ EEM Program from 2013-2018.

None of the KPI thresholds have been reached for any of the receptors so far in the SO₂ EEM Program. Table 1 summarizes the findings of each program in terms of the KPI thresholds.

Program	KPI Threshold	KPI threshold exceeded (2013-2018)
Human Health	BC Interim Air Quality Objective for 1-hour SO ₂ in ambient air <i>Threshold: 75 ppb</i>	NOT EXCEEDED - Average below 1 ppb at all sites, more than half the hours in the year - The average of only the hours with the highest daily concentration is still less than 1 ppb for more than half the days at each site
Vegetation	Visible injury to vegetation caused by SO ₂ <i>Severity; symptoms of SO₂ injury caused by smelter</i>	NOT EXCEEDED No visible injury
Terrestrial Ecosystems (Soils)	Critical load exceedance risk caused by S deposition from smelter <i>Threshold: based on size of area of acidification and rate of change (100 – 200 years)</i>	NOT EXCEEDED Area of exceedance less than 1% of the study area (3653 km²), close to smelter
	Long-term soil acidification due to S deposition <i>Threshold: in long-term soil plots, degree of decrease in cation pool, over 10-year period</i>	NOT EXCEEDED No change in soil conditions
Aquatic Ecosystems	Water chemistry <i>Thresholds based on numbers of lakes with acidification (decrease in pH), causal relation to smelter</i>	NOT EXCEEDED Only one small fishless lake close to the smelter shows signs of any acidifying change related to smelter emissions, and had before construction of the new smelter.

Table 1. Receptor programs KPIs and performance (2013-2018)

Key Recommendations Going Forward

In the CR Report the QPs report on what they learned through the first six years of the SO₂ EEM Program, and describe their recommendations for each program for

the next phase of the studies in the program. These are summarized in Table 2 below; more details are available in the CR report.

Program	What was learned (2013-2018)	Key Recommendations and Changes
Atmospheric Pathways	- SO₂ and S deposition lower than predicted in STAR. - Only about 8% of smelter emissions are deposited within study area.	- Continue monitoring SO₂ levels in residential areas (Riverlodge and Kitimaat Village sites); and at Kitimat Haul Road station - Continue monitoring station at the Service Centre commercial area to provide information on the dispersion model performance - Continue passive sampling network in the Kitimat Valley; change some locations - Discontinue precipitation chemistry monitoring at the Haul Road station
Human Health	Higher peak concentrations, due to weather, are rare, short-lived, well under KPI threshold	The CAAQS threshold replaces the initial 75 ppb threshold; this is 70 ppb in 2020 and decreases to 65 ppb in 2025.
Vegetation	- Visible injury unlikely at low predicted SO₂ concentrations - Health of the vegetation has not changed following the smelter modernization	- Establish a terrestrial ecosystem line of evidence, based on soils critical load KPI and informative indicators on plant biodiversity and plant health - Establish a monitoring program to detect long-term effects on terrestrial ecosystems, using plant biodiversity plots and monitoring lichen plots
Terrestrial Ecosystems (Soils)	- The areas predicted to show a risk of critical load exceedance are close to smelter and under the 42 tpd limit - The area of critical load exceedance is less than 1%, compared to the threshold of 5%.	- Conduct study on wetland geochemistry and sulphur storage capacity - Assess aluminum solubility in mineral soils - Long-term soil plots: the KPI should be base saturation in top 30 cm of mineral soil to assess soil chemistry changes; and return to 5-year sampling frequency.
Aquatic Ecosystems (lakes, streams, and aquatic biota)	- The sensitive lakes have been shown to respond much less strongly to smelter SO₂ emissions than was originally predicted. One small fishless lake near the smelter shows some signs of acidification, as it had before the construction of the new smelter. A second lake has shown signs of acidification, but there is no consistent evidence relating the acidification trend to the smelter and no KPIs have been exceeded. - Lake pH measurements that are used to evaluate the KPI were found to be more variable than anticipated.	- The KPI should be changed to acid neutralizing capacity - Sampling and lake chemistry » Continue with the fall sampling of the 7 sensitive lakes. » Intensive sampling of one lake (LAK006) » Continue annual fall sampling, including the less sensitive lake (LAK016) and 3 control lakes, and discontinue sampling of the insensitive lakes (LAK 007, LAK024, and LAK034).

Table 2. What was learned through the CR and key recommendations going forward





The Monitoring Studies

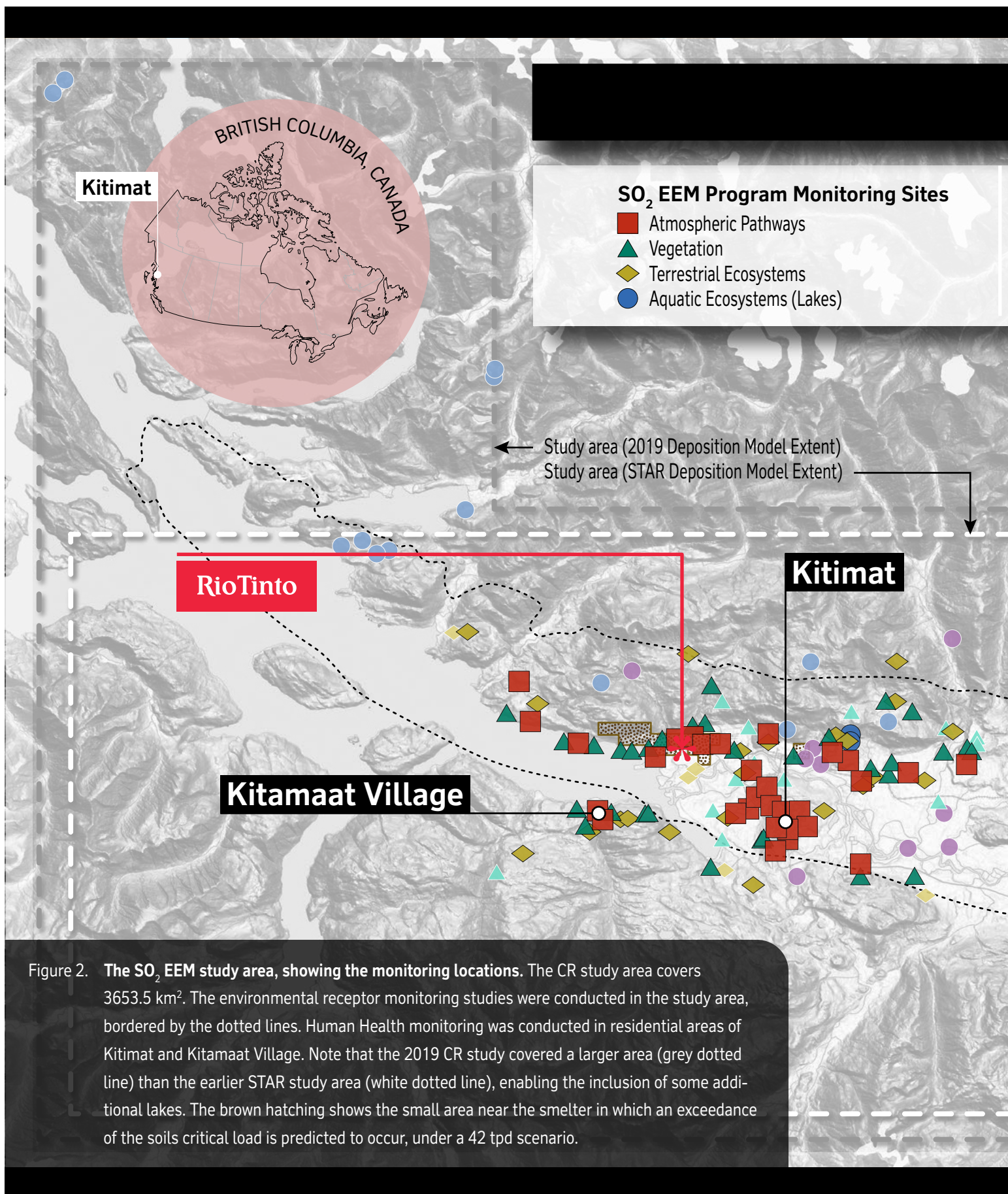
The SO₂ EEM Program

The sulphur (S) from the smelter is sulphur dioxide (SO₂) gas, emitted high into the air from tall stacks. It is dispersed with the wind, but, depending on conditions, lower but varying amounts will be present in the air in the community. When it dissolves in water, such as through contact with rain or fog, the SO₂ gas is transformed into sulphuric acid (H₂SO₄) and is deposited on the environment in wet and dry forms.

At higher levels, these two forms of sulphur can have effects on human health and the environment. SO₂ gas in the air can be a respiratory irritant for asthmatics, and can damage vegetation. Acidic deposition from sul-

phuric acid can increase the acidity of soils and surface water, affecting vegetation, terrestrial ecosystems, and aquatic ecosystems.

The SO₂ EEM program includes five study programs that evaluate whether concentrations of SO₂ and sulphur deposition are causing harm. These include four receptor monitoring programs, and the atmospheric pathways program that produces data in support of the receptor programs. The study area and the location of the monitoring activities are shown on the map, Figure 2 on page 8.



SO₂ EEM Program

Supporting Sampling Sites

- ▲ Vegetation
- ◆ Terrestrial Ecosystems
- Aquatic Ecosystems (Lakes)
- Aquatic Ecosystems (Streams)



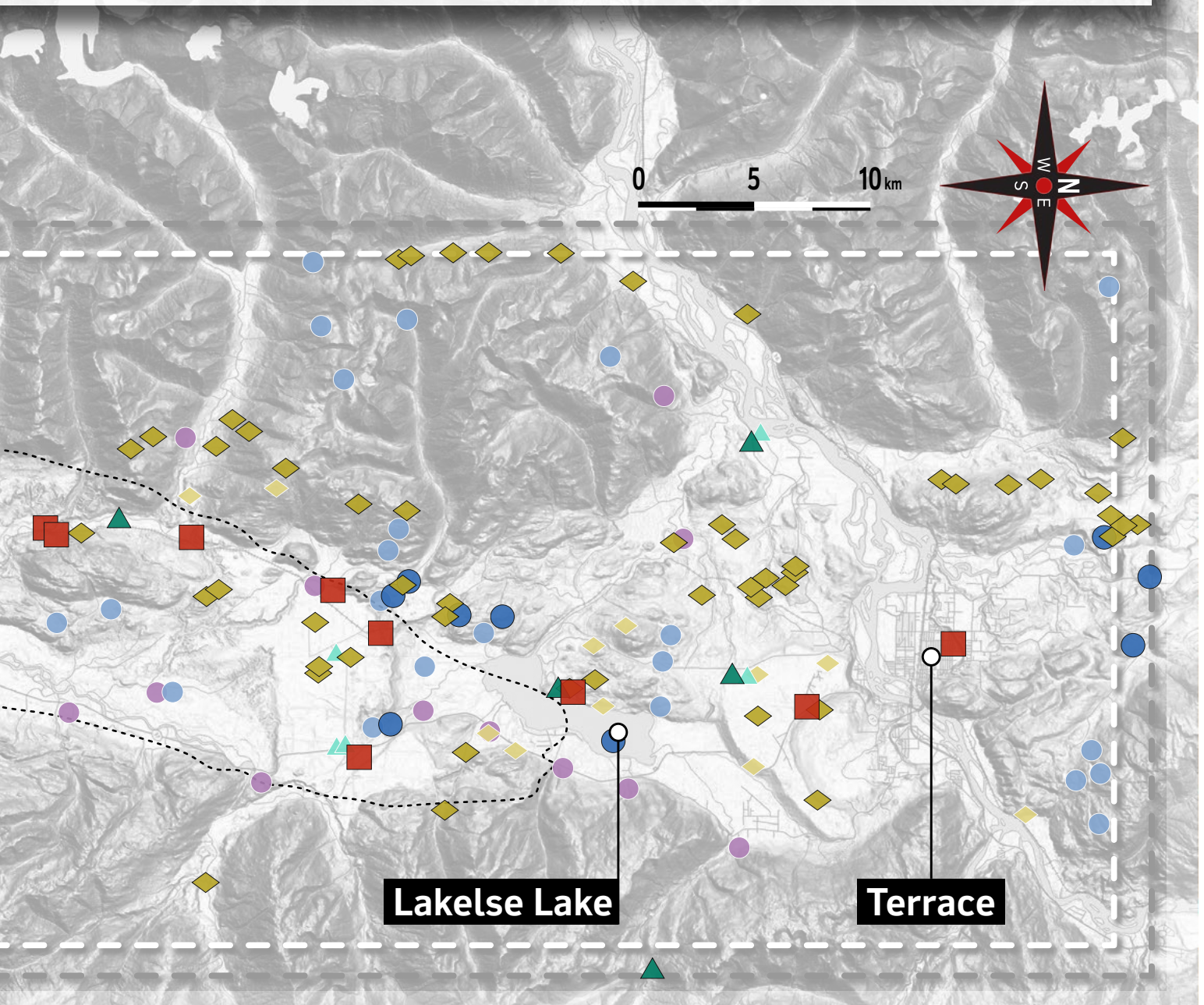
Critical Load Exceedances



3-Year (2106, 2017, 2018) Average Modelled Total Sulphur Deposition
7.5 kg SO₄²⁻/ha/yr isopleth ("42 tpd" scenario)



Rio Tinto Site



The SO₂ EEM Program studies were based on the source-pathways-receptors (SPR) model, a structured understanding of the sources, pathways and effects of SO₂. Each pathway can potentially affect multiple receptors: human health and vegetation share the SO₂ concentration pathway, while vegetation, soils and aquatic ecosystems share the sulphur deposition pathway.

There are two key aspects of the SO₂ EEM program that are represented in the SPR model.

- The source (S; the SO₂), including its generation and chemical transformation, and the two key pathways (P) by which it may contact the four receptors (R): humans, vegetation, terrestrial ecosystems, and aquatic ecosystems and biota.
- The adaptive management process, shown with the bottom arrows, which depicts the monitoring

and evaluation of effects on receptors through the two pathways, and the application of mitigation measures to reduce the source emissions, if effects exceed thresholds.

To apply the adaptive management approach, the QPs defined a set of indicators – observable and measurable factors related to the effects of exposure to sulphur –for each receptor, based on scientific knowledge of the types of impacts that exposure to sulphur may have on the receptor. Primary indicators were adopted as “key performance indicators” (KPIs). For each KPI a threshold was defined that would provide early warning of potential harm caused by emissions from the smelter, and was linked to specified mitigation actions. The KPIs and thresholds were endorsed by the BC Ministry of Environment and incorporated into the permit conditions.

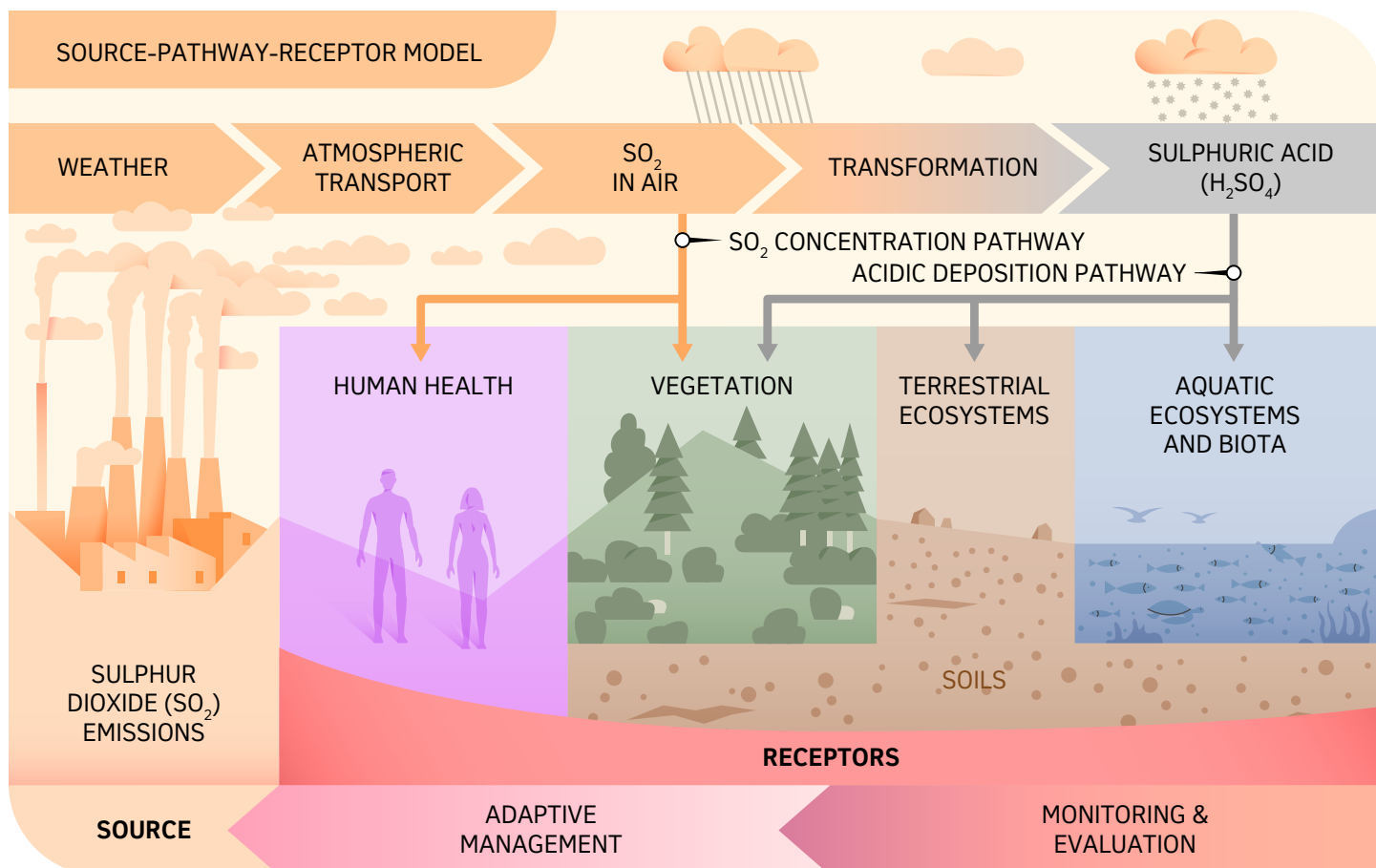


Figure 3. Source - Pathways - Receptor Model





Annual lake water sampling

The Study Programs

The atmospheric pathways program models and monitors concentrations of SO_2 in the air and S deposition onto soils, vegetation and water bodies. The four receptor monitoring programs, and the applicable KPIs, are summarized here.

At high levels, SO_2 can be a respiratory irritant for asthmatics.

The KPI for the 2013-2018 SO_2 EEM Program was based on the BC Interim Air Quality Objective for 1-hour SO_2 .

Levels of SO_2 in ambient air are monitored in residential areas in Kitimat and Kitimaat Village.

Human Health Program



Riverlodge monitoring station





Vegetation Monitoring Program



Plants require sulphur and take up SO_2 from the air and sulphur from the soil, but can be injured by excessive amounts.

The KPI is based on SO_2 concentrations in air that are known to cause visible injury to plant species, and inspections that assess plant health and provide early warning of any impacts.

Terrestrial Ecosystems Monitoring Program



Soils can acidify from wet and dry deposition of sulphur. Increased soil acidity can adversely affect vegetation.

The program has two KPIs:

- critical load exceedance risk, a predictive indicator of areal extent of acidity and the rate of acidification.
- an observation-based indicator of acidification in long-term soil plots attributable to sulphur deposition.



**Sulphur Dioxide
Environmental Effects Monitoring
for the Modernized Kitimat Smelter**

The KPI is based on water chemistry, indicating the health of the aquatic ecosystem. This provides earlier warning of effects than using aquatic biota as a KPI.

Aquatic Ecosystems Monitoring Program



Lake water chemistry monitoring on Lake 28



Aerial view of the District of Kitimat, BC



Sulphur Dioxide
Environmental Effects Monitoring
for the Modernized Kitimat Smelter

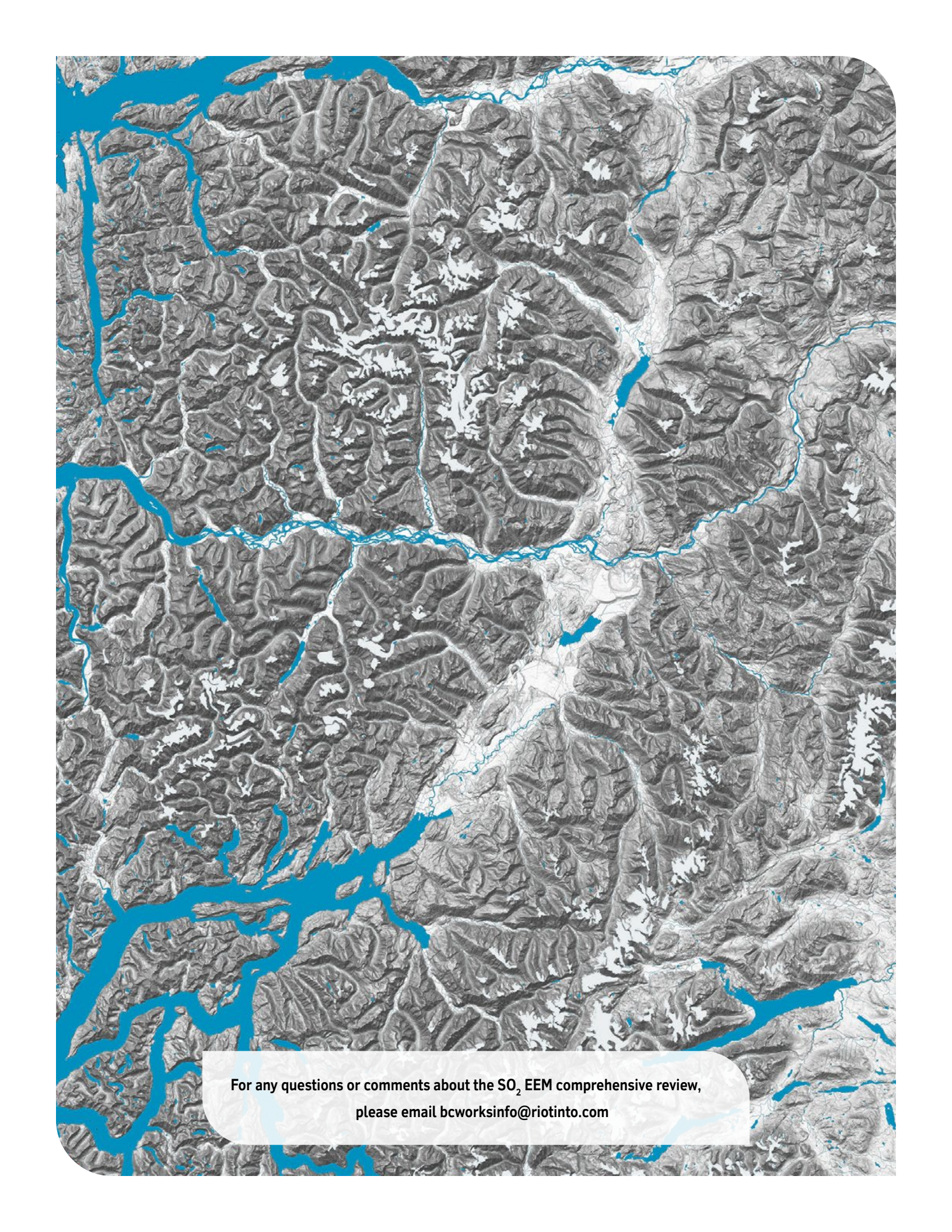


Next Steps

The consultation period for the SO₂ EEM comprehensive review was held until August 31, 2020. Questions and comments that were received during that period have been taken into account in the finalization of the report.

Discussions with the BC Ministry of Environment on updating the SO₂ EEM program will occur this year, based on the recommendations from the comprehensive review.

The draft updated SO₂ EEM program (Phase II) will be brought to the KPAC for consultation in 2021.



For any questions or comments about the SO₂ EEM comprehensive review,
please email bcworksinfo@riotinto.com