FINAL REPORT

KITIMAT AIRSHED NETWORK REVIEW

VANCOUVER, BC

NETWORK REVIEW
RWDI # 2105554
August 3, 2023

SUBMITTED TO

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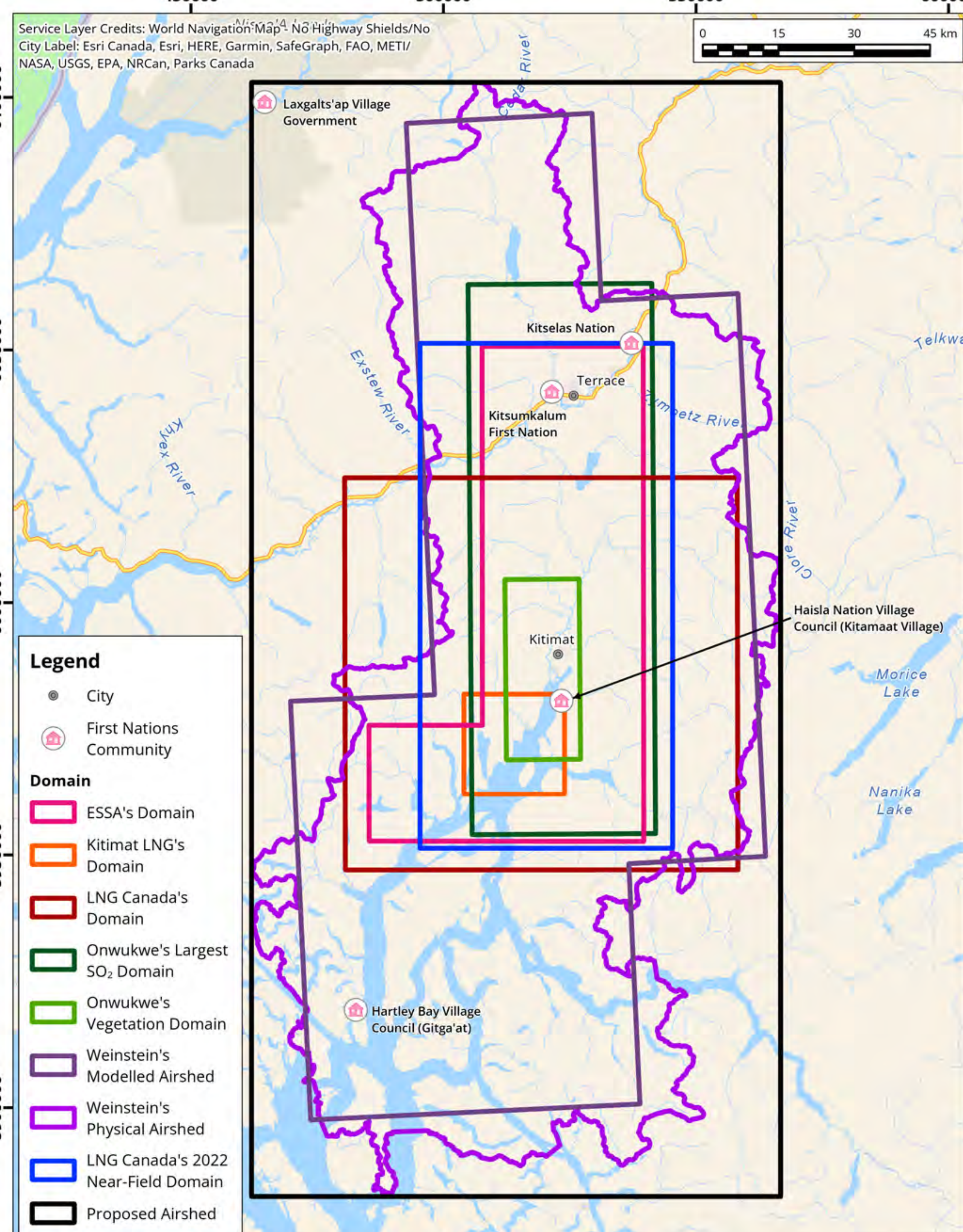
EXECUTIVE SUMMARY

The Kitimat Airshed Group (KAG) retained RWDI AIR Inc. (RWDI) to review the KAG airshed network. This study was comprised of three tasks: a focused literature review, definition of the geographic boundaries of the Terrace-Kitimat Valley (TKV) airshed, and an assessment of the network's ability to meet the objectives set by the KAG.

RWDI completed a focused review of the literature relevant to ambient air contaminant concentrations and related impacts in the TKV airshed. Recognizing the value of the physical airshed boundary chosen by Ben Weinstein (Weinstein, 2015), and balanced against the findings from the literature review, RWDI recommends the cautionary approach of the proposed airshed domain shown in Figure 1.

The review of the existing air monitoring network led to the recommendations as listed below. These recommendations were developed assuming a full buildout of the LNG Canada facility, as required by the Environmental Assessment Certificate Application. The recommendations include:

1) Maintain all current continuous monitoring stations.
2) Continue the passive SO_2 sampling network, as per the recommendations of the ESSA et al review.
3) Maintain a passive SO_2 station at the Claque Mt. Trail at the BC Hydro right of way.
4) Add a passive SO_2 station at Kemano.
5) If NO_2 or O_3 concentrations trend higher at existing Kitimat Whitesail (KW) or Terrace Skeena Middle School (TSMS) stations, consider the addition of NO_2 and O_3 monitoring at Lakelse Lake.
6) If another NO_2 emitter is added to the airshed (e.g., a second LNG facility or marine terminal) or NO_2 concentrations trend higher, consider adding NO_2 monitoring at Kitimat Riverlodge (KR), Kitimat Haul Road (KHR), Kitimat Industrial Avenue (KIA), or a location in Douglas Channel (if emission source is located south of the smelter).
7) Consider the addition of SO_2 monitoring south in the Douglas Channel if another industrial emitter is added near to the Kitimat LNG site.
8) Perform a preliminary review of the air quality monitoring network within the next ten years to decide if a new major review is warranted.



Map Document: D:\GIS\desktop\2105554_KitimatAirshed\P2105554_Kitimat.aprx

Comparison of Modelling Domains and Airshed Boundaries

True North

Drawn by: RCL	Figure: 1
Approx. Scale:	1:1,100,000
Date Revised:	Nov 10, 2022

Map Projection: WGS 1984 UTM Zone 9N

Kitimat Airshed Network Review - Kitimat, B. C.

Project #: 2105554

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NOMENCLATURE

AAQO	Ambient Air Quality Objectives (includes BC AQO and CAAQS)
AQO	(BC) Air Quality Objectives
AQTDR	Air Quality Technical Data Report
BC	British Columbia
BC EAO	British Columbia Environmental Assessment Office
BC ENV	BC Ministry of Environment and Climate Change Strategy
CAAQS	Canadian Ambient Air Quality Standards
CAC	Criteria Air Contaminant
CAMx	Comprehensive Air Quality Model with Extensions
CCME	Canadian Council of Ministers of the Environment
CEA Agency	Canadian Environmental Assessment Agency
CMAQ	Community Multiscale Air Quality
CO	Carbon monoxide
D1HM	Daily 1-hour maximum
D8HM	Daily 8-hour maximum
ECCC	Environment Canada and Climate Change
EEM	Environmental Effects Monitoring
FEM	Federal Equivalent Method
KAG	Kitimat Airshed Group
KHR	Kitimat Haul Road
KHV	Kitamaat Haisla Village
KIA	Kitimat Industrial Avenue
KMP	Kitimat Modernization Project
KPI	Key Performance Indicator
KR	Kitimat Riverlodge
KRS	Kitimat Rail Station
KSR	Kitimat Smeltersite Road
KTCAC	Kitimat Terrace Clean Air Coalition
KW	Kitimat Whitesail
KYC	Kitimat Yacht Club
LNG	Liquefied Natural Gas
LSA	Local Study Area
MMscfd	Million standard cubic feet per day
MSC	Meteorological Services of Canada
Mtpa	Million tonnes per year
NO	Nitric oxide
NO_2	Nitrogen dioxide
NO_X	The sum of NO_2 and NO
O_3	Ozone
PBL	Planetary Boundary-Lcoayer
PM_{10}	Coarse Particulate Matter <10 micro meters
$PM_{2.5}$	Fine Particulate Matter <2.5 micro meters
RSA	Regional Study Area
RWDI	RWDI AIR Inc.
SMOKE	Sparse Matrix Operator Kernel Emissions Modeling System
SO_2	Sulphur dioxide
SSJ	St. Joseph's station
TBAC	Terrace BC Access Centre
TEOM	Tapered Element Oscillating Microbalance
TKV	Terrace-Kitimat Valley
TSMS	errace Skeena Middle School
VOCs	Volatile Organic Compounds
WRF	Weather Research and Forecast Model

VERSION HISTORY

Index	Date	Pages	Author
Draft V1	November 21, 2022	All	RWDI
Draft V2	December 2, 2022	All	Trudi Trask Christian Reuten
Final	April 5, 2023	All	Trudi Trask Christian Reuten
Final Version 2	July 20, 2023	All	Trudi Trask Christian Reuten Ministry of Environment and Climate Change
Final Version 3	August 3, 2023	All	Trudi Trask Christian Reuten Ministry of Environment and Climate Change

1 INTRODUCTION

The Kitimat Airshed Group (KAG) retained RWDI AIR Inc. (RWDI) to review the KAG airshed network. This study is comprised of three tasks: a focused literature review, definition of the geographic boundaries of the Terrace-Kitimat Valley (TKV) airshed, and an assessment of the network's ability to meet the objectives set by the KAG. The three tasks are presented in sections 2, 3, and 4. Conclusions and recommendations are presented in section 5, and references are listed in section 7. Section 4.3 regarding the Air Quality Health Index (AQHI) was provided by the Ministry of Environment and Climate Change.

The review is focused on criteria air contaminants with applicable objectives. Monitoring of other air contaminants, such as hydrogen fluoride (HF) and polycyclic aromatic hydrocarbons (PAHs), and wet deposition are also performed in the TKV but are not within the scope of this review.

2 TASK 1: LITERATURE REVIEW

RWDI completed a focused review of the literature relevant to ambient air contaminant concentrations and related impacts in the TKV airshed. The reviewed literature is organized in five sections, one for each group of related publications ("bodies of work"), in subsections 2.2 to 2.6.

RWDI used the "Appendix B List of Supporting Documents, Studies and Publications' in the RFP document as a starting point and searched for additional academic publications and applicable environmental assessments on the British Columbia Environmental Assessment Office (BC EAO) EPIC website.

The literature review focuses on supporting tasks 2 and 3, specifically, to search for information to define the geographic boundaries of the TKV airshed (task 2) and to assess the ability of the monitoring network to meet its objectives (task 3). For Task 2, the airshed boundary chosen by Ben Weinstein (Weinstein, 2015) was used as a starting definition and compared against the findings of each study. Each of the following reviewed literature sections contains two subsections summarizing material relevant to tasks 2 and 3, respectively.

2.1 Standards and Objectives

The modelling and monitoring results presented in the following sections are compared against the relevant standards at the time the study was completed. The collection of studies reviewed include objectives for ambient air quality and critical levels for ecosystems.

The ambient air quality objectives for the contaminants of concern for the TKV airshed, as set by the B.C. Provincial Air Quality Objectives (AQO), and the Canadian Ambient Air Quality Standards (CAAQS), as adopted by B.C., are shown in Table 2-1 (BC ENV, 2021).

Table 2-1: B.C. Ambient Air Quality Objectives (contaminants relevant to TKV airshed)

Contaminant	Avg. Period	Air Quality Objective		Source
		$\mu g/m^3$	ppb	
Nitrogen Dioxide (NO_2)	1 – hour	113	60 [1]	2020 CAAQS Provincial AQO
	Annual	32	17 [2]	2020 CAAQS Provincial AQO
Ozone (O_3)	8 – hour	123	62 [3]	2020 CAAQS
Particulate Matter <2.5 microns ($PM_{2.5}$)	24 – hour	25 [4]	-	Provincial AQO
		27 [5]	-	2020 CAAQS
	Annual	8 [6]	-	Provincial AQO
		8.8 [7]	-	2020 CAAQS
Particulate Matter <10 microns (PM_{10})	24 – hour	50	-	Provincial AQO
Sulphur Dioxide (SO_2)	1 – hour	183	70 [8]	2020 CAAQS
	Annual	13	5 [9]	2020 CAAQS

Notes:

[1] Achievement based on annual 98th percentile of daily 1 hour maximum (D1HM), averaged over three consecutive years.
[2] Achievement based on annual average of 1-hour average concentrations over one year.
[3] Achievement based on annual 4th highest daily 8-hour maximum, averaged over three consecutive years.
[4] Achievement based on annual 98th percentile of daily average, over one year.
[5] Achievement based on annual 98th percentile of daily average, averaged over three consecutive years.
[6] Achievement based on annual average, over one year. Planning goal of 6 μg/m3 provides voluntary target to guide airshed planning efforts and encourage communities to maintain good air quality in face of economic growth and development.
[7] Achievement based on annual average, averaged over three consecutive years.
[8] Achievement based on annual 99th percentile of D1HM, averaged over three consecutive years, effective January 1, 2020; used to inform new air management decisions beginning January 1, 2017, and all air management decisions beginning January 1, 2020.
[9] Achievement based on annual average of 1-hour concentrations over one-year, effective January 1, 2020.

The Canadian Ambient Air Quality Standards (CAAQS) set by the Canadian Council of Ministers of the Environment (CCME) set four management levels for nitrogen dioxide (NO2), sulphur dioxide (SO2), fine particulate (PM2.5), and ozone (O3) over various averaging periods as seen in Table 2-2. The current CAAQS were established for 2020, with decreased management levels coming into effect in 2025.

Table 2-2: Canadian Ambient Air Quality Standards (CAAQs) Management Levels

Air quality management levels	Management Levels for the Ozone CAAQS (parts per billion)		Management Levels for the Annual Fine Particulate Matter CAAQS (micrograms per cubic metre)		Management Levels for the 24-hour Fine Particulate Matter CAAQS (micrograms per cubic metre)		Management Levels for the 1-hour Sulphur Dioxide CAAQS (parts per billion)		Management Levels for the Annual Sulphur Dioxide CAAQS (parts per billion)		Management Levels for the 1-hour Nitrogen Dioxide CAAQS (parts per billion)		Management Levels for the Annual Nitrogen Dioxide CAAQS (parts per billion)	
	2020	2025	2015	2020	2015	2020	2020	2025	2020	2025	2020	2025	2020	2025
Red	>62	>60	>10.0	>8.8	>28	>27	>70	>65	>5.0	>4.0	>60	>42	>17.0	>12.0
Orange	57 to 62	57 to 60	6.5 to 10.0	6.5 to 8.8	20 to 28	20 to 27	51 to 70	51 to 65	3.1 to 5.0	3.1 to 4.0	32 to 60	32 to 42	7.1 to 17.0	7.1 to 12.0
Yellow	51 to 56		4.1 to 6.4		11 to 19		31 to 50		2.1 to 3.0		21 to 31		2.1 to 7.0	
Green	≤50		≤4.0		≤10		≤30		≤2.0		≤20		≤2.0	

Notes:

[1] Table is taken from: https://ccme.ca/en/air-quality-report#slide-2
[2] Fine Particulate Matter refers to $PM_{2.5}$

Some of the studies reviewed compare modelled ambient SO_2 and NO_X (the sum of NO_2 and nitric oxide, NO) concentrations to guidance from the World Health Organization (WHO) for critical levels to vegetation as shown in Table 2-3 and Table 2-4.

Table 2-3: Critical Levels of SO_2 for Vegetation

Vegetation Type	Critical Level SO_2 (in μg/m^3)	Time Period
Cyanobacterial lichens	10	Annual mean
Forest ecosystems	20	Annual mean and half-year mean (Oct.-Mar.)

Note: Source: https://unece.org/fileadmin/DAM/env/documents/2017/AIR/EMEP/Final__new_Chapter_3_v2__August_2017_.pdf

Table 2-4: Critical Levels of NO_X for Vegetation

Vegetation Type	Critical Level NO_X (Expressed as NO_2) (in μg/m^3)	Time Period
All	30	Annual mean

Note: Source: https://unece.org/fileadmin/DAM/env/documents/2017/AIR/EMEP/Final__new_Chapter_3_v2__August_2017_.pdf

2.2 Work by Weinstein, B.R., 2015

2.2.1 Summary

RWDI reviewed the photochemical modelling work completed by Weinstein (Weinstein, 2015). The work investigated the worst-case ambient concentrations of O_3 and its precursors focusing on select spring and summer periods in 2010. During the growing season, there are substantial biogenic emissions of volatile organic compounds (VOCs) in the TKV. The study looked at worst-case ambient concentrations of O_3 resulting from additional future large industrial facilities, proposed as of 2015. The anticipated high industrial emissions of NO_X, paired with high biogenic VOC emissions, could potentially contribute to an O_3 issue in the airshed.

Photochemical modelling was completed using the Comprehensive Air Quality Model with Extensions (CAMx) using meteorological inputs generated by the Weather Research and Forecast Model (WRF). The research was focused on three cases:

1. Control case: can worst-case photochemical O_3 concentrations in spring and summer be replicated by the model?
2. Test case: where and what are the O_3 maxima if all proposed industrial facilities in the TKV are constructed?
3. Sensitivity analysis: what is the current and future sensitivity of the TKV to NO_X and VOC emissions?

The control case included the existing Rio Tinto aluminum smelter (as operated in 2010), mobile sources, and biogenic sources. Modelling was also completed for the Bulkley Valley for model evaluation, as there was insufficient O_3 monitoring in Kitimat or Terrace.

The following proposed sources were added in the test case:

- Expansion of the Rio Tinto Alcan aluminum smelter;
- a proposed LNG Canada facility;
- a proposed Kitimat LNG terminal;
- a proposed Douglas Channel LNG;
- a proposed Triton LNG;
- a proposed Kitimat Clean oil refinery; and
- all marine shipping emissions associated with each of these projects.

As of 2022, only the smelter expansion and construction of the LNG Canada facility are moving forward, all other projects have been cancelled.

Some limitations of the modelling were identified. The control case modelling was able to emulate observed daytime O_3 peaks, but overnight titration by NO was less adequately replicated due to inadequacies in the emission inventory. The WRF model failed to reproduce afternoon peak temperatures on days when measured temperatures exceeded 30°C. The control case omitted VOC emissions from the smelter, adding uncertainty; however, biogenic emissions were the largest source of VOC in the region (by two orders of magnitude).

The research found that increased industrial emissions would not contribute to valley-wide O_3 increases greater than 5 ppb in the spring, as biogenic VOC emissions are minimal throughout the airshed during this season. However, increased industrial emissions would, at times, contribute to a greater than 55% increase in O_3 concentrations, particularly downwind of Kitimat, under specific meteorological conditions during the summer. The test case (with additional industrial emissions) resulted in elevated O_3 overnight and during some daytime hours at low elevation in the spring (mostly near Kitimat but sometimes upwards of 80 km downwind). The test case modelling predicted O_3 hotspots in the summer to the south at Miskatla Inlet, which traps pollutants, and to the north at Lakelse Lake as illustrated in Figure 4.21 of (Weinstein, 2015). No meaningful increases in O_3 were predicted to occur within the community of Kitimat itself, and at no time did O_3 concentrations exceed the provincial one-hour objective. The study found that the airshed is currently sensitive to NO_X emissions, but that construction of all proposed industrial projects would likely change the O_3 sensitivity to VOCs, especially in and around Kitimat.

2.2.2 Discussion of Airshed Boundaries

Weinstein identified a physical airshed boundary that roughly follows the highest ridges of the topography delineating the TKV. For the investigation of photochemical O_3 formation in the TKV, Weinstein used a more regular airshed, deemed "Weinstein's airshed" for this report, which was roughly defined as a rectangle with some "cut-outs" to the northeast, southeast and to the northwest (shown in Figure 1.2 of (Weinstein, 2015)). The O_3 hotspots discovered in the study fell well within the boundaries of the airshed. Elevated concentrations were seen at the edges of all three of the cut-outs of the airshed boundary and along the western-most edge for some modelled dates. The highest concentrations of isoprene (the largest biogenic VOC) emissions were along the north-south valley between Terrace and Kitimat and westward from Terrace (illustrated in Figure 2.15 of (Weinstein, 2015)).

2.2.3 Discussion of Monitoring Network

The O_3 events examined in Weinstein's report occurred in 2010, when there was no active O_3 monitoring in the TKV airshed. Monitoring data from the closest station with ambient O_3 monitoring at the St. Joseph's station (SSJ) in Smithers, BC was used. Currently two ambient monitoring stations in the TKV airshed monitor for O_3, the Kitimat Whitesail (KW) and Terrace Skeena Middle School (TSMS) stations. The KW location has been monitoring O_3 since July 2019 and is located in a residential area of Kitimat. The TSMS station has been monitoring O_3 since March 2015 and is located in a residential area of Terrace. The NO_2 and O_3 trends from these stations are presented in sections 4.2.2 and 4.2.3, respectively.

Weinstein's modelling predicted 8-hour average ozone concentrations above or near the CAAQS green management level (50 ppb) near Lakelse Lake and Kitimat (Figures 4.21 and 4.14 in (Weinstein, 2015)).

Annual average concentrations and 3-year rolling averages of the annual 4th highest daily 8-hour maximum (D8HM) concentrations of O_3 have remained at similar levels (above 40 ppb) since 2015 and are similar in magnitude to the trends seen in 2015 at St. Josephs station (as shown in Figure 12 and Figure 13 in section 4.2.3 below). The 3-year rolling averages of annual 98th percentiles of daily 1-hour maximum (D1HM) concentrations of NO_2 have increased at the Terrace Skeena Middle School (TSMS) station since 2015, which were similar to those observed at Kitimat Rail Station (KRS) in 2010, dropping slightly in 2021 (as shown in Figure 10 and Figure 11 in section 4.2.2 below).

The modelling conducted by Weinstein predicted O_3 hotspots in the summer to the south at Miskatla Inlet and to the north at Lakelse Lake. Given the predicted trend in O_3 and the lack of NO_2 monitoring stations, Lakelse Lake should be considered as an additional monitoring location.

2.3 Work by Onwukwe, C., 2020

2.3.1 Summary

RWDI reviewed the work completed by Dr. Chibuike Onwukwe for fulfillment of his Doctorate degree (Onwukwe C. , 2020) and associated publications. Publications reviewed in this section include:

- Onwukwe, C., 2020: Community multiscale air quality (CMAQ) modelling of the atmospheric quality and pollutant deposition over the Terrace-Kitimat Valley of northwestern British Columbia, Canada. Doi:10.24124/2020/59101.
- Onwukwe, C., P.L. Jackson, 2020: Meteorological downscaling with WRF model version 4.0 and comparative evaluation of planetary boundary layer schemes over a complex coastal airshed. J. Appl.Meteor. Climatol., 59, 8, 1295-1319.
- Onwukwe, C., P.L. Jackson, 2020: Evaluation of CMAQ modelling sensitivity to planetary boundary layer parameterizations for gaseous and particulate pollutants over a fjord valley. Atmospheric Environment, 233, 117607.
- Onwukwe, C., P.L. Jackson, 2021: Gridded bias correction of modelled $PM_{2.5}$ for exposure assessment, and estimation of background concentrations over a pristine valley region of northwestern British Columbia, Journal of the Air and Waste Management.
- Onwukwe, C., P.L. Jackson, 2020: Acid wet-deposition modelling sensitivity to WRF-CMAQ planetary boundary layer schemes and exceedance of critical loads over a coastal mountain valley area of northwestern British Columbia, Canada. Atmospheric Pollutant Research, in press, 1-14.

The publications quantify ambient $PM_{2.5}$ and SO_2 concentrations and nitrogen and sulphur deposition resulting from anticipated industrial emissions. The body of work presents a stepwise comprehensive evaluation of appropriate configurations for the chemical transport model components including Community Multiscale Air Quality (CMAQ) model and WRF meteorological driver. The work included sensitivity tests to optimize the configurations in WRF for the complex terrain, dominated by sharp elevation gradients and frequently humid conditions.

The stepwise configuration of the model included:

1. Diagnosing the capacity of six planetary boundary-layer (PBL) schemes to represent pollutant dispersion and dilution;
2. Evaluating CMAQ model performance for five PBL schemes;
3. Improving the characterization of $PM_{2.5}$ over complex terrain by applying a correction to the inherent bias of the chemical transport model;
4. Evaluating acid deposition modelling for various parameterizations of the PBL; and
5. Intercomparison of atmospheric datasets and PBL schemes for precipitation downscaling.

Following configuration of the chemical transport model, the impacts of expected additional industrial emissions in the airshed were modelled. The study included two scenarios:

1. An increase in SO_2 emissions from the Rio Tinto Alcan smelter as part of the Kitimat Modernization Project (KMP) (Chapter 7 in (Onwukwe C. , 2020)); and
2. Increases in NO_X and SO_2 from the addition of two new liquefied natural gas (LNG) facilities: LNG Canada and Kitimat LNG (Chapter 8 in (Onwukwe C. , 2020).

The study quantified existing and incremental ambient SO_2 concentrations and incremental and cumulative terrestrial ecosystem effects of NO_X and SO_2. The terrestrial ecosystem effects included the critical load acidity and critical load of nitrogen deposition examining the critical levels for sensitive lichen, forests and natural vegetation, and soils.

The optimization of the chemical transport model configuration completed by Onwukwe can serve as a valuable blueprint for future modelling in the region. Noteworthy findings from the optimization for setting an airshed boundary include:

1. Diurnal SO_2 concentrations peaking during summer were mostly overestimated at locations 8 km downwind and underestimated at locations 60 km downwind of large industrial emission sources.
2. The model underestimated peak ambient $PM_{2.5}$ and NO_2 concentrations occurring in cooler seasons and originating mostly from fugitive ground-level sources.
3. Northerly winds are more frequent during winter, and southerly winds are more frequent in the summer months with lower precipitation resulting in smaller wet deposition in the summer.
4. Disparities in mixing strengths among PBL schemes were greater in the summer when conditions were generally less stable with moist, warm air blowing inland than in winter when the valley channels cold, stable air from the interior. Performance of the various PBL schemes for surface meteorological parameters was close to what had been reported previously in the scientific literature. The correct choice of PBL schemes was critical for ozone in the summer, but all schemes performed poorly in the winter.
5. The TKV interior is subject to sulphur deposition when onshore winds prevail which is mainly in the dry summer season. “East-moving winds originating from the Pacific Ocean scavenge the valley’s atmospheric contaminants, some of which are eventually deposited on west facing slopes” (Onwukwe & Jackson, 2020a) particularly in the inland areas near Terrace.
6. Forest soils in the vicinity of a large aluminum smelter in Kitimat were estimated to exceed critical load of acidity.

The study modelled the full year of 2017 using the WRF-SMOKE-CMAQ modelling platform applying a 36 × 106 km grid with 1-km horizontal resolution for different meteorological driver options. Hourly ambient air monitoring records for five monitoring stations (Terrace, Riverlodge, Haul Road, Whitesail, and Kitamaat Haisla Village) were used to compare $PM_{2.5}$, NO_2, and SO_2 from the model.

Conclusions in the study are presented for each scenario: increased smelter emissions and addition of two LNG facilities. With respect to this review, the focus is on the predicted impacts to ambient concentrations and deposition.

Increased emissions from the smelter were predicted to increase ambient SO_2 concentrations by 50% as shown in Figure 7.1 of (Onwukwe C. , 2020) and increase the area where critical limits for protection of lichen and soils are exceeded (Figure 7.2). Exceedance areas were predicted to increase by 50–88% for lichen and 37–67% for soils. Cumulatively, 16–18 km^2 of plant habitat and 10–11 km^2 of soil in an area contiguous with the smelter site was predicted to be damaged. Three rare endemic lichens may become locally extinct and foliar sulphur will rise in vegetation in areas with new exceedances.

Chapter 8 of the study concluded that additional emissions from two LNG projects will cause at least 50% and 150% rise in ambient SO_2 and NO_X concentrations, respectively (Figure 8.3 of (Onwukwe C. , 2020)). Cumulative NO_X concentrations are expected to remain below harmful levels with a negligible increase in areal exceedance of nitrogen deposition. Direct harm to vegetation from exposure to NO_X concentration was deemed to be a low concern. The highest modelled SO_2 concentration was less than the 2020 CAAQS. Emissions from these two LNG projects are not predicted to result in violations of national and provincial objectives for ambient air quality. However, due to geographical constraints, the study warns that increased industrialization would warrant prolonged monitoring of pollutant concentrations for adaptive management of emissions.

Additional industrialization was predicted to impact vegetation and increase the area where critical load of acidity is exceeded by roughly 30%, with an additional 4 km^2 being exposed to SO_2 concentrations that are directly harmful to vegetation (Figure 7.2 of (Onwukwe C. , 2020)). The exceedance of baseline critical load of acidity is caused by the smelter within its proximity, while additional sulphur deposition was modelled west of the Kitimat River. The area where critical level of protection of lichen (the most sensitive of floral communities) is exceeded, is predicted to increase by 22-25% (Figure 8.4 of (Onwukwe C. , 2020)). The increase in nitrogen and sulphur deposition from pre-existing levels was predicted to be modest (20–50 % rise) within the valley and less over high elevations. Spatial deposition was found to be controlled by onshore winds, which weaken closer to the valley, and would not increase significantly outside of the Kitimat area.

The work notes that prolonged acidic deposition alters the soil chemistry resulting in conditions that are favorable to fewer species and that regeneration of original plant communities in other North American regions (with acidity loadings an order of magnitude lower) has not been successful. The author recommends setting target loads of nitrogen and sulphur deposition as one step to prevent adverse changes to the natural environment.

2.3.2 Discussion of Airshed Boundaries

The TKV deposition domain, shown in black in Figure 5.1 of (Onwukwe C. , 2020), is much smaller than Weinstein's Airshed. It encompasses but does not reach much beyond the hot spots found by Weinstein (Miskatla Inlet to the south and Lakelse Lake to the north).

The baseline (pre-modernization of the smelter and no additional LNG) predicted the peak $PM_{2.5}$ concentrations to be located within Weinstein's boundaries and focused on Terrace and Kitimat. The study found sulphur deposition in areas surrounding and to the east of Kitimat and close to the smelter and nitrogen deposition around the populated area of Terrace and nearby slopes. The spatial plots in Figure 5.3 (Onwukwe C. , 2020) show high nitrogen deposition around Terrace and extending beyond the Onwukwe/Jackson deposition domain (as shown in Figure 3.1 of (Onwukwe C. , Community multiscale air quality (CMAQ) modeling of the atmospheric quality and pollutant deposition over the Terrace-Kitimat Valley of northwestern British Columbia, Canada, 2020)). This suggests a larger domain than Weinstein's airshed may be beneficial to capture peak deposition. For the KMP scenario with increased emissions from the smelter, high increases of annual ambient SO_2 concentrations are predicted towards the south-west approaching the TKV deposition domain boundary (Figure 7.1 in (Onwukwe C. , 2020)).

2.3.3 Discussion of Monitoring Network

Onwukwe used 2016 to 2018 ambient and meteorological data to calibrate the model used in his work including ambient concentrations of $PM_{2.5}$, SO_2, and NO_2.

$PM_{2.5}$ concentrations were used from the Kitimat Haul Road (KHR), Kitimat Riverlodge (KR), Terrace (TSMS) and Kitamaat Haisla Village (KHV) stations. Although $PM_{2.5}$ was also monitored at Kitimat Whitesail (KW), there appears to be a gap in data from the KW station in 2017. As well, $PM_{2.5}$ data for 2017 from the Kitamaat Haisla Village is now missing as compared to the low values quoted in Onwukwe's work. The annual 98th percentile of 24-hour daily average $PM_{2.5}$ has shown a downward trend since 2014 (shown in Figure 15). Annual average ambient $PM_{2.5}$ has trended down since 2018 at the Terrace (TSMS), Whitesail (KW), Riverlodge (KR), and Kitamaat Haisla Village (KHV) stations and since 2019 at Haul Road (KHR).

Seasonal mean and annual SO_2 concentrations for 2017 from the Whitesail (KW) and Terrace (TSMS) stations were used in Onwukwe's work. The annual SO_2 concentrations at these stations have fluctuated slightly since 2017, decreasing from 2017 and then increasing from 2018 to current at Terrace and from 2020 to current at Whitesail (KW) (shown in Figure 8). Ambient SO_2 concentrations observed at the Haul Road (KHR) station were not used Onwukwe's model and have been 5-15 times the concentrations at Whitesail (KW) since 2015.

Seasonal mean and annual NO_2 concentrations for 2017 were only available and used from the Terrace (TSMS) station in Onwukwe's work. NO_2 monitoring was added to the Whitesail (KW) station in 2019. Annual average NO_2 concentrations at the Terrace (TSMS) station have decreased since 2018. The current NO_2 monitoring network in the airshed is sparse/limited with only two stations, one in Kitimat (Kitimat Whitesail (KW)) and one in Terrace. (Terrace Skeena Middle School (TSMS)).

The areas predicted by Onwukwe to experience an increase in SO_2 are well covered by the current monitoring network which shows concentrations trends and locations patterns in alignment with the results of Onwukwe. For example, Figure 7.1b (of (Onwukwe C. , 2020)) shows the relative increase in SO_2 in areas near to and south of the industrial areas near the Rio Tinto smelter. These increases would be captured by the Haul Road (KHR) station. The modelling completed (as illustrated in Figure 7.1b) by Onwukwe predicts relative increases in average annual SO_2 levels between the post- and pre-modernization of the smelter to be medium (60-70%) southwest of the smelter, medium (70% increase) north of Kitimat, extending to Terrace and beyond, and high (90-130%) in the vicinity of the smelter. It is not clear, but unlikely that increases in SO_2 to the southwest will extend to the populated area of Hartley Bay. The area of SO_2 spatial exceedance of lichen (Figure 7.2) is expected to increase in the Kitimat industrial area, west of the Kitimat River. The current SO_2 monitoring network is expected to capture the patterns of SO_2 as predicted by Onwukwe's modelling of the post-modernization of the smelter.

Onwukwe predicted SO_2 from the addition of LNG facilities to increase 150% in areas near the smelter (Figure 8.3), as predicted for the post-modernization scenario (Figure 7.1). However, the addition of LNG facilities was also predicted to increase SO_2 by over 100% in the nearby Kitamaat Haisla Village. The current SO_2 network is expected to adequately capture these increases.

Onwukwe predicts the relative increase of NO_X and SO_2 from additional LNG in Kitimat. Figure 8.3 of (Onwukwe C. , 2020) predicts high (150%) increases in NO_X throughout the southern two-thirds of the modelled area from the northern tip of Maitland Island to Lakelse. The relative increases in NO_X (up to 150%) predicted by Onwukwe would push the baseline NO_X concentrations above the green CAAQs management levels. The limited measurements of NO_2 in the Kitimat area (only the Kitimat Whitesail (KW) station has been operating since 2019, Terrace Skeena Middle School (TSMS) in operation since 2015) provide a limited understanding of the spatio-temporal field of NO_2 concentrations in the region. Although NO_2 has not been a pollutant of concern based on the current emission sources, the addition of LNG industry and marine traffic is predicted to increase regional concentrations. Given that Weinstein found that the airshed is currently sensitive to NO_X emissions, a more comprehensive understanding of the spatio-temporal field of ambient NO_X concentrations may be warranted.

The extent of the area modelled for vegetation effects is much smaller than for ambient air quality, and thus any need to modify the ambient network to capture increases predicted by the vegetative modelling are well covered in consideration of the ambient air quality changes.

2.4 ESSA SO_2 EEM Comprehensive Review

2.4.1 Summary

Rio Tinto retained ESSA Technologies Ltd. Et al to complete a comprehensive review of their SO_2 Environmental Effects Monitoring (EEM) Program including review of Key Performance Indicators (KPIs). RWDI reviewed the following documents related to this work:

- ESSA Technologies, J. Laurence, Risk Sciences International, Trent University, and Trinity Consultants, 2020: 2019 Comprehensive Review of Sulphur Dioxide Environmental Effects Monitoring for the Kitimat Modernization Project – Volume 1, V.3 Final. Prepared October 15, 2020, for Rio Tinto, B.C. Works, Kitimat, B.C.
- ESSA Technologies, J. Laurence, Risk Sciences International, Trent University, and Trinity Consultants, 2020: 2019 Comprehensive Review of Sulphur Dioxide Environmental Effects Monitoring for the Kitimat Modernization Project – Volume 2: Technical Appendices (Appendix 3), V.3 Final. Prepared for Rio Tinto, B.C. Works, Kitimat, British Columbia.
- Trinity Consulting, 2021: Network Optimization Report for SO_2, draft report. Prepared for Rio Tinto, B.C. Works, Kitimat, B.C.
- Trinity Consulting, 2020: Kitimat Airshed Boundary [Memorandum].

The EEM program was developed to monitor effects on human health, vegetation, terrestrial ecosystems, and aquatic ecosystems following a technical assessment for the KMP in 2012/13. In addition to a KPI for each of the four potential effected receptors, the EEM program has thresholds for increased monitoring, receptor-based mitigation, or facility-based mitigation, as appropriate. The EEM review used CALPUFF dispersion modelling and monitored ambient SO_2 concentrations to assess impacts to human health, vegetation, and terrestrial and aquatic ecosystems. The EEM review modelled three emission scenarios using the CALPUFF model:

1. Historical emissions from the smelter during 2016-2018 which averaged 29.3 tonnes per day (tpd);
2. A 42-tpd scenario representing the highest level of SO_2 emissions allowed under the permit; and
3. A 35-tpd scenario representing SO_2 emissions of a magnitude that is midway between actual emissions and the maximum allowable.

The EEM review found that none of the KPI thresholds for any receptor type had been reached and noted that no signs of harm were observed under present or predicted future conditions. The specific findings for each of the receptor types are described below.

The annual calculation for human health KPI began in 2017 and was found to not be exceeded. The KPI was based on the BC Interim Air Quality Objectives (IAQO), which is being updated to align with the CAAQS of hourly averaged SO_2 concentrations of 70 ppb in 2020 and 65 ppb starting in 2025. The review found that maximum hourly average SO_2 concentrations across all stations (44.7 ppb) occurred at KR station (Lower Kitimat) in 2017 (ESSA Technologies Ltd. et al, 2020).

No KPi thresholds were found to be exceeded for vegetation and no significant differences in plant health throughout the Kitimat Valley have been observed post-KMP, at the time of completion of the EEM review. The review found that the locations of vegetation sampling and inspection sites align well with the predicted path of the plume. The review recommended discontinuing the vegetation KPI and replacing with measures of plant health and biodiversity and recommended specific changes to the sampling and inspection program.

ESSA et al found that the thresholds for increasing monitoring for the two terrestrial (soil) KPIs were not reached and that there was no statistically significant decrease in soil properties over the study period. The study recommended keeping both terrestrial KPIs and establishing plant biodiversity plots within the accessible exceeded areas south of the smelter.

In the EEM review, seven informative indicators provide evidence of lake acidification, but aquatic ecosystems KPI thresholds were found not to be exceeded. The EEM program for the aquatic ecosystems was adjusted during 2013-2018, and additional changes were recommended in the review.

The EEM review updated the CALPUFF modelling from the modelling completed in 2013 in the SO_2 Technical Assessment Report (STAR) (ESSA Technologies, et al., 2013) using as-built source parameters and actual 2016–2018 SO_2 emission rates from the smelter, combined with corresponding 2016–2018 WRF processed meteorological data. The 2016–2018 CALPUFF modelling was found to align with observations better than the STAR model at all residential monitors.

The regional scale CALPUFF annual SO_2 modelling for the EEM review was used to assess risks to vegetation, soil, and aquatic ecosystems. The hourly and annual modelling results were presented in terms of the BC AQOs to illustrate short-term and annual average spatial distribution, but the human health assessment used monitoring, not modelled data. Compared to the continuously monitored data, the model overpredicted annual average SO_2 concentrations by 35 to 75% at the four continuous SO_2 monitors. The model over-predicted the 99th percentile of daily 1-hour peak concentration at all stations (except Kitamaat Haisla Village (KHV) station in 2018) by 10 to 51%.

The review found strong linear agreement between the CALPUFF modelling and passive sampling. To the north of the smelter, modelling was found to consistently overpredict by 2.2 times (indicating good model spatial performance). To the south of the smelter, the model underpredicted by an average of 58%. The modelling predicted exceedances of the CAAQS in areas close to the smelter in the 42-tpd scenario. The modelled hourly peak SO_2 concentrations for the 42-tpd scenario are shown in Figure 3-13 of (ESSA Technologies Ltd. et al, 2020).

2.4.2 Discussion of Airshed Boundaries

The geographic area modelled using CALPUFF as part of the EEM review is smaller than and contained within Weinstein's Airshed (as seen in Figure 3-13 of (ESSA Technologies Ltd. et al, 2020)). The review found when compared to monitored results that the model overpredicted, particularly to the north of the smelter. Thus, Weinstein's airshed is expected to include the locations of SO_2 hourly maxima resulting from the KMP north of the smelter. The review also found that the model underpredicted SO_2 south of the smelter. Weinstein's airshed extends significantly farther than the airshed used in the modelling to the south.

2.4.3 Discussion of Monitoring Network

The EEM review included ambient SO_2 concentrations over the period 2016 to 2018, finding the maximum hourly averaged concentration for all stations (44.7 ppb) occurred at Riverlodge (KR) Station in 2017. However, ambient concentrations have increased since the 2016-2018 period of this review (Figure 8 and Figure 9 in section 4.2.1 below).

The Atmospheric Appendix Section 3.1.1 of the EEM review includes further details on the continuous monitoring network and equipment. As mentioned earlier, the local scale CALPUFF model was used to evaluate the SO_2 monitoring network with data from the four continuous monitors at the Haul Road (KHR), Riverlodge (KR), Whitesail (KW), and Kitamaat Haisla Village (KHV) stations.

The EEM review mentions of the addition of continuous SO_2 monitoring at Lakelse Lake in 2018 but had incomplete data at the time of the review. Additionally, the SO_2 data from Lakelse Lake station was used for sulphur deposition but was not used in the comprehensive review analysis, because it is not part of the quality assurance program of the BC Ministry of Environment and Climate Change Strategy (BC ENV). Data from the Lakelse Lake (LKL) station is included in the hourly SO_2 trends shown in Figure 9 in section 4.2.1 below.

The EEM review included an assessment of two other atmospheric monitoring networks: SO_2 passive sampling and pSO42–monitoring using filter packs established by Rio Tinto. The SO_2 passive sampler network began with a pilot program at three stations in 2015 and expanding to 16 sites throughout the Kitimat Valley in 2016 through 2018. The SO_2 passive sampling program includes two networks (see Figure 3-1 of (ESSA Technologies Ltd. et al, 2020)):

- The Valley Network included 16 monitoring sites primarily located along the Wedeene and Bish roads to capture the plume path.
- A second network established in urban and residential areas of Kitimat to support the 'multi-seasonal air quality' and the 'air quality network optimization' studies. During 2016, the urban network included 17 sites but expanded to 22 sites during 2018.

The EEM review combined the continuous SO_2 analyzer data with the passive sampling data, providing valuable information on the extent and position of the plume and the concentration gradient. The EEM review included several findings specific to the monitoring network as presented in the "Atmospheric Pathways Summary" of Comprehensive Review Report (ESSA Technologies Ltd. et al, 2020). The findings specific to the SO_2 monitoring network include:

1. The Kitimat Riverlodge (KR) station is in a suitable location to capture the highest SO_2 concentrations within the town of Kitimat. RWDI notes that the 1-hour peak SO_2 concentrations at Kitimat Riverlodge (KR) have been increasing annually and are approaching the yellow management levels (30 ppb) as in Figure 3-5 of (ESSA Technologies Ltd. et al, 2020). Therefore, Kitimat Riverlodge (KR) is an important station to continue operating as SO_2 emissions in the region increase.
2. The Kitimat Whitesail (KW) monitor location does not provide added benefit for measuring the maximum SO_2 air concentrations within Kitimat.
3. The Kitamaat Haisla Village (KHV) station is in the most suitable location within Kitamaat Haisla Village.
4. The Haul Road station (KHR) is capturing the highest SO_2 concentration near the fenceline of the smelter. Modelling found that SO_2 concentrations at Haul Road (KHR) increased with increased smelter emissions (post-KMP), as illustrated in Figure 3-2 of (ESSA Technologies Ltd. et al, 2020).
5. The existing four SO_2 monitoring stations provide limited spatial variability information, but they confirm that the residential areas of Kitimat and Kitamaat Haisla Village continue to experience generally low concentrations of SO_2.
6. The residential stations (Kitimat Riverlodge (KR), Kitimat Whitesail (KW), and Kitamaat Haisla Village (KHV)) are predicted to be more influenced by meteorological conditions than changes in smelter emissions.
7. The highest monthly average concentrations in the summer months occur in the Service Centre area, as indicated by passive sampling data, and it was recommended that a new continuous SO_2 monitoring should be considered in this area. Since the EEM review was completed, SO_2 monitoring was added to the Kitimat Industrial Ave (KIA) station within the Service Centre of Kitimat.
8. Passive sampling agreed well with co-located continuous monitoring. The passive sampling urban network study confirmed that the entire Kitimat urban area has low SO_2 concentrations, with the highest average monthly concentrations of SO_2 close to and south of the smelter (about 12 $\mu g/m^3$).
9. Only a very small fraction of total sulphur in the atmosphere is particulate sulphate.

The EEM review included several recommendations:

1. Continue SO_2 continuous monitoring at all or most of the current sites.
2. Consider establishing a temporary or fixed continuous SO_2 monitoring station within the Service Centre commercial area.
3. Continue the passive sampling network, adding sites to the east and west of the current sites located to the north of the smelter (possibly by relocating sites from the north–south network).
4. Evaluate if additional sites can be established south of the smelter to align with biodiversity plots.
5. Continue wet deposition monitoring at Lakelse Lake and consider discontinuing the Kitimat Haul Road (KHR) wet deposition monitor.

RWDI's review of this work agrees with the findings regarding the SO_2 network, that the monitoring network overall is representative of expected emissions and the existing continuous sites should be maintained. As reflected in the recommendations for locations for additional passive sampling, the modelling by ESSA et al found there may be SO_2 peaks to the west and southwest of current stations (Figure 3-13 of (ESSA Technologies Ltd. et al, 2020)), but as these locations are only closer to the industrial emissions and mountains, without additional receptors, additional continuous monitoring is not warranted.

The EEM review also found that using the Terrace Skeena Middle School (TSMS) station as SO_2 background may be overpredicting modelled SO_2 in non-populated areas. The review attempted to correct this by applying background SO_2 concentrations based on Williams Lake for model performance evaluation. In discussion with KAG, Kemano has been indicated an alternative potential background location. A passive monitor at Kemano would allow qualitative comparison of background SO_2 concentrations to those at the Terrace Skeena Middle School (TSMS) and Williams Lake stations. While passive background measurements would not be sufficient for establishing a baseline to use with dispersion modelling, the qualitative comparison could guide the decision on which is the most appropriate station to use as a background and/or whether to establish continuous SO_2 monitoring at Kemano.

2.5 LNG Canada Environmental Assessment Certificate Application, 2014

2.5.1 Summary

An Application for the LNG Canada Export Terminal Project was submitted to the BC EAO and the Canadian Environmental Assessment Agency (CEA Agency) in 2014. RWDI reviewed the "Air Quality Technical Data Report LNG Canada Export Terminal" (LNG Canada, 2014).

The report assessed the air quality impact of four cases:

1. Base case: Kitimat LNG terminal and implementation of the KMP at the Rio Tinto Alcan smelter.
2. Project-only case: The LNG Canada project includes a 26 million tonnes per year (mtpa) liquefied natural gas (LNG) processing facility with LNG storage, power generation, a marine terminal supporting infrastructure and temporary construction infrastructure, and shipping of LNG in carriers during operations (BC EAO, 2021).
3. Application case: Base case plus project.
4. Cumulative: Application case plus the Enbridge Northern Gateway and Kitimat Clean Refinery projects.

An Environmental Assessment Certificate (#E15-01) was issued in June 2015. Additional amendments have been made to the Environmental Assessment Certificate since June 2015. The LNG Canada Export Terminal has been in the construction phase since 2019. The Terminal will be constructed in phases, with the first phase having a design capacity of approximately 13 mtpa of LNG and a further 13 mtpa of design capacity to be added in subsequent phase(s). Construction of the first phase was 70% complete as of September 2022 and expects to be operational in 2025 approximately five to six years following issuance of permits (Business Intelligence for B.C., 2022).

The Air Quality assessment used CALPUFF, CALMET, and WRF to model dispersion of expected stationary emissions sources and applied the SCREEN3 model to disperse expected marine shipping emissions. A CALPUFF modelling domain of 78 km by 78 km, centered on the Project site, was sized to support both the facility local study area (LSA) (for project-only assessment) and the regional study area (RSA) (for the cumulative assessment). The LSA and RSA for the assessment of air quality from project emissions consisted of a 40 km by 40 km area, as shown in Figure 2.3-1 of (LNG Canada, 2014). The LSA and RSA for the assessment of acidic deposition consisted of a 40 km by 125 km grid as shown in Figure 2.3-2 of (LNG Canada, 2014). The LSA for marine shipping was defined to extend 2 km on either side of the marine access route as shown in Figure 2.3-3 of (LNG Canada, 2014).

The EA application reports that for the project-only assessment, the selected LSA Figure 2.3-1 of (LNG Canada, 2014) encloses the effects that are 10% or more of the AAQO (as applicable in 2014).

The application assessment compared background SO_2 concentrations from this assessment to work previously completed by Rio Tinto Alcan in 2013. The LNG Canada assessment predicted higher maximum SO_2 concentrations (for 1-hour, 3-hour, and 24-hour averaging periods) near the Rio Tinto fence line, but lower maximum SO_2 concentrations (for all averaging periods) in the residential grid. The assessment details the differences in modelling approaches between the two studies.

The application report concludes that air quality in the RSA will not change appreciably from base-case conditions when the project is fully operational. It also states that air quality in the District of Kitimat is already compromised by SO_2 emissions from the operation of the RTA facility and that the Project adds a very small increment to the effects predicted for the RTA facility alone (predicted to be 4.4% of SO_2 emissions in the region). The results of the assessment include that application, cumulative, and base cases are expected to have 1-hour (Figure G-1 of Appendix G of (LNG Canada, 2014)) and 24-hour (Figure G-31 of Appendix G of (LNG Canada, 2014)) SO_2 exceedances around Kitimat and Kitamaat Haisla Village. The maximum 1-hour SO_2 for the project alone case (123 $\mu g/m^3$) did not exceed the objectives in place at the time of the assessment (450 $\mu g/m^3$), nor would this maximum exceed 2020 CAAQS (183 $\mu g/m^3$ or 70 ppb) or 2025 CAAQS (170 $\mu g/m^3$ or 65 ppb).

The maximum 1-hour NO_2 amounts for each of the four cases (Figures G-6 and G-36 of Appendix G of (LNG Canada, 2014)) did not exceed the objectives in place at the time of the assessment and would not exceed the current 2020 CAAQS. The maximum 1-hour NO_2 amounts for the project-only case (Figures G-6 and G-36 of Appendix G of (LNG Canada, 2014) would not exceed any current or future standard. While the maximum 1-hour NO_2 amounts for the base, application, and cumulative cases are not predicted to exceed the 2020 CAAQS (113 $\mu g/m^3$ or 60 ppb), the value (91.6 $\mu g/m^3$) would exceed the 2025 CAAQS (79 $\mu g/m^3$ or 42 ppb).

The report provides a comparison of the RSA emission estimates for each of the four cases and the percent increase attributable to the project as compared to the cumulative case. The report concludes that while the percentage contributions of carbon monoxide (CO) and VOC from the facility are higher than percentage contributions of SO_2, the amounts remain insubstantial compared to natural sources. It also states that the project will contribute a higher percentage of NO_X to the cumulative regional total than SO_2 but conversion to NO_2 will be O_3 limited. The assessment did not include an investigation of O_3 quoting work completed by Stantec in 2013, which concluded that O_3 was not an issue in Kitimat.

Changes in potential facilities since the assessment was completed affect the base and cumulative cases. The base-case scenario included the Kitimat LNG Terminal (KLNG), which was cancelled. Additional LNG facilities are being pursued in the region, but a quantitative comparison is not readily available. The Kitimat LNG facility contributed most of the NO_X and CO emissions in the base case. The cumulative case included the Enbridge Northern Gateway project and the Kitimat Clean refinery project, both of which have been cancelled. These projects were expected to contribute about 5% of SO_2 and 13% of NO_X emissions in the RSA.

2.5.2 Discussion of Airshed Boundaries

The 78 km by 78 km area used for the assessment of air quality from project emissions is smaller than the airshed proposed by (Weinstein, 2015). The LNG Canada area makes up approximately the middle third of the airshed proposed by Weinstein and extending 20 km to the west on the northern portion of the LNG Canada assessment area. The base-case scenario estimated maximum 1-hour average ground-level SO_2 concentration of up to 45 $\mu g/m^3$ for the northwest corner of the LNG RSA (extending beyond Weinstein's airshed). The assessment compared the maximum 1-hour average ground-level SO_2 concentrations to the 1-hour SO_2 AAQO of 450 $\mu g/m^3$ (note that the 2020 1-hour SO_2 CAAQS is 183 $\mu g/m^3$, dropping to 170 $\mu g/m^3$ in 2025). Thus, the area excluded from Weinstein's airshed was predicted to have base-case 1-hour SO_2 concentrations of over 10% of the 2020 CAAQS.

2.5.3 Discussion of Monitoring Network

The Air Quality Technical data report to support the Environmental Certificate Application for LNG Canada included a discussion of previous air quality assessments in the Kitimat area between 2005 and 2014 and an assessment of baseline atmospheric conditions. The assessment of baseline atmospheric conditions used 1981 to 2010 climate normal for two reporting stations in Kitimat and one station in Terrace. The previous air quality assessments included Kitimat LNG Terminal Project, 2005; Enbridge Northern Gateway, 2010; and Rio Tinto Sulphur Dioxide Technical Assessment Report (STAR), 2013. Data from five ambient stations were used to characterize the background air quality conditions. One of the five stations, Kitimat Rail (KRS), closed in 2010; the remaining four local stations remain in operation. A sixth station, Smithers St. Joseph's, was included as the only regional station collecting CO data.

The assessment of ambient concentrations in 2014 included SO_2, NO_2, CO (Smithers), $PM_{2.5}$, and H_2S. There were no ambient monitors for carbon monoxide, volatile organic compounds, or ozone in the TKV in 2014. As of 2019, there are two ozone monitoring stations. There are no significant emission sources of CO and VOC in the region.

The LNG Canada TDR characterized the background concentrations based on maximum 1-hour and 24-hour concentrations and highest annual average. It appears as though the highest values were chosen without consideration of the use of the 98th or 99th percentiles and multi-year averaging periods as prescribed by the latest AAQOs, as the maxima for SO_2 (shown in Table 2-5) are all much higher than the 3-year rolling average of the 99th percentile of the D1HM (presented in Figure 8 in section 4.2.1 below).

Concentrations of SO_2 observed in 2014 were higher in the industrial area of Kitimat than in the residential area, as continues to-date. None of the maximum concentrations exceeded the most stringent applicable AAQO in place in 2014 for the various averaging periods. The LNG Canada assessment predicted that the base and cumulative cases would have 1-hour and 24-hour SO_2 exceedances around Kitimat and Kitamaat Haisla Village (Figures G-1 and G-31 of Appendix G of (LNG Canada, 2014)). Compared to the 2025 CAAQS, peak exceedances of the 1-hour SO_2 ambient concentration were predicted to occur near the Kitamaat Haisla Village (KHV) and Riverlodge (KR) stations. Cumulative annual ambient SO_2 concentrations were predicted to exceed in the industrial areas near the smelter. The maximum 1-hour SO_2 concentration from the project alone was predicted to be at a value which would exceed the 2025 CAAQS east of the Kitimat Industrial area.

Section 4.2.1 below presents the annual and 1-hour maximum ambient concentrations of SO_2 measured by the network over the entire operating period. The 1-hour maximum observed SO_2 concentrations presented in Table 4.2-5 of the LNG Canada AQ TDR for the period 2011-2013 (reprinted in ppb in Table 2-5 below) are larger than the 3-year rolling average of the 99th percentile of the D1HM (presented in Figure 9) for all years at three of the stations, with the exception of the Kitimat Haul Road (KHR) station. All stations show an increase in the 3-year rolling average of the 99th percentile of the D1HM (presented in Figure 9) from the period of the study (2011-2013) to 2021. The annual average SO_2 concentrations for the period 2011-2013 are similar to or lower than the station trends for 2015-2021.

The LNG Canada AQ TDR assessment of the base case included 15,290 tonnes/year of SO_2 emitted from Rio Tinto Alcan and 27 tonnes of SO_2 from Kitimat LNG (now cancelled) producing a maximum base-case 1-hour ambient concentration of 3,390 $\mu g/m^3$ (1,800 $\mu g/m^3$, 99th percentile, averaged over 3 years) and a maximum annual average of 32.5 $\mu g/m^3$. The maximum SO_2 emissions from Rio Tinto Alcan were 12,019 in 2018 (NPRI Source) resulting in a 3-year rolling average of the annual 98th percentile of the D1HM of 74 ppb (193 $\mu g/m^3$) and maximum annual average of 4.2 ppb (11 $\mu g/m^3$) at Kitimat Haul Road station in 2020. Thus, the LNG Canada assessment overestimated the baseline SO_2 concentrations as compared to the observed ambient concentrations by a factor of nine for the hourly maximums, and by a factor of almost three for annual maximums. The geographical areas predicted to have peak SO_2 concentrations are well covered by the existing network for populated areas. Additional peak areas include Minette Bay construction/quarry and areas north of Kitimat along the Kitimat River.

Table 2-5: Observed Concentrations of SO_2 (2011-2013) (in ppb) from LNG Canada Air Quality TDR, Table 4.2-5 (LNG Canada, 2014)

Data Category	Kitimat Rail (KRS)	Kitimat Haul Road (KHR)	Kitimat Whitesail (KW)	Kitimat Haisla Village (KHV)
1-hour maximum (ppb)	52	72	35	28
24-hour maximum (ppb)	10.2	25.7	4.1	2.8
Highest annual average (ppb)	1.6	3.7	0.7	0.3
Overall average (ppb)	1.6	2.6	0.6	0.3

The maximum 1-hour NO_2 amounts for each of the four cases in the LNG Canada assessment predicted values which would exceed current 2020 CAAQS (Figures G-6 and G-36 of Appendix G of (LNG Canada, 2014)). The maxima were predicted to occur west of the LNG Canada facility and southwest of the facility along the western shore of the Douglas channel. The existing station at Haul Road is in the vicinity of the predicted 1-hour base case maximum NO_2 concentration, but KHR does not currently measure NO_2. The maximum 1-hour NO_2 concentration for the cumulative case was predicted to occur in an unpopulated area, southwest of Kitimat along the Douglas Channel, near the proposed Kitimat LNG site. Because this second location is unpopulated and the Kitimat LNG Project has been cancelled, there are no benefits of ambient measurement in this area.

Section 4.2.2 presents the annual and 1-hour maximum ambient concentrations of NO_2 measured by the current network. The annual and 1-hour maximum observed NO_2 concentrations presented in Table 4.2-6 of the LNG Canada AQ TDR are for the period 2007 to 2009. The 1-hour maximum observed for this period as reported in the LNG Canada AQ TDR (86.7 $\mu g/m^3$ or 46 ppb) is higher than the 3-year rolling averages of the annual 98th percentile of the D1HM (as shown in Figure 11) for all years and stations. However, the highest annual average concentration observed for this period as reported in the LNG Canada AQ TDR (4.4 $\mu g/m^3$ or 2.3 ppb) is lower than the average of recent years for the Terrace Skeena Middle School (TSMS) station and higher than the recent annual average values for Kitimat Whitesail (KW) (as shown in Figure 10).

The assessment of the observed $PM_{2.5}$ concentrations in the LNG Canada AQ TDR found annual average $PM_{2.5}$ concentrations to be less than half of the BC AQO of 8 $\mu g/m^3$ for the observed period. However, as discussed in section 4.2.4 and shown in Figure 14, more recent ambient data shows higher annual average $PM_{2.5}$ concentrations, with peak values in 2014 and a downward trend to 2021. More recent ambient data for the Kitimat Whitesail (KW) and Kitimat Haul Road (KRH) sites find the 98th percentile of the 24-hour daily average $PM_{2.5}$ concentration to be higher than the 24-hour maxima observed over the observation period of the LNG Canada TDR. For the Kitimat Rail (KRS), Kitimat Riverlodge (KR), and Kitamaat Haisla Village (KHV) sites, the trend is reversed with 24-hour maxima over the observation period of the LNG Canada TDR higher than the recent the 98th percentile of the 24-hour daily average $PM_{2.5}$ trends (as shown in Figure 15 in section 4.2.4 below).

The LNG Canada TDR also summarized the ambient H_2S concentrations at three stations, for which measurements ended in 2009, coinciding with the closure of the pulp mill.

In support of the LNG Canada Project, a passive ambient monitoring network operated from July 2013 through February 2014 recording monthly average concentrations of SO_2, NO_2, NO_X, SO_2, O_3, and VOCs at 13 stations. The LNG Canada AQ TDR provides a summary of the average concentrations of SO_2, NO_2, and H_2S. The SO_2 concentrations from the 2014 passive monitoring program are consistent with and slightly higher than the 2021 annual averages for the monitoring conducted near the Kitimat Haul Road (KHR) and Kitamaat Haisla Village (KHV) stations (as shown in Figure 2). Consistent with continuous ambient monitoring, the 2014 passive monitoring program found SO_2 concentrations to be the highest near Kitimat Haul Road (KHR), with lower concentrations at other locations.

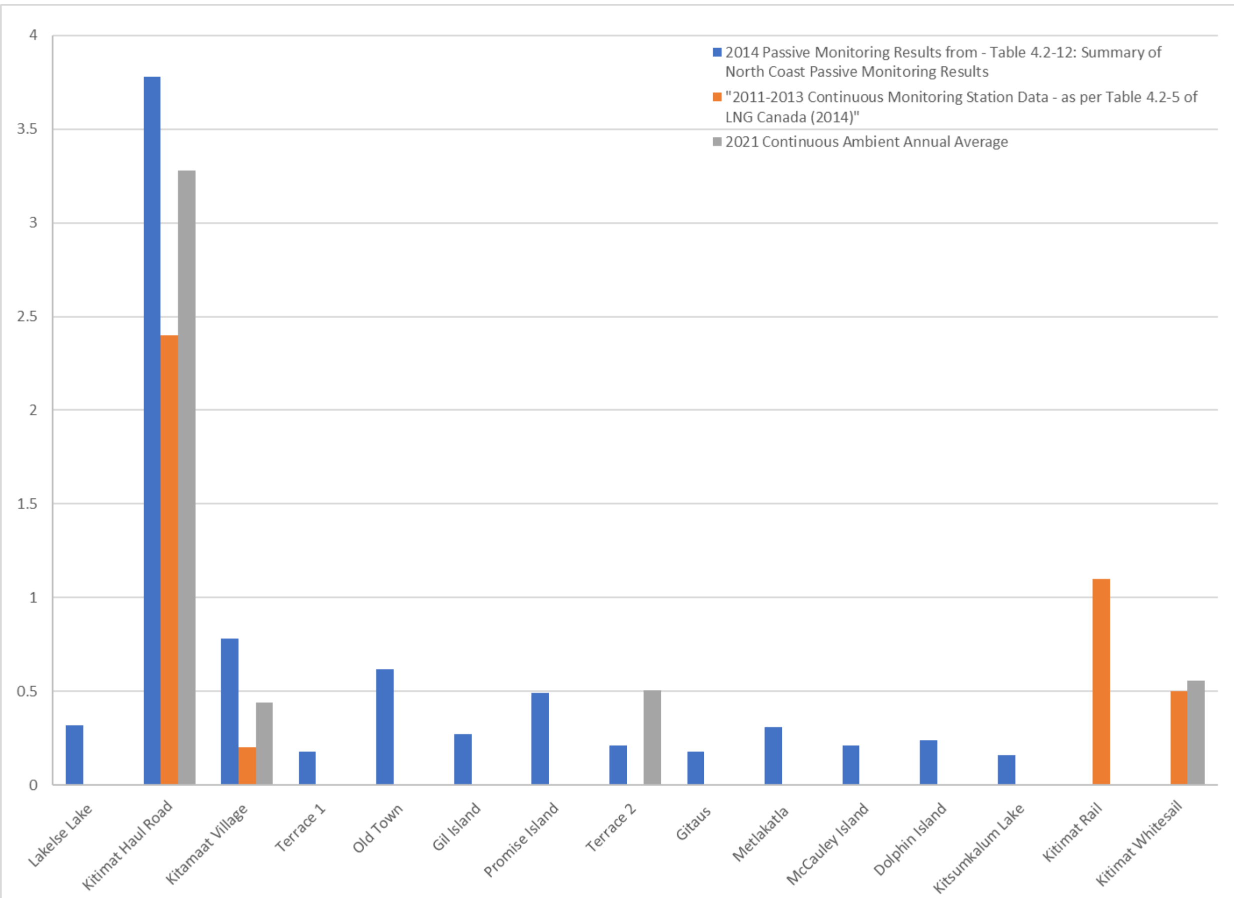


Figure 2: Comparison of Passive and Continuous SO_2 Monitoring by LNG Canada (2014) to 2021 SO_2 Continuous Monitoring

2.6 Technical Data Report – Air Quality Assessment Report for the LNG Canada Export Terminal, 2022

2.6.1 Summary

Phase 1 of the LNG Canada Project is currently under construction and will be seeking an authorization for air emissions under the Environmental Management Act, Waste Discharge Regulation, supported by the Air Quality Technical Data Report ("AQTDR") (Stantec Consulting Ltd., 2021).

The assessment outlined in the AQTDR quantified criteria air contaminant (CAC) emissions of NO_X, SO_2, $PM_{2.5}$, and CO during the project under three categories (routine, non-routine, and marine vessel emissions). The routine Project emissions were evaluated for several cases including the Base Case with the maximum permitted emissions from the Rio Tinto smelter, two Project-Alone Cases (Phase 1 and Phase 2), the Application Case (Base Case + Project Phase 1 + Marine traffic), and a Future Case (Base Case + Project Phase 1&2 + Marine traffic). Three non-routine emission scenarios were modelled for a range of facility conditions during commissioning, upset, and normal operations.

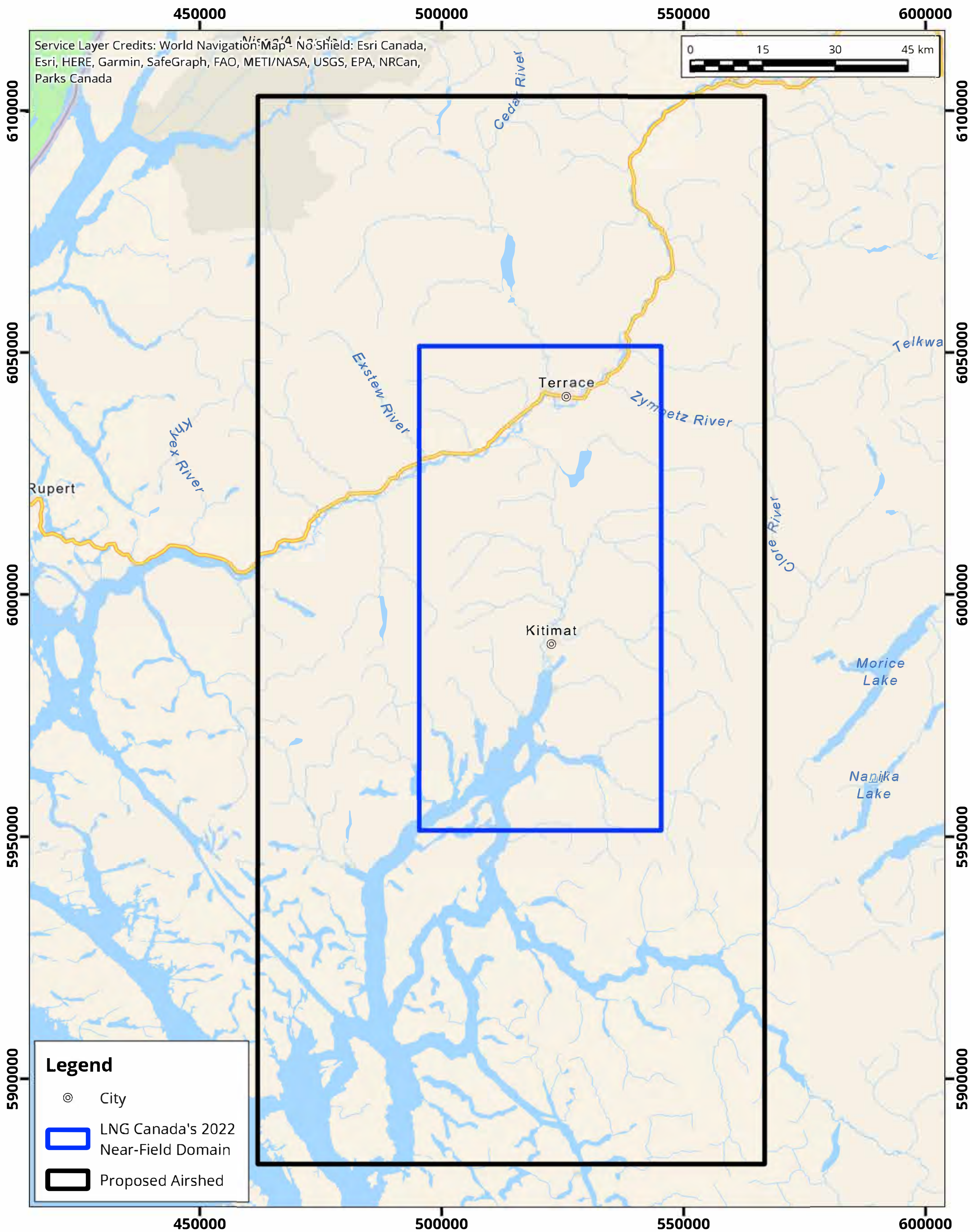
The AQTDR compared the predicted concentrations of SO_2 from the Base Case to the measurements from March 2016 through December 2020 at the Kitimat Whitesail (KW) and Kitimat Riverlodge (KR) monitoring stations using US EPA recommended methods for dispersion modelling assessment. The assessment of the dispersion model performance found the model to overpredict concentrations beyond the recommended range of a factor of two, meaning that the assessment is overly conservative.

2.6.2 Discussion of Airshed Boundaries

Two CALPUFF modelling domains were employed for this work:

1. A near-field domain of 55 km wide and 110 km long, shown in Figure 3 together with the proposed airshed further discussed in section 3 below. The near-field domain was intended to capture concentrations greater than 10% of the BC Ambient Air Quality Objectives (AQO) and was deemed to be of sufficient size to assess the potential effects of CACs and acid deposition.
2. A far-field domain of 120 km wide and 200 km long, as a failsafe to capture relevant concentration results beyond the near-field domain.

A smaller 35 km by 35 km subset of the domain was depicted in the isopleth maps reviewed for the discussion of the monitoring network.



Map Document: D:\GIS\desktop\2105554_KitimatAirshed\P2105554_Kitimat.aprx

Proposed Airshed and LNG Canada Near-Field Domain

True North

Drawn by: RCL	Figure: 3
Approx. Scale:	1:1,100,000
Date Revised:	Nov 2, 2022

Map Projection: WGS 1984 UTM Zone 9N

Kitimat Airshed Network Review - Kitimat, B. C.

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Discussion of Monitoring Network

CAC emissions from the LNG Canada Project were modelled for routine operations and non-routine conditions during commissioning, upset, and normal operations. A summary of the spatial variation in the predicted maximum concentrations and concentrations above the AQOs is described for routine and non-routine operations in the sections below.

2.6.2.1 Modelling of Routine Scenarios

Exceedances of NO_2 were not predicted by any of the routine scenarios modelled as part of the LNG Canada TDR. The maximum predicted 1-hour and annual NO_2 concentrations were predicted to occur at the following locations: on the southern and western edges of the Rio Tinto and LNG Canada sites, southwest of these sites, near both the Kitimat Whitesail (KW) and Kitimat Riverlodge (KR) monitoring stations, and at the northern limit of the District of Kitimat along the rail line.

The maximum NO_2 concentrations, as predicted by the LNG Canada modelling at locations near the industrial area (1-hour NO_2 for Base, Project and Application cases) and within Kitimat (annual NO_2 in Base Case), are likely to be captured by existing NO_2 monitoring at Kitimat Whitesail (KW) and Kitimat Haul Road stations (KHR). The addition of NO_2 monitoring at Kitimat Riverlodge (KR) and Kitimat Industrial Ave (KIA) stations could capture additional peaks as predicted by the modelling. The modelling also predicted peak NO_2 at a location at the northern end of the District of Kitimat limits, near the rail line and west of the Kitimat River. However, as the maximum values (for all scenarios) are still well below the AQOs, additional monitoring in the residential, industrial, and uninhabited areas is not warranted at this time. If elevated NO_2 concentrations approaching AQOs are observed at KW and KHR, once LNG Canada is operating at full capacity, KAG should reconsider the addition of NO_2 instrumentation.

The LNG Canada TDR predicted exceedances of 1-hour and annual SO_2 for scenarios that included the maximum permitted emissions from Rio Tinto (i.e., base, application, and future cases). For these scenarios, exceedances of the 1-hour SO_2 AQO were predicted to occur across the District of Kitimat extending south into Kitimat Arm and north through the valley, except for Kitamaat Haisla Village. Exceedances of the annual SO_2 AQO were predicted to occur across the western side of Kitimat extending south into Kitimat Arm and north through the valley and including portions of the Kitimat residential area. The maximum 1-hour and annual SO_2 values were predicted to occur on the western edge of the smelter for scenarios including maximum permitted emissions from the smelter and west of the smelter for Project-only scenarios.

The peak SO_2 concentrations in routine scenarios including maximum permitted emissions from Rio Tinto are predicted to occur close to the smelter and are reasonably captured by the Kitimat Haul Road (KHR) station. The maximum SO_2 concentrations for Project-only scenarios are predicted to occur in the uninhabited mountains west of the industrial area. As exceedances were predicted throughout Kitimat in scenarios with maximum emissions from the smelter, monitoring is best focused on capturing concentrations as representative indicators of potential exposure to the population as served by the Kitimat Whitesail (KW), Kitimat Riverlodge (KR), and Kitamaat Haisla Village (KHV) monitoring stations. Additionally, Rio Tinto has conducted studies to optimize the SO_2 monitoring network associated with emissions from the smelter. The 1-hour and annual maximum SO_2 concentrations predicted west of the industrial area in the uninhabited mountains for the project scenarios are well below the AQOs and do not warrant additional monitoring.

The LNG Canada TDR predicted exceedances of 24-hour and annual $PM_{2.5}$ for scenarios that included the maximum permitted emissions from Rio Tinto (i.e., base, application, and future cases). Exceedances of the 24-hour and annual $PM_{2.5}$ AQOs (for cases including the Base Case) were predicted to occur within the southwestern portion of the Rio Tinto site and slightly to the southwest. The maximum 24-hour and annual $PM_{2.5}$ values were predicted to occur west of the smelter in uninhabited areas for Project-only scenarios. The maximum and annual $PM_{2.5}$ values predicted for the Project-only scenarios were significantly below the AAQOs.

$PM_{2.5}$ is currently monitored at the Kitimat Haul Road (KRH) station, which would address the maxima predicted near the smelter site. The annual and 24-hour maximum $PM_{2.5}$ concentrations predicted west of the industrial area in the uninhabited mountains for the project scenarios are a fraction of the AQOs and do not warrant additional monitoring.

2.6.2.2 Modelling of Non-routine Scenarios

The SO_2 concentrations were modelled for several non-routine scenarios reflecting differences in the sulphur content of the inlet gas during regular operations, upset flaring, and start-up. The 1-hour daily maximum SO_2 concentrations were predicted to occur west of the smelter or within the LNG Canada site boundary. In some scenarios, the concentrations exceeded the BC AQO (183 µg/m^3). The maximum 1-hour SO_2 concentration was predicted to occur in similar areas, i.e., west of the smelter and slightly north of the LNG Canada site boundary. The predicted maximum 1-hour SO_2 concentration exceeded the BC AQ Guideline for intermittent emissions (450 µg/m^3) in the mountains west of and in areas south of the smelter; in areas north and east of the LNG Canada site; north of the industrial area; and in residential areas of Kitimat.

2.7 Kitimat LNG Terminal Environmental Assessment Certificate Application, 2005

2.7.1 Summary

An Application for the Kitimat LNG Terminal Project was submitted to the BC EAO and the CEA Agency in 2005. Section 7.1 of the Application, the "Assessment of Project Effects, Mitigations Requirements and Residual Effects on the Atmospheric Environment" (Kitimat LNG Terminal, 2005) was reviewed for this report.

This project was subsequently granted an Environmental Assessment Certificate (was approved) and construction began. The Project then made an application to amend the Certificate, which was withdrawn in July 2021 following announcement from both investors to divest the Project in 2019.

The facility was to be located on the western shore of Kitimat Arm, south of Kitimat in Emsley Cove. The Terminal was planned to receive and store LNG unloaded from tankers, re-gasify the LNG into natural gas and deliver natural gas via an 18-km pipeline. The terminal was designed with an initial send out rate of 610 million standard cubic feet per day (MMscfd).

The air quality assessment included point sources in existence at the time of the application including Alcan Smelters and Chemicals Ltd. (now Rio Tinto), Eurocan Pulp and Paper Co., Kentron Construction (an aggregate and ready-mix concrete plant), and Methanex Kitimat facility (a methanol refinery). Both Eurocan Pulp & Paper and Methanex Kitimat are no longer in operation. Emissions of CACs for the year 2000 from point, area, mobile, and other sources were presented in the application. Eurocan Pulp and Paper Co. was the dominant source of TSP, PM_{10}, $PM_{2.5}$, SO_X, CO, VOC, and NH_3. The Methanex Kitimat facility was the dominant source of NO_X. Marine vessels were a significant contributor to SO_X emissions.

The United States Environmental Protection Agency (U.S. EPA) Industrial Source Complex – PRIME version (ISC-PRIME) dispersion model was used for a modelling domain area approximately 5 km by 5 km, centered on the facility location (Figure 7.1-1 of (Kitimat LNG Terminal, 2005). Meteorological data derived from the Kitimat Whitesail meteorological station from January 1999 through December 2003 was applied.

The assessment assumed that the existing industries would consistently improve environmental performance and rated the resulting environmental effects as neutral with respect to air quality. Applying assumptions about the fuels that would be replaced by additional natural gas from this facility, the assessment concluded that the "cumulative environmental effects of the LNG terminal, in combination with past, present and future projects that are likely to be carried out, on Atmospheric Environment (Air Quality) are rated positive".

Table 7.1-32 in (Kitimat LNG Terminal, 2005b) presents maximum predicted ground-level concentrations of $PM_{2.5}$, NO_2, and SO_2 from the project alone, without background concentrations. The 1-hour (Appendix Figure 10 of (Kitimat LNG Terminal, 2005b)) and 24-hour SO_2 concentrations from the project alone, without background concentrations were predicted to be higher than the Level A BC Ambient Air Quality Objectives (AAQO) of the time for 1-hour (450 $\mu g/m^3$) and 24-hour (160 $\mu g/m^3$). The maxima were predicted to occur to the east of the lower portion of the Kitimat LNG Terminal property boundary on Emsley Point (1-hour) and approximately 750 m south of the facility over water (24-hour and annual average). If the 2025 CAAQS for 1-hour SO_2 were applied to the results of the assessment, the area exceeding the green air management level would be larger than the exceedance area for the AAQO encompassing the entire facility and extending over halfway into Kitimat Arm. Appendix E of (Kitimat LNG Terminal, 2005b) concluded that after the addition of ambient background concentrations:

1. All maximum predicted ground-level NO_2 concentrations were less than the applicable NAAQO values;
2. $PM_{2.5}$ maximum concentration were predicted to be less than the proposed Canada-Wide Standard; and
3. All SO_2 maxima were predicted to be greater than the applicable BC AAQO.

If the modelling results from 2005 were compared to current standards, the predicted maximum 1-hour (Appendix Figure 14 of (Kitimat LNG Terminal, 2005b)) and annual NO_2 and 24-hour $PM_{2.5}$ concentrations would exceed the 2020 CAAQS for the project plus background case. The background 1-hour and annual SO_2 concentrations (based on monitoring data from the Kitimat Haul Road during the period) would exceed the 2025 CAAQS (1-hour would also exceed the 2020 CAAQS). The project-only case would exceed the 1-hour and annual SO_2 CAAQS.

Specific results from this EA are of limited use as results were only provided for the project-only case, and this project has been cancelled. In addition, the ISC-PRIME model was a very simple dispersion model by comparison with more recent versions of current models such as CALPUFF. The patterns and magnitude of the results only provide a glimpse of what a future LNG facility in a similar location may contribute to the airshed.

2.7.2 Discussion of Airshed Boundaries

The isopleths provided in the Appendix of the assessment (Kitimat LNG Terminal, 2005b) only apply to the 5 km by 5 km grid centered on the facility location and only include the contributions from the project (Figure 7.1-1 of (Kitimat LNG Terminal, 2005). The limited scope of this study including the area modelled and the expected emission sources does not provide much useful information in setting a boundary for the airshed. The airshed boundary as proposed by Weinstein encompasses the entire modelled area of this study.

2.7.3 Discussion of Monitoring Network

The Environmental Assessment Certificate Application for the Kitimat LNG Terminal was completed in 2005 applying ambient monitoring data results from the monitoring network of the time. None of the current ambient stations existed in 2005 when this work was completed. The summary of ambient background concentrations presented in the Application found that all pollutants were below the threshold levels of the time. Ambient standards have changed significantly since 2005 including changing the measuring periods and become more stringent. Ambient concentrations tabulated in 2005 would exceed 2025 CAAQS for 1-hour and annual SO_2 and NO_2 for the project case and 24-hour $PM_{2.5}$ for the cumulative case (including ambient background). The large industrial emitters of $PM_{2.5}$ and NO_2 included in the ambient background in operation in 2005 have closed.

The maximum 1-hour concentrations of SO_2 and NO_2 reported in the Kitimat LNG study are above the 3-year rolling averages of 99^{th} and 98^{th} percentile of 1-hour values observed in the last ten years. The maximum 1-hour concentrations of $PM_{2.5}$ reported in the Kitimat LNG study is lower than maximum of annual 98^{th} percentile of 24-hour average concentrations of $PM_{2.5}$ over the last 10 years (20 $\mu g/m^3$ at Terrace Skeena Middle School (TSMS) in 2018).

Given the extensive changes since 2005, including closure of industrial sources, retirement of ambient monitoring stations, and establishment of new monitoring stations, the work completed to support the Kitimat LNG Terminal is not informative for evaluating the current and future monitoring needs. Unfortunately, the Application does not provide an assessment of ambient air quality in the Kitimat Valley that might provide historical patterns of ambient pollutants, either.

The monitoring network has significantly expanded since the completion of the Kitimat LNG Terminal EA. The terminal was to be located further down Douglas Channel than any current or planned facilities. If the modelling results from 2005 were compared to current standards, the project-only case would exceed the 1-hour and annual SO_2 and NO_2 CAAQS. If another facility is planned to be located near the site of the Kitimat LNG Terminal site, additional SO_2 and NO_2 monitoring would be recommended at the fence line or in the area surrounding such a facility.

2.8 Cedar LNG Terminal Environmental Assessment Certificate Application, 2021

2.8.1 Summary

Documents to support an Application for the Cedar LNG Terminal Project were submitted to the BC EAO and the Canadian Environmental Assessment Agency (CEA Agency) in February 2022 with additional amendments to the Air Quality Dispersion modelling in March 2022. The initial Application (dated February 2022) included an assessment of effects to Air Quality in section 7.2 (Cedar LNG, 2022) supported by a Technical Data Report (Stantec Consulting Ltd., 2021) completed in November 2021. On March 13, 2023, BC ENV issued the Environmental Assessment Certificate (EAC) (BC ENV, 2023a).

At the time of completion of air dispersion modelling (November 2021) and issuance of Cedar LNG's EAC, the nearby Kitimat LNG Project had a valid EAC. The Kitimat LNG Project was to be located 7 kilometres southwest of the Cedar LNG Project. The original EAC Application for the Cedar LNG Project assumed that the Kitimat LNG Project could restart at any time and included air emissions from the Kitimat LNG Project under the base case (existing conditions) and application case (existing conditions + Cedar LNG Project emissions) modelling scenarios.

After the submission of the EAC Application for Cedar LNG, the BC EAO indicated that the Kitimat LNG Project was anticipated to request that EAC be cancelled in the near future and thus, the BC EAO requested updated air dispersion modelling and assessment for Cedar LNG of four valued components: air quality, vegetation resources, freshwater fish, and human health.

The documents reviewed regarding the proposed Cedar LNG Project include:

- Cedar LNG Project Environmental Assessment Certificate Application Section 7.2 Valued Components Effects Assessment Air Quality (Cedar LNG, 2022);
- Cedar LNG Project Technical Data Report (Stantec Consulting Ltd., 2021);
- Updated Air Quality Dispersion Modelling Results Technical Memo (Stantec Consulting Ltd., 2022a);
- Model Performance Technical Memo (Stantec Consulting Ltd., 2022b);
- Regulatory Coordination issues Tracking Table for Cedar LNG Project (BC EAO, 2022a);
- Draft Table of Conditions for the Cedar LNG Project (BC ENV, 2022);
- Draft Potential Federal Conditions (BC EAO, 2022c); and
- Draft Assessment Report for Cedar LNG Project (Project) (BC EAO, 2022b).

The BC EAO completed its assessment of the Project and referred it onwards to the provincial and federal decision makers on November 16, 2022. With respect to air quality, the proposed provincial conditions include participation in the Kitimat Airshed Group and development of a Construction Environmental Management Plan (CAMP) (BC ENV, 2022). The draft potential federal conditions include a requirement to provide an annual summary report for NO_2, SO_2, and $PM_{2.5}$ concentrations from existing monitoring stations in the Kitimat area for the first three years of operation (BC EAO, 2022c). The pre-operation and post-operation air quality is to be compared to air quality modelling results, AQOs, and residual effects characterization criteria in the Application. The EAO also proposes a condition to require a community feedback process including receiving, addressing, and reporting on community concerns related to air quality (BC EAO, 2022b).

Both the original and updated air quality assessments included air dispersion modelling of base, project-alone, and application cases. In the original assessment (November 2021), the base and application cases included the Kitimat LNG Project. In the updated assessment (March 2022), the base and application cases did not include the Kitimat LNG Project. The project-alone case did not change between the assessments. For the updated assessment, the Cedar LNG Project was also asked to produce an additional supplemental assessment using baseline values derived from measurements. Two sets of baseline values were developed: high percentile values based on section 9.1.4 of the Modelling Guidelines (v 2015) and low percentile baselines consistent with the approach used in the Ajax Mine EA (2015).

With respect to air quality, the conclusions of the original air quality assessment (November 2021) remained unchanged with the additional assessment completed in March 2022. The updated assessment concluded that air quality in the vicinity of the Project is unlikely to be substantially exacerbated by the Cedar LNG Project. Emissions from the Project were predicted to result in small, localized deterioration in air quality, with the largest effects within 100 m to 1 km of the plant in remote, unoccupied areas. The effects are predicted to diminish substantially with increasing distance from the plant.

The 98th percentile of the daily 1-hour maximum (D1HM) NO_2 concentration for the base (102.6 μg/m^3) and application cases (103 μg/m^3) are expected to exceed the 2025 CAAQS (79 μg/m^3) but remain below the current AQO (113 μg/m^3). The NO_2 dispersion results differed slightly in the March 2022 assessment from the November 2021 assessment. The November 2021 assessment found the 98th percentile of the D1HM NO_2 concentration (118.6 μg/m^3) in the base and application cases to exceed the 2020 AQO. Removing the Kitimat LNG Project in the March 2022 assessment resulted in a decrease in the predicted base case D1HM by over 13%. Another notable difference in the two assessments are the locations of the predicted NO_2 maxima in the base and application cases. In the original assessment (November 2021), the D1HM and annual NO_2 maxima were predicted to occur at the fence line of the Kitimat LNG Project. In the March 2022 assessment, the spatial maximum of D1HM NO_2 is predicted to occur in the Kitimat town center and the annual NO_2 maximum is predicted to occur adjacent to the LNG Canada Export Terminal jetty.

The base and application case maxima from dispersion modelling (March 2022) are predicted to exceed the 2020 BC AQOs for 1-hour and annual SO_2 and 24-hour $PM_{2.5}$. The predicted maximum values and locations remained unchanged between the original and updated assessments for SO_2 and $PM_{2.5}$, because Rio Tinto's activities dominate SO_2 and $PM_{2.5}$ emissions. The 99th percentile of the predicted D1HM SO_2 concentration for the base and application cases (1,176 μg/m^3) exceed the current BC AQO (183 μg/m^3) and are predicted to occur in the Kitimat town centre. The maximum annual SO_2 average is predicted to be above the AQO (13 μg/m^3) for with both the base and applications cases (43.6 and 43.9 μg/m^3). The SO_2 spatial maxima are expected to occur within the Kitimat Town centre.

The base and application case maxima for the 98th percentile of the predicted 24-hour average $PM_{2.5}$ concentrations (29.4 and 29.6 μg/m^3) are greater than the AQO (25μg/m^3). The maximum annual $PM_{2.5}$ for the base (7.2 μg/m^3) and application (7.5 μg/m^3) cases are predicted to be below the BC AQO (8 μg/m^3). Both the $PM_{2.5}$ maxima are predicted to occur adjacent to the jetty at Rio Tinto.

A comparison of the maximum concentrations for the application case between the original and updated dispersion modelling is shown in Table 2-6.

Table 2-6: Cedar LNG Dispersion Modelling Results with (Nov. 2021) and without (Mar. 2022) Impact from Kitimat LNG.

Contaminant	Averaging Period	Application Case Maxima (µg/m³)		BC AQO (2025 CAAQS))
		Mar. 2022 [1],[2],[3]	Nov. 2021 [4]	
Nitrogen Dioxide (NO_2)	1 – hour	103.0 [**HP 131.4**; LP 108]	**118.6**	113 (79)
	Annual	12.1 [HP 14.9; LP 12.9]	23.1	32 (23)
Sulphur Dioxide (SO_2)	1 – hour	**1,176** **[HP 1,252; LP 1,178]**	**1,176**	183 (170)
	Annual	**43.9** **[HP 45.2; LP 44.0]**	**43.9**	13 (11)
Particulate Matter <2.5 microns ($PM_{2.5}$)	24 – hour	**29.6** **[HP 40.9; LP 32.5]**	**29.7**	25 (27)
	Annual	7.5 [**HP 11.9**; LP 8.2]	7.6	8 (8.8)
Carbon monoxide (CO)	1 – hour	1,818 [HP 2,700; LP 2,801]	2,032	14,300
	8 – hour	319 [HP 1,069; LP 542]	481	5,500

Notes:

[1] March 2022 Application Case Maximum values from Table 3 of (Stantec Consulting Ltd., 2022a)

[2] [HP/LP] = results from modelling with high percentile (HP) or low percentile (LP) monitoring data as baseline

[3] Values in Bold are higher than BC AQO.

[4] November 2021 Application Case Maximum values from Table 12 of (Stantec Consulting Ltd., 2021)

At the request of ENV, the March 2022 assessment included a supplemental assessment of the base and application cases, which used two different baseline values derived from measurements: a high percentile (HP) baseline consistent with section 8.1.4 of the Guideline (BC ENV, 2015), and low percentile (LP) baseline consistent with the approach used in the Ajax Mine EA.

The high percentile baseline resulted in predicted maxima beyond the BCAQO for the base and application cases for 1-hour NO_2 and annual $PM_{2.5}$, in addition to 1-hour and annual SO_2 and 24-hour $PM_{2.5}$, as seen in the March 2022 assessment. The low percentile baseline resulted in predicted maxima beyond the BCAQO for the base and application cases for 1-hour and annual SO_2 and 24-hour $PM_{2.5}$, consistent with the March 2022 assessment. No significant difference in location of the maxima between the supplemental and March 2022 assessment were predicted for any of the contaminants or cases. The predicted area of exceedance for 24-hour $PM_{2.5}$ changed with the inclusion of the high percentile baseline, adding an area of exceedance to the north and slightly west of the industrial area. Google Maps satellite and street view suggest activities in this area include a quarry with blasting and off-road recreational activities such as snowmobiling, both of which can generate PM. The difference can be seen in comparing Figure B.17 to Figure A.17 of (Stantec Consulting Ltd., 2022a).

The March 2022 assessment also looked at the valued components of vegetation resources, freshwater fish, and human health.

Regarding vegetation resources, the updated modelling (with removal of the Kitimat LNG Project) resulted in smaller areas of predicted exceedances than those presented in the EAC Application. The original conclusion of the vegetation valued component are unchanged as the there is little difference in the resulting incremental change due to the project case, which remained unchanged. The EAC Application states that Cedar LNG's contribution to cumulative effects on vegetation resources is relatively small in comparison to the changes from past and present projects and activities. The Project is stated to contribute to a 1% increase of vegetated area above the critical level of sulphur dioxide, and a 2% increase of vegetated area above calculated critical loads of acidity (Section 7.4 of (Cedar LNG, 2022). The exceedance areas for acid deposition as per the March 2022 re-modelling are all within the proposed airshed.

Regarding surface water quality, the removal of Kitimat LNG from the air quality modelling resulted in a less than 6% decrease in the magnitude of predicted critical load exceedances in surface water quality compared to those presented in the EAC Application (Stantec Consulting Ltd., 2022a). The EAC Application predicted that the potential cumulative effects on fish habitat within the freshwater fish RAA due to riparian vegetation losses to be low in magnitude, occur multiple times, and would be long-term and reversible (Section 7.6 of (Cedar LNG, 2022)). The original conclusions of the freshwater fish valued component remain unchanged as there is little difference in the incremental change due to the Project emissions between the base and application cases.

Regarding human health impacts, the EAC Application concluded that the likelihood of residual effects on human health is low, and no substantial adverse residual effect for human health is predicted (Section 7.12 of (Cedar LNG, 2022)). The March 2022 assessment found the removal of the Kitimat LNG Project reduces the inhalation health risk within the local and regional assessment area.

2.8.2 Discussion of Airshed Boundaries

The review of the Cedar LNG Application was added to this report following the completion of section 3 and thus did not contribute to the discussion on the Airshed Boundary. However, the local and regional study areas included in the EAC Application are contained within the proposed Airshed Boundary as per section 3.5.

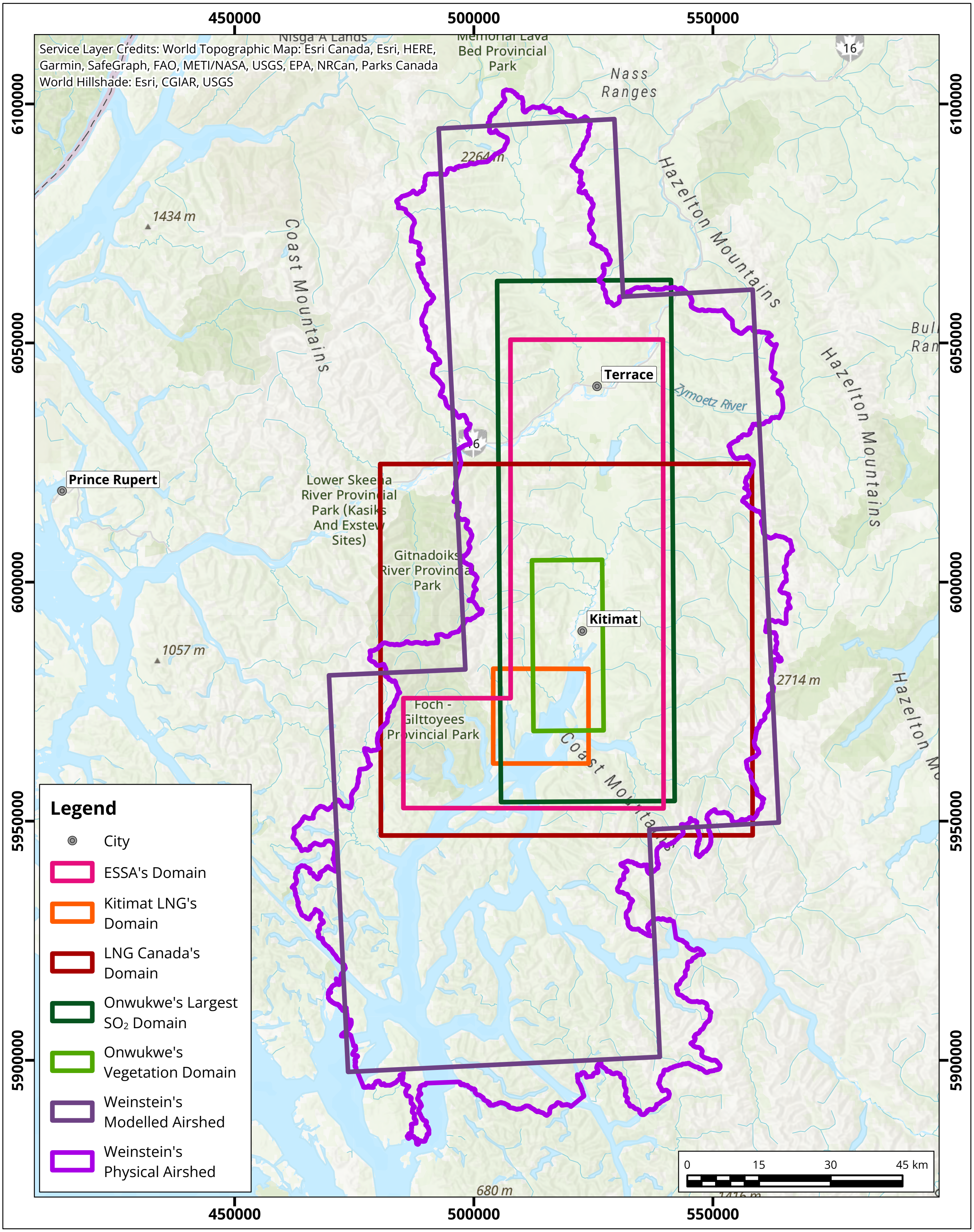
2.8.3 Discussion of Monitoring Network

Cedar LNG represents an additional emission source in the TKV south of the existing industrial sources. Cedar LNG will be a substantial contributor of NO_2.

The original assessment (November 2021) included Kitimat LNG farther south down the Douglas channel. Dispersion modelling for the base and application cases including Kitimat LNG predicted exceedances of 1-hour NO_2 at the fence line of KLNG. The updated dispersion modelling, without Kitimat LNG, predicts maximum values for the base and application cases in the Kitimat town centre (near to the hospital) but not exceeding the BC AQO, but would exceed future 2025 CAAQS. Given the location of the predicted maximum NO_2, an additional NO_2 monitoring should be added, while the ideal location for capturing the maximum would be a new station near to the hospital, adding NO_2 to the Kitimat Riverlodge (KR) station is a reasonable proxy. The annual NO_2 and 24-hour and annual $PM_{2.5}$ maxima are predicted to occur adjacent to the jetty at Rio Tinto within the industrial area.

2.9 Summary of Modelling Domains

Figure 4 summarizes most of the modelling domains and airsheds used in the literature that was reviewed in the previous subsections. It is noted that all modelling domains fall mostly within Weinstein's modelling domain ("Weinstein's Modelled Airshed" shown in dark purple). The purple boundary ("Weinstein's Physical Airshed") is roughly based on the topographic barriers surrounding the TKV. This and other choices are further discussed in the next section.



Comparison of Modelling Domains and Airshed Boundaries

True North

Drawn by: RCL

Figure: 4

Approx. Scale: 1:1,100,000

Date Revised: Feb 17, 2022

Map Projection: WGS 1984 UTM Zone 9N

Kitimat Airshed Network Review - Kitimat, B. C.

Project #: 2105554

Map Document: C:\GIS\2105554_KitimatAirshed\Figures Work\P2105554_Kitimat.aprx

3 TASK 2: TERRACE-KITIMAT VALLEY AIRSHED BOUNDARIES

As mentioned in Task 1 of this report, the airshed as defined in the work by Ben Weinstein ("Weinstein's airshed") was used as the starting point for the definition of a TKV airshed. A broad range of criteria can be applied to define an airshed. These criteria can be categorized according to three distinct approaches to defining an airshed. Section 3.1 discusses these approaches and the hybrid approach chosen in this report. Section 3.2 characterizes the criteria used to suggest modifications to the Weinstein's airshed. Additional considerations are discussed in section 3.3. Finally, section 3.4 presents options for alternative airshed definitions.

3.1 Approaches to Defining an Airshed

One way of categorizing criteria for defining an airshed is by breaking them up into three approaches that are based on:

1. Legal/Administrative Boundaries.
2. Natural Barriers.
3. Threshold Criteria.

These are further discussed in the following three subsections. Subsection 3.1.4 presents the hybrid approach deployed in this report to develop airshed options.

3.1.1 Legal/Administrative Boundaries

Defining an airshed based on legal or administrative boundaries is appealing for the benefit of regulatory authority and enforcement powers. On the downside, transport of air contaminants between adjacent airsheds can cause inter-airshed conflicts, because rarely are air contaminants constrained by legal or administrative boundaries.

A prime example of legal airsheds are countries for the purpose of greenhouse gas (GHG) emissions. Countries are the largest entities with legal enforcement power. They make international pledges for GHG reductions and provide annual National Inventory Reports. This is also the most extreme example of inter-airshed conflict, because GHG emissions have the greatest impact after global dispersion.

In the context of criteria air contaminants, the Lower Fraser Valley (LFV) is a hybrid example of two administrative entities (Metro Vancouver and Fraser Valley Regional District) managing an airshed that is administratively defined but also roughly coincides with natural barriers.

3.1.2 Natural Barriers

Over wide, open land areas such as the Canadian Prairies, there are no substantial barriers to the transportation of air contaminants. However, in areas with complex topography such as in the LFV or the TKV, high mountain ranges pose substantial barriers to airflow, trapping or recirculating air contaminants on diurnal and sub-daily time scales. To a lesser extent, that also applies to adjacent large bodies of water.

An airshed tends to be more representative of the physical reality of air contaminant concentrations inside and outside of the airshed when the airshed boundary can be based on such natural barriers. Weinstein's physical airshed boundary following the highest ridges (see Figure 4 in section 2.8 above) is a result of applying this approach.

3.1.3 Threshold Criteria

Theoretically, air contaminant emissions, especially those with substantial half-lives in the atmospheric environment, could eventually impact every location on Earth. Defining a global airshed is neither practical nor helpful. More meaningful is the definition of the airshed based on an impact threshold, i.e., the airshed is defined as the area where air contaminant concentrations are below the threshold. Such a definition has the appeal of an apparent objectivity, because it is scientifically well-defined and supported, and it can be related for example to air quality objectives, standards, or criteria. However, the choice of the thresholds is inevitably subjective. The choice depends, for example, on the particular interests of different stakeholders.

The biggest problem with an airshed definition based on threshold criteria is that the area above a given threshold limit is only very inaccurately known. Few, if any, airsheds in the world have sufficient spatial coverage to provide high confidence in the spatial distribution of an air contaminant field, especially for extreme statistics such as an annual one-hour maximum. In all cases, the threshold contour would require complementary numerical modelling, which has its own shortcomings. This approach is further complicated by the need to consider several air contaminants and associated statistics/averaging periods. Finally, an airshed definition based on threshold criteria and observations and modelling is not robust to changes in:

- model versions and assumptions;
- additional observations;
- changes in air quality objectives, standards, and criteria; and
- changes in emissions, background concentrations, and climate.

Recognizing both the appeal and the shortcomings of this approach to defining an airshed, it was integrated into a hybrid approach presented in the next subsection.

3.1.4 Hybrid Approach to Defining the Airshed

The hybrid approach deployed in this study recognizes Weinstein's physical airshed boundary based on physical barriers (Figure 4 in section 2.8 above) as a starting point. Given the large area of the airshed and relatively small number of measuring locations, further investigation of the adequacy of the airshed boundary had to be based on a review of the numerical modelling result in the literature, which was presented in section 2. That led to the use of regularly shaped airsheds such as Weinstein's modelling airshed (also shown in Figure 4), which approximates Weinstein's physical airshed. The next main step is the investigation of potential candidates for threshold criteria which is presented in the next section.

3.2 Threshold Criteria

RWDI understands that the KAG seeks an airshed boundary which would capture all potential impacts from reasonably anticipated future emitting (industrial and other) activities in the region. As expertly presented in the SO_2 EEM program and review (ESSA Technologies Ltd. et al, 2020), impacts could be to one or more receptor type: human health, vegetation, terrestrial ecosystems, or aquatic ecosystems.

In addition to various receptor types, there is also a range stringency of potential thresholds. The more stringent the criteria, the larger the airshed area. The least stringent threshold-based definition for the airshed would focus on current or predicted areas of exceedance of one of these types of receptors over a limited timeframe. A more stringent airshed definition would include all geographic areas in which predicted concentrations would trigger management actions (a much lower threshold than exceedances) for all receptor types. The most stringent and comprehensive airshed definition would include all geographic areas where impacts are above the background and would require a good understanding of background values.

Threshold definitions are discussed in detail in the following subsections, organized by receptor type. Note that a summary of the suggested expansions of the airshed beyond Weinstein's boundaries will be presented later in section 3.4 (Figure 5).

3.2.1 Human Health Impacts and CAAQS

For human health impacts, the CCME's CAAQS set four colour-coded management levels for NO_2, SO_2, $PM_{2.5}$, and O_3 over various averaging periods as seen in Table 2-2 in section 2.1. Each management level provides recommended air quality management actions with increasing stringency. The lowest (green) level recommends monitoring actions, with management actions triggering at the next (yellow) level. A comparison to the CCME management levels should be used in considering the airshed boundary.

Additionally, guidance from BC on setting a modelling domain can inform setting a comprehensive geographical extent. The BC Air Quality Dispersion Modelling Guideline advises that modelling domains should be established based on isopleths resulting from project-only cases that represent 10% of the ambient air objective (BC ENV, 2015). Although this definition is meant to apply to project-level assessment, it could be used to guide the domain selection for the airshed. While an exhaustive comparison of geographical extents above the 10% of ambient air objective to modelling results from all literature for all the pollutants and averaging times would be beyond the scope of this work, a focused comparison for the pollutants of interest from some literature review is generally informative.

Dispersion modelling completed to support the eAs for Kitimat LNG and LNG Canada both predicted 1-hour NO_2 values above the 2025 CAAQS. The LNG Canada modelling was completed more recently (LNG Canada, 2014) and included more relevant potential sources: the assessment for Kitimat LNG included now closed facilities and did not include the Rio Tinto KMP. The 1-hour NO_2 maxima for the cumulative case for LNG Canada could be the most informative for assessing the geographical extent of the 10% trigger. Ten percent of the 2025 1-hour objective for NO_2 is equivalent to 4.2 ppb (about 11 μg/m^3).

A review of maximum predicted 1-hour average ground-level NO_2 concentrations in Figure G-36 of (LNG Canada, 2014) found that areas predicted to have concentrations at or above 10% of the maximum predicted 1-hour average ground-level NO_2 concentrations for the cumulative LNG Canada case would be all contained within Weinstein's modelling airshed.

For evaluation of the geographical extent of ambient SO_2 concentrations meeting the 10% threshold, the work completed by ESSA et al is informative. Ten percent of the 2025 CAAQS for 1-hour and annual objectives for SO_2 are 6.5 ppb (17 μg/m^3), and 0.4 ppb (1.0 μg/m^3), respectively. The results for maximum 1-hour SO_2 for the 42-tpd scenario (KMP) from Figure 3-13 of (ESSA Technologies Ltd. et al, 2020) show the 10% trigger included within Weinstein's airshed to the north and east of Kitimat. The ESSA et al model domain cuts off at the 10% trigger concentration to the west of Kitimat and may extend past the boundary of Weinstein's airshed. For the 2016-2018 actual scenario (29.3 tpd), ESSA et al found the modelling to be underpredicted south of Kitimat. Using the 10% of 2025 CAAAQs as an airshed guideline and the modelling done by ESSA et al, would warrant extending Weinstein's airshed to the south-west of Kitimat.

A comparison of the 10% of CAAQS trigger level for ozone is less informative, as background concentrations during peaks are well above this trigger value throughout Weinstein's airshed. More informative is the pattern of O_3 concentrations, specifically where mid-range concentrations approach the edges of Weinstein's airshed. Peak O_3 modelling by Weinstein suggests that the airshed would need to be expanded in the southeastern, northeastern, and southwestern cut-outs and to the west of southern portion of the airshed to capture the mid-range (near green level air quality management levels) within the airshed boundary. Figure 4.14 of (Weinstein, 2015) shows O_3 plumes migrating through a peak day to the north-east "cut-out" with onshore wind patterns. The O_3 concentrations predicted on the edge of this cut-out area are above the 10% CAAQ trigger levels but below the lowest management levels CAAQS (green level = 50 ppb for 8-hour O_3). Figure 4.6 of (Weinstein, 2015) illustrates O_3 concentrations at near management levels extending into the "cutout" in the southeast along Douglas Channel. Figure 4.13 of (Weinstein, 2015) shows the O_3 plume travelling to the western extents of the southern portion of the airshed on a peak summer evening to concentrations nearing management levels.

3.2.2 Vegetative, Terrestrial and Aquatic impacts

Similar to the identification of areas predicted to have pollutant concentrations relevant to human health objectives, RWDI reviewed the literature for identification of areas that may experience pollutant concentrations with impacts to vegetative, terrestrial or aquatic environments. The work completed by Onwukwe and ESSA et al addressed vegetative impacts.

Onwukwe modelled the expected exceedance areas for critical load to vegetation (lichen) for increased emissions from the KMP and for the addition of two LNG facilities in the region. The critical load of acidity was also modelled. Onwukwe found areas of exceedance for critical load of acidity and vegetation (lichen) in Kitimat (Figures 7.2 and 7.3 of (Onwukwe C. , 2020)) in areas near Rio Tinto and well within Weinstein's airshed for the increased emission scenario with KMP. The areas of exceedance for critical load of acidity and vegetation (lichen) for the addition of LNG facilities (Figures 8.4 and 8.6 of (Onwukwe C. , 2020)) was found to be larger than that of the KMP scenario. The area of exceedance was still focused on Kitimat but extending farther north and south. The areas of exceedance for the LNG facilities scenario are also well within Weinstein's airshed.

The ESSA et al review modelled ambient SO_2 concentrations against critical levels for sensitive lichens (3.6 ppb = 10 µg/m^3) and natural and forest ecosystems (7.2 ppb = 20 µg/m^3) and SO_4^{-2} deposition against the critical load for sensitive lichens (2.5 kg/ha/year). The annual average SO_2 concentration above 4 ppb (corresponding roughly to the critical annual average concentration of 10 µg/m^3 to protect sensitive lichens) was exceeded at sites close to the smelter on Rio Tinto property and at sites north and south of the industrial area of Kitimat outside of Rio Tinto property (Figure 5-5 of (ESSA Technologies Ltd. et al, 2020)) for the highest SO_2 scenario (42 tpd). Not including the background deposition, three-year modelled SO_4^{-2} deposition was predicted to exceed the critical levels for sensitive lichen for both the 2016-2018 actual (29.3 tpd) and the KMP (42 tpd) scenarios along the north-south length of the domain, and extending beyond the domain for the KMP scenario (Figure 5-5 of (ESSA Technologies Ltd. et al, 2020)). One could infer from the isopleth patterns, that this critical level for sensitive lichen will be contained within Weinstein's airshed. The ESSA et al review concluded that while deposition and literature predict that some lichens will be affected, measurements and observations to date show risk to vegetation to be unlikely to very unlikely and of minor consequence.

The ESSA et al review found that even the largest areas where critical loads for terrestrial ecosystems (soils) will be exceeded are relatively small but greatly in excess of critical load. The exceedance area will be located primarily south and north of the smelter and predominately within the fence line.

Regarding the aquatic ecosystem, the ESSA et al review found 1 of 14 lakes in the EEM program (a 1-ha fishless lake close to the Kitimat smelter) to show evidence of increased sulphur-induced acidification related to the smelter. The review modelled critical load exceedances for the KMP (42 tpd) scenario (Figure 7-6 of (ESSA Technologies Ltd. et al, 2020)). The review found that two sensitive lakes north of Terrace on the edge of the domain were predicted to exceed critical loads, though this has not been observed. These lakes are outside of the predicted SO_4^{-2} deposition area. The EEM program did not include lakes outside the domain.

Expanding Weinstein's airshed to the west and east in the northern end of the airshed could include additional sensitive forest and aquatic ecosystems (as seen in Figure 5-15 of (ESSA Technologies Ltd. et al, 2020)), but none of the literature reviewed suggested that ecosystems would be impacted from industrial activity in the Kitimat Terrace valley.

3.3 Additional Considerations

3.3.1 Airflows over Waterways

Annie Seagram (Seagram, 2014) demonstrated that long-range transportation of pollutants is possible over water bodies in regions. Significant on and offshore wind patterns further complicate the flow patterns. Through the Douglas Channel and its many side channels, flows are more confined. However, airflows over smooth water surfaces experience little dispersion so that concentrations drop off more slowly and deposition may occur along the edges of these bodies at concentrations higher than expected at similar distances over rougher terrain. Thus, the final airshed definitions should consider the enhanced contaminant transport over the various waterbodies especially south of the TKV.

3.3.2 Sensitive Receptors

The TKV is a pristine natural environment with few population centres with sensitive receptors, potentially sensitive ecosystems, and traditional land-use. Thus, all potentially populated areas, even those with very small populations or infrequently populated, were considered for inclusion in the geographic boundary for the airshed.

The former village of Kemano historically housed a semi-permanent population and currently operates as a workcamp. Kemano is located in the "cut-out" in the southeast of Weinstein's airshed. Therefore, Kemano is no longer of concern for population exposure, but the adjacent waterways may facilitate longer air contaminant transport. That makes Kemano interesting for the characterization of longer-range transport over the waterways south of the TKV.

Discussion with the KAG identified a local fishing camp to be considered for inclusion in the airshed boundary. Further review found that the nearest camp to be on Princess Royal Island, which was determined to be too far (about 40 km south of Weinstein's airshed) to be impacted by emissions generated in the valley.

Consideration was also given to whether there are populations in the north-east "cut-out" of Weinstein's airshed. The communities of Kitselas and Usk are included within Weinstein's airshed. Expansion of Weinstein's airshed in the north-east "cut-out" to a regular rectangle could add Pitman, Grand Trunk, Ritchie, and possibly Cedarvale and Woodcock. The communities of Kitwanga and Gitsegukla would remain just outside of the expanded rectangular airshed.

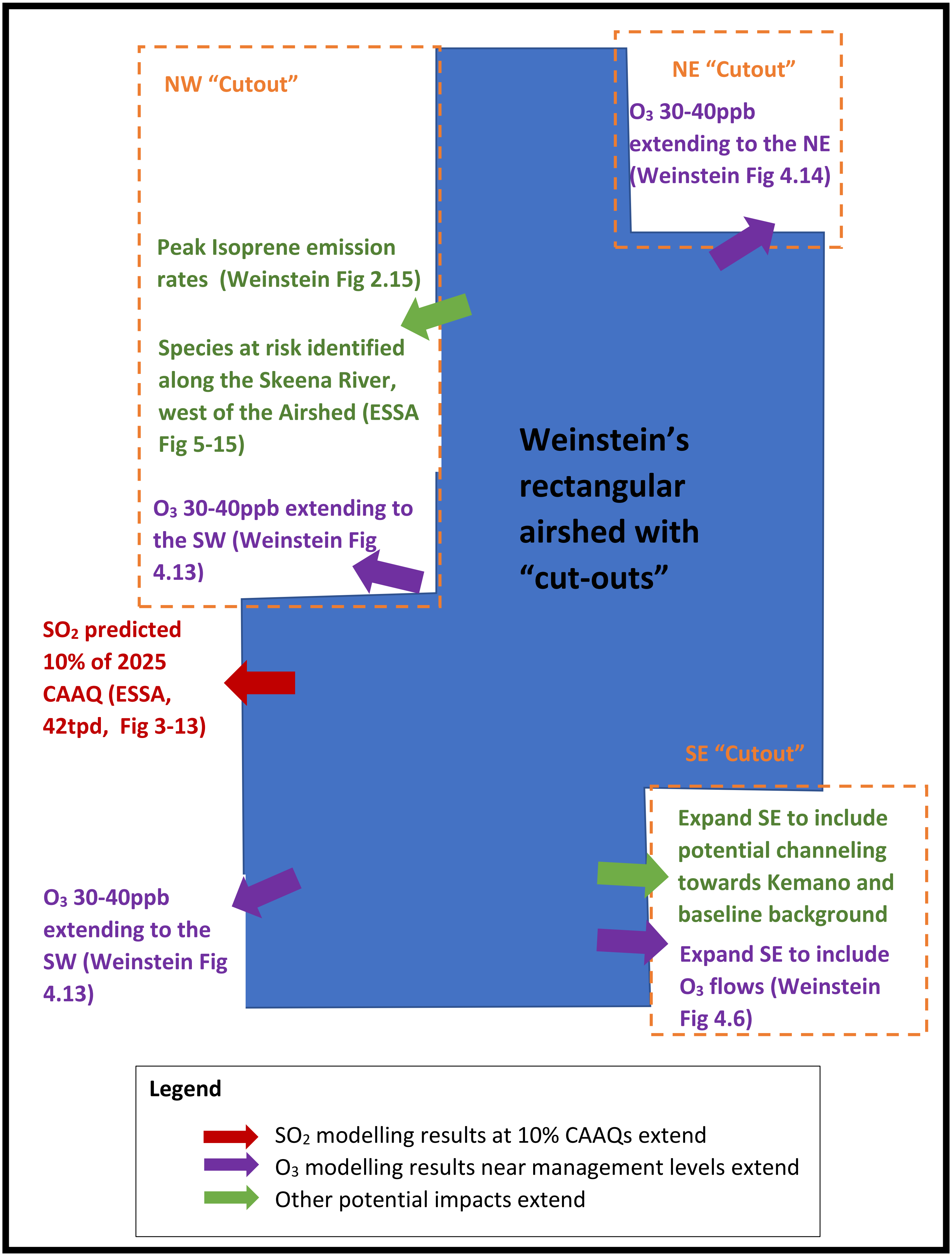
The airshed definition should include any reasonably expected future populations, which at this time, Weinstein's airshed does.

3.3.3 Locations of Future Emission Sources

The literature review underscores the industrial potential in the region, due to natural gas pipelines and marine access. The review also illustrates how the changing policies and economics can greatly impact decisions for industrial development. The oldest work reviewed, the EA for Kitimat LNG, included two large industrial facilities that have since closed. The work completed by Weinstein included five newly proposed industrial facilities, of which only one is now moving forward and currently in construction. Although many of the specific previously proposed projects have now been cancelled, at least one additional new LNG project (Cedar LNG) is in the application phase, and additional industrial development in the valley is likely. The airshed definition should be both geographically and temporally relevant, encompassing potential future industrial or other development sites and associated potentially impacted areas.

3.4 Airshed Options

Weinstein's airshed can be roughly approximated by a rectangle with three "cut-outs" (removed sections) in the (1) northeast, (2) southeast, and (3) northwest (Figure 4 in section 2.8 above). Weinstein's airshed is the largest domain used by the studies reviewed and encompasses all other study areas except for the LNG Canada domain, which extended to the west beyond Weinstein's domain. The following subsections summarize the reasoning to expand the airshed boundary in each of the cut-out directions based on the considerations in sections 3.2 and 3.3. Figure 5 provides a graphical summary.


NW "Cutout"
Peak Isoprene emission rates (Weinstein Fig 2.15)
Species at risk identified along the Skeena River, west of the Airshed (ESSA Fig 5-15)
O_3 30-40ppb extending to the SW (Weinstein Fig 4.13)
NE "Cutout"
O_3 30-40ppb extending to the NE (Weinstein Fig 4.14)
Weinstein's rectangular airshed with "cut-outs"
SO_2 predicted 10% of 2025 CAAQ (ESSA, 42tpd, Fig 3-13)
SE "Cutout"
Expand SE to include potential channeling towards Kemano and baseline background
Expand SE to include O_3 flows (Weinstein Fig 4.6)
O_3 30-40ppb extending to the SW (Weinstein Fig 4.13)
Legend
SO_2 modelling results at 10% CAAQs extend
O_3 modelling results near management levels extend
Other potential impacts extend

3.4.1 Expansion towards the Northeast

Reasons to extend the northeastern boundaries of Weinstein's airshed include capturing potential O_3 peaks and additional human, sensitive forest, and aquatic receptors. Weinstein's O_3 modelling (Figure 4.14 of (Weinstein, 2015)) shows O_3 plumes (near management levels) on peak days with onshore winds migrating to the northeast cut-out. Moreover, the EEM review by ESSA et al identified sensitive vegetation and lakes in the northern areas of the modelled domain.

3.4.2 Expansion towards the Southeast

Expanding the airshed in the southeastern "cut-out" would capture pollutants carried down the eastern arm of the Douglas Channel towards Kemano with limited overwater mixing. On the other hand, Rio Tinto staff have noted that ambient measurement data from Kemano indicate it to be a relevant indicator of background concentrations. In either case, an expansion of the airshed towards the southeast to include Kemano would help determine if measurements performed at Kemano are always suitable as background or only after excluding periods when overwater channeling might carry air contaminants from the emission sources in the TKV to Kemano.

Ozone modelling by Weinstein predict future concentrations nearing CAAQS management (green) level at the boundaries to the southeast and northeast cut-outs and to the west at both the northern cutout and the southern edge.

3.4.3 Expansion towards the Northwest

Air dispersion modelling results in the literature illustrated O_3 plumes of interest extending into the southern part of the northwestern cut-out. While modelling did not predict any notable concentrations in the northern portion of the western cut-out, environmental factors indicate a benefit of extending this boundary. Vegetation species at risk have been identified along the Skeena River traveling west from Terrace. Vegetation along the Skeena is also predicted to produce significant isoprene (VOC) emissions that may contribute to O_3 formation in the region.

3.4.4 Expansion towards the Southwest

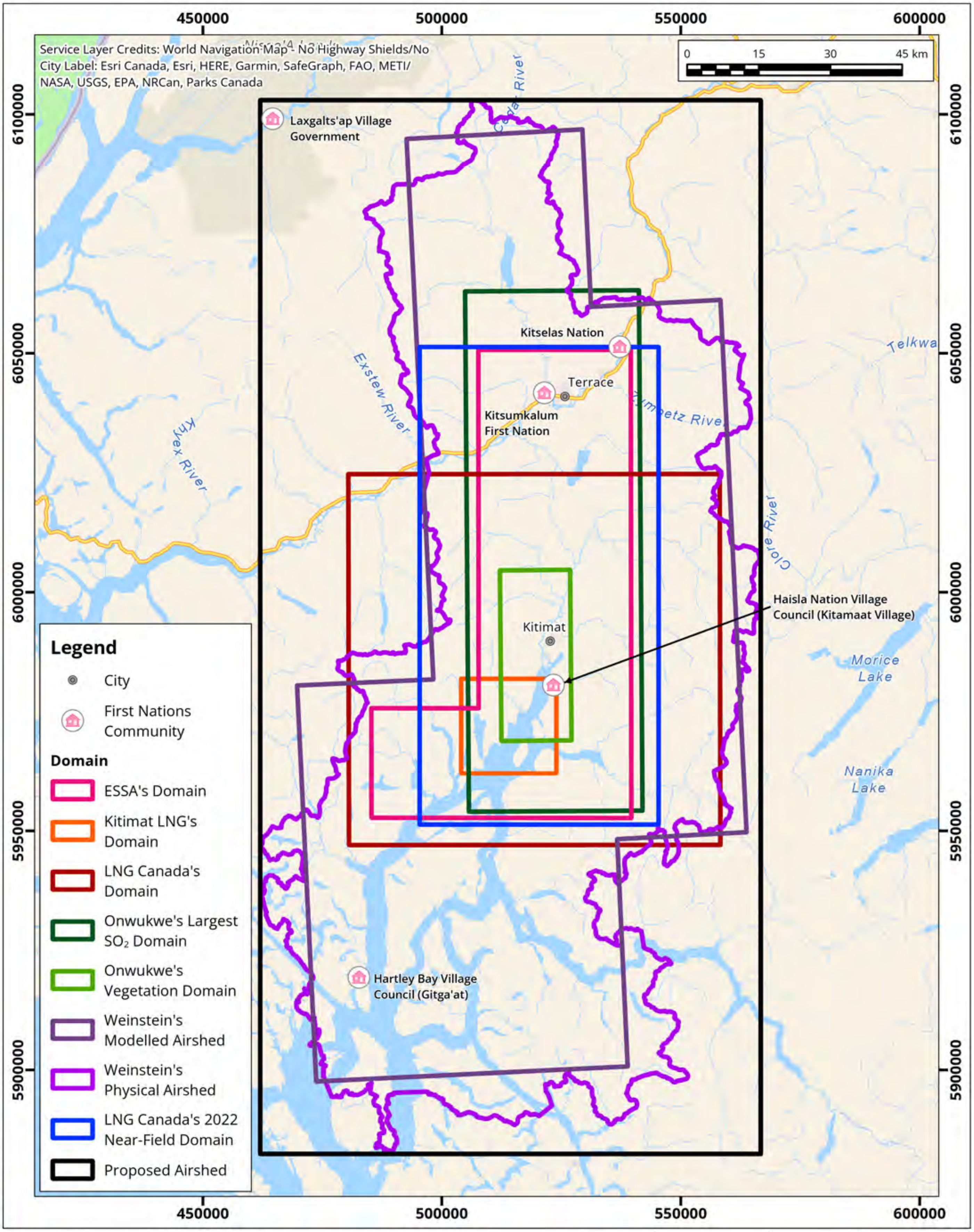
Sulphur dioxide modelling completed by Trinity Consulting as part of the work by ESSA et al predicted ambient concentrations above the 10% of 2025 CAAAQs modelling domain trigger as required by the BC Air Quality Dispersion Modelling Guideline (BC ENV, 2015) and could warrant extending Weinstein's airshed westwards in the southwestern portion of the airshed. Modelling of O_3 also shows the plume travelling to the western extents of the southern portion of the airshed on a peak summer evening to concentrations nearing management levels.

3.5 Proposed Airshed

The final decision on an airshed definition could include any combination of the expansions to Weinstein's modelling airshed that were summarized in the previous section. It is not possible to determine quantitatively the ideal size of expansions, because all of them lie outside of any modelling or monitoring to-date. The final decision must be based on extrapolations using the trend of modelling results towards the domain boundaries and experience with flows in complex terrain.

RWDI recognizes the value of Weinstein's physical airshed. A cautionary approach suggests inclusion of all expansions summarized in the previous section. This should be balanced against the findings from the literature review that no serious issues are predicted near the domain boundaries of Weinstein's modelling airshed.

Figure 6 is the same as Figure 4 plus the smallest rectangle that is aligned with the x and y coordinate axes of the WGS 1984 UTM Zone 9N map projection and that fully comprises Weinstein's physical airshed (shown as a dark rectangle labelled "Proposed Airshed" in the legend). This proposed airshed shows substantial expansions from the cut-out areas of Weinstein's modelling airshed and a moderate expansion in the south. It addresses all the expansion suggestions in the previous section while still leaning on Weinstein's physical airshed. The alignment with the UTM coordinate system makes it a potential standard domain for future air dispersion modelling.



Map Document: D:\GIS\desktop\2105554_KitimatAirshed\P2105554_Kitimat.aprx

Comparison of Modelling Domains and Airshed Boundaries

Map Projection: WGS 1984 UTM Zone 9N

Kitimat Airshed Network Review - Kitimat, B. C.

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Drawn by: RCL	Figure: 6
Approx. Scale:	1:1,100,000
Date Revised:	Nov 10, 2022

4 TASK 3: NETWORK ASSESSMENT

4.1 Objectives

The network's stakeholders and end-users include First Nations, government agencies, NGOs, members of the public, and industry. The overarching purpose of the network is to enable the assessment of overall air quality in the region and provide information related to air quality to all stakeholders.

The KAG provided requirements, objectives, and guiding principles of the ambient air quality monitoring network in the TKV airshed in the original RFP. To facilitate this review, the guiding principles were grouped with the requirements and objectives as applicable (Table 4-1).

Table 4-1: Network Requirements, Objectives, and Guiding Principles

Category	Description
	Requirements
Data Quality	The monitoring network should meet the needs of stakeholders and allow them to make decisions about air quality management based on representative and credible data. Credible data means that data are free of measurement bias (due to instrument type and/or location); that they have gone through necessary quality control (QC), quality assurance (QA) and validation processes; and that annual reporting requirements have been met.
Spatial Coverage	The network should provide appropriate geographical coverage to allow the understanding of air quality impacts from current and foreseeable future emission sources (including expected climate change impacts). A network should strive to reduce redundancy–- i.e., achieve the maximum amount of information from a given set of instruments and station locations.
	Objectives and Associated Guiding Principles
Air Quality Interpretation & Determination	Assessing attainment of provincial and federal objectives and standards, as well as measuring and understanding baseline concentrations.
Air Quality Analysis	Measuring and understanding the spatio-temporal distribution of air pollutants, short- and long-term trends, identifying conditions under which elevated pollutant concentrations occur, estimating transboundary transport, and identifying hot spots. All relevant air pollutants should be measured by the network. A suitable air quality monitoring network should be accompanied by a meteorological monitoring network, particularly wind speed and wind direction (other parameters include temperature, humidity, pressure, precipitation). For the purposes of this network, transboundary transport refers to emissions that originate from outside of the airshed.

Category	Description
Air Quality Reporting	Reporting credible data in near real-time (including AQHI). AQHI reporting includes the AQHI+ SO_2 system that is in place for Kitimat. Data viewed in near-real time has not been verified by government agencies; the validation process is typically completed by March of the following calendar year.
Air Quality Management & Mitigation	Direct management of air quality through issuing of advisories and alerts, evaluating and responding to complaints, as well as triggering mitigation measures. KAG may make mitigation recommendations based on data that are collected and analyzed.
Human Health & Environmental Impact Assessment	Understanding the effects associated with existing or new emission sources through impact assessment work, including activities such as (but not limited to) estimating / understanding population and environmental exposure, evaluating the performance of dispersion model output, conducting source apportionment studies, performing fence line monitoring, and identifying potential permit non-compliances. KAG is not responsible for establishing or implementing mitigation measures associated with air discharge permits; this is the responsibility of regulating agencies and associated permittees.
Additional Guiding Principles	
Funding	These objectives have been developed with the assumption that there is, and will continue to be adequate funding to satisfy the objectives as stated.
Network as a Whole	It is not expected that all objectives are satisfied at each monitoring station; the goal is for the network as a whole to achieve the objectives.
Airshed Boundaries	It is expected that monitoring can be used to inform the delineation of airshed boundaries in conjunction with air quality dispersion modelling.
Methods and Instruments	Air quality monitoring can utilize a variety of monitoring methods and instrument types.
Siting	Monitoring locations should provide representative data for all population centres – including Kitimat and Kitamaat Village – that are part of the airshed as defined by the third-party network review. All monitoring locations must conform to siting requirements set by provincial and/or federal agencies. Modelling can be used as a tool to inform monitoring location selection.

4.2 Existing Continuous Air Monitoring Network

The current continuous monitoring network in the TKV airshed is composed of seven stations. Their locations are presented in Figure 7 and in Table 4-3 along with the parameters that are measured and the period during which they have been measured. All stations, except for the Kitimat Yacht club, which is a dedicated meteorological station, monitor at least one of the following criteria air contaminants: SO_2, NO_2, O_3, $PM_{2.5}$, and PM_{10}. Additionally, the Kitimat Haul Road (KHR) and Kitimat Riverlodge (KR) stations also monitor for hydrogen fluoride (HF), however as there are no AAQOs for HF, this parameter was deemed out of scope for the review and is not included in the further discussion.

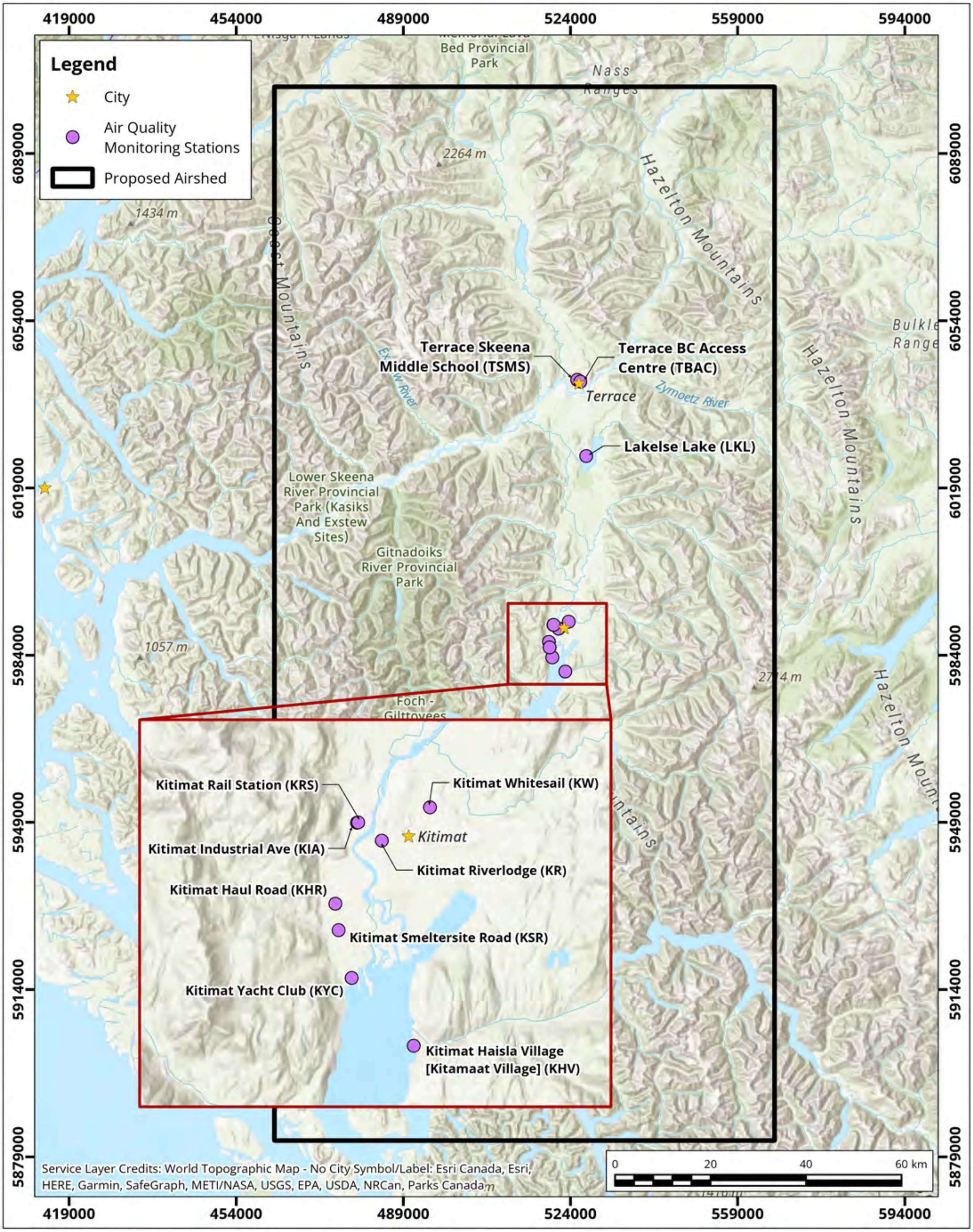
Air temperature and wind speed and direction are recorded at six of the seven stations, providing additional information about the source of contaminants and environmental conditions linked to changes in concentrations.

There were an additional three stations that are now decommissioned but provide historical trends. These stations are also presented in Figure 7 and in Table 4-2 and Table 4-3.

Hourly concentrations of CACs available from each of the seven active stations as well as three now decommissioned stations were obtained from (BC ENV, 2023c) and compiled annually. Concentrations were compared to current BC AAQO and CAAQS where applicable.

Table 4-2: Location of ambient air quality and meteorology stations in the TKV

Station Name	Station Location	
	Latitude (°N)	Longitude (°W)
Lakelse Lake (LKL)	54.37827	-128.5799
Kitamaat Haisla Village (KHV)	53.97323	-128.65077
Kitimat Haul Road (KHR)	54.02919	-128.70269
Kitimat Industrial Ave (KIA)	54.06100	-128.68800
Kitimat Riverlodge (KR)	54.05389	-128.67136
Kitimat Whitesail (KW)	54.06691	-128.63913
Kitimat Yacht Club (KYC)	54.00000	-128.69200
Kitimat Rail Station (KRS)	54.06110	-128.68720
Kitimat Smelter site Road (KSR)	54.01880	-128.70059
Terrace BC Access Centre (TBAC)	54.51830	-128.59750
Terrace Skeena Middle School (TSMS)	54.52167	-128.60750



Air Quality and Meteorology Monitoring Stations within the Proposed Airshed

True North

Drawn by: RCL	Figure: 7
Approx. Scale:	1:1,100,000
Date Revised:	Mar 6, 2023

Map Projection: WGS 1984 UTM Zone 9N

Kitimat Airshed Network Review - Kitimat, B.C.

Project #: 2105554

Map Document: D:\GIS\desktop\2105554_KitimatAirshed\P2105554_Kitimat.aprx

Table 4-3: Observed air quality and meteorological parameters at the currently active and historical stations in the TKV and the period during which these parameters have been monitored. All data for stations shown are reported on an hourly interval.

Station Name	Active or Historical Station	Air Quality parameters					Meteorology			
		SO_2	NO_2	O_3	$PM_{2.5}$	PM_{10}	Wind speed	Wind direction	Air temperature	Relative humidity
Lakelse Lake (LKL)	Active	2018-2021	-	-	-	-				
Kitamaat Haisla Village (KHV)	Active	2010-2021	-	-	2013-2021(1)	-	2011-2021	2014-2021	2011-2021	-
Kitimat Haul Road (KHR)	Active	1996-2021	-	-	2013-2021(1)	2020-2021(5)	1996-2021	1996-2021	1996-2021	-
Kitimat Industrial Ave (KIA)	Active	2020-2021	-	-	-	-	-	-	-	-
Kitimat Riverlodge (KR)	Active	2011-2021	-	-	2002-2021(2)	1998-2021(3)	2010-2021	2014-2021	2011-2021	-
Kitimat Whitesail (KW)	Active	2015-2021	2019-2021	2019-2021	2013-2021	-	1997-2021	1997-2021	1997-2021	2011-2021
Kitimat Yacht Club (KYC)	Active	-	-	-	-	-	2011-2021	2011-2021	2011-2021	-
Kitimat Rail Station (KRS)	Historical	1996-2010	1997-2010	1997(4)	2002-2010	1998-2010	-	-	-	-
Kitimat Smeltersite Road (KSR)	Historical	2012-2016	-	-	2013-2016(1)	-	-	-	2012-2016	2012-2016
Terrace BC Access Centre (TBAC)	Historical	-	-	-	2003-2015	1996-2015	1996-2015	1996-2015	1996-2015	2009-2015
Terrace Skeena Middle School (TSMS)	Active	2015-2021	2015-2021	2015-2021	2015-2021	-	2015-2021	2015-2021	2015-2021	2015-2021

Notes:

"-" indicates that the parameter is not measured at the station.
The periods indicated for each station-parameter pair include partial years and do not exclude any gaps in the record.
Only criteria air contaminants with applicable objectives are included in this table as per the focus of the review. Some stations may have monitor additional contaminants not included in this table.
(1): $PM_{2.5}$ is measured using a Beta Attenuation Monitor.
(2): $PM_{2.5}$ was measured using a TEOM during 2002-2013. The equipment was transitioned to a SHARP in 2013 with some overlap.
(3) PM_{10} was measured using a TEOM during 1998-2017. The equipment was transitioned to a SHARP in 2013 with a period of overlap from 2013 to 2017
(4): O_3 concentrations only available for part of 1997.
(5) The Kitimat Haul Road (KHR) station monitored PM_{10} over a period of time in 2020-21 during a campaign to replace aluminum smelting pots that were failing prematurely

4.2.1 Sulphur Dioxide (SO_2)

Annual average concentrations and 3-year rolling averages of annual 99th percentiles of daily 1-hour maximum (D1HM) concentrations of SO_2 are presented in Figure 8 and Figure 9, respectively, and are compared to the annual and 1-hour 2020 CAAQS.

Annual average SO_2 concentrations (shown in Figure 8) have remained below the 2020 annual CAAQS (5 ppb) since the inception of the monitoring program with the installation of the first monitor at Kitimat Haul Road station (KHR) in 1996. Annual average SO_2 concentrations at the KHR station have historically been higher than the future 2025 annual CAAQS (4 ppb). If historical trends continue to 2025, the annual average SO_2 will exceed the 2025 CAAQS. The Kitimat Haul Road station (KHR) station consistently measures the highest concentrations of any station except for the Kitimat Smeltersite Road station (KSR) during its short operating period. The high concentrations observed at KHR are likely related to the station's proximity to the aluminum smelter in the downwind direction. Observed concentrations have not shown a noticeably overall trend aside from a significant decrease from 2010 to 2015 when the Rio Tinto facility was undergoing modernization. The Kitamaat Haisla Village (KHV), Kitimat Riverlodge (KR), Kitimat Whitesail (KW), and the Terrace Skeena Middle School (TSMS) stations have all observed similarly low concentrations. Because of their lower concentrations and shorter time series, it is difficult to discern a clear trend for these stations, especially for the annual averages. These stations are likely far enough from sources of SO_2 that they are sampling background plus residual SO_2 from the sources that did not entirely clear out over longer periods and distances. For the daily one-hour maximum statistics, these stations appear to be trending similar to Kitimat Smeltersite Road station (KSR) which suggest that emissions of SO_2 from the smelter might occasionally reach the more distant stations in noticeable concentrations. The Kitimat Industrial Ave station (KIA) has only had one full year of observations, but so far, it is recording mid-level concentrations similar to those recorded at the Kitimat Rail Station (KRS) before it was decommissioned in 2010.

The 1-hour CAAQS (shown in Figure 9) is formulated as a 3-year average of the annual 99th percentile of daily 1-hour maxima serving as both an indicator of peak SO_2 concentrations and longer-term trends. Similar to annual averages, KHR consistently observed the highest peak concentrations (except for the Kitimat Smelter site (KSR)); with exceedances of the 2020 CAAQS (70 ppb) from 2004 to 2008 and from 2018 to 2021. There was no overall trend in peak SO_2 concentrations at KHR. An exceedance of the 2020 CAAQS was also observed at KSR in 2014, and there were no exceedances at any of the other stations. Peak concentrations were much lower and showed more inter-station variability than the annual averages. The highest peak concentrations have been observed at KRS and the lowest at TSMS. The Kitimat Riverlodge (KR) station is the only station with a discernable upward trend. All other stations exhibit no noticeable trend in peak SO_2 concentrations. Rio Tinto operates an SO_2 monitoring station at Lakelse Lake north of Kitimat which is not part of the BC ENV network. Hourly SO_2 data was available for June 2018 to current, thus three years (2019, 2020, and 2021) of the annual 99th percentile of daily 1-hour maxima for Lakelse Lake (LKL) is shown in Figure 9, with 1-, 2-, and 3-year averages, as available. The 1-hour SO_2 concentrations at LKL are slightly above those seen at Terrace Skeena Middle School (TSMS).

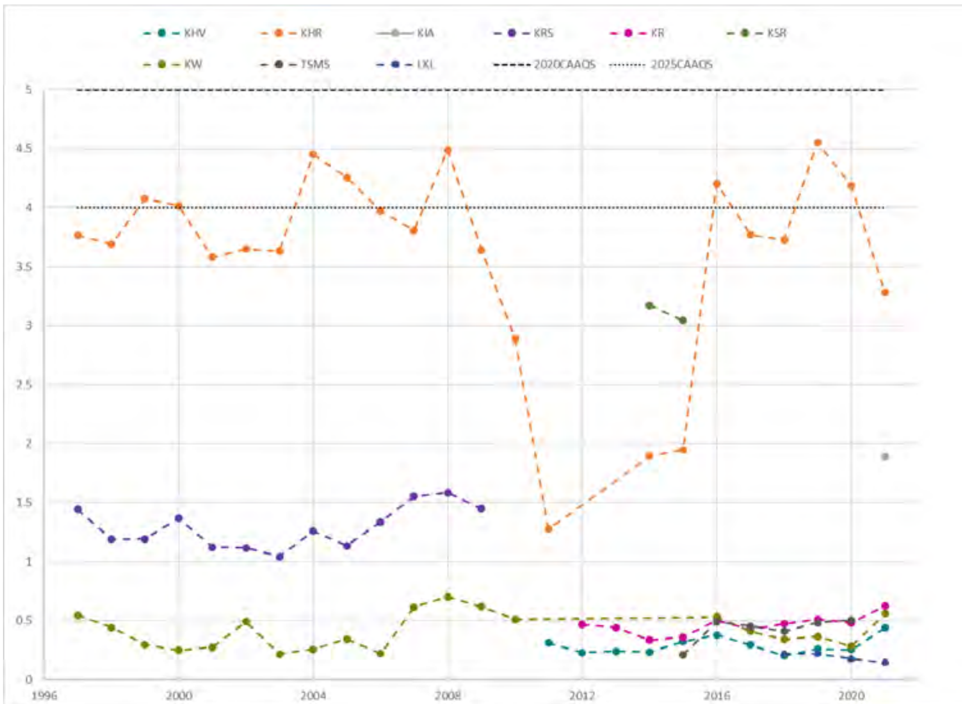


Figure 8: Annual average SO_2 concentrations.

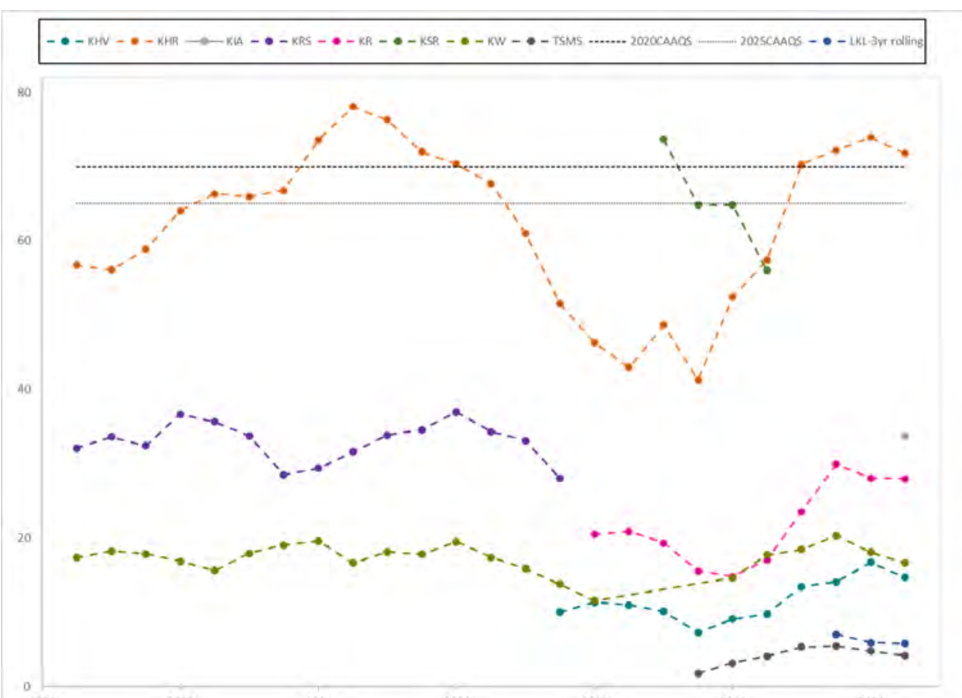


Figure 9: 3-year rolling averages of the annual 99th percentile of the D1HM of SO_2 concentrations.

Note:

Partial averages were allowed for periods that did not have 3 complete years of data for the purpose of better following the trends. E.g., SO_2 concentrations at Kitimat Haul Road station (KHR) were less than 75% complete in 2012 and 2013. As a result, the 3-year averages shown in the figure are 2010-2011 in 2012, 2011 in 2013, 2014 in 2014 and 2014-2015 in 2015.

4.2.2 Nitrogen Dioxide (NO_2)

Annual average concentrations and 3-year rolling averages of annual 98th percentiles of daily 1-hour maximum (D1HM) concentrations of NO_2 are presented in Figure 10 and Figure 11, respectively, and are compared to the annual and 1-hour 2020 CAAQS.

Annual average concentrations are far below the annual 2020 CAAQS (17 ppb) and future 2025 CAAQs (12 pbb) at both stations. At this point, spatial and temporal coverage of NO_2 measurements in the TKV are too limited to draw substantial conclusions. The Terrace Skeena middle School (TSMS) station has exhibited a decreasing trend since 2018 whereas NO_2 concentrations at the Kitimat Whitesail (KW) station increased from 2020 to 2021. As this station continues to operate, there should be a better opportunity to identify the long-term trends in the area. The KRS station provides some additional historical context, showing a generally decreasing trend from 1998 through to 2009.

Much like those for SO_2, the 1-hour NO_2 CAAQS are formulated to keep a long-term view on peak concentrations. Neither station has recorded any exceedances of the 1-hour 2020 CAAQS (60 ppb) since their inception and all recorded values are below the 2025 CAAQS (42 ppb). Similar ranges of peak concentrations are observed at the TSMS station as there were at the KRS station when it was in operation. Peak concentrations at both currently operating stations (TSMS and KW) decreased from 2020 to 2021.

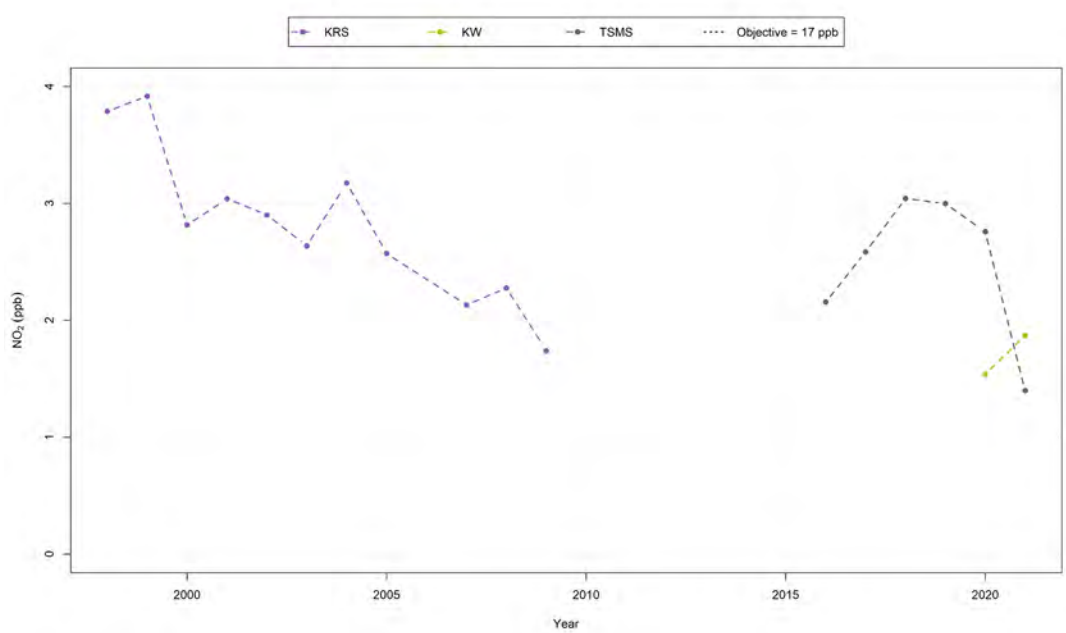


Figure 10: Annual average NO_2 concentrations.

Note:

The annual CAAQS thresholds of 12 and 17 ppb are not shown on this plot because of the large difference in concentrations that would have resulted in more difficulty in viewing the plot.

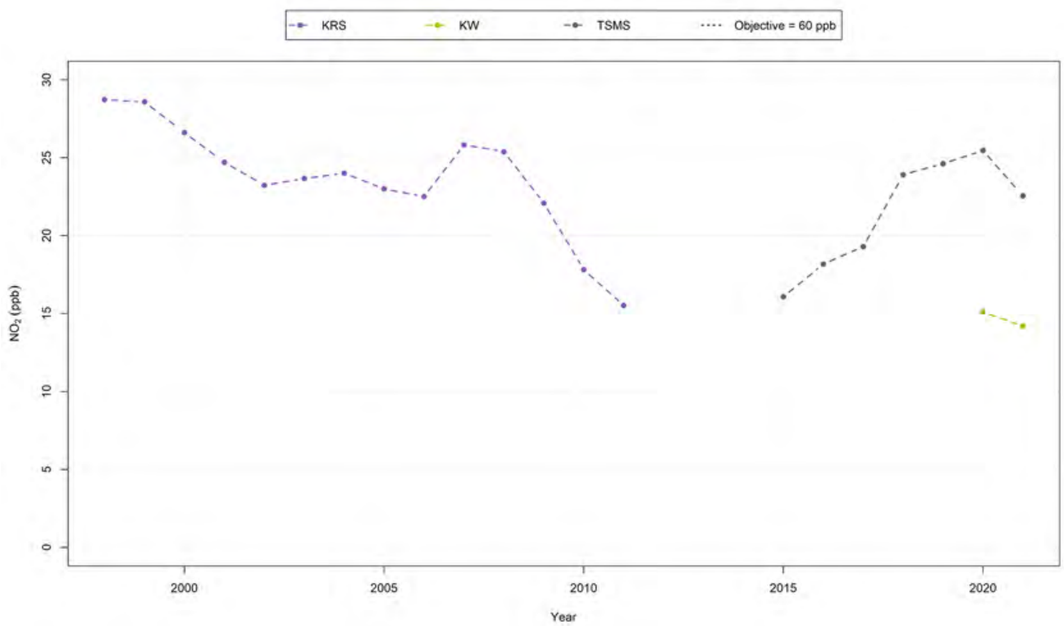


Figure 11: 3-year rolling averages of the annual 98th percentile of the D1HM of NO_2 concentrations.

Notes:

[1] Partial averages were allowed for periods that did not have 3 complete years of data for the purpose of better following the trends. E.g., the first year of observations at TSMS was 2015 and the value displayed in the figure above is the 98th percentile of D1HM in 2015. In 2016, it is the rolling average of 2015 and 2016 and in 2017 and onward, the values displayed are the full 3-year averages.

[2] The CAAQS thresholds of 42 and 60 ppb are not shown on this plot because of the large difference in concentrations that would have resulted in more difficulty in viewing the plot.

4.2.3 Ozone (O_3)

Annual average concentrations and 3-year rolling averages of the annual 4th highest daily 8-hour maximum (D8HM) concentrations of O_3 are presented in Figure 12 and Figure 13, respectively, and are compared to the 1-hour 2020 CAAQS. Ozone data from an additional station from outside of the airshed, St. Joseph's station (SSJ) in Smithers, BC, is also presented. The SSJ station was used in the work by Weinstein and is presented to compare to concentrations observed at stations added within the TKV since that work was completed.

Annual average concentrations show no discernable trend over time at either the KW or TSMS station. Concentrations are similar at both stations. The annual averages at TSMS and KW were higher than observed at SSJ in 2016 and 2017. The 8-hour peak concentrations of O_3 are lower at TSMS and KW than at SSJ for 2015 through 2019.

Peak concentrations, illustrated by the 8-hour CAAQS metric, fall well below the 8-hour 2020 CAAQS (62 ppb) and future 2025 CAAQS (60 ppb). There is no discernable trend over time and concentrations are marginally greater at the TSMS station than at KW for the 2 years for which there was overlap.

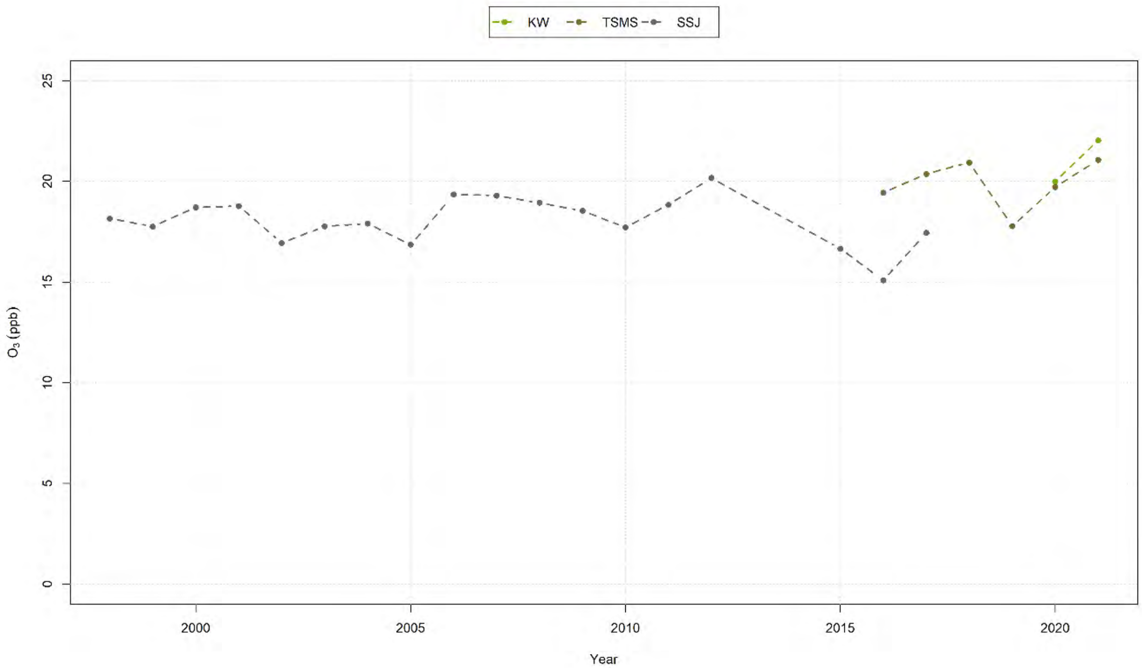


Figure 12: Annual average O_3 concentrations.

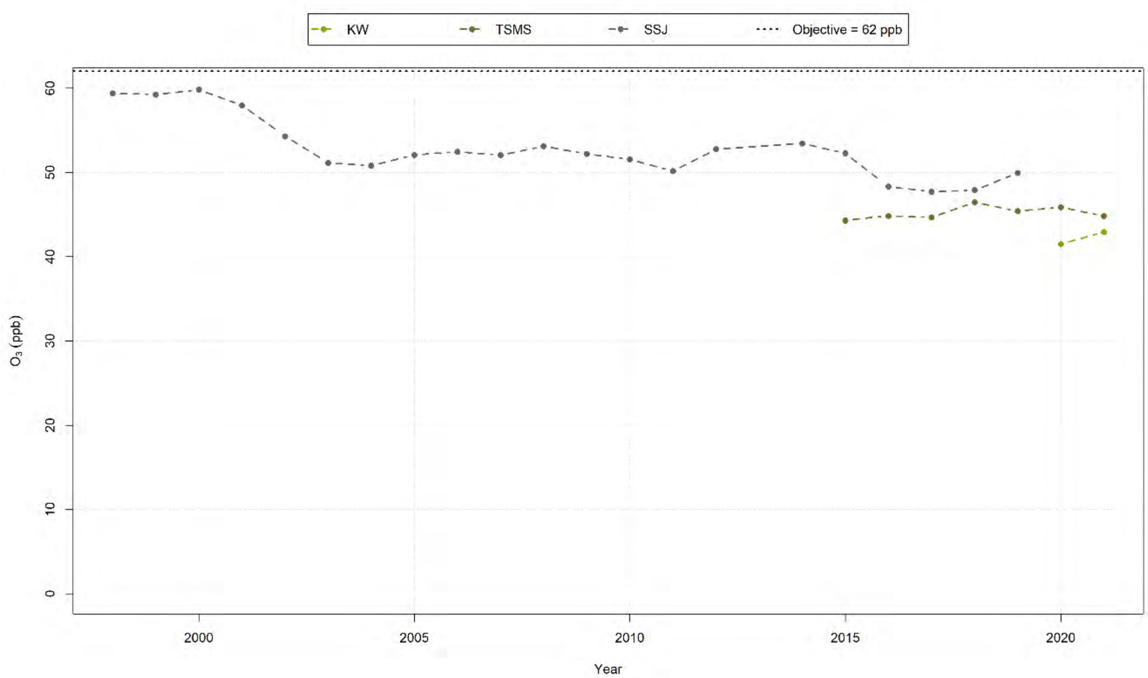


Figure 13: 3-year rolling averages of the annual 4th highest daily 8-hour maximum O_3 concentration.

Note:

Partial averages were allowed for periods that did not have 3 complete years of data for the purpose of better following the trends. E.g., the first year of observations at TSMS was 2015 and the value displayed in the figure above is the 4th highest D8HM in 2015. In 2016, it is the rolling average of 2015 and 2016 and in 2017 and onward, the values displayed are the full 3-year averages.

4.2.4 Particulate Matter of a Diameter less than 2.5 µm ($PM_{2.5}$)

Annual average concentrations and annual 98th percentile of 24-hour average concentrations of $PM_{2.5}$ are presented in Figure 14 and Figure 15, respectively, and are compared to the annual (8 µg/m^3) and 24-hour (25 µg/m^3) BC ambient air quality objectives (BC AAQO). The BC AAQO are used here instead of the CAAQS, because the former are more conservative thresholds to judge airshed health. Both plots show a discontinuity between a first set of stations/instruments that were decommissioned by 2015 (last valid annual average in 2014) and another set of stations that has come online since 2013 (first valid annual average in 2014) but in different locations. Only the Kitimat Riverlodge (KR) station spans the period shown in Figure 14 and Figure 15. However, the station was equipped with a Tapered Element Oscillating Microbalance (TEOM) in its first several years of operation, which was replaced by a newer Federal Equivalent Method (FEM) BAM 1020 instrument after 2013. Results from these instruments are not directly comparable: for example, Metro Vancouver (2022) indicates consistently and significantly lower concentration readings from the TEOMs in comparison to newer FEM instruments.

The Kitimat Smeltersite Road (KSR) station recorded an exceedance of the annual BC AAQO for $PM_{2.5}$ in 2014. There were no other exceedances at any of the other stations. Annual average $PM_{2.5}$ concentrations at Kitimat Smeltersite Road (KRS), Terrace BC Access Centre (TBAC), and the TEOM at Kitimat Riverlodge (KR) show no trend, and the three stations recorded similar concentrations (2001-2014). All stations agree with an overall downward trend in the period during which they have been operating since 2014.

The annual 98th percentile of 24-hour daily average $PM_{2.5}$ concentrations show more inter-station and inter-annual variability than was observed for the annual averages. Nonetheless, overall trends are similar: stations operating prior to 2014 show no discernable trend in $PM_{2.5}$; concentrations at stations operating after 2014 agree with an overall downward trend over time.

Wildfires can substantially increase ambient PM concentrations with important implications for human health. However, to assess the effectiveness of mitigation measures for anthropogenic PM, it is desirable to remove wildfire episodes from the data. We plotted time series of daily box and whisker plots from all available stations for $PM_{2.5}$ and PM_{10} from June 1 through September 30 of each calendar year. The time series did not show extended periods of elevated statistics that could be clearly identified as wildfires. This simplified approach leaves the possibility that wildfires had weaker impacts on PM concentrations for periods of up to a few days. For example, in 2018, an approximately one-week period of elevated PM was observed in July, and two extremely elevated two- to three-day events were observed in August/September. A detailed inspection of concurrent time series of different air contaminants and known periods of wildfires would be required to confirm the impact of wildfires which was beyond the scope of this network review. In conclusion, it is possible that wildfires contributed somewhat to the year-to-year variability of the 24-hour statistics, but it is unlikely that they noticeably affected annual averages.

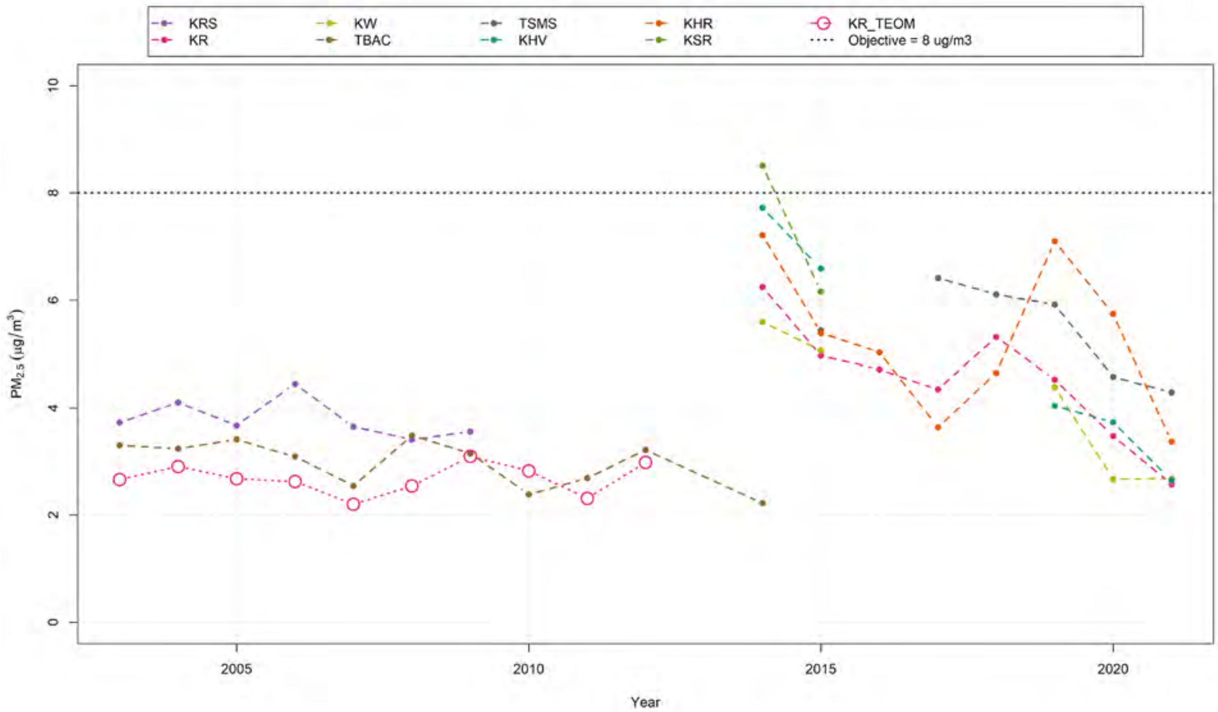


Figure 14: Annual average $PM_{2.5}$ concentrations.

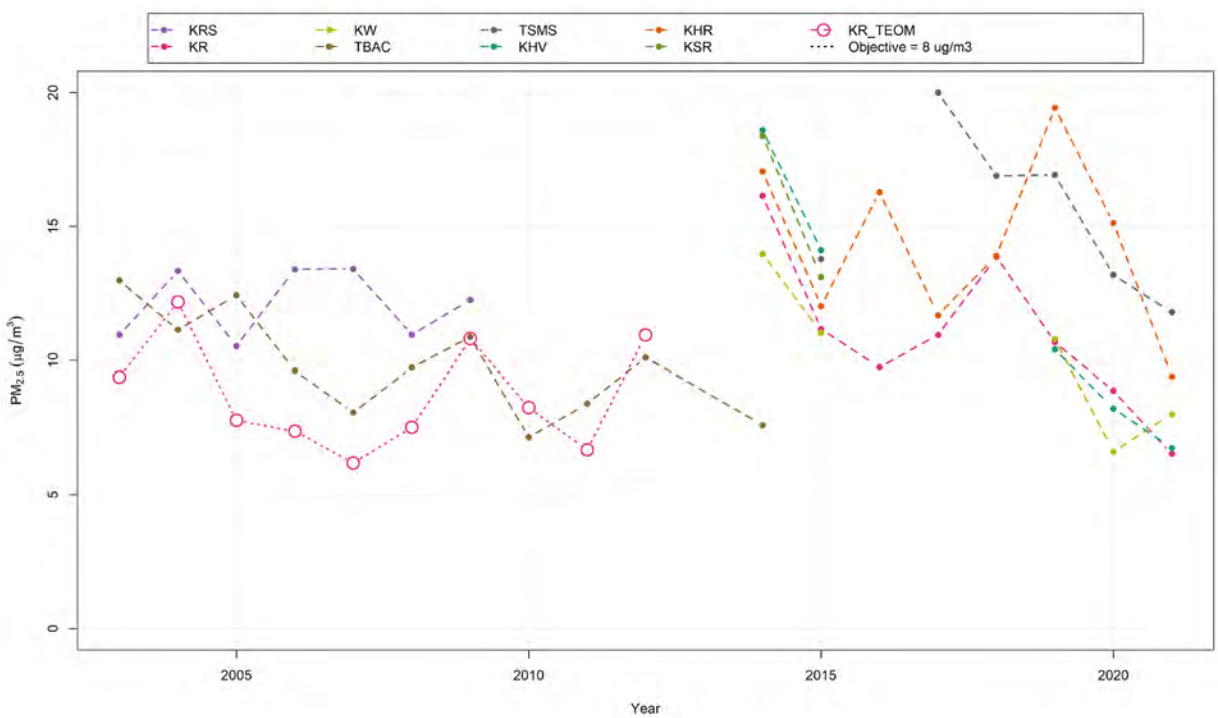


Figure 15: Annual 98th percentile of 24-hour daily average $PM_{2.5}$ concentrations.

Note:

The BCAAQO threshold of 25 µg/m³ is not shown on this plot because of the large difference in concentrations that would have resulted in more difficulty in viewing the plot.

4.2.5 Particulate Matter of a Diameter less than 10 µm (PM_{10})

Annual average concentrations and annual maxima of 24-hour average concentrations of PM_{10} are presented in Figure 16 and Figure 17, the latter including a comparison with the 24-hour BC AAQO. PM_{10} is also measured at the Kitimat Haul Road (KHR) station, but data was not included as the station had less than 50% data completeness in 2020 and 2021.

Annual average PM_{10} concentrations do not show any general trend prior to 2014. Onward from 2014, measurements at Kitimat Riverlodge (KR) show a decline over time.

The Kitimat Rail Station (KRS) and Terrace BC Access Centre (TBAC) recorded exceedances of the 24-hour BC AAQO for PM_{10} over many of the years during which those stations were operating. Kitimat Riverlodge (KR) also exceeded the 24-hour BC AAQO in 2014, but concentrations have since remained below the threshold. For comparison purposes, the TEOM at Kitimat Riverlodge (KR) did not record any exceedance in 2014, and peak PM_{10} concentrations (even more so for the annual averages) are lower for the TEOM than they are for the newer FEM instrument. There are no noticeable trends in peak PM_{10} concentrations in the period examined by this study.

The number of annual exceedances of the 24-hour PM_{10} objective are shown in Figure 18. The Kitimat Riverlodge (KR) station has both a TEOM and a newer BAM1020 instrument for PM10. No annual exceedances of the 24-hour PM_{10} objective were recorded by the TEOM at the KR station and thus, is not shown in Figure 18.

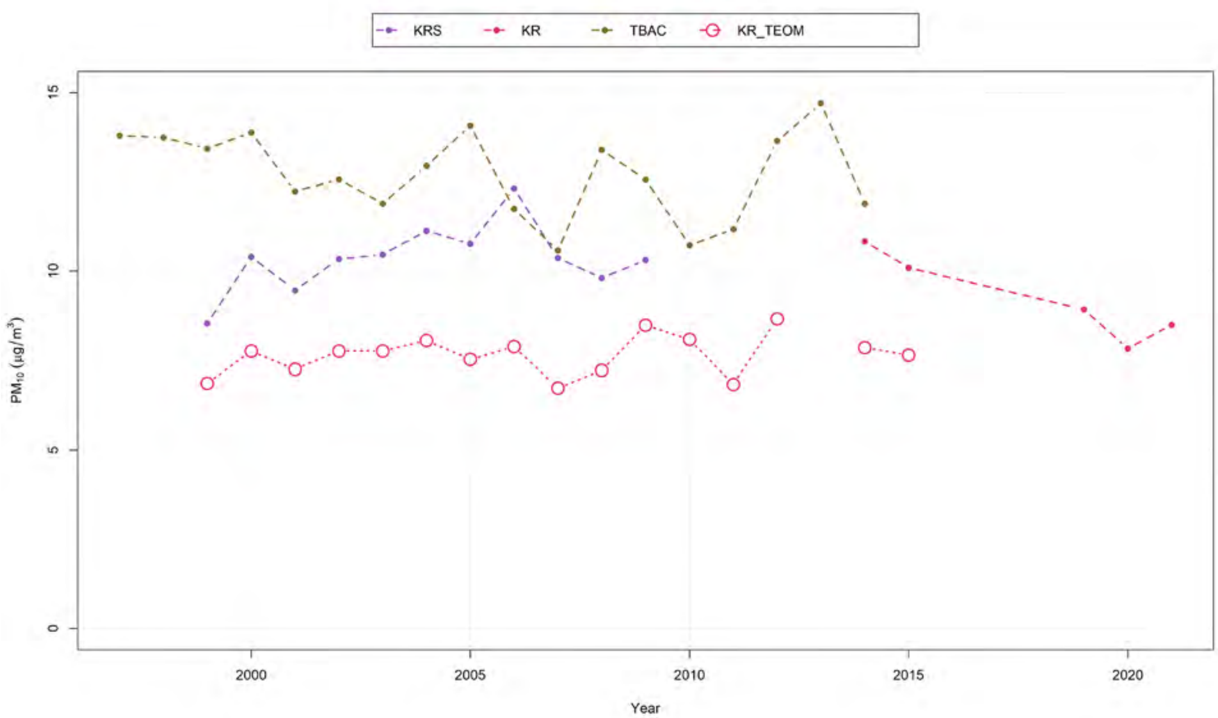


Figure 16: Annual average PM_{10} concentrations.

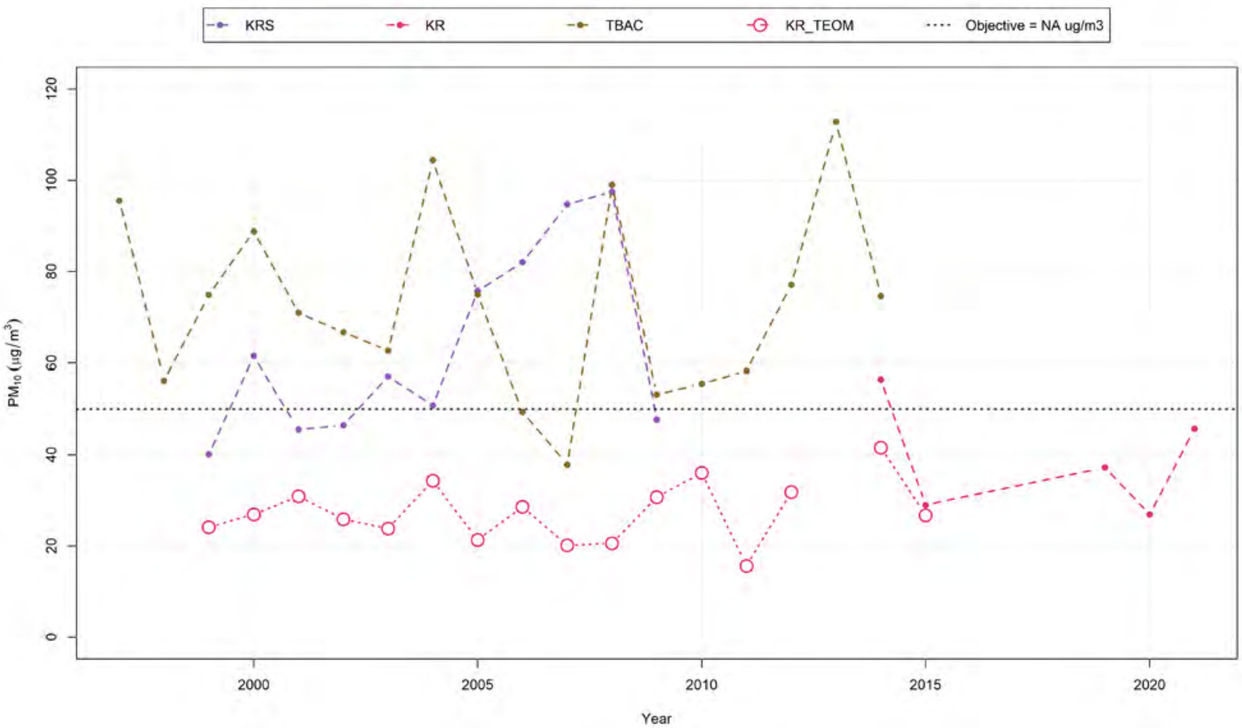


Figure 17: Annual maxima of 24-hour average PM_{10} concentrations.

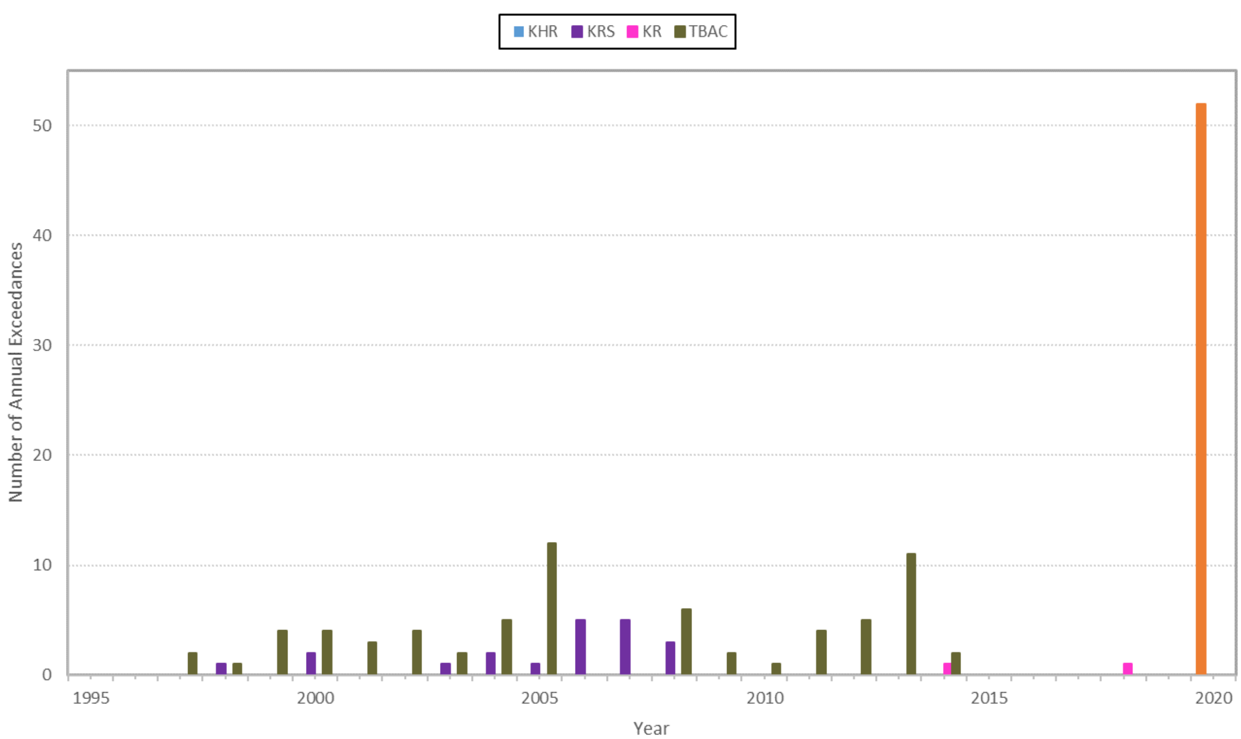


Figure 18: Annual exceedances of the 24-hour PM_{10} Objective

4.3 Air Quality Health Index (AQHI) and AQHI-Plus

The Air Quality Health Index (AQHI) is a tool used to communicate the health risks associated with short-term exposure to a mixture of pollutants in the air. A higher index value indicates a higher health risk associated with the air quality. The index is split into four qualitative Health Risks Categories that cover a range of numerical values: Low (1-3), Moderate (4-6), High (8-10), and Very High (10+). Each category has an associated health message which provides advice for how individuals can reduce exposure to air pollutants (Environment and Climate Change Canada, 2015)The health messages are tailored separately for the general population and the “at-risk” population (those with respiratory or cardiovascular illness, as well as the elderly, children, people who are pregnant, and anyone sensitive to air pollutants).

In British Columbia, the reported value of the AQHI is based on an “AQHI-Plus” system. With the exception of Kitimat, the reported value is taken only as the maximum of: (1) the “AQHI-Classic”, which is calculated using a formula that incorporates the rolling average of the past 3 hours of ambient concentrations of $PM_{2.5}$, O_3, and NO_2 from a single monitoring location (Stieb, et al., 2008) and (2) the “AQHI-$PM_{2.5}$”, which is calculated by dividing the most recent 1-hour $PM_{2.5}$ concentration by 10, then rounding up to the nearest integer on the AQHI scale (Yao, Steib, Taylor, & Henderson, 2019). This AQHI-Plus for $PM_{2.5}$ was originally developed to better reflect the rapid changes in $PM_{2.5}$ during periods of severely degraded air quality due to wildfire smoke and the need for appropriate health messaging during these periods. After an initial pilot period it was implemented on a year-round basis.

In Kitimat, a third formulation is employed that incorporates SO_2 (at times referred to as the “AQHI-SO_2”). This formulation was developed to alert the public to periods of elevated SO_2 in Kitimat. It is based on predefined thresholds of 1-hour SO_2 concentrations, which can result in an adjusted AQHI value and/or a “Special Note” in place of the standard AQHI message (Table 4-4). The AQHI system in Kitimat is often referred to as the “AQHI-Plus for SO_2”, and it is part of the Kitimat SO_2 Alert Pilot Project (BC ENV., 2022).Under the pilot program, the AQHI value reported to the public is the highest value of (1) AQHI-Classic from ambient data at Whitesail, (2) AQHI-$PM_{2.5}$ from ambient data at Whitesail, and (3) AQHI-SO_2 from the maximum 1-hour SO_2 concentrations measured at Whitesail, Riverlodge, and Haisla Village.

Table 4-4: AQHI reporting method for the AQHI-Plus for SO_2 system. The AQHI is based on $PM_{2.5}$, NO_2, and O_3 (as either AQHI-Classic or AQHI-$PM_{2.5}$). A Special Note is only added when additional guidance is required beyond the standard AQHI messaging when SO_2 concentrations are high. Taken from BC ENV (2022).

1-hour SO_2 (ppb)	AQHI	AQHI SO_2	Reported AQHI (AQHI-Plus)	Special Note
0 – 35	1 – 10+	N/A	AQHI	N/A
36 – 184	1 – 3	N/A	AQHI	*
	4 – 10+	N/A	AQHI	N/A
≥ 185	1 – 6	7	7	**
	7 – 10+	7	AQHI	N/A

Special Notes:

* Elevated levels of sulphur dioxide have been reported. Persons with chronic respiratory conditions such as asthma should consider reducing or rescheduling outdoor activities if experiencing symptoms. No effects are expected for the general population. For more information, visit B.C.'s Ministry of Environment and Climate Change Strategy.

** Elevated levels of sulphur dioxide have been reported and the AQHI has been adjusted to reflect an increased health risk for both sensitive populations and the general population. Consider reducing or rescheduling strenuous outdoor activities if experiencing symptoms. For more information, visit B.C.'s Ministry of Environment and Climate Change Strategy.

4.4 Meteorological Monitoring Network

Air temperature and wind speed and direction are recorded at five of the seven stations with air contaminant monitoring within the TKV as listed previously in Table 4-3. Additionally, Kitimat Yacht Club (KYC) is a dedicated meteorological station. Meteorological data is monitored currently at the following stations by the Meteorological Services of Canada (MSC) at Environment Canada and Climate Change (ECCC): Kitimat Hatchery, Kitimat 2, Kitimat Townsite, and Kitimat Forest Avenue with the parameters as shown in Table 4-5.

Table 4-5: Meteorological Parameters Measured at ECCC-MSC Stations in Kitimat

Station Name	Station location		Meteorology			
	Latitude (°N)	Longitude (°W)	Wind speed	Wind direction	Air temperature	Relative humidity
Kitimat 2	54.01	-128.71	-	-	1966-Current	-
Kitimat Forest Ave	54.05	-128.63	2020-Current	2020-Current	2020-Current	2020-Current
Kitimat Hatchery	54.04	-128.68	-	-	1995-Current (Incomplete dataset)	-
Kitimat Townsite	54.05	-128.63	-	-	1954-Current (Incomplete dataset)	-

Climate Normals for the 30-year period from 1990-2010 for the Kitimat Townsite and Kitimat 2 are available from Environment Canada. A summary for the monthly long-term mean temperature and precipitation for Kitimat townsite is shown in Figure 19. Climate Normals Data from Kitimat 2 are similar.

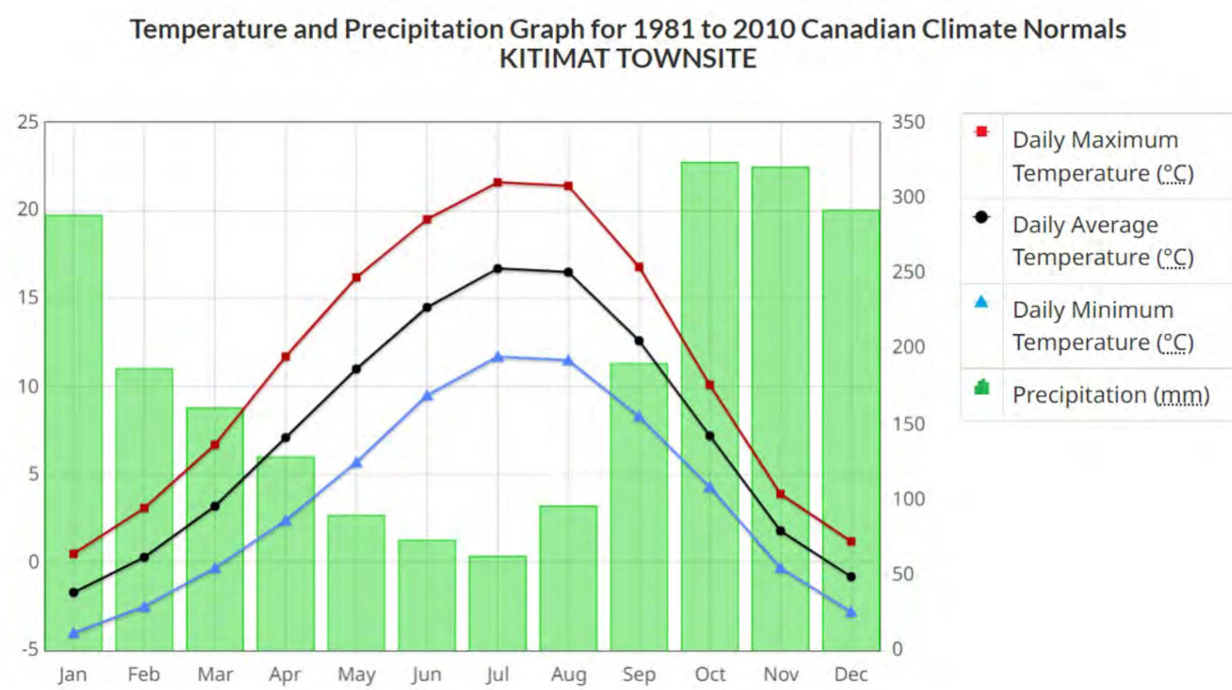


Figure 19: Climate Normals for Kitimat Townsite 1990-2010 from MSC-ECCC.

Average temperature is well below 22° C for all months, with the highest average of 16.7° C occurring in July. Monthly averages are above 10°C from May through September. Average temperature is below 0° C for December and January. Precipitation is highest in winter month, but on average there is still sufficient rain in summer for there to not be a clear wet and dry season.

The longest sufficiently complete wind records – dating from 1997–- are from Kitimat Haul Road (KHR) and Kitimat Whitesail (KW). The series of annual wind roses for the period of record from each station are shown in Figure 20 and Figure 21, respectively. Both stations show the dominance of Northerly and Southerly wind directions aligning with the general orientation of the valley. Wind directions at Kitimat Haul Road (KHR) are rotated slightly compared to Kitimat Whitesail (KW), reflecting the location of the Kitimat Haul Road (KHR) station closer to the western valley slope and the slight turn of the valley in that area. Note that for the purpose of a general characterization of winds in this section, no data QA or completeness checks were performed before generating Figure 20 to Figure 22. However, the first year of operation at Kitimat Haul Road (KHR), 1996, was removed, because it was missing too much data to be meaningful.

Figure 22 shows wind roses for the entire period of record at Kitimat Whitesail (KW) broken out by season. In the winter there is a stronger northerly component, while in summer there is stronger southerly component.

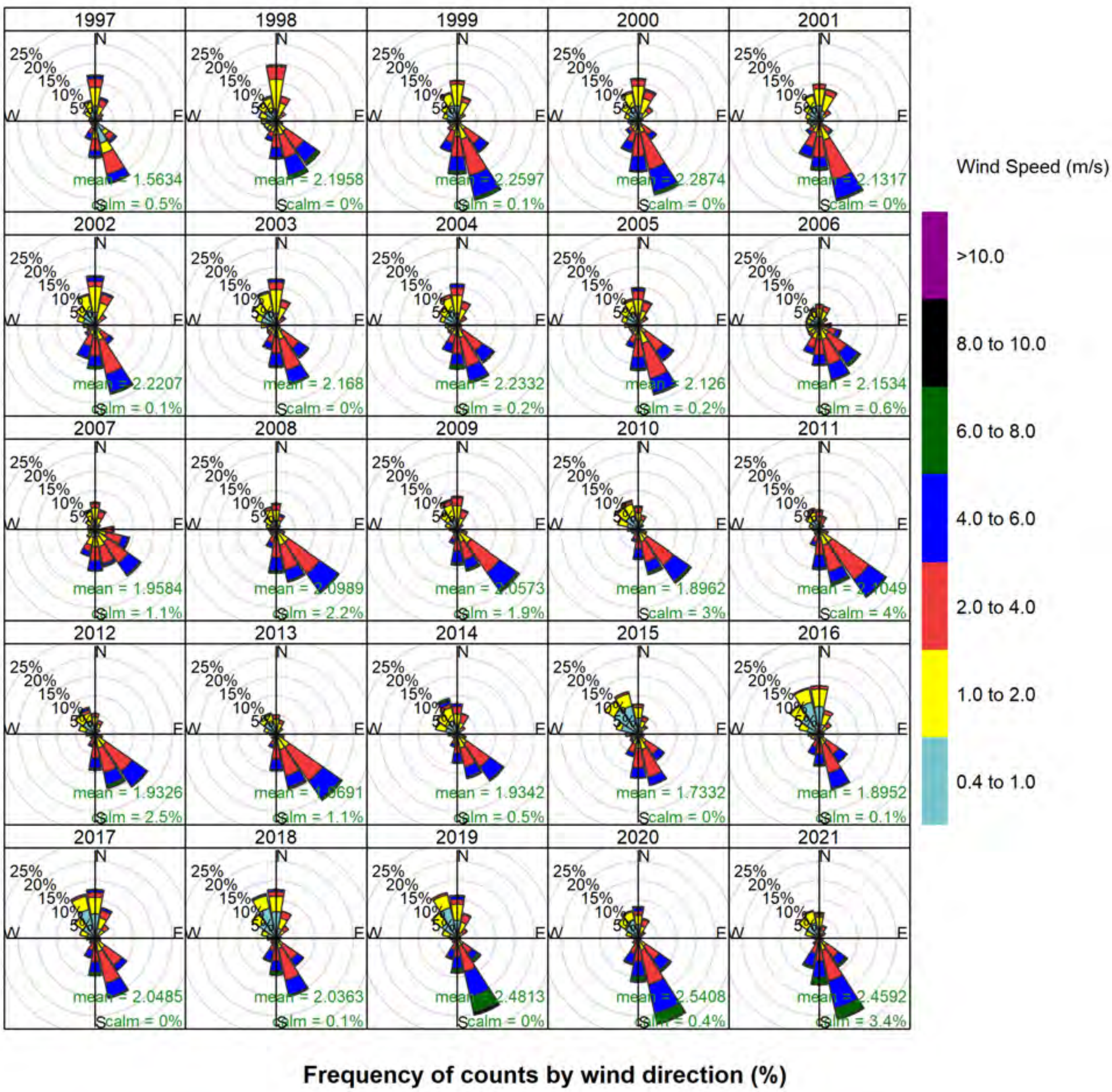


Figure 20: Annual Wind Roses measured at Kitimat Haul Road (KHR), 1997-2021.

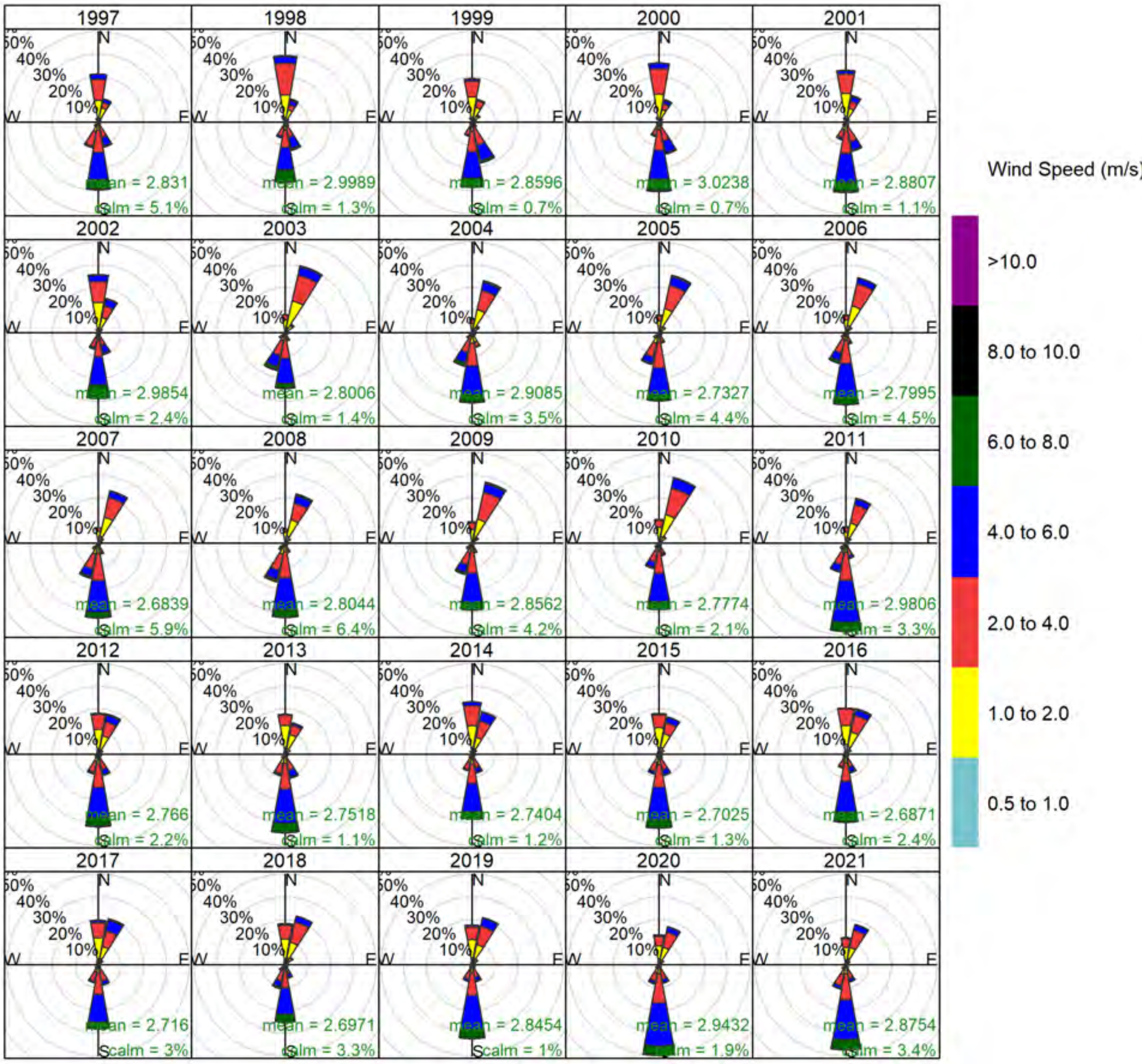


Figure 21: Annual Wind Roses measured at Kitimat Whitesail (KW), 1997-1921.

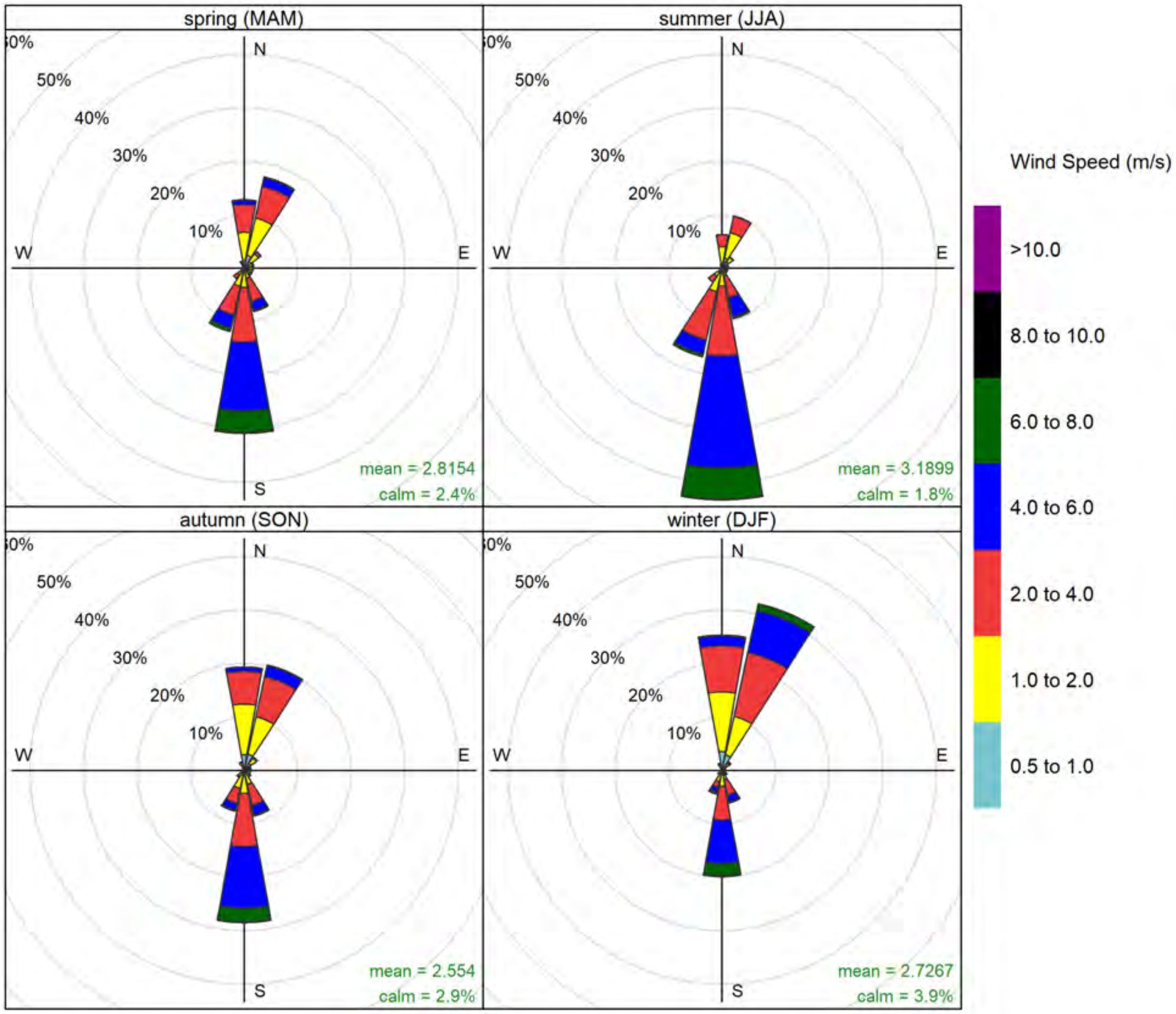


Figure 22: Seasonal Wind Roses for Kitimat Whitesail (KW), 1997-2021.

4.5 Passive Sampling Air Monitor Network

Two different groups have been conducting passive monitoring in the KTV: Rio Tinto has conducted passive SO_2 monitoring, and the Kitimat Terrace Clean Air Coalition (KTCAC) has conducted both SO_2 and NO_2 passive monitoring.

4.5.1 SO_2 Passive monitoring by Rio Tinto

As part of the EEM monitoring program, Rio Tinto conducts passive SO_2 monitoring to collect information on the spatial variation in SO_2 concentrations. The EEM review included a review of Rio Tinto's passive SO_2 network over the period 2016-2018. Section 2.4.3 presents the passive network and findings as part of the work completed by ESSA. Over the three-year period, 240 passive samplers were deployed (including 50 duplicate exposures) in two networks, Valley and Urban (see Section 2.4.3 for further description).

Concentrations from the passive samplers were compared to those from the continuous sampling stations with good agreement. The highest SO_2 concentrations were observed closest to the smelter and followed a logarithmic decay with distance from the smelter. The average yearly spring-autumn concentrations from the passive monitoring ranged from 0.53 ppb to 5.17 ppb, with an average of 2.23 ppb in the Valley network. The average yearly spring-autumn concentrations from the passive monitoring ranged from 0.26 ppb to 0.59 ppb, with an average of 0.42 ppb in the Urban network.

The ESSA review of the EEM Program recommended continuing the passive sampling network to provide information on spatial variability and to allow evaluation of the CALPUFF model performance. The ESSA review also recommended adding passive sampling sites to the east and west of the current sites located to the north of the smelter (possibly by relocating sites from the north–south network). The review recommends evaluating if additional sites can be established south of the smelter to align with biodiversity plots.

The comprehensive passive sampling network provides spatial variability and agreement to the continuous network, which confirms the locations of the continuous SO_2 monitoring. The passive sampling conducted by Rio Tinto does not indicate the need for additional continuous SO_2 monitoring locations, aside from the recently added Kitimat Industrial Avenue (KIA) station.

4.5.2 Passive monitoring by the Kitimat Terrace Clean Air Coalition

The Kitimat Terrace Clean Air Coalition (KTCAC) conducted passive air quality sampling in Terrace and Kitimat during the summers of 2018 through 2021. 2021 represents KTCAC's fourth summer of SO_2 sampling and first summer of NO_2 sampling. The 2021 Passive Air Sampling Report (Stannus, 2022) was reviewed for this work.

The KTCAC passive network includes 13 samplers. The biggest challenge with passive sampling – at least for gaseous pollutants like SO_2 and NO_2 – is the time average, which does not match any published or enforced objectives. The approximate 1-month sample is not suitable for comparison against objectives based on shorter averaging periods such as 1-hour objectives, because the annual average of 1-hour average concentrations does not provide any information on the spread of 1-hour averages and their annual maxima or high percentiles. The annual average of twelve continuous 1-month averages should be equal to the annual average of continuously sampled 1-hour averages. However, twelve consecutive calendar months of passive sampling are unavailable, and passive sampling over the summer months, only, might not be representative of an annual average since SO_2 concentrations could vary seasonally.

The passive sample results are very low. It most cases, the 30-day samples for SO_2 and NO_2 are in the range of 1 ppb or less. For SO_2, out of 48 total samples, there was one sample above 2 ppb and one above 3 ppb, versus the 2020 CAAQS annual average objective of 5 ppb. These results are in general agreement with most of the continuous measurements shown in Figure 8 above except for the highest observations at Kitimat Haul Road (KHR). The highest concentrations from the 1-month samples were measured at the Kitimat River dyke at Saunders (KTCA21-04) and the Claque Mt. Trail at the BC Hydro right of way (KTCAC21-11A). The passive sampler at Kitimat River dyke at Saunders (KTCA21-04) is located very near to the Kitimat Industrial Avenue (KIA) station, which also showed SO_2 concentrations higher than those in the populated area of Kitimat in 2021. The passive sampler at Claque Mt. Trail at the BC Hydro right of way (KTCAC21-11A) had the highest SO_2 concentrations and was located northwest of the KIA station.

Modelling conducted in the literature review has predicted higher concentrations in this area, consistent with the passive sampling results. Although SO_2 concentrations from these two passive samplers are relatively higher than those observed at the other passive samplers, the concentrations are well below predicted concentrations. Continuing to conduct passive sampling near the Claque Mt. Trail sampler is warranted.

For NO_2, out of 16 total samples, there were 2 above 2 ppb, versus the 2020 CAAQS annual average objective of 17 ppb.

The 4-month averages (average of four 1-month samples at each location) were similarly very low. For SO_2, among the 13 locations, there was a single site at which the 4-month average was above 1 ppb, versus an annual objective of 5 ppb. For NO_2, among the 4 locations there was also a single site at which the annual average was above 1 ppb, versus the 2020 CAAQS of 17 ppb.

These values indicate good air quality (meaning well below any published objectives) over the time periods sampled and suggest that the annual objective would likely not be exceeded were such measurements available. As noted above, it is impossible to infer from the 1-month samples if 1-hour average concentrations would meet the objectives.

There are 720 hours in month. The 1hr CAAQS objectives for SO_2 and NO_2 are 70 and 60 ppb. This means a single excursion above the CAAQS level would raise the 30-day average by about 0.1 ppb. With 30-day values in the range of 1 ppb, any such excursion would have to be minimal in number, and ambient concentration would have to be approximately zero otherwise. This is not likely.

The same is true of the annual averages in that ambient concentrations in remainder of the year would have to orders of magnitude higher than what was measured over the four-month campaign. For SO_2, the average over the remaining 8 months would need to be > 7ppb (versus 4-month average of at most 1.4ppb); that's possible but unlikely. For NO_2, the average over the remaining 8 months would need to be > 25 (versus 4-month average of at most 1.9ppb); again, that's possible but highly unlikely.

4.6 Attainment of Objectives for the Monitoring Network

The TKV airshed ambient air quality network monitoring objectives include requirements, objectives, and guiding principles for the network shown in Table 4-1 in section 4.1 above.

4.6.1 Data Quality and Spatial Coverage

The requirements for data quality and spatial coverage include that the monitoring network should:

- meet the needs of stakeholders and allow them to make decisions about air quality management based on representative and credible data;
- be based on credible data that are free of measurement bias; have gone through necessary quality control (QC), quality assurance (QA) and validation processes; and that annual reporting requirements have been met;
- provide appropriate geographical coverage to allow the understanding of air quality impacts from current and foreseeable future emission sources (including expected climate change impacts); and
- strive to reduce redundancy.

Stakeholders include industry, government regulators, air quality researchers, and the public. The interests of stakeholders include determining the impact of air emission from industrial sources for air quality management and regulatory purposes and understanding potential air quality impacts experienced by the public. The monitoring network meets the needs of the stakeholders if it contains representative and credible data.

From the literature and modelling reviewed, the current network (including the addition of KIA station in 2020) is well situated to capture SO_2 concentrations as they may impact human population. Existing ambient stations were shown to be located close to the locations of model predicted peak concentrations. Additionally, agreement between passive and continuous monitoring further confirmed that peak concentrations are captured by the continuous network. Specifically, modelling by Onwukwe and ESSA et al showed peak SO_2 concentration west and north of the smelter (see Figure 3-13 of (ESSA Technologies Ltd. et al, 2020), and west of Kitimat. The ESSA et al EEM review concluded that the continuous monitoring network is capturing the highest SO_2 concentrations near the fence line of the smelter (at KHR) and within the town of Kitimat (at KR). ESSA et al modelling predicted higher SO_2 within the service center area of Kitimat than at KR, as is now captured by the KIA station added in 2020. The review also found that the Kitamaat Haisla Village station is appropriately placed. ESSA et al review found agreement between passive and continuous sampling and with the updated (CALPUFF) modelling. There is also agreement in the trends observed between the continuous stations and the passive sampling conducted by KTCAC (based on the limited one year of passive data reviewed).

$PM_{2.5}$ is measured at five sites within the airshed, and modelling confirmed that station locations are suitable to capture peak $PM_{2.5}$ in the airshed. Onwukwe's modelling produced $PM_{2.5}$ annual mean and 98th percentiles of daily concentrations with 11% of the observed values. This work predicted $PM_{2.5}$ peak concentrations near the KHR, KR, and KW stations in Kitimat; and near TSMS and the unpopulated islands southwest of Terrace along the Skeena River (as shown in Figure 7 of (Onwukwe & Jackson, 2021)). The peak annual $PM_{2.5}$ concentration exceeded the AAQO in 2015 at the now closed KSR, and (annual and 24-hour) peaks are now captured by KHR in Kitimat, and TSMS in Terrace.

Although monitoring of PM_{10} is currently limited, additional monitoring is not warranted. PM_{10} is currently monitored at the Kitimat Riverlodge station (KR). The Kitimat Haul Road (KHR) station monitored PM_{10} in 2020-21 during a campaign to replace aluminum smelting pots that were failing prematurely. Historically, PM_{10} was also monitored at KRS in Kitimat and TBAC in Terrace. There are no Canada wide standards for PM_{10}, only provincial AAQOs. PM_{10} typically tracks with $PM_{2.5}$, as is seen at the historical KRS and KR TEOM stations.

For the current and near future emissions (including LNG Canada), the NO_2 monitoring network is deemed to be suitable. Additional NO_2 monitoring may be warranted should NO_2 concentrations approach Objectives, if significant additional emission sources be added to the airshed, or to better understand the NO_2/O_3 pattern within the airshed. Ambient NO_2 is currently monitored at one station in Kitimat (KW) and one station in Terrace. The annual average and 1-hour concentrations at all current and historical stations have been well below the current (2020) and future (2025) CAAQS. The addition of LNG facilities in the region will introduce additional NO_2 emissions into the airshed and is predicted to increase NO_2 concentrations.

Modelling by Onwukwe (as shown in Figure 8.3 of (Onwukwe C. , 2020) for ERA5) shows the relative change in NO_2 concentration potentially increasing up to 150% in a plume extending geographically northward to Lakelse Lake.

The modelling by Onwukwe also showed annual peaks in NO_2 concentration in Terrace, but well below the annual threshold.

Ozone is adequately monitored for the protection of health within the TKV airshed. For complete scientific study of NO_2 and influence on O_3, these parameters could be added to a station at Lakelse Lake. Ozone is currently measured at one station in Kitimat (KW) and one station in Terrace (TSMS), these stations also monitor NO_2. Generally, O_3 shows no specific trend and is well below the CAAQS. The modelling by Weinstein found 8-hour summertime peaks of O_3 at Lakelse Lake. Such a station could capture the predicted 55% in O_3 during summer conditions and improve understanding of the diurnal trends. However, as even the predicted elevated O_3 concentrations are well below threshold, the addition of these species at this location is more informative than protective of public health. Considering Onwukwe's work found that NO_2 concentrations peaked in cooler seasons, the contribution to O_3 may be less significant.

The KAG objectives include having an ambient network with credible data. "Credible data means that data are free of measurement bias (due to instrument type and/or location); that they have gone through necessary quality control (QC), quality assurance (QA) and validation processes; and that annual reporting requirements have been met." The BC ENV applies Environment Canada's Standard Operating Procedures (SOPs) for instrument calibration and maintenance and technicians visit stations monthly and perform checks to ensure the equipment is working properly (BC Gov, 2023a).

Compared to emission sources, the expected impacts from climate change are secondary impacts and are not expected to effect air quality nor siting of network. The local meteorology and local emissions dominate the AQ in the local airshed.

Current monitoring network approximately covers area of expected impacts indicated by modelling studies and passive monitoring. The results of passive monitoring is not suggesting that there is any potential location for continuous monitoring that is currently unsampled for the protection of health. A key benefit of passive monitoring is to identify areas "missed" by permanent monitoring stations. The passive sampling conducted by KTCAC and modelling by Onwukwe and ESSA et al warrant continued passive SO_2 sampling northwest of the KIA station, such as the Claque Mt. Trail at BC Hydro ROW.

This review finds that none of the stations in the network are redundant. To characterize the spatial and temporal variability of an air contaminant, the monitoring network needs to function as one spatio-temporal instrument. For example, there needs to be confidence that the network is not missing transient peaks in the spatial field. The addition of Kitimat Industrial Ave (KIA) in 2020 (in a similar location to the historical KRS) may appear geographically redundant to Kitimat Riverlodge (KR), but a gradient of SO_2 exists between hugging the mountain towards the flatter area in Kitimat, that warrants the existence of this station. In addition to this technical objective of the monitoring network, there are other considerations such as public perception. For example, while measurement of $PM_{2.5}$ and SO_2 at Kitimat Whitesail (KW) may be technically redundant (to Riverlodge) , it may be important to the public as it provides additional information to be protective of all neighbourhoods.

4.6.2 Air Quality Data Interpretation, Analysis and Reporting

Under the category of air quality data interpretation, analysis and reporting, the network needs to serve the following purposes:

To interpret and analyze the air quality data, the network must be able to be used to:

- assess attainment of provincial and federal objectives and standards;
- measure and understand baseline concentrations;
- measure and understand the spatio-temporal distribution of air pollutants, short- and long-term trends;
- identify conditions under which elevated pollutant concentrations occur;
- estimate transboundary transport; and
- identify hot spots.

This requires that the network measures all relevant air pollutants and is accompanied by a meteorological monitoring network, particularly wind speed and wind direction.

The ambient network in the Kitimat Airshed includes all contaminants federally regulated by the CAAQS and five of the seven contaminants regulated by the BC AQO. The two AQO contaminants not included in the network, formaldehyde and total suspended particulate (TSP), are not relevant to the emission sources in the network. BC also regulates carbon monoxide (CO) and total reduced sulphur (TRS) compounds through the Pollution Control Objectives. Neither of these contaminants are released in significant amounts within the Kitimat Airshed to be of concern. Air temperature and wind speed and direction measurements are co-located at five of the seven stations with air contaminant monitoring, meeting the meteorological objective.

BC ENV uses monitoring from the current stations to assess attainment of the provincial and federal objectives and standards and/or to manage to air quality (For example, the Haul Rd. station is located at the fenceline and is this intended to assess local air quality in the immediate vicinity of that location, while other stations are further from local sources and more indicative of wider attainment of air quality objectives). in Kitimat and across the Province. Ambient concentrations of NO_2, O_3, and $PM_{2.5}$ at the Kitimat Whitesail (KW) station are used to calculate the AQHI and SO_2 concentrations from Whitesail (KW), Riverlodge (KR), and Kitamaat Haisla Village (KHV) are added to calculate the AQHI+ SO_2.

Section 4.6.1 discusses how the literature review was used to evaluate the network's ability to measure and understand the spatio-temporal distribution of air pollutants, identify conditions under which elevated pollutant concentrations occur, and identify hot spots.

Transboundary transport is best assessed through modelling not monitoring or by monitors at airshed boundaries. Although there are several potential emission sources from new industrial projects within the Skeena Bulkley Valley and surrounding area encompassing Prince Rupert, this would include sources many outside of the TKV airshed, the airshed by definition will tend to not include emissions from other airsheds.

Section 4.2 presents the short- and long-term trends of the contaminants of concern. While some stations have closed and other stations are new within the last two years, the current network of stations is sufficient to determine both short- and long-term trends for SO_2, NO_2, O_3, $PM_{2.5}$, and PM_{10}.

5 CONCLUSIONS AND RECOMMENDATIONS

This section summarizes the recommendations developed from this network review with respect to the airshed and monitoring network followed by recommendations for future reviews of the TKV air quality monitoring network.

5.1 Recommendations for Airshed

The proposed airshed boundary is shown in Figure 6 in section 3.5 above. The proposed airshed applies a cautionary approach by including all expansion suggestions in the section 3.4 while still leaning on Weinstein's physical airshed. The alignment with the UTM coordinate system makes it a potential standard domain for future air dispersion modelling.

5.2 Recommendations for Network

The current network is well designed to capture SO_2, $PM_{2.5}$, NO_2, and O_3 concentrations as they may impact human populations. None of the continuous monitoring stations are redundant. Although some stations may not add to the scientific understanding of air quality patterns, they are useful indicators to measure air quality within the populated areas.

The recommendations for monitoring SO_2 from the comprehensive EEM review by ESSA et al remain valid and should be pursued. These include continuous SO_2 monitoring at the KIA station and continuing the passive sampling network in the Kitimat Valley. Continued passive sampling is recommended at the Claque Mt. Trail. Dispersion modelling has predicted higher SO_2 concentrations in this area and higher concentrations have been captured by passive monitoring here as well. The KAG might want to consider passive sampling at Kemano to measure SO_2 background concentrations for comparison Terrace and Williams Lake.

The LNG Canada 2014 assessment predicted 1-hour maximum NO_2 for base case to be near Haul Road station, though this assessment also included a significant increase in NO_2 emissions from the now cancelled Kitimat LNG project. If another industrial project (such as a second LNG facility) is added to the airshed, additional NO_2 monitoring may be warranted. The location of the new facility would influence the siting of additional NO_2 monitoring, though Kitimat Haul Road (KHR) and Kitimat Industrial Avenue (KIA) are likely candidate stations for additional NO_2 monitoring. The Cedar LNG Project is a future source of additional NO_2 in the airshed and was approved March 14, 2023. The air quality assessment (Stantec Consulting Ltd., 2022a) for this project predicts maximum 1-hour NO_X to approach the current BC AQO and exceed the 2025 CAAQS in the Kitimat Town Centre. Adding NO_2 continuous monitoring to the Riverlodge (KR) station could capture future peaks.

The findings of the updated LNG Canada AQTDR (2022) do not suggest changes to the monitoring network at this time. If measured NO_2 concentrations begin to trend higher once LNG Canada and potentially other incremental industrial facilities are in operation, the addition of NO_2 instrumentation at existing stations such as Kitimat Riverlodge (KR) and Kitimat Haul Road (KHR) should be considered.

The addition of industry in the region may lead to an increase in NO_2 and O_3 with a potential new hotspot in the vicinity of Lakelse Lake, as noted by Weinstein (2015) and Onwukwe (2020). As there are currently only two stations measuring NO_2 and O_3, in Terrace and Kitimat, the addition of NO_2 and O_3 monitoring at Lakelse Lake could provide additional scientific information on the pollution profile. There is a time lag in O_3 formation due to chemical reaction rates. While NO_X titration of O_3 close to sources is fast, secondary formation is slower. Thus, O_3 concentrations will be decreased near NO_X sources, but may increase further downwind, after NO_X/VOC reactions have had time to develop. Current NO_2 and O_3 concentrations are well below thresholds, and there is no significant population to protect at Lakelse Lake. Therefore, there is currently no need to add NO_2 or O_3 monitoring for management of public health. Should NO_2 concentrations increase significantly at existing NO_2 monitors with the addition of NO_2 emission sources, the establishment of NO_2/O_3 monitoring at Lakelse should be revisited.

If continuous monitoring of NO_2 is added at the Riverlodge (KR) station, the addition of continuous monitoring of O_3 would allow for the calculation of AQHI+ at Riverlodge in addition to Whitesail. The Riverlodge station does generally have slightly higher PM2.5 hourly concentrations than Whitesail, and the latest dispersion modelling for the Cedar LNG Project predicts higher NO2 closer to Riverlodge then Whitesail. An economical option would be to relocate the existing O_3 monitor from Whitesail to Riverlodge.

Comparing the findings of the Kitimat LNG assessment in 2005 to current standards, the project-only case would exceed the 1-hour and annual SO_2 and NO_2 CAAQS. If another facility is planned near the site of the Kitimat LNG Terminal site, additional SO_2 and NO_2 monitoring would be recommended at the fence line or in the area surrounding such a facility.

The review of the existing air monitoring network led to the following recommendations as listed below. These recommendations were developed assuming a full buildout of the LNG Canada facility, as required by the Environmental Assessment Certificate Application. In summary, the specific recommendations for the monitoring network include:

1) Maintain all current continuous monitoring stations.
2) Maintain the passive SO_2 sampling network, as per the recommendations of the ESSA et al review.
3) Maintain a passive SO_2 station at the Claque Mt. Trail at the BC Hydro right of way.
4) Add a passive SO_2 station at Kemano to establish a background SO_2 level.
5) If NO_2 or O_3 concentrations trend higher at existing Kitimat Whitesail (KW) or Terrace Skeena Middle School (TSMS) stations, consider the addition of NO_2 and O_3 continuous monitoring at Lakelse Lake.
6) As Cedar LNG is approved to proceed, adding another NO_2 emitter to the airshed, it is recommended to consider adding NO_2 continuous monitoring at Kitimat Riverlodge (KR), and a location in Douglas Channel near to Cedar LNG. Should additional NO_2 emitters be added to the airshed or NO_2 concentrations trend higher, consider adding NO_2 continuous monitoring at Kitimat Haul Road (KHR), or Kitimat Industrial Avenue (KIA).
7) Consider the addition of SO_2 continuous monitoring south in the Douglas Channel if another industrial emitter is added near to the Kitimat LNG site. The potential addition of the Cedar LNG Project is not expected to make significant increases to the SO_2 load in the airshed, thus does not warrant additional SO_2 monitoring.

8) If continuous monitoring of NO_2 is added at the Riverlodge (KR) station, consider relocating the existing O_3 monitor from Whitesail to Riverlodge to allow for the calculation of AQHI+ at Riverlodge which tends to measure higher PM2.5 hourly concentrations.

5.3 Recommendation on Future Network Reviews

It is recommended that the KAG plans to perform network reviews in the future. Potential triggers for future network reviews include:

- Substantial changes in emissions;
- Changing air quality objectives;
- New monitoring technologies;
- Advancements in the understanding of air contaminant emissions and their impacts on the environment, including human and wildlife health; and
- Substantial changes in climate that could affect ambient concentrations.

The time scale of change of these triggers is roughly about ten years. Metro Vancouver has been performing network reviews approximately every 10 to 15 years. Metro Vancouver's last two reviews were vastly different in nature, which is indicative of the broad range of reasons to review an air quality monitoring network. It is therefore recommended that the KAG performs a preliminary review in no later than ten years from now, potentially earlier if triggered by substantial changes such proposed new developments, to determine if a new review of the TKV air quality monitoring network is warranted.

6 STATEMENT OF LIMITATIONS

This report entitled ***Kitimat Airshed Network Review Report*** was prepared by RWDI AIR Inc. (“RWDI”) for the Kitimat Airshed Group (“KAG”) (“Client”). The findings and conclusions presented in this report have been prepared for the Client and are specific to the project described herein. The conclusions and recommendations contained in this report are based on the information available to RWDI when this report was prepared.

The conclusions and recommendations contained in this report have also been made for the specific purpose(s) set out herein. Should the Client or any other third party utilize the report and/or implement the conclusions and recommendations contained therein for any other purpose or project without the involvement of RWDI, the Client or such third party assumes any and all risk of any and all consequences arising from such use and RWDI accepts no responsibility for any liability, loss, or damage of any kind suffered by Client or any other third party arising therefrom.

Finally, it is imperative that the Client and/or any party relying on the conclusions and recommendations in this report carefully review the stated assumptions contained herein and to understand the different factors which may impact the conclusions and recommendations provided.

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