Final Report

$PM_{2.5}$ Supplement to the Kitimat Airshed Emissions Effects Assessment

Prepared for
British Columbia Ministry of Environment
Environmental Protection Program
3729 Alfred Avenue, PO Box 5000, Smithers, BC V0J 2N0

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Abbreviations and Terms

List of Symbols and Abbreviations

%ile	percentile
CAAQS	Canadian Ambient Air Quality Standards
CCME	Canadian Council of the Ministers of Environment
KAEEA	Kitimat Airshed Emissions Effects Assessment
KM LNG	Kitimat Liquified Natural Gas
KMP	Kitimat Modernization Project
LNG	Liquefied Natural Gas
NO_2	nitrogen dioxide
NO_3	nitrate
NO_X	nitrogen oxides
PM	particulate matter
$PM_{2.5}$	particulate matter up to 2.5 micrometers in diameter
PM_{10}	particulate matter up to 10 micrometers in diameter
QA	quality assurance/quality control
RTA	Rio Tinto Alcan
SO_2	sulphur dioxide
SO_4	sulphate, a salt of sulphuric acid
SO_X	sulphur oxides
US EPA	United States Environmental Protection Agency

List of Measurement Units

g/s	grams per second
ppb	parts per billion
t/d	tonnes per day
$\mu g/m^3$	micrograms per cubic metre (µ can also be shown as u)

Glossary of Terms

ambient	of the surrounding area or environment
CALMET	a diagnostic 3-dimensional meteorological model that forms a component of the CALPUFF system
CALPUFF	an air quality dispersion model that forms part of an advanced non-steady-state meteorological and air quality modelling system of the same name
MESOPUFF-II	a variable-trajectory puff superposition model suitable for modelling the transport, diffusion, and removal of air pollutants from multiple point and area sources at transport distances beyond the range of conventional straight-line Gaussian plume models
meteorology	the interdisciplinary scientific study of the atmosphere
percentile	a measure used in statistics indicating the value below which a given percentage of observations in a group of observations fall

1 Introduction

A Kitimat Airshed Emissions Effects Assessment (KAEEA) (ESSA et al. 2014) was conducted in 2014 to predict impacts of atmospheric emissions of SO_2 and NO_X from a range of alternative development scenarios in the Kitimat Valley on human health and the environment. While that assessment focused on SO_2 and NO_X, the work also included atmospheric dispersion and deposition modelling of $PM_{2.5}$, for study at a later date. That additional study has now been completed, and the $PM_{2.5}$ assessment methods and results regarding the risk to human health are described in this supplement. The information in this report will assist the Province of BC in ongoing regulatory decision-making, and public communications relative to proposed industrial emissions in the Kitimat area.

The location of the study area and the industrial facilities explored in the scenarios are the same as for the KAEEA (Figure 1-1), and included an existing aluminum smelter, four proposed LNG terminals, a proposed oil refinery, and gas turbine powered electrical generation facilities, as well as related marine transportation sources. The assessment also included emissions from shipping related to these facilities, along a route in Douglas Channel shown in Figure 1-2.

Two of the 12 scenarios (Figure 1-3) from the KAEEA were selected for this study. The first was the 'high-emission' bookend scenario from that assessment (J_m), chosen to characterize the worst-case risk for human health due to $PM_{2.5}$ from the suite of available scenarios. The second scenario was chosen after examining the results from Scenario J_m.

Scenario J_m showed ambient concentrations of $PM_{2.5}$ in populated areas that were below the BC ambient $PM_{2.5}$ annual and 24 hour guidelines, and were classified in the yellow and orange risk categories. The results also indicated that the 'low-emission' bookend scenario from the KAEEA, Scenario A, would be classified as yellow across all receptor locations. The second scenario for this study was therefore chosen as the one with best chance of facilitating reasonable interpolations approximating ambient $PM_{2.5}$ concentrations across the emission differences between these bookends. Scenario C was chosen because it represents reductions in emissions of both of NO_2 and SO_2, each by approximately one third that of Scenario J_m.

The emissions of $PM_{2.5}$, as well as emissions of SO_2 and NO_2 (both of which contribute to secondary formation of $PM_{2.5}$) for these two scenarios are listed in Table 1-1 and shown graphically in Figure 1-4.

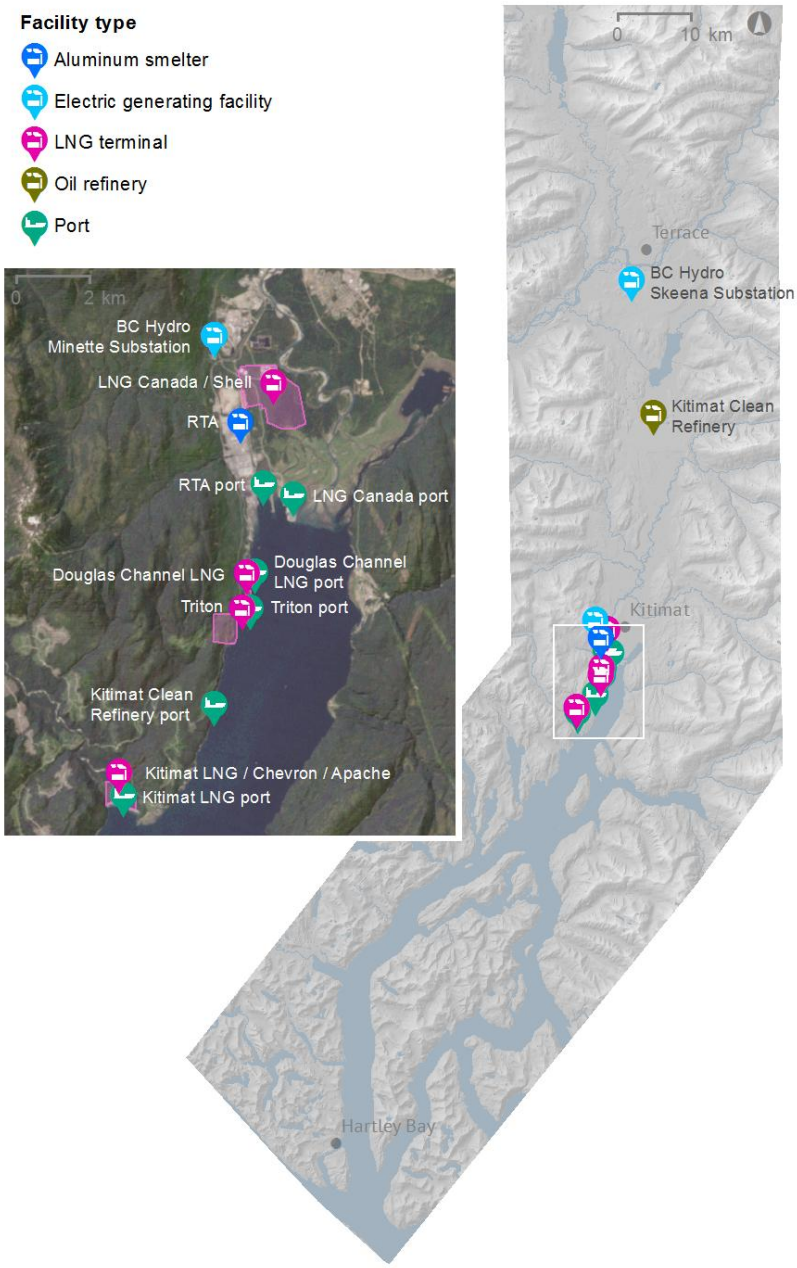

Figure 1-1. Locations of the stationary emissions sources modelled in the scenarios. The larger map shows the study area, and the inset zooms in on the facilities at the head of Douglas Channel.

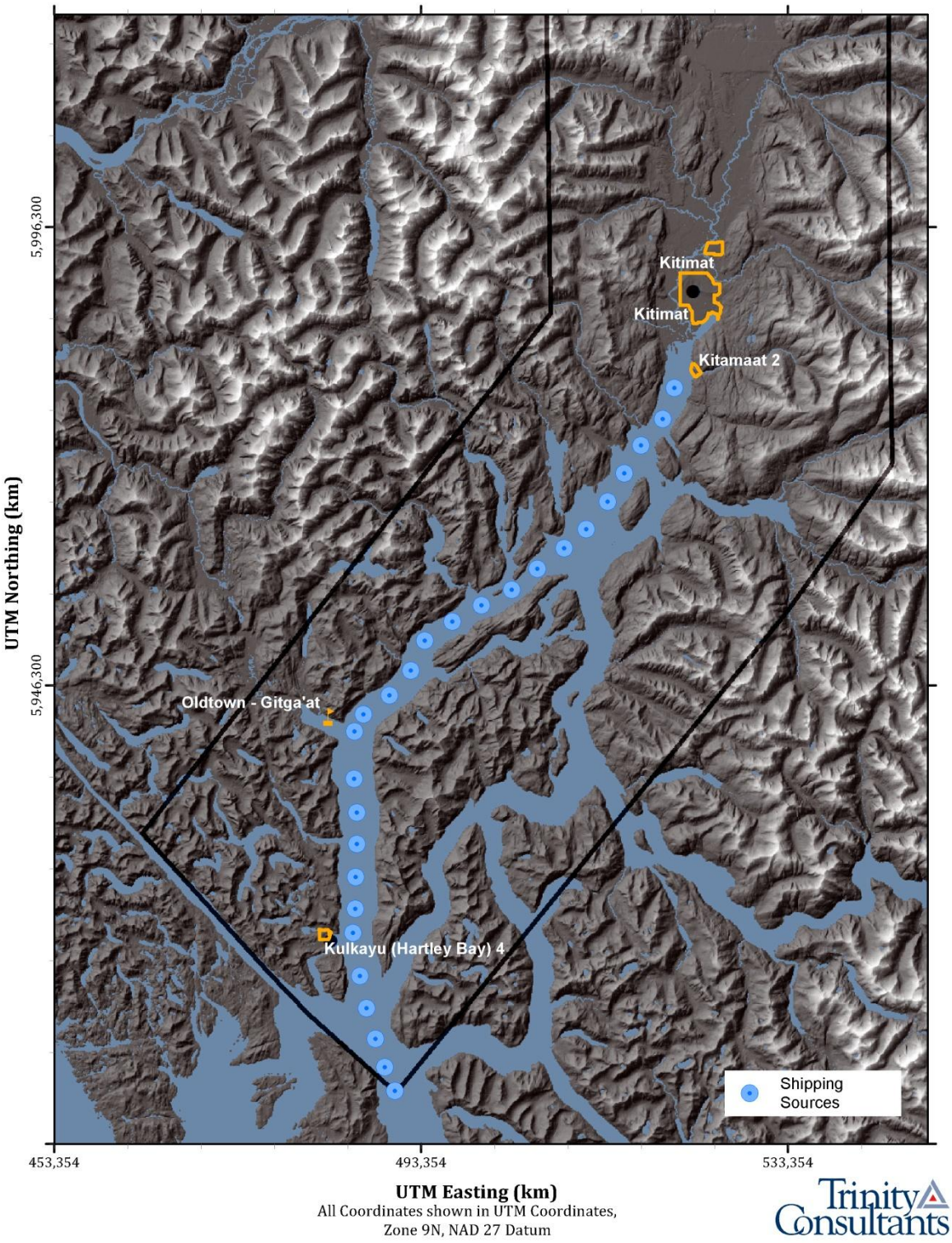

Figure 1-2. Locations of the shipping emissions sources modelled in the scenarios.

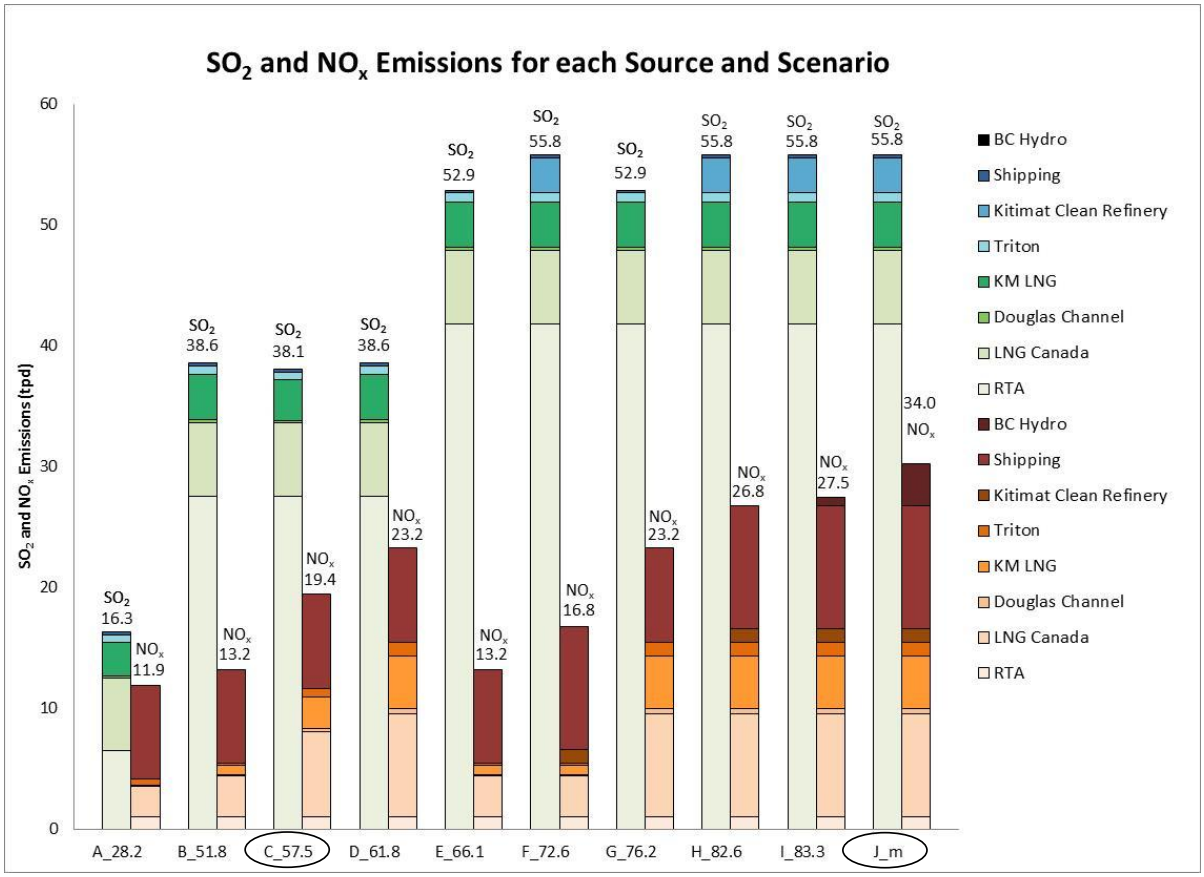

Figure 1-3. Bar chart illustrating relative emissions and sources for the 12 KAEEA scenarios, and the two chosen for this study.

Table 1-1. Primary $PM_{2.5}$ emissions, as well as SO_2 and NO_x emisssions which contribute to secondary formation of $PM_{2.5}$, from sources modelled for each scenario. The numbers are *estimates* based on the available design information for these sources.

	Scenario J_m						Scenario C					
Facility	g/s			t/d			g/s			t/d		
	SO_2	**NO_X**	**$PM_{2.5}$**	**SO_2**	**NO_X**	**$PM_{2.5}$**	**SO_2**	**NO_X**	**$PM_{2.5}$**	**SO_2**	**NO_X**	**$PM_{2.5}$**
RTA	484.14	11.67	18.24	41.83	1.01	1.58	318.86	11.67	16.41	27.55	1.01	1.42
LNG Canada	70.05	99.28	5.58	6.05	8.58	0.48	69.90	81.84	4.28	6.04	7.07	0.37
Douglas Channel	3.25	4.65	0.95	0.28	0.40	0.08	2.84	2.85	0.57	0.25	0.25	0.05
Triton	8.50	13.29	1.91	0.73	1.15	0.16	7.65	8.16	1.15	0.66	0.70	0.10
KM LNG	43.18	50.36	4.42	3.73	4.35	0.38	38.67	30.56	2.68	3.34	2.64	0.23
Refinery	33.15	13.17	7.02	2.86	1.14	0.61	0.00	0.00	0.00	0.00	0.00	0.00
Shipping	3.70	117.74	2.37	0.32	10.17	0.20	2.87	89.75	1.82	0.25	7.75	0.16
BC Hydro Minette	4.44E-05	40.00	3.11	3.84E-06	3.46	0.27						
Total	645.97	350.15	43.59	55.81	30.25	3.77	440.80	224.82	26.91	38.1	19.4	2.32

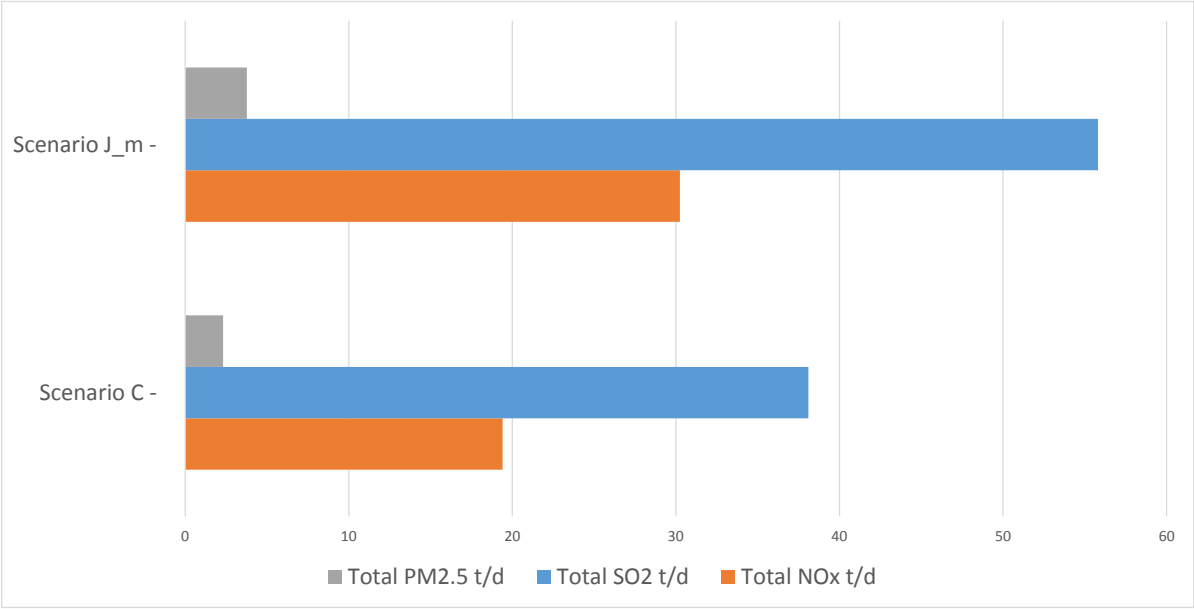

Figure 1-4. Bar chart illustrating relative emissions of SO_2, NO_X and $PM_{2.5}$ for the two scenarios.

2 Air Dispersion Modelling

2.1 Methods

All modeling methods used to produce the $PM_{2.5}$ air concentrations presented in this report were consistent with the methods described in the 2014 Kitimat Airshed Emission Effects Assessment (KAEEA) report (ESSA et al. 2014). As part of the 2014 KAEEA scope of work, $PM_{2.5}$ emissions data were collected, and the CALPUFF dispersion model was used to predict $PM_{2.5}$ results and output the data. However, the original project scope did not include post processing or synthesis of the $PM_{2.5}$ output data, because NO_2 and SO_2 were the pollutants of primary interest at that time. As such, the same layering methods, model domain, CALMET dataset, sampling grid, atmospheric chemistry, and QA procedures were used as a basis to generate results for this $PM_{2.5}$ supplement.

Of the methods used in the KAEEA as a basis for generating $PM_{2.5}$ results, the atmospheric transformation is of particular interest, because secondary $PM_{2.5,}$ which is produced from chemical transformation of SO_2 to SO_4 and NO_X to NO_3, is included in the $PM_{2.5}$ results. This secondary $PM_{2.5}$ is included in addition to the *primary* $PM_{2.5}$ concentrations from the $PM_{2.5}$ emissions directly emitted from the sources. The details of the atmospheric transformation used in the KAEEA to predict secondary $PM_{2.5}$ formation are detailed in the following section.

Atmospheric Transformation

This CALPUFF modelling analysis applies the MESOPUFF-II chemical transformation algorithms, where the concentrations of NO_2, SO_2, ammonium sulphate, ammonium nitrate, nitric acid, and $PM_{10}/PM_{2.5}$

may be tracked.[1] There are two user-selected input parameters that affect the MESOPUFF II chemical transformation: ammonia and ozone background concentrations. We applied a constant background ammonia concentration of 0.5 ppb, based on the recommended background for a forested area as described in the modelling protocol in Appendix 7.6-1, Volume 3 of the KMP SO_2 Technical Assessment (ESSA et al. 2013b). A constant background ozone concentration was also applied, using the CALPUFF default of 80 ppb.

The high ozone concentration of 80 ppb is the recommended CALPUFF default, as a conservative assumption to avoid the situation where limited ozone results in a slower reaction rate of SO_2 to SO_4, or NO_X to NO_3. This assumption results in potentially higher reaction rates and total sulphur deposition rates than would occur when using site-specific ozone data; thus, the assumption is conservative when considering total sulphur deposition rates and when considering secondary $PM_{2.5}$ concentrations, but it could be less conservative when considering SO_2 air concentrations. Based on a sensitivity study performed as part of the KMP SO_2 assessment, CALPUFF SO_2 air concentrations are not noticeably affected when a site-specific regional ozone background concentration is used. Specifically, a 0% change in SO_2 concentrations and a 2% to 5% change in SO_4 concentrations were detected between the study results and the original CALPUFF results. A decrease in SO_4 concentration would result in a corresponding increase in SO_2 concentration (SO_2 not converting to SO_4 in the study when it did in the orginal results). Even though the same number of molecules of SO_2 and SO_4 are affected by the study, the change in SO_4 was more noticeable on a percentage basis, because the total concentration of SO_2 was much higher than that of SO_2.

While secondary $PM_{2.5}$ is in the form of ammonium sulphate ($(NH_3)_2SO_4$) and ammonium nitrate ($NH_3(NO_3)$), CALPUFF tracks these two pollutants as sulphate (SO_4) and nitrate (NO_3). Therefore, the post-processing performed to determine the total $PM_{2.5}$ (primary + secondary) needs to account for the total molar mass as described with the following equation:

$$PM\,2.5_{Total} = PM\,2.5_{\mathrm{Pr}imary} + \left(Conc(SO4) \times \left(\frac{MW_{(NH3)2SO4}}{MW_{SO4}} \right) \right) + \left(Conc(NO3) \times \left(\frac{MW_{(NH3)NO3}}{MW_{NO3}} \right) \right)$$

2.2 Results

Modelling Background Concentrations based on Monitoring Data

For comparison of maximum air concentrations to established thresholds, standard procedure (and that applied for the KMP SO_2 Technical Assessment (ESSA et al. 2013a,b)) is to add a modelling background concentration to modelled air concentrations to predict the total maximum air concentrations after the new/modified sources begin operation (i.e., total air concentrations = modelled concentrations due to new and existing emissions sources plus modelling background concentration from non-modelled emissions).

The $PM_{2.5}$ concentration results presented in this report apply a modelling background concentration that varies depending on the neareast representative monitor, as presented in Table 2-1, below. For all remote areas not near a $PM_{2.5}$ monitor, the modelling background concentration is determined based

[1] Although these other concentrations are tracked, this report focuses only on the results of $PM_{2.5}$ modelling.

on the Kitamaat Village monitoring station, consistent with the domain-wide representative monitor selected for SO_2 in the KAEEA (ESSA et al. 2014) and the KMP SO_2 Technical Assessment (ESSA et al. 2013a,b). While applying the same background concentration for all locations is the most common approach used in modelling analyses, this report applies location-specific background concentrations for the individual areas defined for the human health effects assessment. Using the nearest monitor versus a "natural background" monitor may result in double counting of emissions from the Rio Tinto Alcan Aluminum smelter (the only existing source in the assessment). However, other sources near the monitors, such as residential wood stoves, are not included as modelling input. Therefore, using the nearest representative monitor ensures that the results conservatively account for any localized impacts from local sources of particulate matter emissions.

Table 2-1. $PM_{2.5}$ monitoring background concentrations.

$PM_{2.5}$ Monitoring Background Concentration			
Area	$PM_{2.5}$ Annual Average ($\mu g/m^3$)	$PM_{2.5}$ 24-Hour 98th percentile ($\mu g/m^3$)	Representative Station*
Service centre	3.63	13.50	Kitimat Station (Railsite) (E224788)
Kitimat	3.09	11.60	Riverlodge (E216670) and Whitesail (E223615)
Kitamaat village	2.18	10.32	Kitamaat Village (E282711)
Giga'at Old Town	2.18	10.32	Kitamaat Village (E282711)
Hartley Bay (Kulkayu)	2.18	10.32	Kitamaat Village (E282711)
Terrace	3.20	10.90	Terrace BC Access Centre**
Kitimat-Stikine E	3.20	10.90	Terrace BC Access Centre**
Kitsumkaylum 1	3.20	10.90	Terrace BC Access Centre**
Kshish 4	3.20	10.90	Terrace BC Access Centre**
Kitselas 1	3.20	10.90	Terrace BC Access Centre**

*Monitoring background concentration based on the highest year of complete data from 2005-2012 from the highest representative monitor.
**Terrace BC Access Centre data are from 2009-2014.

Modelled $PM_{2.5}$ Concentrations

Figure 2-1 and Figure 2-2 show the predicted annual average and 24-hour 98th percentile $PM_{2.5}$ concentrations (8th highest daily average at each location), respectively, for Scenario J_m. Figure 2-3 and Figure 2-4 show the predicted annual average and 24-hour 98th percentile $PM_{2.5}$ concentrations for Scenario C. The secondary $PM_{2.5}$ in the forms of ammonium sulphate and ammonium nitrate are shown separately in these figures. The areas shown in the figures represent the 10 areas selected for the human health effects assessment which is discussed futher in Section 3.2. The two areas nearest to the proposed sources, Kitimat and the Service Centre, show the highest quantity of primary $PM_{2.5}$, while the areas farthest from the proposed sources (e.g., Terrace) show higher fractions of secondary particulate

matter. This higher fraction of the modelled $PM_{2.5}$ in the form of secondary $PM_{2.5}$ at farther distances is expected, because the formation of secondary $PM_{2.5}$ takes place over time. Conversely, primary $PM_{2.5}$ disperses and becomes less concentrated over distances, so lower primary $PM_{2.5}$ is seen in locations farther from the emission sources. For all locations and averaging periods, the total concentrations are well below the BC Air Quality Objectives (see Figure 2-1 to Figure 2-4). Also consistent across all locations and averaging periods, the primary contributor to each total $PM_{2.5}$ concentration is the monitoring background concentration.[2]

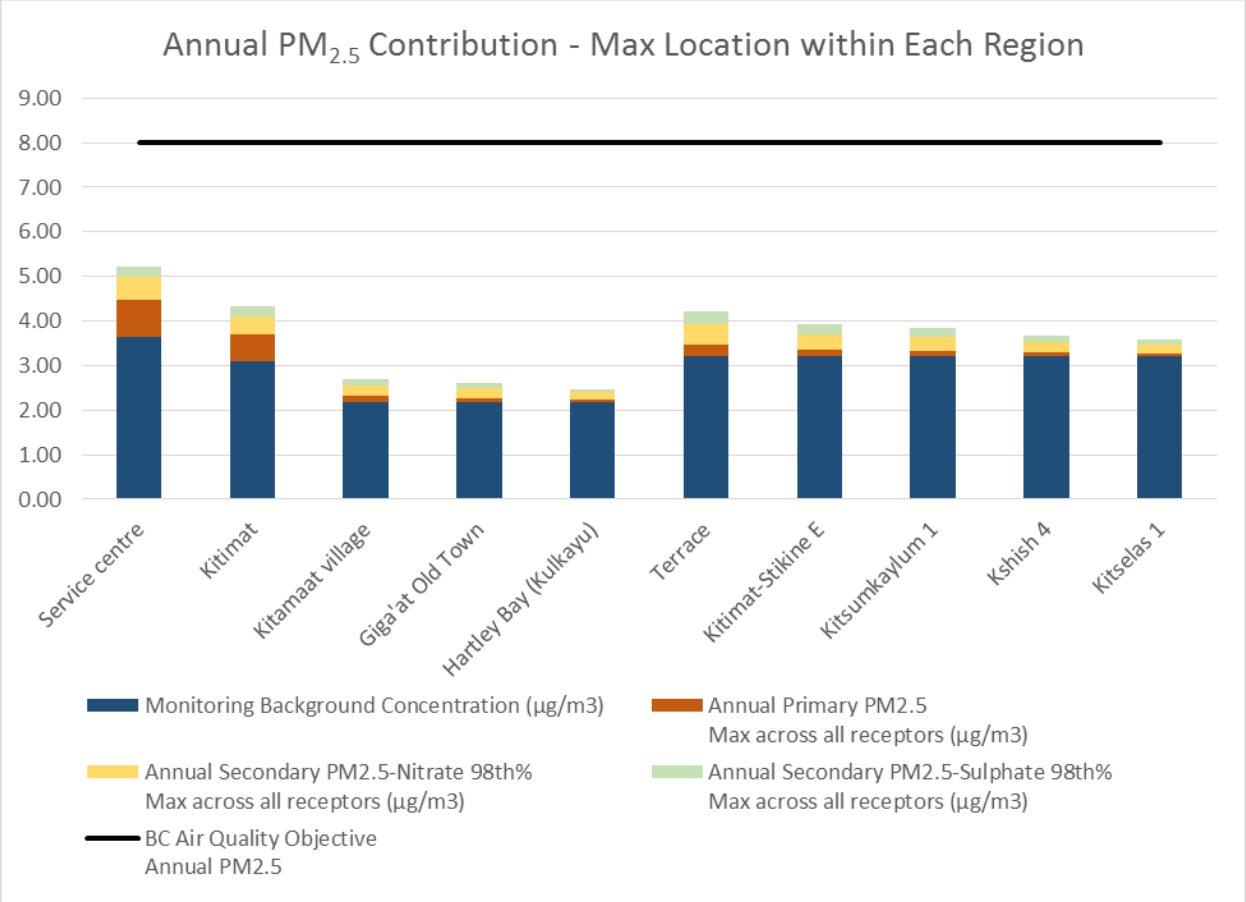

Figure 2-1. Scenario J_m, 98th percentile $PM_{2.5}$ concentrations, Annual average. Comparision of background, primary and secondary levels to BC Air Quality Objective values from http://www.bcairquality.ca/regulatory/pm25-objective.html.

[2] As discussed in the previous section, the monitoring background concentrations may conservatively double count some emissions, but there can be localized emissions of $PM_{2.5}$ from sources like wood stoves. Because of the possibility for localized $PM_{2.5}$ emissions, the nearest representative monitor is used.

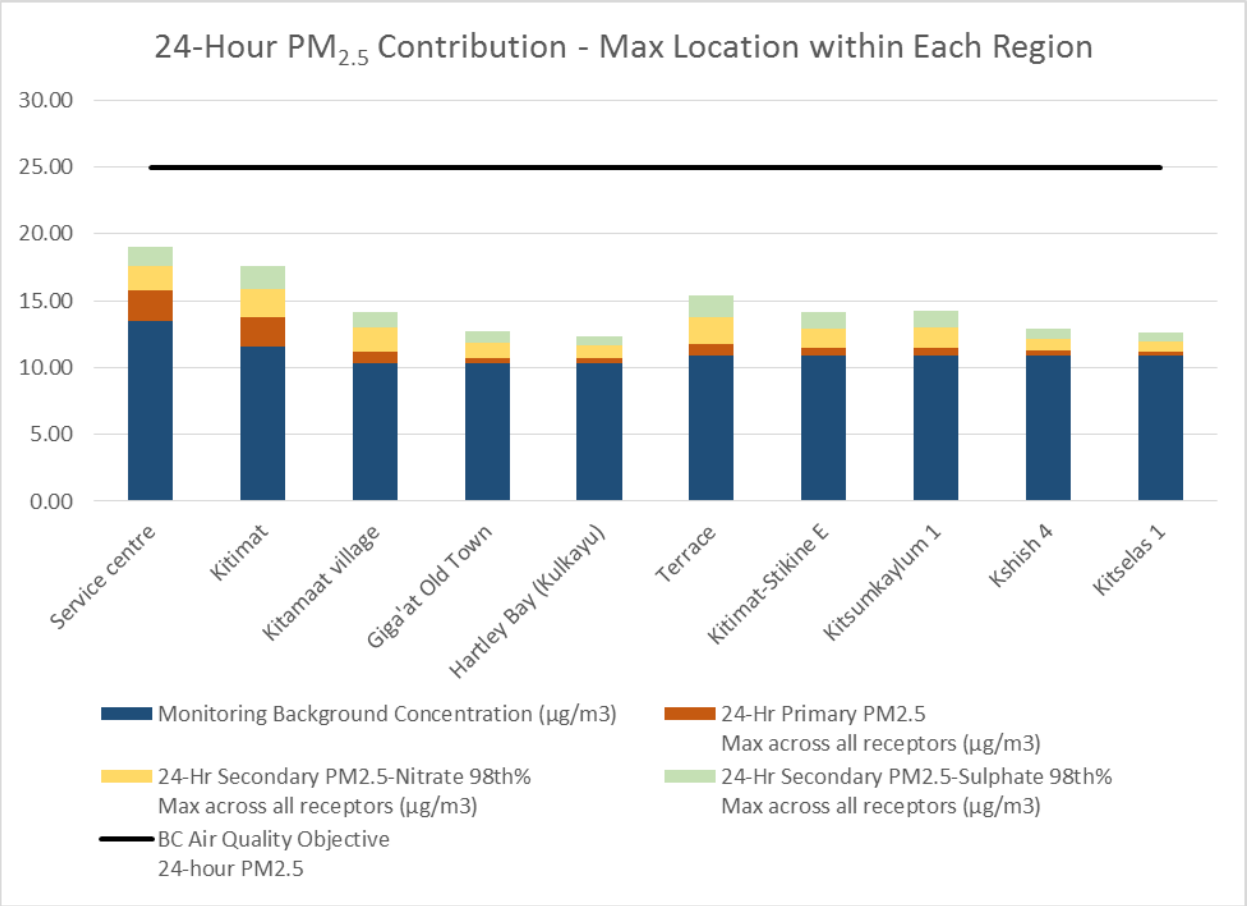

Figure 2-2. Scenario J_m, 98th percentile $PM_{2.5}$ concentrations, 24-Hour average. Comparision of background, primary and secondary levels to BC Air Quality Objective values from http://www.bcairquality.ca/regulatory/pm25-objective.html.

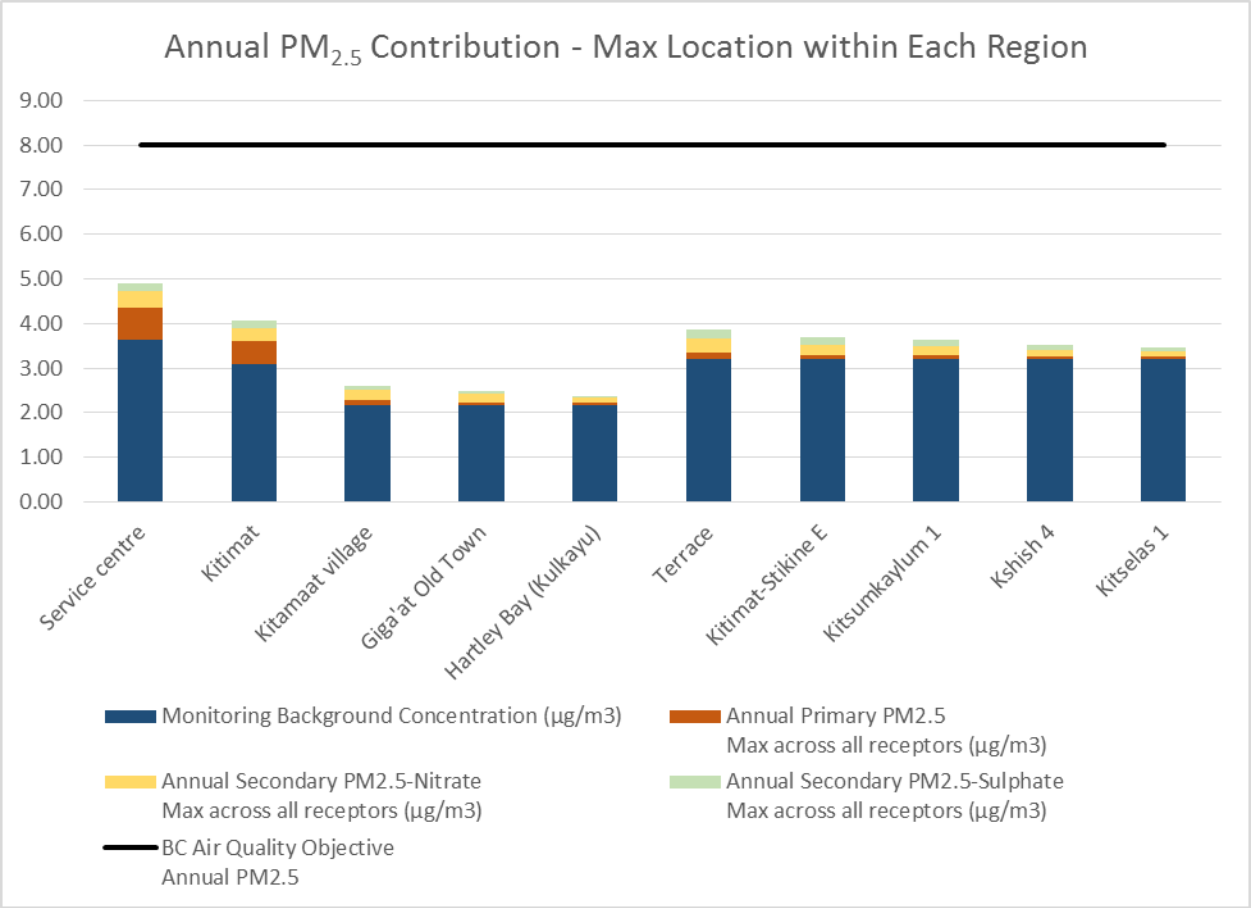

Figure 2-3. Scenario C, $PM_{2.5}$ concentrations, Annual average. Comparision of background, primary and secondary levels to BC Air Quality Objective values from http://www.bcairquality.ca/regulatory/pm25-objective.html.

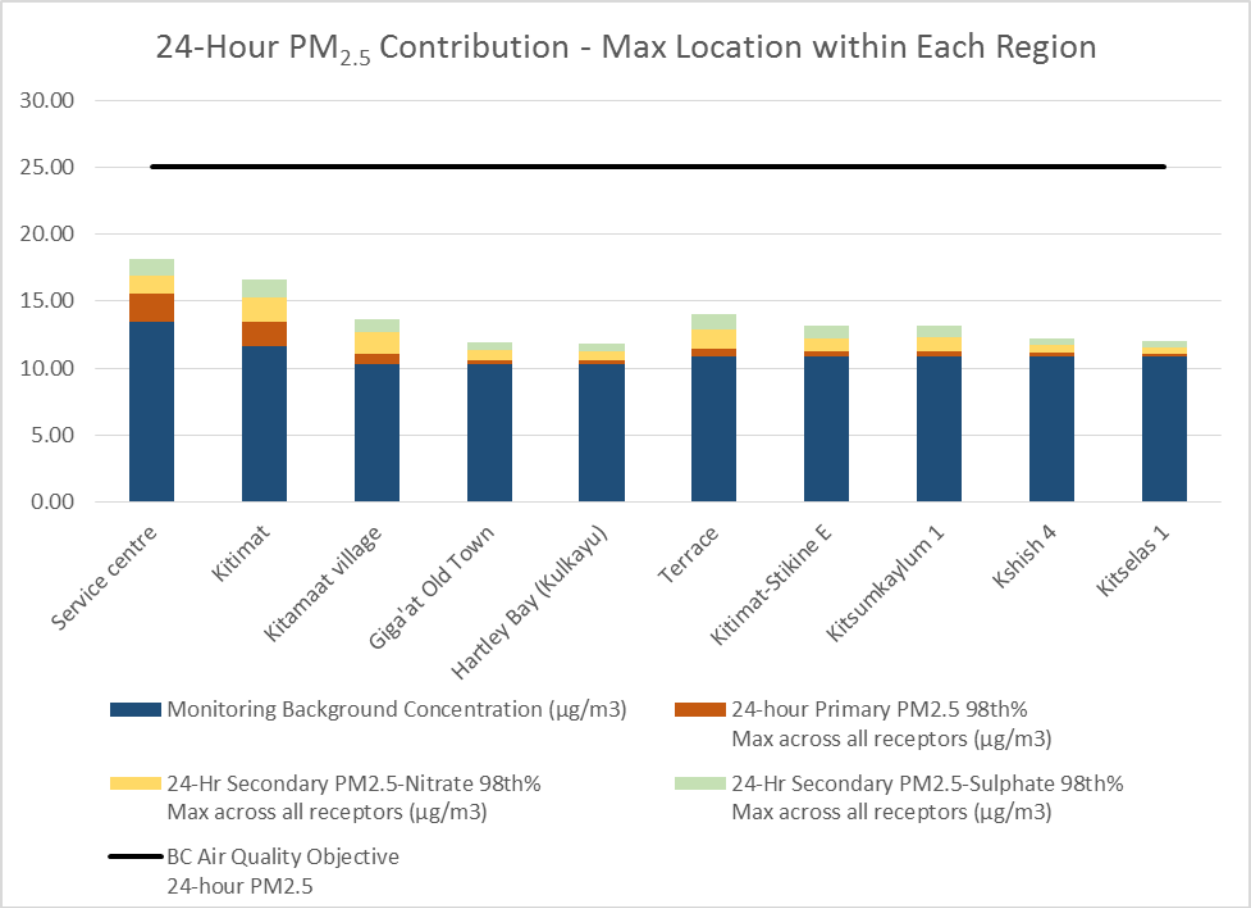

Figure 2-4. Scenario C, 98th percentile $PM_{2.5}$ concentrations, 24-Hour average. Comparision of background, primary and secondary levels to BC Air Quality Objective values from http://www.bcairquality.ca/regulatory/pm25-objective.html.

Main Sources and Implications of Quantitative Scientific Uncertainty

The primary source of uncertainty in the air dispersion and deposition modelling is the preliminary nature of the emission rates and stack parameters for the LNG facilities, oil refinery, and marine transportation emissions. This remains true for the $PM_{2.5}$ concentrations presented in this report. While we made several conservative assumptions with respect to transportation emissions, little information is available regarding the level of uncertainty or extent of assumptions from proponent data. With respect to local scale results in the town of Kitimat and near the facilities, the absence of building data needed to predict building downwash effects is also expected to result in uncertainty to varying extents. In general, it is expected that the absence of building downwash results in under-prediction in locations near the facility. This under-prediction from building downwash is not expected to be significant at distances approaching the nearest residential areas in Kitimat and Kitamaat Village.

Meteorological data uncertainty is typically and consistently the key source of uncertainty in any predictive air dispersion modelling analysis, because it is not possible to know with any certainty what the weather will be in future years and how well the modelled meteorological year represents future years. However, comparing the modelled year used in this study (2008) to recent years can provide

good insight into how much conditions vary year to year in the airshed and where the modelled year falls within the variable range. Therefore, we conducted an analysis comparing the meteorological data in 2008 to a 10-year period from 2003 to 2012, as presented in Appencix 7 of the KAEEA report (ESSA et al. 2014). In addition to comparing meteorological data across a 10-year period, understanding the sensitivity of the CALPUFF model results to variation in meteorological data also aids in providing insight into the model uncertainty. As such, we summarized a previous sensitivity study and conducted two new sensitivity studies as part of the current assessment: a precipitation sensitivity study, and a study comparing near-field concentrations for one scenario for three years using previously prepared 2006 and 2009 CALMET data in addition to the 2008 data used for all scenarios. The conclusions of these studies are summarized in Section 2.3 of the KAEEA report, and generally confirmed that variation in meteorological data can result in notable variation from year to year, particularly when considering short-term averaging periods or very specific locations (versus comparing annual average values across a larger region).

While CALPUFF is capable of predicting secondary $PM_{2.5}$ concentrations as are presented in the previous section, it should be noted that the US EPA Guidance on $PM_{2.5}$ modelling (US EPA 2014) does not name CALPUFF as a recommended model for predicting secondary $PM_{2.5}$ concentrations as part of an ambient air impact assessment. The reason for not recommending the use of CALPUFF could be because the CALPUFF model is not the US EPA recommended model for near-field impacts where secondary $PM_{2.5}$ formation may be of interest, or because the MESOPUFF II chemistry is considered to be simplified compared to the complex photochemical transformations that take place in reality (e.g., the MESOPUFF II transformations do not consider sunlight or complex ozone reactions; rather, MESOPUFF II uses ozone background concentrations as an indication of reactivity in a given hour). However, CALPUFF is the U.S. EPA recommended model for long range transport and evaluation of visibility and deposition impacts in "Class I" areas (e.g., national parks). For these visibility and deposition impact assessments, transformation from SO_2 to ammonium sulfate (secondary $PM_{2.5}$ from SO_2) is important, because the primary and secondary particulate matter concentrations are directly used to determine visibility impacts (i.e., SO_2 and NO_X emissions are required to be modelled for visibility impact assessments, but do not directly affect visibility results of the CALPUFF modelling system; rather, they indirectly affect results through the sulphate and nitrate secondary particulate matter concentrations estimated by CALPUFF). Because of the importance of chemical transformation in predicting visibility impacts, it can be inferred that the US EPA has confidence in CALPUFF's ability to accurately and/or conservatively predict ammonium sulphate concentrations in order to adequately protect Class I areas from visibility impacts. Additionally, the assumptions built into the MESOPUFF II scheme and the use of the default ozone background concentration is expected to result in a conservatively high estimate of the reaction rates that form secondary $PM_{2.5}$ (NO_X to NO_3 and SO_2 to SO_4).

3 Human Health

3.1 Methods

The CCME has recently published Proposed Air Management Threshold Values for Ozone and Particulate Matter ($PM_{2.5}$) (CCME 2012). These are illustrated in Figure 3-1. The key properties of this categorization scheme are the provision of three thresholds for ambient concentrations (specifically, thresholds for various statistics of the ambient concentrations, such as the annual mean or a percentile value of hourly

concentrations). These three thresholds divide potential concentrations into four categories that are associated with colours.

These four categories are:

- Green: the lowest category associated with very low exposures. A threshold value separates the Green and Yellow category, and is associated with the upper end of a range of ambient concentrations associated with "clean" environments.
- Red: the highest category is associated with concentrations above the threshold set at the level of the Canadian Ambient Air Quality Standards (CAAQS).
- Yellow: a third threshold lies midway between the "background" levels that separate Green and Yellow, and the CAAQS levels. Concentration values below this level, but higher than Green, are assigned Yellow.
- Orange: above the midway threshold, but below the Red category, the concentration values are assigned to the category labelled Orange.

Management Level	Management Actions	Proposed Air Management Threshold Values					
		Ozone (ppb)		$PM_{2.5}$ Annual ($\mu g/m^3$)		$PM_{2.5}$ 24h ($\mu g/m^3$)	
		2015	2020	2015	2020	2015	2020
RED	**Actions for Achieving Air Zone CAAQS**						
Threshold		63 ppb	62 ppb	10.0 µg/m3	8.8 µg/m3	28 µg/m3	27 µg/m3
ORANGE	**Actions for Preventing CAAQS Exceedance**						
Threshold		56 ppb		6.4 µg/m3		19 µg/m3	
YELLOW	**Actions for Preventing AQ Deterioration**						
Threshold		50 ppb		4.0 µg/m3		10 µg/m3	
GREEN	**Actions for Keeping Clean Areas Clean**						

Figure 3-1. Illustration of the CCME Air Management Categorization Scheme (extracted from CCME 2012).

The risk categorization scheme used for this health assessment is derived from the CCME approach and adapted to be compatible with the BC Air Quality Objectives for $PM_{2.5}$ (BCMOE 2014). Table 3-1 illustrates this scheme, with threshold values provided for the 98th percentile of 24-hour averaged $PM_{2.5}$ and annual average concentrations[3]. The BC Air Quality Objectives are 8 µg/m^3 for the annual average and 25 µg/m^3 for the 24-hour period. The lower threshold is taken from the CCME table above. The middle threshold (separating yellow from orange) is taken as half-way between the upper and lower

[3] Values for upper thresholds taken from: http://www.bcairquality.ca/reports/pdfs/aqotable.pdf (Table 1, including Note I associated with this table). The 98th percentile is implemented as the 8th highest value in the year (98% of 365 days is 357.7, so the 358th lowest, or 8th highest day is used).

thresholds, in accordance with the CCME scheme. To avoid undue precision, in the case of the middle threshold for 24-hour average $PM_{2.5}$, the half-way value of 17.5 µg/m^3 is rounded down to 17 µg/m^3.

Table 3-1. Adaptation of the CCME Air Management Categorization Scheme to apply British Columbia Air Quality Objectives for $PM_{2.5}$.

Annual Average $PM_{2.5}$	24-Hour Average $PM_{2.5}$ (98th %ile)
8 µg/m^3	25 µg/m^3
6 µg/m^3	17 µg/m^3
4 µg/m^3	10 µg/m^3

IMPORTANT: The colour categories used in the human health effects assessment component of this study have the meanings intended by the CCME (CCME 2012) and do not have the same interpretation as the risk categories for the environmental receptors in the primary Kitimat Airshed Emissions Effects Assessment report (vegetation, soils, lakes).

3.2 Results

As part of the 2014 Kitimat Airshed Emissions Effects Assessment (ESSA et al. 2014), to which this report is a supplement, 10 locations were identified in the airshed for the human health effects assessment of $PM_{2.5}$ (Figure 3-2). Comparison of modelled concentrations to the thresholds described above was performed for each location. For clarity, they have been grouped and labelled “near” and “far”. The calculations were conducted in the same way for both categories. The industrial area designated in Figure 3-2 is not equivalent to the industrial sites themselves, rather it is the commercial area commonly referred to in Kitimat (and in the KMP SO_2 Technical Assessment Report (ESSA et al. 2013a)) as the “Service Centre”.

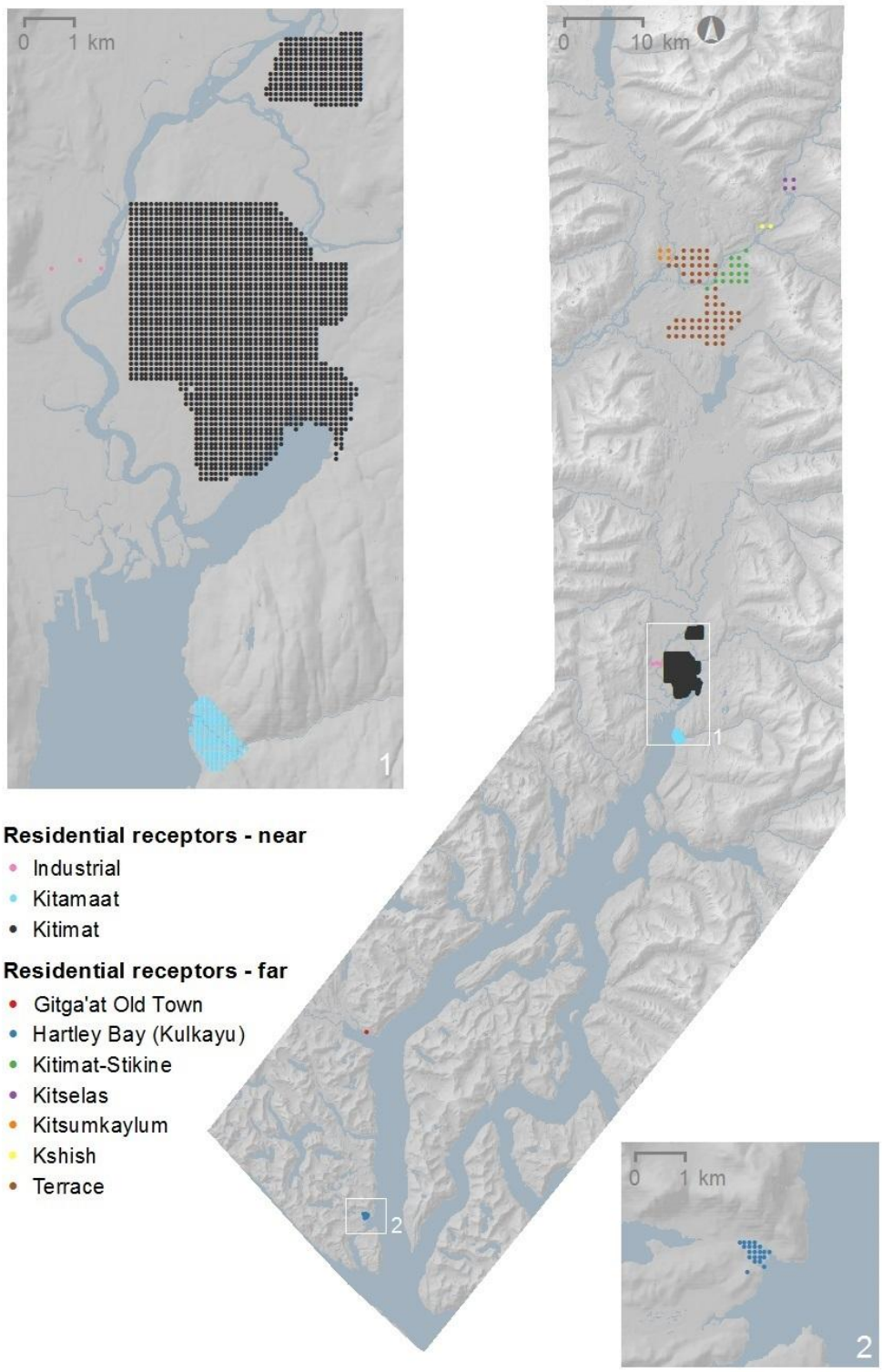

Figure 3-2. Locations considered for the human health effects assessment.

Categorization of Annual Average Concentrations of $PM_{2.5}$

Annual average concentrations for near- and far-field regions are presented below, including primary, secondary and background concentrations. For each region, the maximum annual average among the receptors is shown.

Scenario	Source of $PM_{2.5}$	Near-field Regions		
		Service Center	Kitimat	Kitamaat Village
C	Primary (P)	0.71	0.50	0.12
	Secondary Nitrate (S_N)	0.38	0.31	0.20
	Secondary Sulphate (S_S)	0.19	0.17	0.11
	Secondary (S)	0.57	0.48	0.31
	Modelled Total (P+S)	1.28	0.98	0.43
	Background (B)	3.63	3.09	2.18
	Total (P+S+B)	4.91	4.07	2.61
J_m	Primary (P)	0.84	0.60	0.14
	Secondary Nitrate (S_N)	0.51	0.41	0.25
	Secondary Sulphate (S_S)	0.24	0.22	0.14
	Secondary (S)	0.75	0.64	0.38
	Modelled Total (P+S)	1.60	1.24	0.52
	Background (B)	3.63	3.09	2.18
	Total (P+S+B)	5.23	4.33	2.70

Scenario	Source of $PM_{2.5}$	Far-field Regions						
		Hartley Bay	Old Town	Terrace	Kitimat-Stikine E.	Kitsum-kaylum	Kshish	Kitselas
C	Primary (P)	0.04	0.06	0.16	0.09	0.08	0.06	0.05
	Second. Nitrate (S_N)	0.12	0.18	0.30	0.22	0.20	0.14	0.11
	Second. Sulphate (S_S)	0.04	0.07	0.21	0.17	0.15	0.11	0.09
	Secondary (S)	0.16	0.25	0.52	0.40	0.35	0.26	0.21
	Modelled Total (P+S)	0.20	0.31	0.68	0.49	0.43	0.32	0.26
	Background (B)	2.18	2.18	3.2	3.2	3.2	3.2	3.2
	Total (P+S+B)	2.38	2.48	3.88	3.69	3.63	3.52	3.46
J_m	Primary (P)	0.05	0.08	0.27	0.15	0.13	0.10	0.08
	Second. Nitrate (S_N)	0.16	0.24	0.46	0.34	0.31	0.22	0.18
	Second. Sulphate (S_S)	0.06	0.09	0.29	0.24	0.21	0.16	0.13
	Secondary (S)	0.22	0.34	0.76	0.57	0.52	0.38	0.31
	Modelled Total (P+S)	0.28	0.42	1.01	0.73	0.65	0.48	0.40
	Background (B)	2.18	2.18	3.20	3.20	3.20	3.20	3.20
	Total (P+S+B)	2.46	2.60	4.21	3.93	3.85	3.68	3.60

For each scenario, the risk categorization is based on the Total $PM_{2.5}$ in the last row, which includes primary, secondary nitrate, secondary sulphate and background sources of $PM_{2.5}$. In both scenarios, the annual average concentrations of $PM_{2.5}$ are categorized as Yellow in Service Centre and Kitimat. Terrace is categorized as Green in Scenario C and as Yellow in Scenario J_m. All other locations (Kitamaat Village and Far locations other than Terrace) are Green in both scenarios.

Categorization of 24-Hour Average Concentrations of $PM_{2.5}$

The categorization of 24-hour average concentrations for $PM_{2.5}$ is based on the 98th percentile of the modelled concentrations and is presented below for near- and far-field regions. For each region, the maximum of the 98th percentile values among the modelled gridpoints is shown. Note that, contrary to the annual average concentration statistics above, when considering multiple variable sources that contribute to a sub-total or total concentration (primary added to secondary, or two types of secondary particulate), the percentile values *are not expected to be additive*.

Scenario	Source of $PM_{2.5}$	Near-field Regions		
		Service Center	Kitimat	Kitamaat Village
C	Primary (P)	2.02	1.88	0.77
	Secondary Nitrate (S_N)	1.43	1.77	1.62
	Secondary Sulphate (S_S)	1.2	1.35	0.96
	Secondary (S)	2.41	2.49	2.38
	Modelled Total (P+S)	4.43	4.37	3.15
	Background (B)	13.5	11.6	10.32
	Total (P+S+B)	17.16	15.26	13.40
J_m	Primary (P)	2.32	2.18	0.82
	Secondary Nitrate (S_N)	1.77	2.06	1.9
	Secondary Sulphate (S_S)	1.39	1.76	1.08
	Secondary (S)	2.98	3.09	2.57
	Modelled Total (P+S)	4.40	4.54	3.30
	Background (B)	13.50	11.60	10.32
	Total (P+S+B)	17.90	16.14	13.62

Scenario	Source of $PM_{2.5}$	Far-field Regions						
		Hartley Bay	Old Town	Terrace	Kitimat-Stikine E.	Kitsum-kaylum	Kshish	Kitselas
C	Primary (P)	0.25	0.29	0.59	0.37	0.39	0.23	0.20
	Second. Nitrate (S_N)	0.70	0.76	1.35	0.98	0.98	0.58	0.47
	Second. Sulphate (S_S)	0.52	0.60	1.23	0.94	0.89	0.55	0.48
	Secondary (S)	1.15	1.31	2.57	1.76	1.75	1.07	0.91
	Modelled Total (P+S)	1.4	1.6	3.16	2.13	2.14	1.3	1.11
	Background (B)	10.32	10.32	10.90	10.90	10.90	10.90	10.90
	Total (P+S+B)	11.73	11.92	14.07	13.05	13.03	12.17	12.02
J_m	Primary (P)	0.36	0.43	0.88	0.56	0.35	0.58	0.30
	Second. Nitrate (S_N)	0.94	1.14	1.95	1.42	1.49	0.88	0.74
	Second. Sulphate (S_S)	0.7	0.83	1.64	1.27	1.25	0.79	0.68
	Secondary (S)	1.68	1.91	3.37	2.55	2.58	1.64	1.39
	Modelled Total (P+S)	2.09	2.22	4.09	3.10	3.20	1.99	1.76
	Background (B)	10.32	10.32	10.90	10.90	10.90	10.90	10.90
	Total (P+S+B)	12.41	12.54	14.99	14.00	14.10	12.89	12.66

For each scenario, the risk categorization is based on the total $PM_{2.5}$ in the last row, which includes primary, secondary nitrate, secondary sulphate and background sources of $PM_{2.5}$. For both scenarios, the 98th percentile 24-hour average concentrations of $PM_{2.5}$ are categorized as Yellow in all locations

except for the Service Centre which is categorized as Orange. It is worth noting that the estimate of the background alone would be classified as Yellow in all locations, and that the largest difference between the Service Centre and other nearby locations is in the estimate of the 98th percentile of background $PM_{2.5}$.

Summary of Categorization of Results

The human health categorization has been conducted using a modified version of the CCME air quality categorization scheme, adjusted to apply the two BC Air Quality Objectives for $PM_{2.5}$. This includes thresholds which categorize modelled concentrations into four categories, depicted by the colours Green, Yellow, Orange and Red, which are related to the need for increased efforts to manage air quality as described by the CCME (CCME 2012).

The results of the risk categorization are provided in Table 3-2.

Table 3-2. Human health effects categorization.

Criterion	Scenario	Locations	Categorization
$PM_{2.5}$ Annual Average	C, J_m	Service Centre, Kitimat	Yellow
	C	Terrace	Green
	J_m	Terrace	Yellow
	C, J_m	Kitamaat Village and Other Far	Green
$PM_{2.5}$ 24-Hour Average (98th Percentile)	C, J_m	Service Centre	Orange
	J_m	All Other Near and Far	Yellow

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