Air Quality Technical Data Report

LNG Canada Export Terminal

October 2014

LNG CANADA

Opportunity for British Columbia. Energy for the world

Joint venture companies

Mitsubishi Corporation

AUTHORSHIP

Peter Reid, Principal ..... Discipline Lead, Co-Author

Michael Schroeder, Senior Air Quality Scientist ..... Independent Senior Reviewer

John Spagnol, Senior Air Quality Scientist ..... Co-Author

John Gallagher, Air Quality Scientist ..... Co-Author

Jason Wang, Air Quality Engineer ..... Emissions Specialist

EXECUTIVE SUMMARY

LNG Canada Development Inc. is proposing to construct and operate a liquefied natural gas (LNG) facility (including an LNG processing and storage site and marine terminal) in the District of Kitimat, British Columbia, and to export LNG from the facility by shipping. This proposed project is called the LNG Canada Export Terminal (the Project). The Application Information Requirements for the Project identified air quality as a valued component. This air quality technical data report presents baseline information, methods, and results of dispersion modelling conducted for the Project to support the anticipated application for the Environmental Assessment Certificate.

This report reviews existing climate and air quality information, including the results of field studies conducted to address the gap between existing information and that required to complete the assessment.

The assessment primarily involves quantification of criteria air contaminant (CAC) and volatile organic compound (VOC) emissions during construction and operation of the Project, and assessment of the effects of these emissions using appropriate techniques, including dispersion modelling. It includes inventories of Project air emissions, and a summary of air quality dispersion modelling results for existing sources, Project sources, and cumulative effects.

Construction emissions are intermittent, transient, and small compared with operation emissions, so effects of construction emissions are deemed insubstantial and are not included in the dispersion modelling assessment. Four modelling scenarios are evaluated: base case (existing and approved sources), Project-alone case (Project emissions in isolation), application case (base and Project-alone cases), and cumulative case (application and future sources).

For the Project-alone case, there are no predicted exceedances of the existing and interim ambient air quality objectives. For the base case, sulphur dioxide (SO_2) concentrations are predicted primarily to the west of the Rio Tinto Alcan (RTA) facility at levels greater than the applicable and the interim ambient air quality objectives. These levels are a direct result of the SO_2 emissions from the RTA facility. Predicted concentrations did not exceed the objectives for any other substance of interest modelled. The overall findings from the application and cumulative cases are the same as for the base case.

It is concluded that air quality in the regional study area will not change appreciably from base case conditions when the Project is fully operational. Air quality in the District of Kitimat is already compromised by SO_2 emissions from the operation of the RTA facility. The Project adds a very small increment to the effects predicted for the RTA facility alone.

ACRONYMS AND ABBREVIATIONS

AAQO ..... Ambient Air Quality Objectives
AIR ..... Application Information Requirements
asl ..... above sea level
BC ..... British Columbia
MOE ..... British Columbia Ministry of Environment
BOG ..... Boil Off Gas
BTEX ..... benzene, toluene, ethylbenzene, and xylenes
CAAQS ..... Canadian Ambient Air Quality Standards
CAC ..... criteria air contaminant
CALMET ..... meteorological data pre-processor for CALPUFF
CALPUFF ..... (California puff) air quality dispersion model
cm ..... centimetres
CO ..... carbon monoxide
ECA ..... Emission Control Area
H_2S ..... hydrogen sulphide
IMO ..... International Maritime Organization
KLNG ..... Kitimat LNG Project
KMP ..... Kitimat Modernization Project
kg/s ..... kilograms per second
kPa ..... kilopascals
km ..... kilometres
km/h ..... kilometres per hour
LNG ..... liquefied natural gas
LNG Canada ..... LNG Canada Development Inc.
LSA ..... local study area
m ..... metres
m/s ..... metres per second

µm ..... one millionth of a metre
mg/m^3 ..... milligrams per cubic metre
mm ..... millimetres
MM5 ..... regional mesoscale model for weather forecasts and climate projections
NAAQO ..... National Ambient Air Quality Objectives
NCAR ..... National Center for Atmospheric Research
NGL ..... natural gas liquids
NO ..... nitric oxide
NO_2 ..... nitrogen dioxide
NO_X ..... oxides of nitrogen
O_3 ..... ozone
OLM ..... ozone limiting method
PM ..... particulate matter
PM_{10} ..... inhalable particulate matter (<10 µm in aerodynamic diameter)
$PM_{2.5}$ ..... respirable particulate matter (<2.5 µm in aerodynamic diameter)
ppb ..... parts per billion
ppm ..... parts per million
PRIME ..... Plume Rise Model Enhancements
Project ..... LNG Canada Export Terminal
RIVAD/ARM3 ..... Regional Impact in Visibility and Acid Deposition/ Acid Rain Mountain Mesoscale Model
RSA ..... regional study area
RTA ..... Rio Tinto Alcan
SO_2 ..... sulphur dioxide
SCREEN3 ..... single source screening Gaussian plume model
SOI ..... substances of interest
STAR ..... *Sulphur Dioxide Technical Assessment Report*
t/d ..... tonnes per day
t/y ..... tonnes per year

TDR .....technical data report
U.S. EPA..... United States Environmental Protection Agency
US NAAQS .....United States National Ambient Air Quality Standards
VC .....valued component
VOC ..... volatile organic compound
WHO .....World Health Organization
WRF..... Weather Research and Forecasting
µm .....micrometres
µg/m^3 .....micrograms per cubic metre
°C .....degrees Celsius

Note: References to "Section 0" have been updated to refer to the appropriate sections.

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1 INTRODUCTION

LNG Canada Development Inc. (LNG Canada) is proposing to construct and operate a liquefied natural gas (LNG) facility (including an LNG processing and storage site and marine terminal) in the District of Kitimat, British Columbia (BC), and to export LNG from the facility by shipping. This proposed project is called the LNG Canada Export Terminal (the Project).

The purpose of this technical data report (TDR) is to describe the methods and technical details related to the air quality assessment. Information has been generated from existing literature and technical data sources, engineering estimates of emissions, and computer plume dispersion modelling to predict ground-level concentrations for substances of interest. This TDR presents the following key information: 1) a summary of baseline climate and background air quality conditions; 2) Project air emissions, and 3) a summary of air quality dispersion modelling methods and results.

Input from consultation with regulators, Aboriginal Groups, and the public, in combination with professional judgement and past experience of the air assessment team guided the scope of the study. The study was initiated with a review of existing information. Field studies were then conducted to address the gap between existing information and that required to support the anticipated application for the Environmental Assessment Certificate.

The Application Information Requirements (AIR) identified air quality as a valued component (VC). This TDR supports the air quality component of the environmental assessment for the Project as presented in the Environmental Assessment Certificate document. It includes an assessment of criteria air contaminant (CAC) and volatile organic compound (VOC) emissions from both the construction and operation phases of the Project. The TDR also includes an assessment of fogging and icing from cooling tower water vapour discharge. Water vapour has no effect on air quality; however, the presence of fog and ice at ground level is a visual impact and can affect public safety on roads.

The AIR also includes reference to assessing acidifying air emissions (sulphur dioxide [SO_2] and oxides of nitrogen [NO_x]). This work is described herein; however, no conclusions respecting the effect of acidifying emissions are made. Responsibility for assessing the effects of acid deposition rests with the biophysical disciplines contributing to the environmental assessment (e.g., soils, vegetation, and water quality).

1.1 Scope of Assessment

While virtually all Project activities have the potential to emit substances to the atmosphere, only those that have the potential to result in significant adverse effects (either alone or cumulatively with other existing and future emission sources) are assessed. Decisions regarding which emissions to assess are based on experience gained during previous projects with similar conditions and potential issues, as well as feedback from stakeholders and regulators, relevant scientific studies, and professional judgment of the assessment team.

During construction, key Project activities and physical works include the following:

- onshore site preparation for the facility, which includes clearing, grubbing, rock/material removal or fill, grading, compaction, paving, erosion and sediment control
- offshore site preparation for the proposed marine terminals, which includes dredging, disposal at sea, and blasting if needed
- building of the temporary infrastructure, which includes offices, laydown area, maintenance buildings, and sanitary facilities
- LNG facility installation, which includes the LNG treatment, liquefaction, extraction and storage facilities; plant piping; cooling towers; flare system; and site services
- utilities installation, which includes the power supply and handling, water supply and handling, waste collection and treatment, fire protection system, storm water collection, fuelling station, and oil-water separator
- proposed marine terminal and pipeline installations
- workforce accommodation centre building and operation
- road use and vehicle traffic
- clean-up and reclamation, and
- commissioning, which includes start-up and flaring.

During operation, key Project activities and physical works include the following:

- operation and maintenance of the LNG facility, which includes LNG treatment, liquefaction, extraction and storage facilities; plant piping; cooling towers; and flare system
- utilities operation and maintenance
- marine terminals operation and maintenance, which includes berthing and loading
- haul road use and maintenance, and
- shipping, which includes the LNG carriers and support tugboats.

The assessment primarily involves quantification of CAC and VOC emissions during construction and operation of the Project, and assessment of the effects of these emissions using appropriate techniques, including plume dispersion modelling to predict ground-level concentrations of substances of interest.

1.2 Technical Data Report Structure

The structure of the TDR is as follows. The local and regional study areas are defined in Section 2. In Section 3, the substances of interest are described and the corresponding regulatory criteria for air quality are summarized. Section 4 is an overview of previous air quality investigations in the Kitimat area and a characterization of baseline climate and background air quality. Emissions from the Project and other relevant facilities are summarized in Section 5, followed by a description of methods used in the air quality plume dispersion modelling in Section 6. Results of the modelling are presented in Section 7. The predicted ground-level concentrations for substances of interest are compared with the applicable regulatory ambient air quality objectives to evaluate air quality effects in the local and regional study areas. Factors affecting confidence of the assessment are detailed in Section 8, and then key results and findings are reviewed in Section 9.

There are eight appendices in the report containing important supplemental information that is too detailed to include in the report body. The appendices contain:

- the 30-year climate normals used in baseline climate analysis (Appendix A)
- background air quality data from the Project monitoring program (Appendix B)
- the dispersion modelling plan (Appendix C)
- a detailed emission inventory (Appendix D)
- details of the CALMET and CAPLUFF modelling (Appendices E and F, respectively)
- isopleth maps depicting maximum plume dispersion modelling results (Appendix G), and
- results of a study of fogging and icing effects from cooling tower water vapour emissions (Appendix H).

2 STUDY AREAS

The study areas for the air quality assessment are defined below. The study areas were chosen to encompass the geographic extent of possible effects on air quality from Project emissions. Additional information on selection of study areas as they relate to modelling domains is provided in Section 6.4.

2.1 Regional Setting

The Project is located on approximately 300 to 350 hectares (ha) in the District of Kitimat in the North Coast region of BC. The North Coast is a region of complex coastal terrain consisting of ocean inlets, channels, mountains, and narrow river valleys. Kitimat is located at the head of the Kitimat Arm portion of Douglas Channel. The LNG production facility will be at approximately 20 m above sea level (asl), and the marine terminal will be at or near sea level. The Project is bounded by rapidly rising terrain to the east and west, with the narrow Kitimat River valley extending to the north.

2.2 Local Study Area

For the air quality assessment of the LNG facility, the local study area (LSA) consists of a 40 kilometre (km) by 40 km area centred on the facility. This LSA is used to depict and evaluate effects of Project emissions on air quality in the Kitimat area.

The LSA for assessment of acidic deposition is a 40 km by 125 km grid that covers an area from Kitimat Arm to beyond Kitsumkalum Lake, north of Terrace. This larger domain is used for evaluation of regional acidification patterns.

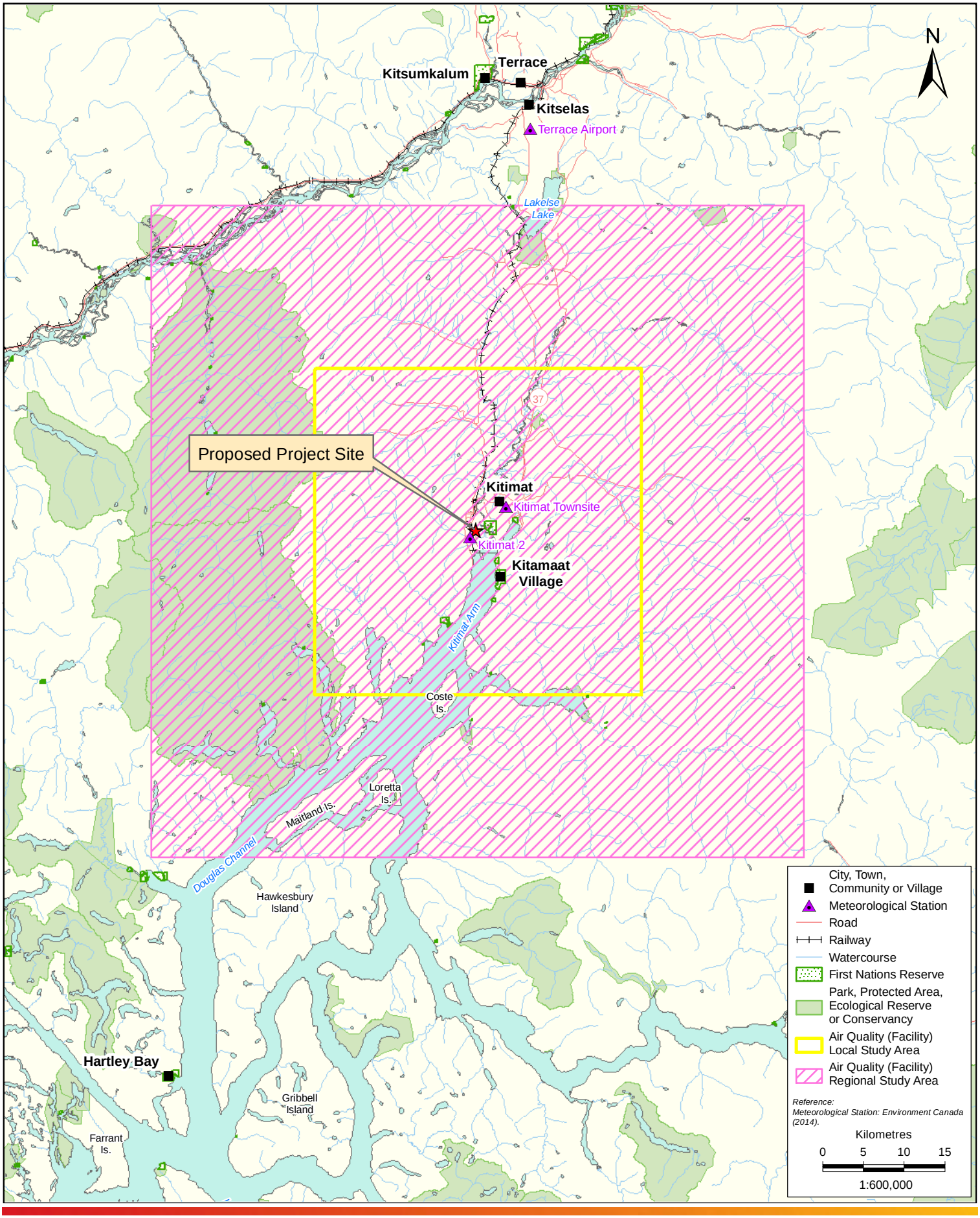
The LSA for shipping is 2 km on either side of the marine access route. Air quality effects for some communities and receptors of interest near the marine access route that fall outside the LSA (e.g., Hartley Bay, Kitkatla, and Metlakatla) are also assessed.

2.3 Regional Study Area

For the air quality assessment of the LNG facility, the regional study area (RSA) consists of a 78 km by 78 km area centred on the facility. This RSA was selected to include other future facilities that could influence the cumulative effects assessment. Figure 2.3-1 shows the boundaries of the Facility LSA and RSA.

The RSA for assessment of acidic deposition is the same as the LSA. Figure 2.3-2 shows this study area.

The RSA for shipping is 5 km on either side of the marine access route. Air quality effects for some communities and receptors of interest near the marine access route that fall outside the RSA (e.g., Kitkatla and Metlakatla) are also assessed. Figure 2.3-3 shows the shipping LSA and RSA.



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AIR QUALITY TECHNICAL DATA REPORT

AIR QUALITY (FACILITY)
LOCAL AND REGIONAL STUDY AREAS

LNG CANADA EXPORT TERMINAL
KITIMAT, BRITISH COLUMBIA

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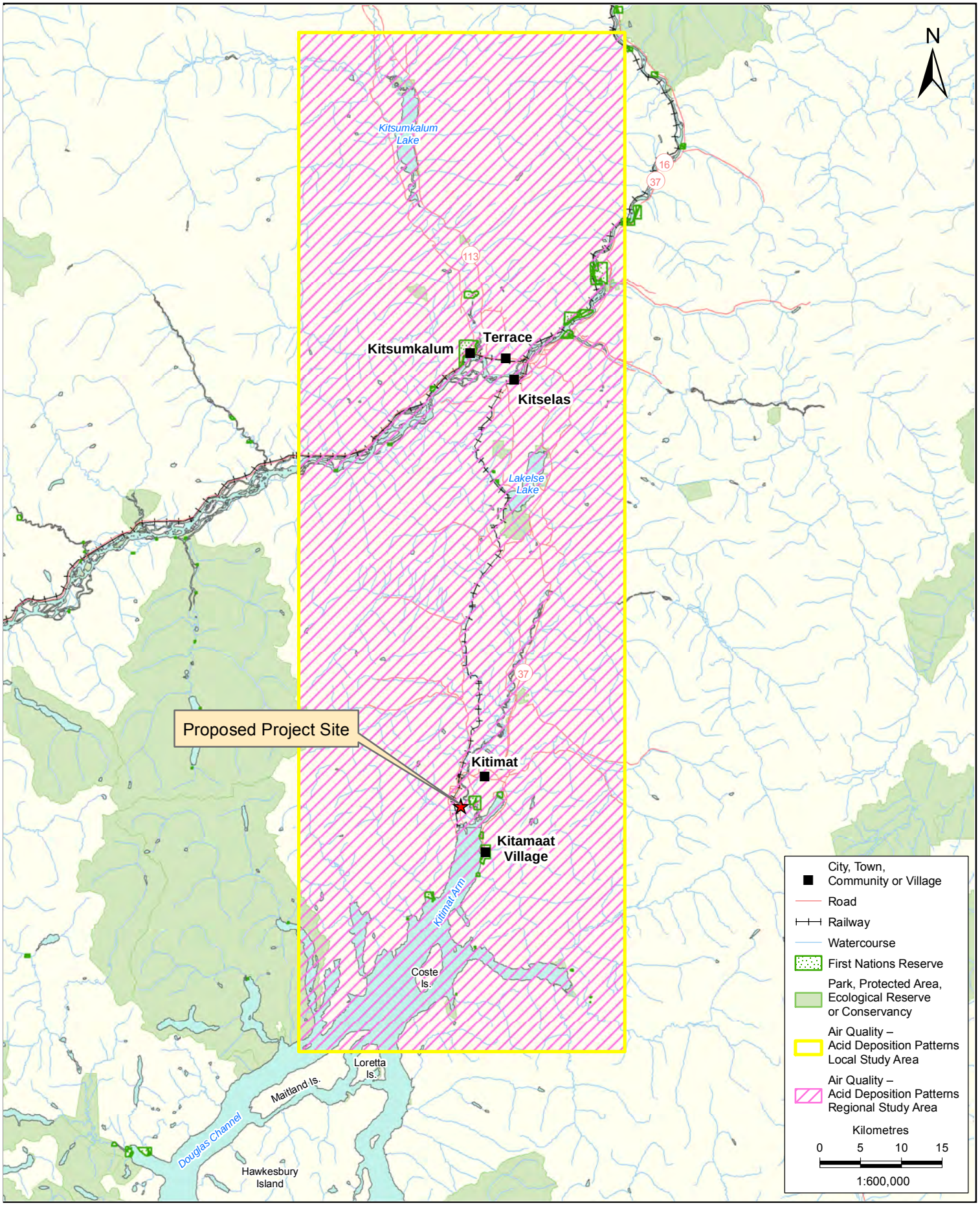

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AIR QUALITY TECHNICAL DATA REPORT

AIR QUALITY (ACIDIC DEPOSITION)
LOCAL AND REGIONAL STUDY AREAS

LNG CANADA EXPORT TERMINAL
KITIMAT, BRITISH COLUMBIA

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AIR QUALITY TECHNICAL DATA REPORT

AIR QUALITY (SHIPPING)
LOCAL AND REGIONAL STUDY AREAS

LNG CANADA EXPORT TERMINAL
KITIMAT, BRITISH COLUMBIA

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3 SUBSTANCES OF INTEREST

Substances of interest (SOI) for the air quality assessment were selected based on stakeholder interactions as well as knowledge of air emissions from the Project and applicable provincial and national air quality objectives. The seven SOI for this assessment are:

- sulphur dioxide (SO_2)
- nitrogen dioxide (NO_2)
- carbon monoxide (CO)
- respirable particulate matter (diameter less than 2.5 micrometres [$PM_{2.5}$])
- hydrogen sulphide (H_2S)
- volatile organic compounds (VOCs), and
- ozone (O_3).

Of these seven SOI, six are considered to be criteria air contaminants (CACs) because there are ambient air quality objectives (AAQO) and standards against which to compare measured or predicted ground-level concentrations. VOCs are a mixture of volatile non-methane hydrocarbons and are not CACs; however, many substances that are VOCs do have applicable regulatory criteria in other jurisdictions.

Ozone was raised as a potential concern by stakeholders; however, it is not quantitatively assessed in this report. Ozone is not emitted by the Project directly, but results from chemical interactions in the atmosphere between precursor substances, some of which are emitted by the Project. Emissions from the Project might also have the effect of consuming O_3 in the reaction of $NO \rightarrow NO_2$. In two technical memoranda (Stantec 2103a, 2013b), it was demonstrated that O_3 is not an issue in Kitimat. The Kitimat region displays little evidence of enhanced O_3 production. The incremental addition of precursor emissions attributable to the Project is unlikely to alter this condition meaningfully. Investigation of O_3 was therefore not included in the environmental assessment.

The six remaining SOI are described in the following subsections.

3.1 Criteria Air Contaminants

3.1.1 Sulphur Dioxide

Sulphur dioxide is a colourless gas with a distinctive and pungent sulphur odour. It is produced during combustion by the oxidation of sulphur compounds present in various fuels. At high concentrations, SO_2 can have negative effects on plant and animal health, particularly with respect to their respiratory systems. In addition, SO_2 can be further oxidized and could combine with water to form the sulphuric acid component of acid rain.

Anthropogenic emissions comprise about 95% of global atmospheric SO_2. The largest anthropogenic contributor to atmospheric SO_2 is the industrial and electric utility combustion of sulphur-containing heavy fuel oils and coal. Oxidation of reduced sulphur compounds (e.g., H_2S) emitted by ocean surfaces accounts for nearly all biogenic emissions; volcanic activity accounts for much of the remainder. Motor vehicles are relatively small contributors to the SO_2 content of the atmosphere (Wayne 1991).

3.1.2 Oxides of Nitrogen

Nitrogen oxides are produced in most combustion processes and are almost entirely made up of nitric oxide (NO) and NO_2. Together, they are referred to as NO_X. The concentration of NO_2 is the regulated form of NO_X. Nitrogen dioxide is an orange to reddish gas that is corrosive and can be irritating to respiratory systems. Most NO_2 in the atmosphere is formed by the oxidation of NO, which is emitted directly by combustion processes, particularly those at high temperature and pressure, such as internal combustion engines.

Anthropogenic emissions comprise approximately 93% of global atmospheric emissions of NO_X. The largest anthropogenic contributor to atmospheric NO_X is the combustion of fuels such as natural gas, oil, and coal. Forest fires, lightning, and anaerobic processes in soil account for nearly all biogenic emissions (Wayne 1991).

3.1.3 Carbon Monoxide

Carbon monoxide is a colourless, odourless gas that can become toxic to humans and other animals at very high concentrations. As a product of incomplete combustion, its sources include fossil fuel and wood combustion. Motor vehicles, industrial processes, and natural sources (e.g., forest fires) are common sources.

3.1.4 Respirable Particulate Matter

Particulate matter (PM) is classified by size of the particles. Particle size and density determine the velocity with which gravitational settling occurs and the ease with which particles penetrate the human respiratory tract. Generally, large particles settle out very close to the source, whereas very fine particles can remain in the atmosphere for many days, travelling long distances. Particulate matter is classified as PM_{10} and $PM_{2.5}$, for particles with diameters less than 10 micrometres (µm) and 2.5 µm, respectively. In recent years, health concerns regarding PM have focussed primarily on the very fine $PM_{2.5}$, which is also referred to as respirable PM. Emissions from combustion processes, both natural and anthropogenic, usually contain $PM_{2.5}$ as well as gases that can potentially undergo gas-to-particle conversion in the atmosphere, creating what are known as secondary particles.

3.1.5 Hydrogen Sulphide

Hydrogen sulphide is a colourless gas. At low concentrations, for example, less than 20 micrograms per cubic metre ($\mu g/m^3$), H_2S is readily detectable by its distinctive rotten eggs odour. At very high concentrations largely restricted to occupational settings, exposure to H_2S carries well understood risks to worker safety, which is mitigated through use of personal protective equipment and training.

Biogenic emissions comprise approximately 96% of global atmospheric H_2S. Reduced sulphur compounds emitted by ocean surfaces account for nearly all biogenic emissions. The largest anthropogenic contributors to atmospheric H_2S are industrial facilities such as pulp and paper mills and petroleum refineries (Wayne 1991).

3.1.6 Volatile Organic Compounds

Volatile organic compounds are carbon-containing (organic) compounds that readily evaporate into air under ambient conditions. Many VOCs are of natural origin, such as methane. Others may be potentially harmful to the environment, either directly through toxic effects or indirectly as a contributor to ground-level ozone and smog formation. Relevant sources of VOCs include heavy equipment, internal combustion engines, and storage tank vapours.

Some VOCs may have short- and long-term adverse health effects. Key signs or symptoms from exposure to VOCs include eye irritation, nose and throat discomfort, headache, allergic skin reaction, declines in serum cholinesterase levels, nausea, fatigue, and dizziness. VOCs may be emitted by a wide array of products, including paints and lacquers, cleaning supplies, and pesticides. Although VOCs are naturally present in the atmosphere and are emitted by vehicles and industrial processes, concentrations of many VOCs are considerably higher indoors than outdoors.

3.2 Applicable Objectives for Air Quality

3.2.1 British Columbia and Canadian AAQO

Ambient criteria for CACs include the BC Ambient Air Quality Objectives (BC AAQO), the National Ambient Air Quality Objectives (NAAQO), and the Canadian Ambient Air Quality Standards (CAAQS). The most stringent of the BC AAQO, NAAQO, and CAAQS are applied in this air quality assessment, resulting in a conservative assessment of potential effects of Project emissions. Air quality objectives and standards are summarized in Table 3.2-1.

Table 3.2-1: Ambient Air Quality Objectives for Criteria Air Contaminants

Substance	Averaging Period	BC Objectives (BC AAQO) (µg/m^3)			Canada Objectives (NAAQO and CAAQS) (µg/m^3)		
		Level A	Level B	Level C	Maximum Desirable	Maximum Acceptable	Maximum Tolerable
SO_2	1-hour	**450**	900	900	450	900	N/A
	3-hour	**375**	665	N/A	N/A	N/A	N/A
	24-hour	160	260	360	**150**	300	800
	Annual	**25**	50	80	30	60	N/A
NO_2	1-hour	N/A	N/A	N/A	N/A	**400**	1,000
	24-hour	N/A	N/A	N/A	N/A	**200**	300
	Annual	N/A	N/A	N/A	**60**	100	N/A
CO	1-hour	**14,300**	28,000	35,000	15,000	35,000	N/A
	8-hour	**5,500**	11,000	14,300	6,000	15,000	20,000
$PM_{2.5}$	24-hour	**25** [a]			28 (27) [c]		
	Annual	**8** (6) [b]			10 (8.8) [d]		
TRS (as H_2S) [e]	1-hour	**7** [e]	28		N/A	N/A	N/A
	24-hour	**3** [e]	6		N/A	N/A	N/A

NOTES:

[a] Based on the 98th percentile value for one year.

[b] The BC AAQO for $PM_{2.5}$ defines a planning goal of 6 µg/m^3 (annual average) intended as a voluntary target to guide airshed planning efforts. The objective is 8 µg/m^3 (BCMOE 2013a).

[c] The CAAQS for 24-hour $PM_{2.5}$ is referenced to the annual 98th percentile of daily 24-hour average concentrations, averaged over three years. The first CAAQS is the standard effective in 2015; the new standard proposed for 2020 is given in brackets (Environment Canada 2013).

[d] The CAAQS for annual $PM_{2.5}$ is referenced to the 3-year mean of annual average concentrations. The first CAAQS shown is the standard effective in 2015; the new standard proposed for 2020 is given in brackets (Environment Canada 2013).

[e] BC AAQO for total reduced sulfur measured as H_2S (BCMOE 2013a). This supersedes previous objectives specific to H_2S.

N/A – Not applicable (no objective has been established for this category).

TRS – total reduced sulphur

Values in bold identify the most stringent objectives applicable to the Project.

No national or BC objectives exist for VOCs.

The national objectives are defined as follows:

- The **maximum desirable level** is the long-term goal for air quality and provides a basis for anti-degradation policy for unpolluted parts of the country, and for the continuing development of control technology.
- The **maximum acceptable level** is intended to provide adequate protection against effects on soil, water, vegetation, materials, animals, visibility, personal comfort, and well-being.
- The **maximum tolerable level** denotes time-based concentrations of air contaminants beyond which, due to a diminishing margin of safety, appropriate action is required to protect the health of the general population.

The CAAQS for 2015 and 2020 were adopted by the Canadian Council of Ministers of the Environment (Environment Canada 2013). The new CAAQS supersede the Canada-Wide Standards for PM and O_3. A review of the 2020 CAAQS is expected in 2015.

In BC, the AAQO are denoted as Levels A, B, and C, which are defined as follows:

- **Level A** is set as the objective for new and proposed discharges and, within the limits of best achievable technology, to existing discharges by planned staged improvements for these operations.
- **Level B** is set as the intermediate objective for all existing discharges to meet within a period of time specified by BC Ministry of Environment (MOE), and as an immediate objective for existing discharges that may be increasing in quantity or altered in quality as a result of process expansion or modification.
- **Level C** is set as the immediate objective for all existing chemical and petroleum industries to reach within a minimum technically feasible period of time.

No national or BC AAQO exist for assessment of exposure to VOCs. In Alberta, AAQO exist for benzene, which is the most toxic of the commonly emitted VOCs. The Alberta AAQO for bezene is 30 µg/m^3 for the 1-hour averaging period and 3 µg/m^3 for the annual averaging period. Benzene makes up a small portion of BTEX (benzene, toluene, ethylbenzene, and xylenes), a group of toxic compounds found in petroleum derivatives. Only a small portion of the total VOCs emitted from the Project will consist of BTEX, and of that only a small portion is benzene. It is estimated for the Project that approximately 0.5% of the total VOCs will be benzene. Therefore, comparing the maximum predicted VOC concentrations to the Alberta benzene AAQO is extremely conservative.

3.2.2 BC Interim AAQO

In mid-2013, the BC government announced the proposed development of new AAQO for SO_2 and NO_2 to be released in mid-2014. In the intervening time, the MOE has requested that proponents consider

selected AAQO from other jurisdictions, namely, the United States Environmental Protection Agency (U.S. EPA) and the World Health Organization (WHO).

The predicted concentrations of CACs are compared against the following interim AAQO in addition to the existing AAQO (Table 3.2-1). Specifically, the following criteria have been cited:

- For the 1-hour SO_2 and NO_2 objectives, the U.S. EPA National Ambient Air Quality Standards (US NAAQS) modified for 1-hour averages (U.S. EPA 2012)
- For the annual NO_2 objective, the WHO Guidelines (WHO 2006).

The interim objectives are listed in Table 3.2-2 in both µg/m^3 and parts per billion (ppb).

Table 3.2-2: Supplemental AAQO for Sulphur Dioxide and Nitrogen Dioxide

Substance	Averaging Period	Supplemental Objectives	
		(ppb)	(µg/m^3)
SO_2	1-hour [a]	75	200
NO_2	1-hour [b]	100	188
	Annual [c]	21	40

NOTES:

MOE has not specified criteria for the 24-hour intervals for SO_2 or NO_2, nor has it specified annual average criteria for SO_2.

All conversions between ppb and µg/m^3 were performed by MOE and are referenced to 101.325 kPa and 25°C.

[a] The U.S. EPA metric for SO_2 references the annual 99th percentile of daily 1-hour maxima, averaged over three consecutive years. This requires the extraction of the highest 1-hour value for each day followed by the calculation of the 99th percentile of those 365 values at each receptor modelled, and then averaging this value over three consecutive years.

[b] The U.S. EPA metric for NO_2 references the annual 98th percentile of daily 1-hour maxima, averaged over three consecutive years. This requires the extraction of the highest 1-hour value for each day followed by the calculation of the 98th percentile of those 365 values at each receptor modelled, and then averaging this value over three consecutive years.

[c] The WHO objective considers the first highest annual average value.

The interim AAQO for 1-hour presented in Table 3.2-2 are not intended to be compared with the first highest (or maximum) predicted SO_2 and NO_2 concentrations in the modelling domain. They are intended to be compared against the fourth and eighth highest (99th and 98th percentile) of the daily 1-hour maximum concentrations, averaged over three consecutive years.

Because the WHO objective for annual NO_2 in Table 3.2-2 considers the first highest annual average value, it is directly compared with the annual average.

4 REVIEW OF EXISTING DATA

The review of existing data includes two separate analyses. The first is a literature review that briefly describes all major works on air quality in the Kitimat region. The second is a description of the baseline atmospheric conditions developed from historical records and monitoring conducted for the Project. This includes a summary of the regional climate, a description of historical air quality in Kitimat, and a description of background air quality on the North Coast.

4.1 Literature Review of Previous Investigations

Three substantial analyses of air quality in the Kitimat region are briefly reviewed in this section. This includes the Kitimat LNG environmental assessment (KLNG 2005), the Enbridge Northern Gateway environmental assessment (Enbridge 2010), the Rio Tinto Alcan (RTA) Sulphur Dioxide Technical Assessment Report (RTA 2013), and the 2014 MOE Kitimat Airshed Emissions Effects Assessment (ESSA 2014).

4.1.1 Results

Kitimat LNG (2005)

The Application for an Environmental Assessment Certificate for the Kitimat LNG Terminal Project (KLNG) included a comprehensive assessment of air quality (KLNG 2005). Included were baseline climate analyses, background air quality investigations, and a dispersion assessment of that project's emissions. The project assessed was a proposed LNG import facility comprised of eight LNG submerged combustion vapourizers, three process-related heaters, and a marine vessel at the jetty. Emissions from electrical generation were not assessed, as it was assumed that project's relatively modest electrical demand would be served by the local grid.

Existing emission sources were characterized through the addition of background air quality concentrations to the predicted concentrations. Background air quality was not modelled because of the distance between Kitimat proper and that project site at Emsley Cove. Future air quality was not modelled because no new announced or proposed facilities were noted.

Major project effects were attributed to marine vessels at the jetty. Because marine fuels contain appreciable amounts of sulphur, small areas affected by SO_2 occurred immediately adjacent to the jetty. The assessment concluded that the residual and cumulative effects were not significant, and the project was approved by the BC Government in June 2006, albeit at a new location in nearby Bish Cove.

After the Environmental Assessment Certificate was approved, an application was made in November 2008 to revise the facility from an LNG import facility to an LNG export facility. Projected emissions

declined with the removal of the eight LNG submerged combustion vapourizers. It is assumed that the liquefaction of LNG will be driven by electrical power available from the grid. The revised certificate was issued in January 2009 with no new air quality dispersion assessment required.

Enbridge Northern Gateway (2010)

The Application for an Environmental Assessment Certificate for the Enbridge Northern Gateway Project included a comprehensive assessment of air quality (Enbridge 2010). Included were baseline climate analyses, background air quality investigations, and a dispersion assessment of base case, Project-alone case, application case, and cumulative (future) case emissions. The project assessed is a proposed petroleum export and import facility comprised of a number of large storage tanks and a jetty accommodating two vessels.

Existing emission sources were characterized through modelling of background air quality (base case) and adding these concentrations to the predicted concentrations. Background air quality was modelled given the proximity to Kitimat.

The major project effect was attributed to marine vessels at the jetty. Because marine fuels contain appreciable amounts of sulphur, small areas affected by SO_2 occurred immediately adjacent to the jetty. The cumulative case also considered the additive effect of marine vessels at the approved KLNG facility.

Just before filing the application, the International Maritime Organization (IMO) announced the implementation of a North American Sulphur Emission Control Area (ECA). The ECA reduces the allowable sulphur in marine fuel by 96%, in effect eliminating the issues related to SO_2 adjacent to both the Enbridge jetty and the nearby KLNG facility.

The assessment concluded the residual and cumulative effects were not significant, and the project was approved by the National Energy Board in late 2013. The project was later approved with conditions by the federal government in June 2014.

Rio Tinto Alcan Sulphur Dioxide Technical Assessment Report (2013)

To support the amendment of the MOE Multimedia Permit authorizing emissions from the RTA facility to accommodate the Kitimat Modernization Project (KMP), RTA produced the *Sulphur Dioxide Technical Assessment Report* (STAR) (RTA 2013). This report included a comprehensive study of existing and modernized facilities, as well as an examination of the human health and ecological responses to the change. The most substantial changes included reductions in some toxic substances and an increase in SO_2 emissions. The proposed increase will see the permitted limit on SO_2 emissions rise from the current 27 tonnes per day (t/d) to a new limit of 42 t/d (a 56% increase).

This study included predictions of atmospheric concentrations of SO_2 and sulfate deposition. Predictions of SO_2 concentrations were important inputs to studies of human health effects and direct effects on vegetation. Predictions of sulfate deposition were used to assess indirect effects on vegetation via soils, potential changes in soils, and potential responses of lakes and streams.

These results provide a useful point of comparison for the Project base case results because they are based on the same emission scenario, modelled using the same source input files.

Results from the STAR (RTA 2013) are summarized in Table 4.1-1, which lists the maximum predicted ground-level SO_2 concentrations modelled over three meteorological years (2006, 2008, and 2009). Modelling of SO_2 concentrations was based on emission rates that represent the requested new limit of 42 t/d.

Table 4.1-1: Post-KMP Maximum SO_2 Model Results

Averaging Period	Year [a]	Maximum Concentration Offsite [b] (µg/m^3)	Maximum Concentration Residential [b] (µg/m^3)	Pollution Control Objectives (µg/m^3)		World Health Organization (µg/m^3)
				Minimum	Maximum	
1-hour	2009	2,630	1,918	450	900	500
3-hour	2006	1,122	874	375	665	N/A
24-hour	2006	261	191	160	260	20
Annual	2006	35	16	25	75	N/A

NOTES:

[a] The year corresponds to the maximum concentration in the residential area; the offsite maximum concentration does not necessarily correspond to the same year.

[b] Modelled concentrations include a background concentration appropriate to the averaging period. Background concentrations are based on monitoring data at the nearby Kitamaat Village monitoring station, as follows: 1.5 ppb (3.9 µg/m^3) for the 1-hour and 3-hour averaging periods, 1.2 ppb (3.1 µg/m^3) for the 24-hour averaging period, and 0.4 ppb (1.0 µg/m^3) for the annual averaging period.

SOURCE: RTA (2013)

The modelled emissions are also compared with the WHO standards and the Pollution Control Objectives. At the requested SO_2 limit, predicted maximum concentrations exceed the 1-hour, 3-hour, and 24-hour averaging period Pollution Control Objectives, as well as the 1-hour and 24-hour WHO standards (RTA 2013).

Kitimat Airshed Emissions Effects Assessment (2014)

The BC Ministry of Environment (MOE) contracted ESSA Technologies to conduct a rapid scoping-level assessment of the potential combined effects on the environment and human health from nitrogen dioxide (NO_2) and sulphur dioxide (SO_2) emissions from a collection of alternative future scenarios representing a

range of existing and proposed industrial facilities in the Kitimat area. This report (ESSA 2014) was publicly released on July 18, 2014.

Twelve scenarios were evaluated, based on a range of existing and proposed facilities with various levels of emissions treatments. Sources included 1) the RTA facility and its planned modernization; 2) a proposed oil refinery; 3) four proposed LNG facilities; 4) BC Hydro gas turbine powered electrical generation facilities; and 5) predicted increases to marine shipping in Douglas Channel.

Of these twelve scenarios, the one identified as "G_76.2" resembles the application case emissions and sources considered in this assessment. Nitrogen dioxide and sulphur dioxide emissions considered in this scenario are approximately 73% and 20% higher respectively than those considered in this report. Given these discrepancies and other differences in dispersion modelling treatment, these results are not comparable to the Project application case results. ESSAs predicted concentrations of NO_2 and SO_2 resemble generally the findings of this work and the RTA STAR work; however, a more detailed comparison of predictions is of limited value.

4.1.2 Discussion

The KLNG (2005) and Enbridge Northern Gateway (2010) environmental assessments share one common element—marine vessel emissions are identified as the main concern. Both were assessed before the IMO declaration of the North American ECA for marine vessels. Given the 96% reduction in marine vessel SO_2 emissions, findings of these assessments are outdated. Since that time it has also been determined that the actions required to achieve the required reductions in SO_2 (fuel switching) have the co-benefit of reducing emissions of NO_X and $PM_{2.5}$. In essence, the subject of these assessments—deleterious effects of SO_2 near the jetty—has been fully mitigated and is no longer of concern.

The STAR (RTA 2013) is relevant in that it presents an assessment of present-day and future SO_2 emissions from the largest source of that substance in the Kitimat River valley. The study concludes that despite the projected 56% increase in SO_2 emissions, the near-field effects are largely unchanged from the present-day effects. This is achieved by improved dispersion of emissions from the higher stacks of the modernized facility compared with the poor dispersion experienced with the circa-1950 facility design. Despite this, offsite effects exceed provincial and other objectives for air quality by a large margin, albeit to a lesser extent in populated areas.

One outcome of the improved dispersion of emissions from the modernized facility compared with that of the present-day facility is the increased acidification effects in the far field. Acidification effects that were previously confined near Kitimat are now free to move far up the Kitimat River valley (due to the increased stack heights). The result is acid deposition to the north that is predicted to be greater than has previously been experienced

The Kitimat Airshed Emissions Effects Assessment (2014) commissioned by the MOE presents one scenario (G_76.2) that resembles the application case emissions and sources considered in this assessment. Because of emissions quantity discrepancies and other differences in dispersion modelling treatment, these results are not comparable to the Project application case results. The predicted concentrations of NO_2 and SO_2 in the Kitimat Airshed Emissions Effects Assessment resemble generally the findings of this assessment and the RTA STAR work, however, a more detailed comparison of predictions is of limited value.

The results presented in both the RTA STAR work and the MOE Airshed study differ from this assessments results in that near-field effects in this work are substantially higher and the far field effects are substantially lower. Both the RTA STAR work and the MOE Airshed study were completed by the same consultants using (as far as can be determined) the same input data for RTAs emissions and the same meteorological input files. Ten chief reasons for the differences in these results are discussed in detail in Section 8.4 of this report.

4.2 Baseline Atmospheric Conditions

The following subsections describe the existing or baseline atmospheric conditions. Included is an analysis of baseline climate and background air quality. Examining baseline conditions allows for an understanding of the existing ambient conditions and helps establish a link between air emissions and potential changes in air quality.

Climate is defined as the weather conditions prevailing in an area in general or over a long time. Section 4.2.1 provides an overview of the region's local and regional climate conditions, with a focus on the primary variables of temperature, precipitation, and wind. On shorter time scales, meteorological conditions (along with topography) determine the transport, dispersion, deposition, and resulting ambient concentrations of SOI that are emitted in an airshed.

An analysis of background air quality is included (Section 4.2.2). It describes air quality conditions in the study area. Data from five air quality monitoring stations in the Kitimat area are compiled to characterize typical and maximum observed concentrations for the SOI.

Additionally, a Project passive ambient monitoring network has been established to cover areas not sampled by the existing network. A description of the passive monitoring network and results to date are included in Section 4.2.3.

4.2.1 Regional Climate

The Project is located on BC's North Coast, a region of temperate rainforest and rugged coastal terrain. The prevailing westerly storm track across the North Pacific, combined with orographic lift from the Coast Mountains, produces high annual precipitation amounts throughout the region. The moderating influence of the ocean limits the seasonal temperature ranges, resulting in relatively mild winters and cool summers. Winds are strongly influenced by topography, with north-south flow being dominant in the Kitimat River valley, whereas a more northeast-southwest orientation to the wind is common in Kitimat Arm and Douglas Channel.

Data from Canadian Climate Normals Stations (Environment Canada 2014) are used to describe mean and extreme weather conditions observed over a 30-year period. For this baseline summary, 1981 to 2010 climate normals are compiled for two reporting stations in Kitimat and one station in Terrace. The station names and locations are listed in Table 4.2-1 and are shown in Figure 2.3-1. The station Kitimat 2 is nearest to the Project and is located in the industrial area west of Kitimat River, about 1.5 km inland from the wharf area. The Kitimat townsite station is located in the residential part of town east of the river. These two stations are inside the LSA for air quality modelling. The Terrace Airport station, which is in the larger modelling domain for acid deposition patterns, is located approximately 55 km north (inland) of Kitimat at an elevation of 217 m asl.

Table 4.2-1: Meteorological Stations Included in Regional Climate Analysis

Station Name	Latitude	Longitude	Elevation (m asl)
Kitimat 2	54°01' N	128°42' W	17
Kitimat townsite	54°03' N	128°38' W	98
Terrace Airport	54°28' N	128°35' W	217

NOTE:
Meteorological station data are from Environment Canada (2014).

A summary of the climate information follows. Monthly climate normals data for the three stations are presented in Appendix A.

4.2.1.1 Temperature

Annual mean temperatures at the three stations range from 6.6°C at Terrace to 7.9°C at Kitimat 2 (Table 4.2-2). Extreme maximum temperatures recorded at Kitimat townsite, Kitimat 2, and Terrace Airport were 36.1°C, 36.7°C, and 37.3°C, respectively. Extreme minimum temperatures ranged from −25.0°C at Kitimat townsite to −26.7°C at Terrace. In Kitimat, monthly mean temperatures are below freezing only in December and January.

Table 4.2-2: Seasonal and Annual Mean Temperatures in Kitimat and Terrace (1981 to 2010)

Station Name	Temperatures (°C)				
	Winter [a]	Spring [b]	Summer [c]	Autumn [d]	Annual
Kitimat 2	−0.1	7.4	16.4	7.8	7.9
Kitimat townsite	−0.7	7.1	15.9	7.2	7.4
Terrace	−2.2	6.4	15.7	6.4	6.6

NOTES:
[a] Winter months: December, January, and February
[b] Spring months: March, April, and May
[c] Summer months: June, July, and August
[d] Autumn months: September, October, and November
Meteorological data from Environment Canada (2014)

4.2.1.2 Precipitation

The North Coast is the wettest region of Canada, with many locations receiving well over 2,000 millimetres (mm) of precipitation per year. Seasonal and annual precipitation totals for Kitimat and Terrace are listed in Table 4.2-3. These amounts include the water equivalent of snowfall. Despite occasional heavy snowfalls in winter, most annual precipitation falls as rain (76% at Terrace and 88% at Kitimat 2). Precipitation varies considerably with distance from the coast, with the mean annual precipitation at the Terrace Airport less than half that at Kitimat 2.

Table 4.2-3: Seasonal and Annual Mean Total Precipitation in Kitimat and Terrace (1981 to 2010)

Station Name	Total Precipitation (mm)				
	Winter [a]	Spring [b]	Summer [c]	Autumn [d]	Annual
Kitimat 2	1,030	490	244	1,012	2,775
Kitimat townsite	767	379	231	834	2,211
Terrace	465	222	165	489	1,341

NOTES:
[a] Winter months: December, January, and February
[b] Spring months: March, April, and May
[c] Summer months: June, July, and August
[d] Autumn months: September, October, and November
Meteorological data from Environment Canada (2014)

Seasonally, the wettest months are during autumn and early winter, during which time the westerly storm track from the Gulf of Alaska ushers a procession of fronts across the North Coast. Periods of high pressure are more common during summer, but low-level onshore flow often keeps the coastal areas cloudy with intermittent drizzle or light rain. Dry periods of several days during winter can occur when offshore flows of dry, cold air from the interior of BC affect the North Coast.

Snowfall occurs at low elevations when moist Pacific air overruns cold air that has become established in the valleys. Mean annual snowfall amounts range from 302.3 centimetres (cm) at Kitimat 2 to 331.5 cm at Terrace Airport. Extreme daily snowfalls of over a metre have been recorded at both Kitimat townsite (112.3 cm) and Terrace Airport (113.4 cm).

The frequency of precipitation is generally high year round, with approximately 200 days per year having measureable precipitation. At Kitimat 2, the mean number of days per month with precipitation greater than or equal to 0.2 mm ranges from 13 days in February to 22 days in October.

4.2.1.3 Wind

Wind directions on the north coast depend on local terrain as the flow is channeled along inlets and valleys. During summer, onshore flow dominates, which generally manifests as a southerly wind in Kitimat. Conversely, the periodic cold outflow winds of winter are from the north. Winds tend to be strongest in the hours just before and after the passage of well-defined fronts and low-pressure systems. For a breakdown of monthly prevailing wind directions and maximum hourly winds speeds, see Appendix A. Additional wind information for the study area is contained in the meteorological model description in Appendix E.

4.2.2 Background Air Quality: Kitimat

As a community that has been home to industrial facilities since the 1950s, Kitimat has been well represented in BC's air quality monitoring network. Monitoring stations have been established on both sides of Kitimat River, which separates the industrial area on the west side from residential areas to the east. Some of the stations have been decommissioned as facilities have closed (e.g., Eurocan pulp mill) and permit requirements have expired, but several stations continue to record data to the present day.

To characterize background air quality conditions in the facility RSA, data from five monitoring stations in Kitimat are analyzed, four of which are still operating. The Kitimat Rail station, which was decommissioned in 2010, is included primarily because it is the only Kitimat station that collected NO_2 data in recent years. Additionally, the Smithers St. Joseph's station is included as the only regional station that collects CO data. The six air quality monitoring stations are listed in Table 4.2-4 along with their dates of operation and substances measured. Locations of the five Kitimat stations are shown in Figure 4.2-1.

Two of the stations—Kitimat Rail and Kitimat Haul Road—are in the relatively industrial area west of Kitimat River, whereas the other three Kitimat stations are in residential areas. The Riverlodge and Whitesail stations are in the District of Kitimat, on the east side of the river. The Kitimat Haisla Village station is located farther south on Kitimat Arm in Kitamaat Village.

Table 4.2-4: Monitoring Stations Included in the Background Air Quality Analysis

Station Name	Latitude	Longitude	Substances Measured	Dates of Operation	
				Start	End
Kitimat Rail	54°04' N	128°41' W	NO, NO_2, PM_{10}, $PM_{2.5}$, SO_2, H_2S	09/10/1996	06/26/2010
Kitimat Haul Road	54°02' N	128°42' W	PM_{10}, $PM_{2.5}$, SO_2	01/11/1996	Ongoing
Kitimat Riverlodge	54°03' N	128°40' W	PM_{10}, $PM_{2.5}$, SO_2, H_2S	04/05/1995	Ongoing
Kitimat Whitesail	54°02' N	128°23' W	PM_{10}, $PM_{2.5}$, SO_2, H_2S	12/07/1996	Ongoing
Kitimat Haisla Village	53°58' N	128°39' W	$PM_{2.5}$, SO_2	01/07/2010	Ongoing
Smithers St Joseph's	54°47' N	127°11' W	NO, NO_2, O_3, CO, PM_{10}, $PM_{2.5}$,	03/06/1997	Ongoing

NOTE:
Station information is from BCMOE (2014).

A summary of background conditions for each substance included in the assessment follows below. The three most recent years of available data (when available) are considered for each station to provide a representative description of recent air quality conditions in the facility RSA. Data are included from years that met the MOE standard of at least 75% completeness for each quarter of the year. Data obtained were from provincial annual summary reports for ambient air quality (BCMOE 2013b).

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AIR QUALITY TECHNICAL DATA REPORT

KITIMAT AIR QUALITY MONITORING STATIONS (CONTINUOUS)

LNG CANADA EXPORT TERMINAL
KITIMAT, BRITISH COLUMBIA

PROJECTION	DRAWN BY
UTM9	SS
DATUM	CHECKED BY
NAD 83	SW
DATE	FIGURE NO.
03-JUN-14	**4.2-1**

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4.2.2.1 Sulphur Dioxide

Sulphur dioxide has been monitored at all five of the Kitimat stations listed in Table 4.2-4; however, SO_2 data from Kitimat Riverlodge did not meet the completeness standard and therefore are not included in the analysis. Maximum 1-hour, 24-hour, and annual average SO_2 concentrations are shown in Table 4.2-5. Observed concentrations were higher in the industrial area of Kitimat than in the residential areas, but none of the maximum concentrations exceeded the most stringent applicable AAQO for the various averaging periods.

Table 4.2-5: Observed Concentrations of SO_2

Data Category	Kitimat Rail	Kitimat Haul Rd	Kitimat Whitesail	Kitimat Haisla Village	Most Stringent AAQO (µg/m^3)
1-hour maximum (µg/m^3)	135	188	90.7	72.1	450
24-hour maximum (µg/m^3)	26.6	67.3	10.6	7.2	150
Highest annual average (µg/m^3)	4.3	9.6	1.9	0.8	25
Overall average (µg/m^3)	4.1	6.9	1.6	0.7	N/A

NOTES:
For each station, the three most recent years of available data were used in the analysis, except for Haisla Village, where only 2011 to 2012 data were available.
N/A – Not Applicable
Air Quality Data Source: BCMOE (2013b)

4.2.2.2 Nitrogen Dioxide

Nitrogen dioxide was measured at the Kitimat Rail monitoring station until June 2010. The three most recent years of data are summarized in Table 4.2-6. The highest 1-hour concentration was 86.7 µg/m^3, which is well below the NAAQO of 400 µg/m^3. The highest observed 24-hour and annual averages were also well below the objectives established for NO_2. The overall average concentration from the three years of data was 3.9 µg/m^3. The Kitimat Rail dataset indicates that even the relatively industrialized part of Kitimat generally had low ambient NO_2 concentrations.

Table 4.2-6: Observed Concentrations of NO_2

Data Category	Kitimat Rail	Most Stringent AAQO ($\mu g/m^3$)
1-hour maximum ($\mu g/m^3$)	86.7	400
24-hour maximum ($\mu g/m^3$)	20.1	200
Highest annual average ($\mu g/m^3$)	4.4	60
Overall average ($\mu g/m^3$)	3.9	N/A

NOTES:
NO_2 data were available only from the Kitimat Rail station. The three most recent years of available data (2007 to 2009) were used in the analysis.
N/A – Not Applicable
Air Quality Data Source: BCMOE (2013b)

4.2.2.3 Carbon Monoxide

Other than brief periods of monitoring from a mobile laboratory, CO concentrations have not been measured in Kitimat. The nearest and most representative station that monitors CO is located in Smithers near St. Joseph's School. Data from this location are summarized in Table 4.2-7.

The average CO concentration from the most recent three years of data was 353.2 $\mu g/m^3$. The highest recorded 1-hour and 8-hour average concentrations are well below the most stringent BC AAQO established for CO. Data from several months of mobile air quality laboratory data measured at the Kitimat city centre during 2010 and 2011 indicate that CO readings were even lower in Kitimat, with an average reading of 108 $\mu g/m^3$ and a maximum 1-hour concentration of 1,176 $\mu g/m^3$ (BCMOE 2014).

Table 4.2-7: Observed Concentrations of CO

Data Category	Smithers St Joseph's	Most Stringent AAQO ($\mu g/m^3$)
1-hour maximum ($\mu g/m^3$)	2,678	14,300
8-hour maximum ($\mu g/m^3$)	1,863	5,500
Overall average ($\mu g/m^3$)	353	N/A

NOTES:
CO data were available only from the Smithers St. Joseph's station. The three most recent years of available data (2009 to 2011) were used in the analysis.
N/A – Not Applicable
Air Quality Data Source: BCMOE (2013b)

4.2.2.4 Respirable Particulate Matter

Respirable (fine) PM has been measured at all five Kitimat stations listed in Table 4.2-4. Only the Kitimat Rail and Riverlodge stations had three complete years of recent data available, and one to two years of data were available for the Kitimat Haul Road, Whitesail, and Haisla Village stations. The data are summarized in Table 4.2-8.

Annual average $PM_{2.5}$ concentrations at all stations were less than half the BC AAQO of 8 µg/m^3. At the Kitimat Rail monitoring site, a $PM_{2.5}$ concentration was higher than the objective of 25 µg/m^3 for one 24-hour period. However, the BC objective for $PM_{2.5}$ is based on the annual 98th percentile value, not the highest 24-hour value. None of the other four sites had daily values above 25 µg/m^3.

Table 4.2-8: Observed Concentrations of $PM_{2.5}$

Data Category	Kitimat Rail	Kitimat Haul Rd	Kitimat Riverlodge	Kitimat Whitesail	Kitimat Haisla Village	Most Stringent AAQO (µg/m^3)
24-hour maximum (µg/m^3)	27.7	9.9	24.9	8.0	23.8	25
24-hour frequency of exceedance (%)	0.09	0	0	0	0	N/A
Highest annual average (µg/m^3)	3.6	3.1	3.1	1.5	2.2	8
Overall average (µg/m^3)	3.5	3.1	2.7	1.5	2.1	N/A

NOTES:
For the Kitimat Rail and Riverlodge stations, the three most recent years of available data were used in the analysis. Only two complete years of $PM_{2.5}$ data were available from the Haisla Village station and only one complete year of data was available from the Kitimat Haul Rd and Whitesail stations.
N/A – Not Applicable
Air Quality Data Source: BCMOE (2013b)

4.2.2.5 Hydrogen Sulphide

Total reduced sulphur, measured as H_2S, was monitored at three of the Kitimat air quality stations. The last complete year of H_2S observations at the Kitimat Rail, Riverlodge, and Whitesail stations was 2009. The 1-hour and 24-hour average data are summarized in Table 4.2-9.

The highest observed 1-hour average H_2S concentrations ranged from 16.7 µg/m^3 at Kitimat Whitesail to 36.0 µg/m^3 at Kitimat Rail. The 1-hour BC AAQO of 7 µg/m^3 was exceeded less than 1% of the time at Kitimat Rail during the three-year period. The 24-hour BC AAQO of 3 µg/m^3 was exceeded 1.6% of the time at Kitimat Rail and much less often at the residential sites. The overall average H_2S concentrations were very low at all three stations, indicating that the area was subject to infrequent elevated

concentrations that might have caused odour issues in Kitimat. These datasets were collected during the operation of the Eurocan pulp mill; it can be assumed that present-day H_2S concentrations are considerably lower. Monitoring of H_2S was discontinued at the Riverlodge and Whitesail stations in 2010 after the closure of the mill.

Table 4.2-9: Observed Concentrations of H_2S

Data Category	Kitimat Rail	Kitimat Riverlodge	Kitimat Whitesail	Most Stringent AAQO (µg/m^3)
1-hour maximum (µg/m^3)	36.0	29.8	16.7	7
1-hour frequency of exceedance (%)	0.93	0.16	0.02	N/A
24-hour maximum (µg/m^3)	8.1	6.4	3.4	3
24-hour frequency of exceedance (%)	1.6	0.3	0.1	N/A
Overall average (µg/m^3)	0.5	0.2	0.1	N/A

NOTES:
For each station, the three most recent years of available data were used in the analysis.
N/A – Not Applicable
Air Quality Data Source: BCMOE (2013b)

4.2.2.6 Volatile Organic Compounds

Although VOCs are not regulated by way of national or BC objectives, they are included as SOI in the air quality assessment. Being a mixture of numerous volatile non-methane hydrocarbons, VOCs are challenging to measure and are not measured at any of the air quality monitoring stations listed in Table 4.2-4. The emissions inventory for the base case (see Section 5.1) indicates that VOC emissions in the facility RSA are small compared with the other SOI emitted. It follows then that ambient VOC concentrations will be very low.

4.2.2.7 Summary

Data from monitoring stations in both the industrial and residential neighbourhoods of Kitimat indicate that air quality is generally good, with very few instances of observed concentrations exceeding the most stringent BC and federal objectives. Historically, there have been exceedances of the 1-hour and 24-hour objectives for H_2S, but those measurements were taken while a pulp mill was still operating in Kitimat.

A summary of background concentrations is provided in Table 4.2-10. These values are determined by taking 98th percentile data from the station with the highest observed concentrations for each SOI. The resulting values for all substances and averaging periods are well within the applicable objectives.

Table 4.2-10: Summary of Background CAC Concentrations in the Kitimat Area

Substance	Averaging Period	Concentration [a] (µg/m^3)	Most Stringent AAQO (µg/m^3) [b]
SO_2 [c]	1-hour	54.7	450
	24-hour	31.8	150
	Annual	6.9	25
NO_2 [d]	1-hour	19.8	400
	24-hour	12.1	200
	Annual	3.9	60
CO [e]	1-hour	970	14,300
	8-hour	931	5,500
$PM_{2.5}$ [d]	24-hour	12.5	25
	Annual	3.5	8
H_2S [d]	1-hour	4.9	7
	24-hour	2.6	3

NOTES:

[a] Representative values for each category are based on the most recent three years of monitoring data available from the station with the highest observed concentrations of the substance of interest. Values are the 98th percentile of monitored concentrations (except for annual averages).

[b] See Table 3.2-1.

[c] SO_2 values are from the Kitimat Haul Road monitoring station.

[d] NO_2, $PM_{2.5}$, and H_2S values are from the Kitimat Rail monitoring station.

[e] Ambient CO data are not measured locally. Suitable background data were obtained from the nearest, most representative station: Smithers St. Josephs.

Air Quality Data Source: BCMOE (2013b)

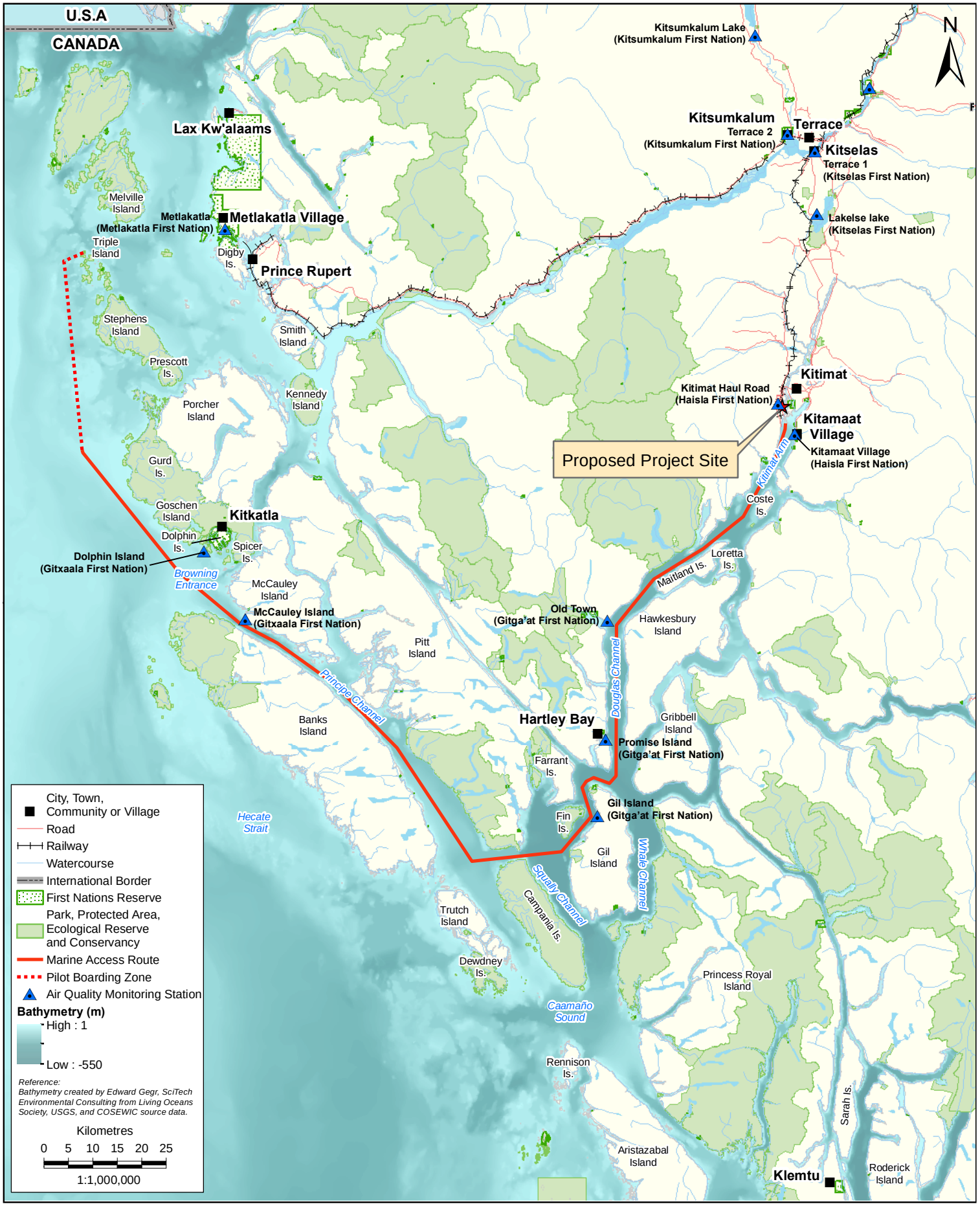
4.2.3 Background Air Quality: North Coast

A passive ambient monitoring network for the Project has been established to cover areas not sampled by the existing Kitimat network described in Section 4.2.2.

The monitoring program uses a multigas passive sampler (Tang et al. 2011). The term passive is used to distinguish the samplers from continuous air samplers that rely on a pump to draw air though a sampling tube. The passive air samplers are small Teflon discs containing the sample media, which are exposed to the ambient air for approximately one month at a time before being shipped to a certified lab for analysis (see Photo 4.2-1). Passive sampling technology is a simple, cost-effective means of characterizing background air quality. The samplers require no power to yield monthly average concentration measurements.

Photo 4.2-1: Multigas Passive Sampler with Rain Shelter on Gil Island

Thirteen stations were installed at the locations marked in Figure 4.2-2. Monthly average concentrations of SO_2, NO_2, NO_X, H_2S, O_3, and VOCs are obtained from each station. Duplicate samplers are deployed monthly for quality control purposes (two samplers at each station). The stations were installed in stages between July 2013 and February 2014. The station names, locations, and installation dates are provided in Table 4.2-11. Station locations were chosen in consultation with local First Nations (see Table 4.2-11). The Kitimat Haul Road and Kitamaat Village stations are considered reference stations for which concentration readings will be compared with nearby continuous monitoring stations.



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AIR QUALITY TECHNICAL DATA REPORT

NORTH COAST AIR QUALITY MONITORING STATIONS (PASSIVE)

LNG CANADA EXPORT TERMINAL
KITIMAT, BRITISH COLUMBIA

PROJECTION	DRAWN BY
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Table 4.2-11: Passive Ambient Air Monitoring Station Information

Station Number	Station Name	First Nation	Coordinates	Elevation (m asl)	Date of Installation
1	Lakelse Lake	Kitselas	54.38 N 128.58 W	120	07/04/2013
2	Kitimat Haul Road	Haisla	54.03 N 128.70 W	21	07/17/2013
3	Kitamaat Village	Haisla	53.97 N 128.65 W	13	07/04/2013
4	Terrace 1	Kitselas	54.49 N 128.58 W	68	09/04/2013
5	Old Town	Gitga'at	53.63 N 129.23 W	11	10/01/2013
6	Gil Island	Gitga'at	53.27 N 129.26 W	15	10/01/2013
7	Promise Island	Gitga'at	53.41 N 129.24 W	17	10/01/2013
8	Terrace 2	Kitsumkalum	54.52 N 128.67 W	65	11/06/2013
9	Gitaus	Kitselas	54.61 N 128.41 W	151	11/29/2013
10	Metlakatla	Metlakatla	54.34 N 130.44 W	41	01/09/2014
11	McCauley Island	Gitxaala	53.63 N 130.35 W	11	02/05/2014
12	Dolphin Island	Gitxaala	53.75 N 130.48 W	17	02/05/2014
13	Kitsumkalum Lake	Kitsumkalum	54.71 N 128.77 W	156	02/07/2014

A summary of results is provided in Table 4.2-12. Monthly results for each station are provided in Appendix B. Results for NO_X are omitted because NO_2 is the regulated CAC. Because of unacceptable uncertainty in the analytical lab results, O_3 and VOC data are subject to reanalysis and subsequent reporting. Thus, only results for SO_2, NO_2, and H_2S are reported in Table 4.2-12. In general, observed concentrations of these substances were low, with some variability between settled/industrial locations and remote/rural stations.

The overall average SO_2 concentration for all stations is 1.75 µg/m^3. The highest station average SO_2 concentration is 8.61 µg/m^3 at Kitimat Haul Road, and the lowest station average is 0.52 µg/m^3 at the Terrace 1 station.

The average NO_2 concentration for all stations is 3.50 µg/m^3. The highest station average NO_2 concentration is 7.69 µg/m^3 at Kitimat Haul Road, and the lowest station average is 0.99 µg/m^3 at McCauley Island.

The average H_2S concentration for all stations is 0.25 µg/m^3. The highest station average H_2S concentration is 1.03 µg/m^3 at Kitimat Haul Road, and the lowest station average is 0.10 µg/m^3 at Metlakatla.

Table 4.2-12: Summary of North Coast Passive Monitoring Results

Station Number	Station Name	Average concentration ($\mu g/m^3$)		
		SO_2	NO_2	H_2S
1	Lakelse Lake	0.83	3.93	0.12
2	Kitimat Haul Road	9.88	8.12	0.92
3	Kitamaat Village	2.05	2.92	0.48
4	Terrace 1	0.46	4.41	0.14
5	Old Town	1.62	2.56	0.24
6	Gil Island	0.71	2.38	0.14
7	Promise Island	1.27	3.76	0.18
8	Terrace 2	0.54	5.32	0.12
9	Gitaus	0.46	3.13	0.11
10	Metlakatla	0.81	3.90	0.14
11	McCauley Island	0.55	1.30	0.14
12	Dolphin Island	0.63	1.43	0.11
13	Kitsumkalum Lake	0.41	1.18	0.14

NOTES:

The average values are for between 9 and 14 months of monthly average data, depending on when sampling was initiated. Station deployment varied between July 2013 and February 2014. Data in this table are representative of measurements through July 2014.

Both O_3 and VOC data were collected from the passive samplers; however, because of unacceptable uncertainty in the analytical results, O_3 and VOC data are subject to reanalysis and later reporting.

Data recorded as below the minimum detection limit were conservatively assumed to be present at the minimum detection limit (0.02 ppb for H_2S and 0.1 ppb for SO_2 and NO_2).

5 EMISSION INVENTORY OVERVIEW

This section provides an overview of CAC and VOC emissions for the base case, the Project construction and operation phases, and the cumulative case. Emission estimation methods and results are described in more detail in Appendix D.

5.1 Base Case Emissions

The base case for dispersion modelling considers emissions from existing sources in the facility RSA. Before commencement of Project construction, the facilities affecting air quality in the facility RSA will include the (post-KMP) RTA facility located adjacent to the Project and the KLNG export terminal at Bish Cove on Douglas Channel. These are the major existing and approved facilities in the RSA. Both facilities include land-based and marine emissions that form the base case for this assessment. Details of the base case air emissions are found in Appendix D. Emission rates from existing land- and marine-based activities at these facilities are summarized in units of tonnes per year (t/y) in Table 5.1-1. The yearly emissions of SO_2 are substantial, mostly as a result of the RTA facility emissions. Emissions of CO, H_2S, and VOCs were not reported for the RTA facility.

Table 5.1-1: Base Case: Annual Emissions for Existing Marine- and Land-Based Facilities

Facility		Emissions (t/y)				
		SO_2	NO_X	CO	$PM_{2.5}$	VOC
RTA	Land-based	15,289	301	NA	508	NA
	Marine-based	0.62	18.6	1.7	0.50	0.75
Total RTA		15,290	320	1.7	509	0.75
KLNG	Land-based	2.10	849	1,085	67.0	24.8
	Marine-based	25.0	20.8	5.2	2.3	0.83
Total KLNG		27.1	870	1,090	68.9	25.6
Total		15,317	1,190	1,092	578	26.3

NOTE:
NA – data not available

5.2 Project Construction Emissions

The Project construction phase, starting in 2015, is planned to be 84 months in duration and will include site preparation, infrastructure installation for the full build-out scenario, and marine terminal construction. Marine vessels will deliver materials for construction. These activities will result in CAC and VOC emissions from fuel-burning exhaust produced by off-road equipment and marine vessels. Fugitive dust generation will occur during construction but will represent a small contribution to emissions totals because of the temporary nature of the dust-generating activities and the considerable natural mitigation that results from the north coast's wet climate (see Section 4.2.1).

Equipment commissioning and testing will result in air emissions resulting from natural gas combustion needed to fuel the engines. Equipment testing will take place for the compressor turbines, incinerators, and flares as discussed in Section 5.3.

Staff movement and some material deliveries will occur by road transport and rail, respectively. Compared with other construction emission sources, these emissions will be insubstantial. Effects from road dust emissions will decrease rapidly from the road sources.

Construction phase emissions are summarized in Table 5.2-1, showing the total emissions for the entire construction period and the annual average contribution to the facility RSA. Details are provided in Appendix D. Comparison with the base case totals (Table 5.1-1) shows that Project construction activities will contribute a small amount to the RSA emission totals.

Table 5.2-1: Project Construction: Off-Road Diesel and Marine Vessel Emissions

Category	Emissions (tonnes)					
	SO_2	NO_X	CO	$PM_{2.5}$	H_2S	VOC
Site preparation	0.19	98.3	55.7	9.2	N/A	8.6
Installation & testing(Phase 1)	0.07	41.6	21.4	3.2	N/A	3.8
Installation & testing (Phase 2&3)	0.07	41.6	21.4	3.2	N/A	3.8
Marine terminal build (Phase 1)	5.6	66.4	8.6	3.7	N/A	2.9
Marine terminal build (Phase 2&3)	5.6	66.4	8.6	3.7	N/A	2.9
Marine shipping (inbound)	7.9	208	28.6	4.4	N/A	12.0
Marine shipping (outbound)	7.9	208	28.6	4.4	N/A	12.0
Shuttle bus service	0.12	21.0	2.05	0.22	N/A	0.0
Onsite pickup trucks	0.03	4.44	0.42	0.06	N/A	0.0
Total over 84 months	27.5	756	175	32.1	N/A	46.1
Average per year	3.9	108	25.1	4.6	N/A	6.6

NOTE:
N/A – Not applicable

5.3 Project Operation Emissions

5.3.1 Routine Operations

The Project includes natural gas receiving and treatment facilities, natural gas liquefaction facilities, LNG storage tanks, and natural gas liquids (NGL) storage tanks. Project CAC and VOC emissions were estimated for the full build-out, i.e., producing 26 million tonnes LNG per annum. Continuous air emissions sources will result from operation of the following components:

- eight mixed-refrigerant compressor turbine drivers
- four acid gas incinerators, and
- five flares: warm, cold, operational, storage and loading, and spare.

Project air emissions will depend on the composition of the inlet gas (after possible upstream processing) and the efficiency of the LNG processing. Inlet gas will be mostly methane with small amounts of higher hydrocarbons. Trace amounts of nitrogen, carbon dioxide, and a variety of reduced sulphur compounds (e.g., H_2S, mercaptans) are present in the gas. Gas composition details are included in Appendix D.

First, the inlet gas will be sent to an acid gas removal unit, where acid gases (e.g., H_2S, mercaptans and carbon dioxide) and remaining impurities will be removed to meet product specifications. The waste gas stream will then be sent to the acid gas incinerator for incineration before being discharged to the atmosphere. It is assumed that acid gas incineration will oxidize the sulphur-containing compounds to SO_2 with at least 99% efficiency. Benzene in the acid gas can be destroyed at 99.99% efficiency if the incinerator temperature is 960°C or more. The incinerator flue gas will contain small amounts of NO_X, CO, $PM_{2.5}$, and much smaller amounts of H_2S and VOCs.

After the acid gas removal unit, the gas stream will be sent through the following systems: a gas dehydration unit, to remove water from the gas stream; a mercury guard bed, to remove traces of mercury; and an NGL extractor unit, to remove NGL. Operation of these units will not produce air emissions.

The gas leaving the NGL extractor unit will be routed to the cryogenic section to be cooled and compressed. Fuel for the gas turbines driving the compressors will be 90% boil off gas (BOG) from the LNG storage tanks blended with 10% inlet gas. Air emissions will be mostly NO_X and CO from the combustion process, with small amounts of SO_2 (from the oxidation of residual total sulphur in natural gas), $PM_{2.5}$, and VOCs (from incomplete combustion).

The flares will act as a vapour relief system and will be used to collect and dispose of natural gas-containing streams that are typically released during start-up and shutdown but also during upset and emergency conditions. There will be five flares available at the facility. A warm flare will dispose of

warm/wet hydrocarbon streams from the front end of the LNG train. A cold flare will handle cold/dry hydrocarbon streams from the liquefaction and refrigeration processes. An operational flare will handle either warm/wet or cold/dry hydrocarbon releases during the start-up of a train. A storage and loading flare will dispose of hydrocarbon streams resulting from BOG compressor failure. A spare flare will be the backup unit in case of failure of one of the other flares. All flares will be supported by a common derrick structure.

During normal operations, the flare pilots will be fueled by inlet gas. It is assumed that 100% of the sulphur-containing compounds will be converted to SO_2. The pilot light gas will also contain small amounts of NO_X, CO, $PM_{2.5,}$ and VOCs.

At full build-out, it is estimated that 350 LNG carriers will visit the terminal every year. Tugs will escort LNG carriers and assist them with berthing and unberthing operations. The effects of marine emissions within 1 km of the berths will overlap with effects of the production facility emissions and are therefore included as part of the facility emissions in the Project-alone case. During berthing, three tugs are required to support the operation. One tug will be onsite when the LNG carrier is loading the product. During a typical port-of-call, each LNG carrier will require about three hours to maneuver in/off the berth and 15 hours to load the vessel. Starting in January 2015, vessels travelling within the North American ECA will be required to use fuel with a maximum sulphur content of 0.1% by weight (MARPOL 2008). It is assumed that one LNG carrier ship will be hotelling (alongside the berth or jetty with only auxiliary systems running) while another is berthing or unberthing. Emissions from LNG carriers and tugboats will contain SO_2, NO_X, CO, $PM_{2.5}$, and VOCs.

The operation phase emissions are detailed in Appendix D. Table 5.3-1 summarizes operation emissions.

Table 5.3-1: Project Operation: Land-Based and Marine-Based Emissions

Source	Emissions (t/y)					
	SO_2	NO_X	CO	$PM_{2.5}$	H_2S	VOCs
Land-based	700	2,581	2,885	198	0.37	68.5
Marine-based	51.6	1,143	162	26.0	N/A	69.5
Total	**752**	**3,723**	**3,047**	**224**	**0.37**	**138**

NOTE:
N/A – Not applicable

Minor air emissions from maintenance activities will have insubstantial effects; they have not been quantified nor carried forward in this assessment.

Table 5.3-2 compares emissions between the base case and the Project-alone case, and provides total emissions that are representative of the application case. The increase in SO_2 emissions attributable to the Project is insubstantial (5%) compared to the base case emissions. Accurate comparisons for CO, H_2S, and VOCs are not possible because emissions data from the RTA facility were not available for these substances.

Table 5.3-2: Comparison of Project Operation vs. Base Case Emissions

Source	Emissions (t/y)					
	SO_2	NO_X	CO	$PM_{2.5}$	H_2S	VOCs
Base case	15,317	1,190	1,092	578	N/A	26.3
Project-alone case	752	3,723	3,047	224	0.37	138
Application case	16,068	4,913	4,139	802	0.37	164
Percent of total attributed to Project	5%	76%	N/A	28%	N/A	N/A

NOTE:
N/A - Not applicable

5.3.2 Marine Access Route Emissions

As well as producing emissions while berthing, hotelling, and unberthing, marine vessels will emit SO_2, NO_X, CO, $PM_{2.5}$, and VOCs when transiting the marine access route (Figure 2.3-3). It is assumed that for each of the 350 LNG carrier visits, one escort tug will be required to escort the LNG carrier for the 13-hour journey from the Project marine terminal to Triple Island. Annual emission totals for this activity are shown in Table 5.3-3.

Table 5.3-3: Project Operation: Marine Vessel Emissions along the Marine Access Route

Source	Emissions (t/y)					
	SO_2	NO_X	CO	$PM_{2.5}$	H_2S	VOCs
LNG carriers (350 per year)	17.4	446	62.9	7.9	N/A	26.1
Escort tugs (350 per year)	0.16	18.6	2.1	1.2	N/A	0.95
Total	**17.6**	**465**	**65.0**	**9.1**	N/A	**27.0**

NOTE:
N/A - Not applicable

5.3.3 Inlet Gas Total Sulphur Content

From 2008 through 2012, natural gas samples from the Saddle Hills and Pipestone Creek compressor stations were analyzed for total sulphur content (the sum of all reduced sulphur compounds in the gas). This analysis showed that concentrations of total sulphur decreased through that period. The most recent years sampled are deemed representative of the expected high-end operating value for total sulphur content, assumed here to be 9 milligrams per cubic metre (mg/m^3). The facility is designed for a maximum inlet sulphur content of 30 mg/m^3 to account for potential short-term spikes.

5.3.4 Upset Flaring

During emergency shutdown, the processing train will stop operating and related emissions will cease. Blowdown refers to the controlled venting and flaring of natural gas contained from part or the whole of the LNG train. Blowdown of the entire LNG train will be an extremely rare event because facility design will include safeguards that allow for a safe shutdown of all ingoing and outgoing gas streams without the need to blowdown any or all of the systems.

During a total blowdown event, it is assumed that the hydrocarbon stream from the front end will be sent to the warm flare, the cold flare will handle the hydrocarbon stream from the liquefaction and refrigeration components, and the storage and loading flare will handle the hydrocarbon stream from the BOG compressors. Only the front end gas will contain sulphur compounds, with an assumed conservative inlet sulphur concentration of 30 mg/m^3. The maximum gas flow capacity to the flares will be 400 kilograms per second (kg/s) per flare. Table 5.3-4 lists the CAC and VOC emissions expected from a total blowdown flaring event.

Table 5.3-4: Upset Flaring Emissions (tonnes) per Event

Source	Emissions (t)					
	SO_2	NO_X	CO	$PM_{2.5}$	H_2S	VOC
Warm flare	0.036	0.41	0.48	0.16	0.0004	1.5
Cold flare	0.000	1.2	1.4	0.47	N/A	4.4
Loading and storage flare	0.000	0.09	0.11	0.035	N/A	0.33
Total	**0.036**	**1.7**	**2.0**	**0.66**	**0.000**	**6.2**

NOTES:
N/A - Not applicable

5.3.5 Cooling Tower Water Vapour Emissions

Freshwater cooling towers will be used to dissipate heat resulting from the LNG refrigeration process. The cooling towers will use cold water from Kitimat River to absorb heat. The resulting warm water will be cooled again by being recirculated back through the towers. Water flow through each tower is expected to be 1,400 tonnes per hour (t/h), from which 385 t/h is expected to evaporate. The water vapour discharges will not contain CACs or VOCs. In certain atmospheric conditions, the water vapour will condense into visible plumes. Additionally, instances of induced fog and icing formation might occur. A summary of the fogging and icing assessment is provided in Section 7.2.5.

5.4 Future Project Emissions

The reasonably foreseeable future projects located in the facility RSA are the Enbridge Northern Gateway project and the Kitimat Clean refinery project. Note that the Enbridge Northern Gateway project was not yet an approved project at the time of modelling work for the LNG Canada assessment. Air emissions from the Northern Gateway project were obtained from previous publications (Enbridge 2010); emission rates for the proposed refinery project were obtained through the BC Environmental Assessment Office (Bailey 2014, pers. comm.). Emissions for the future sources are summarized in Table 5.4-1.

Table 5.4-1: Cumulative Case: Annual Emissions from All Sources

Source	Emissions (t/y)					
	SO_2	NO_X	CO	$PM_{2.5}$	H_2S	VOCs
Application case	16,068	4,913	4,139	802	0.37	164
Foreseeable future projects	888	730	569	221	22.3	291
Total	**16,957**	**5,643**	**4,708**	**1,023**	**22.7**	**455**

5.5 Discussion

Table 5.5-1 lists the emission estimates for each of the assessment cases. The last row shows the relative contribution of Project emissions to the total emissions in the RSA. The SOI most likely to be of concern is SO_2, but the Project contribution is insubstantial at 4.4%. The Project contribution to H_2S emissions is also very low. The Project contributions to CO and VOC emissions are higher, partly because emissions from the RTA facility were not included in the base case totals. Likely, Project contributions are still insubstantial compared to the natural sources of CO and VOCs. The Project contribution to NO_X emissions is also higher; however, most of the NO_X should remain as NO, and the conversion to NO_2 will be O_3-limited.

Table 5.5-1: Summary of the RSA Emission Estimates

Source	Emissions (t/y)					
	SO_2	NO_X	CO	$PM_{2.5}$	H_2S	VOCs
Base case	15,317	1,190	1,092	578	NA	26.3
Project-alone case	752	3,723	3,047	224	0.37	138
Application case	16,068	4,913	4,139	802	0.37	164
Cumulative case	16,957	5,643	4,708	1,023	22.7	455
Project percent increase	4.4%	66%	65%	22%	1.6%	30%

NOTE:
NA – data not available.

6 PLUME DISPERSION MODELLING METHODS

Effects of CAC and VOC emissions from Project operation on ambient air quality were evaluated using plume dispersion modelling. These models provide a scientific link between the emission sources and downwind ground-level concentration profiles associated with the sources. Plume dispersion models incorporate meteorological conditions and terrain influences to account for the transport and dilution of the plume in the atmosphere. The modelling was conducted in accordance with the *Guidelines for Air Quality Dispersion Modelling in British Columbia* (hereafter, the Guidelines) (BCMOE 2008). In accordance with the Guidelines, a detailed dispersion modelling plan (Appendix C) was developed, which was subsequently reviewed and accepted by MOE.

6.1 Plume Dispersion Models

6.1.1 Stationary Emission Sources

The CALPUFF modelling system (CALPUFF and CALMET) was used to assess air quality effects associated with all emission scenarios. The CALPUFF model is a refined model that applies terrain and meteorological data, and uses plume rise, dispersion, and terrain algorithms. The CALPUFF model is a non-steady-state Gaussian puff dispersion model, which incorporates simple chemical transformation mechanisms, complex terrain algorithms, and building downwash. The CALPUFF model is suitable for estimating ground-level air quality concentrations on both local and regional scales, from tens of metres to hundreds of kilometres downwind of emission sources. The CALPUFF model is recognized as a refined model in the Guidelines (BCMOE 2008).

Emission rates from facility operations (Section 5.3 and Appendix D) were input to CALPUFF for short-term (hourly and daily) and long-term (annual) operating scenarios. To include vessel operations at and near the berths, continuous emissions from two tugs and one LNG carrier were modelled as stationary point sources. Emission rates that were estimated for the modelling plan (Appendix C) were updated with the latest engineering information for the Project.

6.1.2 Marine Shipping Emissions

Plume dispersion modelling of marine emissions along the marine access route was completed using the SCREEN3 model, consistent with both the Guidelines (BCMOE 2008) and the modelling plan (Appendix C). SCREEN3 is a single-source Gaussian plume model that provides maximum ground-level concentration predictions for point, area, flare, and volume sources. SCREEN3 is able to account for a variety of effects including building downwash for near-wake and far-wake regions, cavity recirculation, and flare releases. Simple area sources can be modelled with SCREEN3. This model can incorporate the

effects of terrain below stack height on maximum concentrations and can also estimate 24-hour average concentrations resulting from point-source plume impaction for terrain above stack height (U.S. EPA 1995).

6.2 Meteorology

Meteorology plays a major role in determining air quality changes downwind of emission sources. Meteorology over the study area varies with time of day and time of the year, and can vary by location because of terrain and land-cover influences.

The Weather Research and Forecasting (WRF) model was selected as the prognostic model for the CALMET modelling. Historically, the MM5 meteorological model has been the standard model used. However, the MM5 has been officially phased out by the National Center for Atmospheric Research (NCAR). Specifically, NCAR announced on October 31, 2008, that technical support for the MM5 model has been discontinued and strongly encouraged users to move to the new NCAR-supported WRF model. The WRF model provides better algorithms, handling of topography, and programming compared with MM5. It also includes new features and options developed by the Mesoscale & Microscale Meteorology Division at NCAR. A recently published U.S. Western Regional Air Partnership report has demonstrated that WRF outperforms MM5 in overall model accuracy (U.S. WRAP 2012).

The CALMET meteorological model was used to produce hourly three-dimensional meteorological fields (i.e., winds, temperatures, and turbulence) for a three-year period (January 1, 2008 to December 31, 2010). Using three full years of data allows CALMET to reproduce a wide range of meteorological conditions that could occur over the study area. The CALMET model is described in detail in Appendix E.

The SCREEN3 dispersion model uses combinations of wind speed and atmospheric stability class (a 54-case matrix) as an internal screening meteorological dataset (U.S. EPA 1995).

6.3 Modelling Scenarios

Plume dispersion modelling of all SOI was performed in an incremental manner, using four scenarios, or cases. This allows for a more detailed evaluation of the relative contributions of existing and future emission sources on air quality in the study areas.

For activities that might result in a change in ambient air quality in the Facility LSA and RSA, four scenarios were modelled:

- The base case considers emissions from existing sources in the RSA.

- The Project-alone case considers the land-based and marine-based emissions in the facility RSA. The Project-alone case includes estimates of the effects of LNG carriers in transit along the marine access route and effects of upset flaring during emergency situations. An assessment of fogging and icing attributable to water vapour emissions from the cooling towers is also included.
- The application case combines the results of the base case and Project-alone case.
- The cumulative case combines the results of the application case with the effects of emissions expected from other reasonably foreseeable future projects in the facility RSA.

6.4 Modelling Domains, Receptors, and Terrain

6.4.1 Modelling Domains

Near-field domain: Study area extents (Section 2) were established to focus the scope of the effects assessments. The Facility LSA was selected for the Project-alone effects assessment and the RSA was defined to include future facilities that are part of the cumulative effects assessment. The CALPUFF modelling domain of 78 km by 78 km, centred on the Project site, was sized to support both of these study areas. For the Project-alone assessment, the selected LSA encloses the effects that are 10% or more of the AAQO in accordance with the Guidelines (BCMOE 2008). The same is true for the facility RSA supporting the cumulative effects assessment.

Far-field domains: The CALPUFF far-field domain covers an area of 320 km by 320 km centred on the Project site. The purpose of modelling over the far-field domain is to support the acidification assessment and to determine the non-detect extents of the Project effects.

More details can be found in the CALMET and CALPUFF appendices, Appendix E and Appendix F, respectively.

6.4.2 Near-Field Receptors

The “plant boundary” is the term used in the Guidelines (BCMOE 2008) to describe a line of receptors that demarcates public versus worker exposures and is synonymous with “Project boundary” or “fenceline.” Often, the highest predicted concentrations are on or very near to the plant boundary. Within the plant boundary, occupational health and safety criteria are of primary importance. Assessments using the AAQO are applied to areas where there is public access on and beyond the plant boundary. The fenceline for the LNG facilities was determined based on advice in Section 6.3 of the Guidelines (BCMOE 2008). Receptor spacing along the fenceline is set at 20 m intervals. No receptors are defined in the facility area.

A receptor grid protocol described in the Guidelines (BCMOE 2008) is applied for locations outside the plant boundary. The resulting receptor grid amounts to a series of nested Cartesian grids with increasing receptor density with proximity to the site. The receptor grids and their corresponding spacings are as follows:

- 20 m spacing along the Project fenceline, including the marine terminal
- 50 m spacing within 2.8 km by 5.4 km of the LNG facility
- 50 m spacing within a 2.5 km by 3.5 km area centred at the Project-alone case maximum point of impingement
- 50 m spacing along other industrial fencelines
- 250 m spacing within 5.75 km by 8.5 km of the LNG facility
- 500 m spacing within 12 km by 15 km of the LNG facility
- 1,000 m spacing within 40 km by 40 km of the LNG facility, and
- 2,000 m spacing beyond 40 km of the LNG facility.

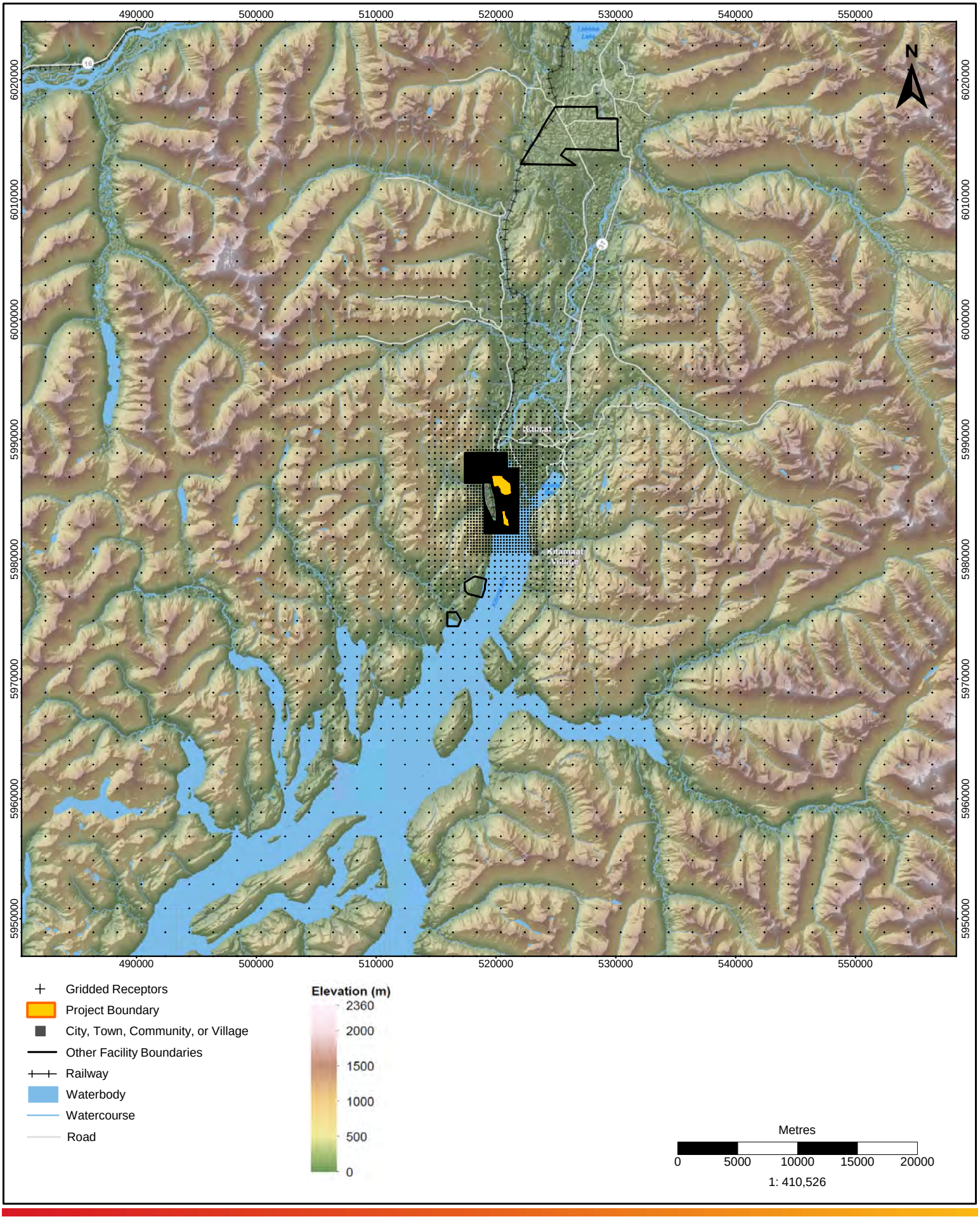
The receptor grid for the facility RSA is shown in Figure 6.4-1, which shows the two facility boundaries: one along the perimeter of the LNG facility and another surrounding the marine berths and lots. The grid array is blanked out in the facility areas because the AAQOs are not applicable there. A more detailed discussion of the model receptor grid is found in CALPUFF Appendix F.

6.4.3 Far-Field Receptors

The nested far-field receptors were created on the 320 km by 320 km CALPUFF modelling domain with the following spacing:

- 1,000 m spacing within a 44 km by 117 km area covering the Kitimat and Terrace regions, and
- 4,000 m spacing beyond the 44 km by 117 km area.

These receptors are sufficient to provide predictions of the magnitude and spatial variations of depositions attributable to Project emissions for the acidification and eutrophication assessment. Ground-level concentrations and deposition of nitrogen- and sulphur-bearing compounds treated by CALPUFF were predicted at these receptors. These predictions are used for the acidification and eutrophication parameter calculations for the base, Project-alone, application, and cumulative cases. Description of effects on vegetation and soils, water quality and human health is found in Section 5.5, Section 5.9, and Section 9.2, respectively, of the Application.



Stantec	LNG CANADA Opportunity for British Columbia. Energy for the world	*AIR QUALITY TECHNICAL DATA REPORT* *Regional Study Area (78 km by 78 km)* **Facility Regional Study Area Model Receptor Grid** LNG CANADA EXPORT TERMINAL KITIMAT, BRITISH COLUMBIA	PROJECTION: UTM9 / DRAWN BY: LL DATUM: NAD 83 / CHECKED BY: JS DATE: 6-MAY-14 / FIGURE NO.: 6.4-1	

6.4.4 Sensitive Receptors

Sensitive receptors in the facility RSA were selected such that maximum predicted ground-level concentrations of SOI could be determined for these locations. Model predictions at sensitive receptor locations support the assessment for other disciplines as follows:

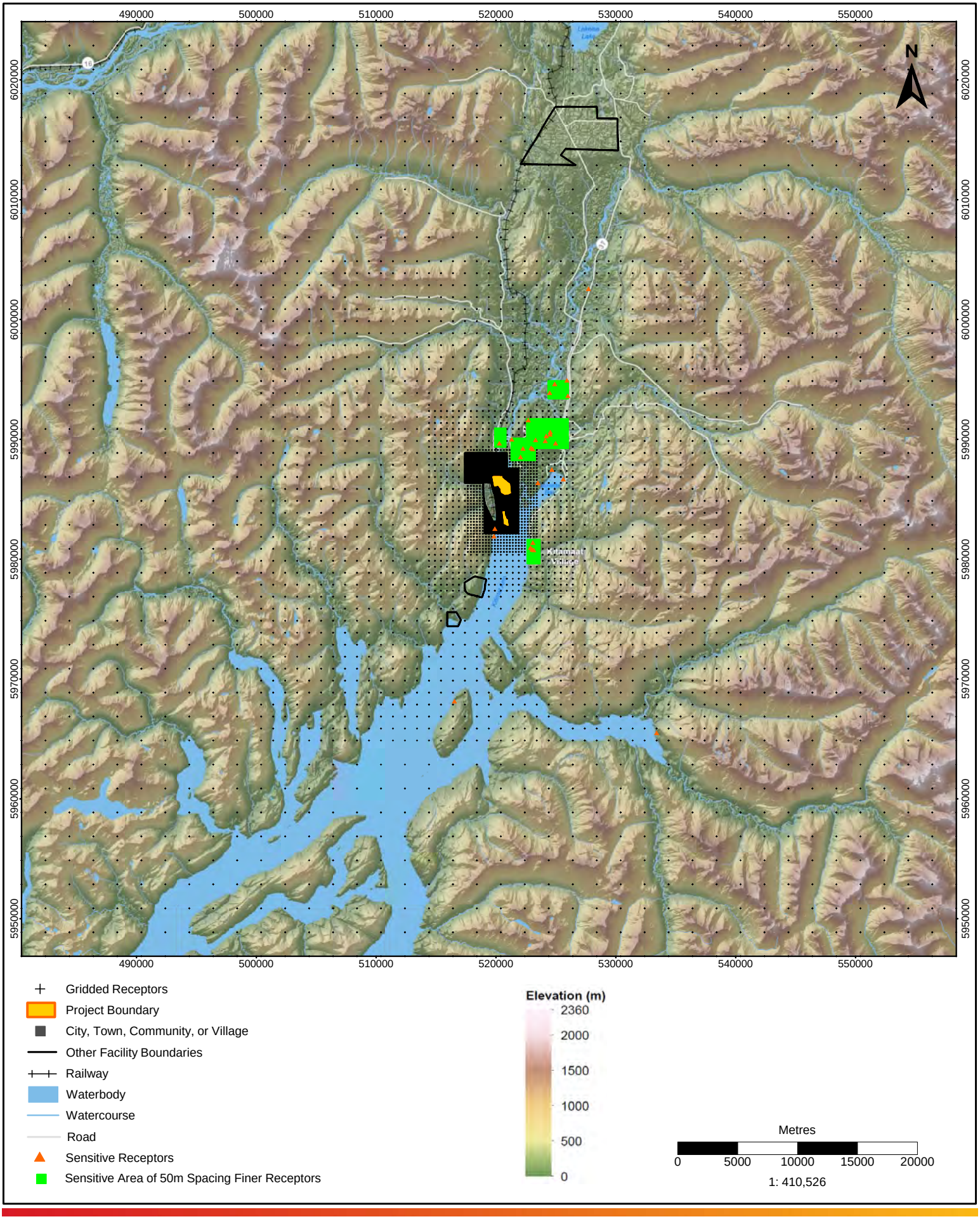
Human Health: Sensitive receptors with a 50 m resolution cover the townships of north Kitimat, upper Kitimat, lower Kitimat, A5 service area, and Kitamaat Village. The human health assessment also uses sensitive receptors at 29 other locations in the facility RSA (Figure 6.4-2).

Water Quality: The water quality assessment uses predictions at 83 sensitive receptor locations at selected lakes and other waterbodies. The sensitive locations treated by RTA modelling are included for comparison purposes.

Maximum predicted ground-level concentrations for the included SOI were obtained through dispersion modelling for the base, Project-alone, application, and cumulative cases. A description of the effects on vegetation, water quality, and human health is found in Section 5.5, Section 5.9 and Section 9.2, respectively, of the Application.

6.4.5 Terrain and Water Body Elevations

Above-sea-level terrain elevations were applied to the CALMET and CALPUFF model grid points, including sensitive receptor points. The elevations were taken from Geobase Canadian Digital Elevation Data (GeoBase 2013) with 1 arc second, 30 m resolution.



Stantec	LNG CANADA Opportunity for British Columbia. Energy for the world	*AIR QUALITY TECHNICAL DATA REPORT* *Regional Study Area (78 km by 78 km)* **Model Receptor Grid with Sensitive Receptors** LNG CANADA EXPORT TERMINAL KITIMAT, BRITISH COLUMBIA	PROJECTION: UTM9 DATUM: NAD 83 DATE: 6-MAY-14	DRAWN BY: LL CHECKED BY: JS FIGURE NO.: 6.4-2

6.5 Atmospheric Chemistry

6.5.1 Nitric Oxide to Nitrogen Dioxide Conversion

The NO_X concentrations are composed of a mixture of NO and NO_2. Most of the NO_X formed as a result of combustion processes is emitted as NO but is oxidized to NO_2 as the dispersing plume entrains ambient air containing O_3. Ambient air quality objectives exist for NO_2 rather than for NO or total NO_X. The Guidelines (BCMOE 2008) include various methods for estimating the NO to NO_2 conversion.

Total Conversion Method: The total conversion method is the preferred method. This method assumes that all NO is converted to NO_2 during plume transport, before plume impingement at ground level. If the predicted NO_2 concentrations are less than the ambient air quality criteria for NO_2, then the predicted NO_X concentrations are reported as NO_2 and no further refinement is required.

Ozone Limiting Method: If the total conversion method results in exceedances of the AAQOs, then the ozone limiting method (OLM) can be used to produce more realistic predictions. The OLM assumes that the conversion of NO to NO_2 in the atmosphere is limited by the ambient O_3 concentrations in the atmosphere. The approach assumes that 10% (on a volume basis) of the NO_X is converted to NO_2 before discharge into the atmosphere. For the remaining NO_X, the following conversion method is applied:

- If 0.9 (NO_X) is greater than the ambient O_3 concentration, then NO_2 = 0.1 (NO_X) + (O_3). The NO_2 concentration is ozone limited.
- If 0.9 (NO_X) is less than the ambient O_3 concentration, then NO_2 = 0.1 (NO_X) + 0.9 (NO_X) = NO_X (i.e., total conversion).

In the application of the OLM, the above relationships assume that concentrations are expressed as parts per billion. BC modelling guidelines indicate that an appropriate O_3 value must be applied based on nearby monitoring data, data from another representative area, or data deemed to be suitable.

The OLM was used in this assessment. The O_3 data came from the Smithers St. Joseph's monitoring station measurements. The O_3 values were applied for each hour of the simulation period.

6.5.2 Formation of Ammonium Sulphates and Ammonium Nitrates

CALPUFF uses several chemical transformation schemes. Two of these are the MESOPUFF II and the Regional Impact in Visibility and Acid Deposition/Acid Rain Mountain Mesoscale Model (RIVAD/ARM3) schemes. The RIVAD/ARM3 chemical transformation scheme was used because it is considered more robust for a rural setting. The RIVAD/ARM3 chemistry scheme treats the NO_2 to ammonium nitrate and SO_2 to ammonium sulphate chemical transformations, with equilibrium between gaseous nitric acid and ammonium nitrate (Scire et al. 2000b) aerosol.

6.5.3 Acidification

CALPUFF was run with deposition options turned on to produce deposition predictions for NO_X, SO_2, nitrates, and sulfates for use in the acid deposition analysis. A separate document (the *Acidification Plan*) was developed with stakeholders to address assessment methods for the effects of acidic wet and dry deposition. This acidic deposition is a result SO_2 and NO_X emissions, their evolution to sulphates and nitrates, and ultimately to sulphuric and nitric acids. CALPUFF was used to predict deposition of substances containing sulphur and nitrogen.

The parameters used for the assessment of acidification and eutrophication were predicted at each of the receptors in both the near-field and far-field domains. The calculation methodology for these parameters is provided in Appendix F. A description of the effects on vegetation, water quality and human health is included in Section 5.5, Section 5.9, and Section 9.2, respectively, of the Application.

6.6 Building Plume Downwash Effects

Buildings or other solid facility structures might affect the flow of air near an emission source, causing building downwash effects on the plume (e.g., eddies on the downwind side), which might reduce plume rise and affect dispersion.

For dispersion modelling purposes, building downwash effects were considered for all Project stacks using the PRIME downwash routine incorporated in the CALPUFF model. Buildings and structures considered in the dispersion modelling are shown in Appendix F, including a plot plan and building and structure heights.

6.7 Fogging and Icing

Each LNG train will have its own cooling water system. The evaporation rate of water from the cooling towers will vary with ambient conditions. The cooling water towers will have anti-plume technology, which will reduce or eliminate the visible plume; therefore, plumes from the cooling towers will not be visible under most conditions. However, in certain high-humidity conditions, water vapour in the cooling tower plumes will condense to form visible plumes. Plumes might be visible at temperatures both above and below the freezing point. This condition is referred to here as “visible plumes aloft.”

In conditions favourable for plume formation, with wind speeds greater than 2.2 metres per second (m/s) or, 8 kilometres per hour (km/h), the water vapour in the cooling tower plumes will be forced to ground level. This condition is referred to here as “fogging.” Fogging might occur at temperatures both above and below freezing. Under freezing (<0°C), high-humidity conditions, with wind speeds greater than 2.2 m/s (8 km/h), the water vapour in the cooling tower plumes will be forced to ground level and will freeze to surfaces. This condition is referred to here as “icing.”

Water vapour emissions from the cooling towers are estimated and the CALPUFF model was used with three years (2008 to 2010) of hourly meteorological data to predict the occurrence of visible plumes aloft, fogging, and icing near the Project.

Specifically, the CALPUFF model was used to predict periods when visible plumes could occur as well as the heights and lengths of the visible plumes. The model was also used to predict the extents and frequencies of fogging and icing resulting from cooling tower emissions.

Periods when the ambient relative humidity was greater than 98% were excluded from the simulation because fog is likely to occur naturally under these conditions. The model simulation therefore predicts incremental visible plume and fog events resulting from cooling tower emissions.

A brief summary of results from the fogging and icing assessment is included in Section 7.2.5. Further details can be found in Appendix H.

7 MODELLING RESULTS

Plume dispersion modelling of CACs and VOCs was conducted to predict the effects of Project emissions on ambient air quality in the study areas. Modelling was completed for the four scenarios described in Section 6.3. The predicted maximum concentrations are compared with the applicable AAQO (Table 3.2-1) for each averaging period. Isopleth maps for selected parameters are provided in Appendix G.

Additionally, predicted effects were modelled at sensitive receptor locations to support the effects assessments of other disciplines. A description of the effects on vegetation and soils, water quality, and human health is found in Section 5.5, Section 5.9 and Section 9.2, of the Application, respectively.

7.1 Base Case

The base case modelling scenario includes emissions from the RTA facility and the KLNG facility at Bish Cove. These two facilities represent the major sources of CAC and VOC emissions in the facility RSA before Project construction. A summary of the base case maximum predicted concentrations is provided in Table 7.1-1. Results for SO_2 include 15 m "flag pole" receptor height (i.e., tree-top height) concentrations; all other results are for ground level. Isopleth maps of maximum predicted concentrations are provided in Appendix G.

Maximum predicted 1-hour (Figure G-1), 3-hour (Figure G-2), 24-hour (Figure G-3), and annual (Figure G-4) average ground-level SO_2 concentrations associated with the base case are 3,390 µg/m^3, 2,170 µg/m^3, 573 µg/m^3, and 32.5 µg/m^3, respectively. Predicted values for maximum SO_2 concentrations at the 15 m receptor height are slightly higher (Figure G-5). Application of the BC interim AAQO (defined in Section 3.2.2) to the SO_2 predictions yields a 1-hour value of 1,800 µg/m^3, which exceeds the interim AAQO of 200 µg/m^3.

These SO_2 maxima are well above the most stringent applicable AAQO. The predicted exceedance area, just to the west of the RTA property, is a direct result of SO_2 emissions from the RTA facility (see Section 5.1).

Maximum predicted 1-hour (Figure G-6), 24-hour (Figure G-7), and annual (Figure G-8) average ground-level NO_2 concentrations associated with the base case are 115 µg/m^3, 61.1 µg/m^3, and 10.3 µg/m^3, respectively. These concentrations are much lower than the most stringent applicable AAQO. The maxima are found next to the KLNG facility because NO_X emissions are larger there compared to the RTA facility. Comparison with the BC interim objectives for NO_2 (defined in Section 3.2.2) indicates that the predicted maximum 1-hour and annual concentrations are also lower than the BC interim AAQO.

Table 7.1-1: Maximum Predicted Ground-Level Concentrations Associated with the Base Case

Substance	Averaging Period	Maximum Predicted Ground-Level Concentration (µg/m^3)	Most Stringent Applicable AAQO [a]	Supplemental AAQO [b]
SO_2	1-hour	3,390 (3,630) [c]	450	N/A
	1-hour [d]	1,800 [d]	N/A	200
	3-hour	2,170 (2,260) [c]	375	N/A
	24-hour	573 (633) [c]	150	N/A
	Annual	32.5 (35.3) [c]	25	N/A
NO_2	1-hour	115	400	N/A
	1-hour [e]	91.6	N/A	188
	24-hour	61.1	200	N/A
	Annual	10.3	60	40
CO	1-hour	657	14,300	N/A
	8-hour	349	5,500	N/A
$PM_{2.5}$	24-hour	18.9 [f]	25 [f]	N/A
	Annual	4.2	8	N/A
H_2S [g]	1-hour	N/A	7	N/A
	24-hour	N/A	3	N/A
VOCs	1-hour	43.1	N/A	N/A
	24-hour	14.3	N/A	N/A

NOTES:

[a] See Table 3.2-1.

[b] See Section 3.2.2.

[c] Values in brackets are tree-top concentrations predicted at 15 m flag pole receptor heights.

[d] The U.S. EPA metric for SO_2 references the annual 99th percentile of daily 1-hour maxima averaged over three consecutive years. This requires the extraction of the highest 1-hour value for each day followed by the calculation of the 99th percentile of those 365 values at each receptor modelled, and then averaging this value over three consecutive years.

[e] The U.S. EPA metric for NO_2 references the annual 98th percentile of daily 1-hour maxima, averaged over three consecutive years. This requires the extraction of the highest 1-hour value for each day followed by the calculation of the 98th percentile of those 365 values at each receptor modelled, and then averaging this value over three consecutive years.

[f] Based on the 98th percentile value for one year

[g] Base case emissions are zero for H_2S.

N/A – Not applicable

Maximum predicted 1-hour and 8-hour average ground-level CO concentrations for the base case are 657 µg/m^3 and 349 µg/m^3, respectively. These concentrations are much lower than the most stringent applicable AAQO.

Maximum predicted 98th percentile 24-hour (Figure G-9) and annual average (Figure G-10) ground-level $PM_{2.5}$ concentrations for the base case are 18.9 µg/m^3 and 4.2 µg/m^3, respectively. These concentrations are lower than the most stringent applicable AAQO.

There are no H_2S emissions for the base case; therefore, no base case concentrations are reported.

Maximum predicted 1-hour and 24-hour average ground-level VOC concentrations for the base case are 43.1 µg/m^3 and 14.3 µg/m^3, respectively. There are no applicable national or BC objectives for total VOCs. The predicted base case concentrations are low for total VOCs. Concentrations of benzene are a very small fraction of the total VOC concentrations (approximately 0.5%). Therefore, the potential toxic effects of total VOC concentrations are far below a level of concern given that the Alberta AAQO for 1-hour average benzene (30 µg/m^3) is in the same order of magnitude. A more detailed assessment of individual VOC species is not warranted.

7.2 Project-alone Case

Air quality effects from Project operation will result from the air emissions described in Section 5.3. Land-based effects will result from routine operations, with infrequent instances of upset flaring. Marine-based effects will result from activities at or near the marine berths and along the marine access route. Dispersion of air emissions from these activities was simulated using CALPUFF, and maximum predicted concentrations were obtained from the output. These results are compared with the existing AAQO (Table 3.2-1) and the interim AAQO (Table 3.2-2). Isopleth maps of maximum predicted concentrations are provided in Appendix G.

7.2.1 Routine Operations

The Project-alone modelling case predicts the effects of emissions from operation of the LNG facility, including the operation of marine vessels within 1 km of the berths. Vessel emissions along the marine access route are assessed separately (see Section 2). For a summary of predicted maximum concentration, see Table 7.2-1.

Maximum predicted 1-hour (Figure G-11), 3-hour (Figure G-12), 24-hour (Figure G-13), and annual (Figure G-14) average ground-level SO_2 concentrations associated with the Project-alone case are 188 µg/m^3, 129 µg/m^3, 30.5 µg/m^3, and 1.5 µg/m^3, respectively. Maximum values at the 15 m receptor tree-top height are essentially the same (Figure G-15). The highest concentrations are predicted to occur

1 km to 2 km to the north-northwest of facility, where the emission plume will tend to impinge on elevated terrain. These concentrations are well below the most stringent applicable AAQO.

Table 7.2-1: Maximum Predicted Ground-Level Concentrations Associated with the Project-alone Case

Substance	Averaging Period	Maximum Predicted Ground-Level Concentration (µg/m^3)	Most Stringent Applicable AAQO [a]	Supplemental AAQO [b]
SO_2	1-hour	188 (188) [c]	450	N/A
	1-hour [d]	123 [d]	N/A	200
	3-hour	129 (128) [c]	375	N/A
	24-hour	30.5 (30.7) [c]	150	N/A
	Annual	1.5 (1.5) [c]	25	N/A
NO_2	1-hour	149	400	N/A
	1-hour [e]	50.0 [e]	N/A	188
	24-hour	42.4	200	N/A
	Annual	7.5	60	40
CO	1-hour	1,590	14,300	N/A
	8-hour	282	5,500	N/A
$PM_{2.5}$	24-hour	4.5 [f]	25 [f]	N/A
	Annual	0.66	8	N/A
H_2S	1-hour	0.10	7	N/A
	24-hour	0.02	3	N/A
VOCs	1-hour	36.3	N/A	N/A
	24-hour	4.2	N/A	N/A

NOTES:

[a] See Table 3.2-1.

[b] See Section 3.2.2.

[c] Values in brackets are tree-top concentrations predicted at 15 m flag pole receptor heights.

[d] The U.S. EPA metric for SO_2 references the annual 99th percentile of daily 1-hour maxima averaged over three consecutive years. This requires the extraction of the highest 1-hour value for each day followed by the calculation of the 99th percentile of those 365 values at each receptor modelled, and then averaging this value over three consecutive years.

[e] The U.S. EPA metric for NO_2 references the annual 98th percentile of daily 1-hour maxima, averaged over three consecutive years. This requires the extraction of the highest 1-hour value for each day followed by the calculation of the 98th percentile of those 365 values at each receptor modelled, and then averaging this value over three consecutive years.

[f] Based on the 98th percentile value for one year

N/A – Not applicable

Evaluation of the BC interim objective for SO_2 (defined in Section 3.2.2) indicates that the predicted 1-hour concentration (123 µg/m^3) is also lower than the interim AAQO for SO_2.

Maximum predicted 1-hour (Figure G-16), 24-hour (Figure G-17), and annual average (Figure G-18) ground-level NO_2 concentrations associated with the Project-alone case are 149 µg/m^3, 42.4 µg/m^3, and 7.5 µg/m^3, respectively. These concentrations are much lower than the most stringent applicable AAQO. Evaluation of the BC interim objectives for NO_2 (defined in Section 3.2.2) indicates that the predicted 1-hour and annual average concentrations are also lower than the interim AAQO.

Maximum predicted 1-hour and 8-hour average ground-level CO concentrations for the Project-alone case are 1,590 µg/m^3 and 282 µg/m^3, respectively. These concentrations are much lower than the most stringent applicable AAQO.

Maximum predicted 98th percentile 24-hour (Figure G-19) and annual (Figure G-20) average ground-level $PM_{2.5}$ concentrations for the Project-alone case are 4.5 µg/m^3 and 0.66 µg/m^3, respectively. These concentrations are lower than the most stringent applicable AAQO.

Maximum predicted 1-hour and 24-hour average ground-level H_2S concentrations for the Project-alone case are 0.10 µg/m^3 and 0.02 µg/m^3, respectively. These concentrations are much lower than the most stringent applicable AAQO.

Maximum predicted 1-hour and 24-hour average ground-level VOC concentrations for the Project-alone case are 36.3 µg/m^3 and 4.2 µg/m^3, respectively. There are no applicable national or BC objectives for total VOCs. The predicted Project-alone case concentrations are low for total VOCs. Concentrations of benzene are a very small fraction of the total VOC concentrations (approximately 0.5%). Therefore, the potential toxic effects of total VOC concentrations are far below a level of concern given that the Alberta AAQO for 1-hour average benzene (30 µg/m^3) is of the same order of magnitude. A more detailed assessment of individual VOC species is not warranted.

7.2.2 Marine Vessels in Transit

Emissions from LNG carriers and their escort tugs will affect areas near the marine access corridor (Figure 2.3-3). At any given time, there will be at most one LNG carrier travelling inbound and another travelling outbound in the corridor. The SCREEN3 model was used to predict ground-level concentrations from the worst-case scenario of two LNG carriers and two tugboats in the same location. Predictions were made for selected communities and locations of interest. Predicted concentrations are a direct result of the marine vessel emission rates (Table 5.3-3) and the distance from the centre of the marine access to the location of interest. In this case, all NO_X reaching the receptors is assumed to be in the form of NO_2. Results are shown in Table 7.2-2. All results are less than the AAQO.

Table 7.2-2: Predicted 1-hour Average Concentrations at the Selected Sites near the Marine Access Route

Station Name	Distance from Centre of Shipping Route (km)	Concentrations (µg/m^3)				
		SO_2	NO_2	CO	$PM_{2.5}$	VOC
Hartley Bay	2	3.6	143	18.2	5.8	7.9
Kitkatla	12	1.5	53.9	7.0	2.0	3.0
Metlakatla Village	27	1.1	34.7	4.6	1.1	2.0
Pitt Island – SW	3	2.8	115	14.5	4.8	6.3
Banks Island – North End	3	2.8	115	14.5	4.8	6.3
Porcher Island	12	1.5	53.9	7.0	2.0	3.0

7.2.3 High Total Sulphur Inlet Gas Scenario

The high total sulphur inlet gas scenario is a non-routine scenario that assumes the inlet gas total sulphur content increases to 30 mg/m^3 from its normal level of 9 mg/m^3. This 30 mg/m^3 sulphur value is based on the design basis of the facility, which was selected to allow for short-term spikes in the inlet gas sulphur content. Results are given in Table 7.2-3. The other SOIs are not affected by a change in inlet gas sulphur level.

Table 7.2-3: Maximum Predicted SO_2 Ground-Level Concentrations Associated with the Project-alone Case with Inlet Gas Total Sulphur Content of 30 mg/m^3

Substance	Averaging Period	Maximum Predicted Ground-Level Concentration (µg/m^3)	Most Stringent Applicable AAQO [a]	Supplemental AAQO [b]
SO_2	1-hour	622	450	N/A
	1-hour [c]	300 [c]	N/A	200
	3-hour	410	375	N/A
	24-hour	96.5	150	N/A
	Annual	5.6	25	N/A

NOTES:

[a] See Table 3.2-1.

[b] See Section 3.2.2.

[c] The U.S. EPA metric for SO_2 references the annual 99th percentile of daily 1-hour maxima averaged over three consecutive years. This requires the extraction of the highest 1-hour value for each day followed by the calculation of the 99th percentile of those 365 values at each receptor modelled, and then averaging this value over three consecutive years.

Maximum predicted 1-hour, 3-hour, 24-hour, and annual average ground-level SO_2 concentrations associated with the high total sulphur scenario of the Project-alone case are 622 µg/m^3, 410 µg/m^3, 96.5 µg/m^3, and 5.6 µg/m^3, respectively. These results are higher than the most stringent applicable AAQOs for the 1-hour and 3-hour averaging times. Evaluation of the BC interim objectives for SO_2 indicates that the predicted concentrations are also greater than these objectives.

Given that this abnormal situation would not persist for more than a few hours to days, comparison against both the annual average and BC interim objective (which involves averaging over three years) is unwarranted. For the predicted exceedances to occur, the high inlet gas scenario must coincide with worst-case meteorology—unlikely occurrence. Actual long-term average SO_2 concentrations for the Project-alone case are likely to be closer to the values indicated in Table 7.2-1.

7.2.4 Flaring Assessment

An emergency upset emission scenario was identified for the Project (see Section 5.3.4). The worst-case scenario assumed a gas maximum flow rate to each flares of 400 kg/s and an inlet gas total sulphur content of 30 mg/m^3. The sulphur oxidation efficiency is assumed to be 98%. See Table 7.2-4 for results for this modelling scenario.

Table 7.2-4: Maximum Predicted 1-hour Average Concentrations Associated with Upset Flaring

Substance	Averaging Period	Maximum Predicted Ground-Level Concentration (µg/m^3)	Most Stringent Applicable AAQO [a]	Supplemental AAQO [b]
SO_2	1-hour	11.2	450	N/A
	1-hour [c]	2.7 [c]	N/A	200
NO_2	1-hour	74.1	400	N/A
	1-hour [d]	4.8	N/A	188
H_2S	1-hour	0.12	7	N/A

NOTES:

[a] See Table 3.2-1.

[b] See Section 3.2.2.

[c] The U.S. EPA metric for SO_2 references the annual 99th percentile of daily 1-hour maxima averaged over three consecutive years. This requires the extraction of the highest 1-hour value for each day followed by the calculation of the 99th percentile of those 365 values at each receptor modelled, and then averaging this value over three consecutive years.

[d] The U.S. EPA metric for NO_2 references the annual 98th percentile of daily 1-hour maxima, averaged over three consecutive years. This requires the extraction of the highest 1-hour value for each day followed by the calculation of the 98th percentile of those 365 values at each receptor modelled, and then averaging this value over three consecutive years.

N/A – Not applicable

The maximum predicted 1-hour average ground-level SO_2 concentration associated with emergency upset flaring is 11.2 µg/m^3. The maximum predicted 1-hour average ground-level NO_2 concentration associated with emergency upset flaring is 74.1 µg/m^3. The maximum predicted 1-hour average ground-level H_2S concentration associated with emergency upset flaring is 0.12 µg/m^3. The predicted flaring concentrations are well below the existing and interim AAQOs.

7.2.5 Fogging and Icing Assessment

For the 2008 to 2010 simulation period, the CALPUFF model was used to predict periods when visible plumes could occur. The heights and lengths of the plumes were also modelled. The model was also used to predict the extents and frequencies of fogging and icing resulting from cooling tower emissions. Periods when the relative humidity was greater than 98% were excluded from the simulation because fog is likely to occur naturally under these conditions. The model simulation therefore predicts the incremental increase in visible plume, fogging, and icing events resulting from cooling tower emissions.

The most frequent visible plume heights are in the 50 m to 75 m range. Visible plumes aloft are least frequent during the spring and most frequent during the summer. No visible plumes were predicted for 81% of the hours modelled. The most frequent visible plume lengths are in the 100 m to 200 m range.

All instances of fogging and icing induced by cooling tower water vapour emissions were assumed to occur near the Project site. Therefore, the assessment focused on a 10 km by 10 km area centred on the Project, which covers nearby roads. The highest frequency of fogging (19 hours per year) is predicted along the Project fenceline to the northeast of the cooling towers. Fogging displays a north-south distribution outside the fenceline to the east of cooling towers. Fogging decreases quickly with increasing distance outside the fenceline. The highest predicted frequencies of fogging outside the fenceline are approximately 2 to 6 hours per year.

The highest frequency of icing (0.67 hours per year, or 2 hours during the 2008 to 2010 period) is predicted on the Project fenceline to the southwest of the cooling towers. Icing is also predicted for a very small area just outside the fenceline to the east of the cooling towers. The highest frequency of icing predicted outside the fenceline is one hour during the 2008 to 2010 period. Icing disappears quickly with increasing distance from the cooling towers.

Further details on the fogging and icing assessment are provided in Appendix H.

7.3 Application Case

The application case modelling scenario aggregates the base case and Project-alone case emissions to assess the Project air quality effects in combination with those of the RTA and KLNG facilities. Results are summarized in Table 7.3-1. Isopleth maps of maximum predicted concentrations are provided in Appendix G.

Table 7.3-1: Maximum Predicted Ground-Level Concentrations Associated with the Application Case

Substance	Averaging Period	Maximum Predicted Ground-Level Concentration (µg/m^3)	Most Stringent Applicable AAQO [a]	Supplemental AAQO [b]
SO_2	1-hour	3,460 (3,706) [c]	450	N/A
	1-hour [d]	1,830 [d]	N/A	200
	3-hour	2,170 (2,260) [c]	375	N/A
	24-hour	592 (654) [c]	150	N/A
	Annual	33.4 (36.3) [c]	25	N/A
NO_2	1-hour	149	400	N/A
	1-hour [e]	91.6 [e]	N/A	188
	24-hour	61.1	200	N/A
	Annual	10.7	60	40
CO	1-hour	1,590	14,300	N/A
	8-hour	349	5,500	N/A
$PM_{2.5}$	24-hour	19.8 [f]	25 [f]	N/A
	Annual	4.3	8	N/A
H_2S	1-hour	0.10	7	N/A
	24-hour	0.02	3	N/A
VOCs	1-hour	43.1	N/A	N/A
	24-hour	14.3	N/A	N/A

NOTES:

[a] See Table 3.2-1.

[b] See Section 3.2.2.

[c] Values in brackets are tree-top concentrations predicted at 15 m flag pole receptor heights.

[d] The U.S. EPA metric for SO_2 references the annual 99th percentile of daily 1-hour maxima averaged over three consecutive years. This requires the extraction of the highest 1-hour value for each day followed by the calculation of the 99th percentile of those 365 values at each receptor modelled, and then averaging this value over three consecutive years.

[e] The U.S. EPA metric for NO_2 references the annual 98th percentile of daily 1-hour maxima, averaged over three consecutive years. This requires the extraction of the highest 1-hour value for each day followed by the calculation of the 98th percentile of those 365 values at each receptor modelled, and then averaging this value over three consecutive years.

[f] Based on the 98th percentile value for one year

N/A – Not applicable

Maximum predicted 1-hour (Figure G-21), 3-hour (Figure G-22), 24-hour (Figure G-23), and annual (Figure G-24) average ground-level SO_2 concentrations associated with the application case are 3,460 µg/m^3, 2,170 µg/m^3, 592 µg/m^3, and 33.4 µg/m^3, respectively. Predicted values for maximum SO_2 concentrations at the 15 m receptor height are slightly higher (Figure G-25). Application of the BC interim AAQO (defined in Section 3.2.2) to the SO_2 predictions yields a 1-hour value of 1,830 µg/m^3, which exceeds the interim AAQO of 200 µg/m^3.

These SO_2 maxima are well above the most stringent applicable AAQO. The predicted exceedance area, just to the west of the RTA property, is a direct result of SO_2 emissions from the RTA facility (see Section 5.1).

Maximum predicted 1-hour (Figure G-26), 24-hour (Figure G-27), and annual average (Figure G-28) ground-level NO_2 concentrations associated with the application case are 149 µg/m^3, 61.1 µg/m^3, and 10.7 µg/m^3, respectively. These concentrations are much lower than the most stringent applicable AAQO. Evaluation of the BC interim objectives for NO_2 (defined in Section 3.2.2) indicates that the predicted 1-hour and annual average concentrations are also lower than the interim AAQOs.

Maximum predicted 1-hour and 8-hour average ground-level CO concentrations for the application case are 1,590 µg/m^3 and 349 µg/m^3, respectively. These concentrations are much lower than the most stringent applicable AAQO.

Maximum predicted 98th percentile 24-hour (Figure G-29) and annual average (Figure G-30) ground-level $PM_{2.5}$ concentrations for the application case are 19.8 µg/m^3 and 4.3 µg/m^3, respectively. These concentrations are lower than the most stringent applicable AAQO.

Maximum predicted 1-hour and 24-hour average ground-level H_2S concentrations for the application case are 0.10 µg/m^3 and 0.02 µg/m^3, respectively. These concentrations are much lower than the most stringent applicable AAQO.

Maximum predicted 1-hour and 24-hour average ground-level VOC concentrations for the application case are 43.1 µg/m^3 and 14.3 µg/m^3, respectively. These values are the same as the base case maxima for VOC. Concentrations of benzene are a very small fraction of the total VOC concentrations (approximately 0.5%). Therefore, the potential toxic effects of total VOC concentrations are far below a level of concern given that the Alberta AAQO for 1-hour average benzene (30 µg/m^3) is of the same order of magnitude. A more detailed assessment of individual VOC species is not warranted.

The relative contributions of the Project-alone and base cases to the application case results can be further analyzed by comparing the concentrations for each case at the maximum point of impingement. Results for SO_2 are listed in Table 7.3-2 and Table 7.3-3.

In Table 7.3-2, the receptor and time were determined for the application case maximum 1-hour SO_2 concentration of 3,463 µg/m^3, and then the Project-alone and base case concentrations were found for that same place and time. The Project contributes 2% of the total 1-hour SO_2 concentration value. Using similar methods, the Project contributes 3% of the SO_2 value for the highest application case annual average.

Table 7.3-2: Comparison of Base Case and Project-alone Case SO_2 Results at the Application Case Maximum Points of Impingement

Averaging Time	Predicted Ground-Level Concentrations (µg/m^3)			Contribution of Base Case	Contribution of Project-alone Case
	Project-alone Case	Base Case	Application Case		
1-hour [a]	75.7	3,387	3,463	98%	2%
Annual [b]	0.90	32.5	33.4	97%	3%

NOTES:

[a] The maximum 1-hour SO_2 value for the application case occurred at hour 2000 on January 19, 2009.

[b] The annual values are for 2009.

In Table 7.3-3, the receptor and time were determined for the Project-alone case maximum 1-hour SO_2 concentration of 188 µg/m^3, and then the application and base case concentrations were found for that same place and time. The Project contributes 17% of the total 1-hour application case SO_2 concentration value. Using similar methods, the Project contributes 5% of the application case SO_2 value for the highest Project-alone case annual average location.

Table 7.3-3: Comparison of Base Case and Project-alone Case SO_2 Results at the Project-alone Case Maximum Points of Impingement

Averaging Time	Predicted Ground-Level Concentrations (µg/m^3)			Contribution of Base Case	Contribution of Project-alone Case
	Project-alone Case	Base Case	Application Case		
1-hour	188	908	1,096	83%	17%
Annual	1.5	26.5	27.9	95%	5%

NOTES:

[a] The maximum 1-hour SO_2 value for the Project-alone case occurred at hour 0700 on December 2, 2009.

[b] The annual comparisons are for 2009.

The predicted exceedance area in the application case lies just to the west of the RTA facility. It is almost entirely attributable to the RTA facility SO_2 emissions, which make up 95.3% of the application case SO_2 emissions. A supplemental assessment of model output shows the following:

- The RTA facility contribution to the application case maximum predicted concentrations at the application case point of maximum impingement (paired in time) accounts for 98% and 97%, respectively, of the 1–hour and annual average ground-level SO_2 concentrations.
- The RTA facility contribution to the application case maximum predicted concentrations at the Project-alone case point of maximum impingement (paired in time) accounts for 83% and 95%, respectively, to the 1–hour and annual average ground-level SO_2 concentrations.

7.4 Cumulative Case

The cumulative case modelling scenario portrays air quality effects from emissions included in the application case plus those of foreseeable future facilities in the RSA. Results are summarized in Table 7.4-1. Isopleth maps of maximum predicted concentrations are provided in Appendix G.

Maximum predicted 1-hour (Figure G-31), 3-hour (Figure G-32), 24-hour (Figure G-33), and annual (Figure G-34) average ground-level SO_2 concentrations associated with the cumulative case are 3,460 µg/m^3, 2,170 µg/m^3, 592 µg/m^3, and 33.5 µg/m^3, respectively. Predicted values for maximum SO_2 concentrations at the 15 m receptor height are slightly higher (Figure G-35).

These SO_2 maxima are well above the most stringent applicable AAQO. The predicted exceedance area, just to the west of the RTA property, is a direct result of SO_2 emissions from the RTA facility (see Section 5.1).

Maximum predicted 1-hour (Figure G-36), 24-hour (Figure G-37), and annual (Figure G-38) average ground-level NO_2 concentrations associated with the cumulative case are 149 µg/m^3, 61.1 µg/m^3, and 11.0 µg/m^3, respectively. These concentrations are much lower than the most stringent applicable AAQO. Evaluation of the BC interim objectives for NO_2 (defined in Section 3.2.2) indicates that the predicted 1-hour and annual average concentrations are also lower than the interim AAQO.

Maximum predicted 1-hour and 8-hour average ground-level CO concentrations for the cumulative case are 1,590 µg/m^3 and 349 µg/m^3, respectively. These concentrations are much lower than the most stringent applicable AAQO.

Maximum predicted 98th percentile 24-hour (Figure G-39) and annual (Figure G-40) average ground-level $PM_{2.5}$ concentrations for the cumulative case are 19.9 µg/m^3 and 4.3 µg/m^3, respectively. These concentrations are lower than the most stringent applicable AAQO.

Table 7.4-1: Maximum Predicted Ground-Level Concentrations Associated with the Cumulative Case

Substance	Averaging Period	Maximum Predicted Ground-Level Concentration (µg/m^3)	Most Stringent Applicable AAQO [a]	Supplemental AAQO [b]
SO_2	1-hour	3,460 (3,710) [c]	450	N/A
	1-hour [d]	1,830 [d]	N/A	200
	3-hour	2,170 (2,260) [c]	375	N/A
	24-hour	592 (655) [c]	150	N/A
	Annual	33.5 (36.4) [c]	25	N/A
NO_2	1-hour	149	400	N/A
	1-hour [e]	91.6 [e]	N/A	188
	24-hour	61.1	200	N/A
	Annual	11.0	60	40
CO	1-hour	1,590	14,300	N/A
	8-hour	349	5,500	N/A
$PM_{2.5}$	24-hour	19.9 [f]	25 [f]	N/A
	Annual	4.3	8	N/A
H_2S	1-hour	10.9	7	N/A
	24-hour	1.8	3	N/A
VOCs	1-hour	304	N/A	N/A
	24-hour	74.9	N/A	N/A

NOTES:

[a] See Table 3.2-1.

[b] See Section 3.2.2.

[c] Values in brackets are tree-top concentrations predicted at 15 m flag pole receptor heights.

[d] The U.S. EPA metric for SO_2 references the annual 99th percentile of daily 1-hour maxima averaged over three consecutive years. This requires the extraction of the highest 1-hour value for each day followed by the calculation of the 99th percentile of those 365 values at each receptor modelled, and then averaging this value over three consecutive years.

[e] The U.S. EPA metric for NO_2 references the annual 98th percentile of daily 1-hour maxima, averaged over three consecutive years. This requires the extraction of the highest 1-hour value for each day followed by the calculation of the 98th percentile of those 365 values at each receptor modelled, and then averaging this value over three consecutive years.

[f.] Based on the 98th percentile value for one year

N/A – Not applicable

Maximum predicted 1-hour and 24-hour average ground-level H_2S concentrations for the cumulative case are 10.9 µg/m^3 and 1.8 µg/m^3, respectively. The maximum predicted 1-hour average is slightly higher than the BC level A objective of 7 µg/m^3. This exceedance applies only to a very small area on the fenceline of the proposed Kitimat Clean facility. Maximum predicted 1-hour H_2S concentrations in Kitimat are between 0.1 µg/m^3 and 0.2 µg/m^3. The maximum predicted 24-hour average is below the most stringent AAQO.

Maximum predicted 1-hour and 24-hour average ground-level VOC concentrations for the cumulative case are 304 µg/m^3 and 74.9 µg/m^3, respectively. There are no applicable national or BC objectives for total VOCs. The increase in VOC concentrations over the application case is due primarily to emissions from the Kitimat Clean facility, and the higher values are limited to a small area near that facility.

8 CONFIDENCE IN THE ASSESSMENT

8.1 General

The ability of a model to predict ambient concentrations depends on the accuracy of the source and emission inventory, the meteorology, and the assumptions used to represent the atmospheric physics and chemistry processes. The U.S. EPA (2005) states:

> *Models are reasonably reliable in estimating the magnitude of highest concentrations occurring sometime, somewhere within an area. For example, errors in highest estimated concentrations of ±10 to ±40% are found to be typical, i.e., certainly well within the often quoted factor-of-two accuracy that has long been recognized for these models.*

The U.S. EPA also states:

> *It is desirable to quantify the accuracy or uncertainty associated with concentration estimates used in decision-making. Communications between modellers and decision-makers must be fostered and further developed.*

The U.S. EPA (2005) indicates that the application of regulatory dispersion models is viewed as a "best estimate" approach and that this approach should be viewed as acceptable to the decision maker.

The ability of a model is often assessed by comparing model predictions with ambient measurements. The comparison needs to recognize that there may also be a level of uncertainty associated with the ambient measurements.

8.2 Emissions and Measurement Uncertainty

Most of the air emissions produced by large natural gas processing projects are the result of processing equipment operations. The highest level of confidence is associated with the estimation of the emissions because these amounts can be measured by manufacturers under controlled conditions. Air emission factors can be produced depending on one or a combination of power output, efficiency, or fuel consumption specifications. Although the limitations might lead to uncertainties for a specific facility at a given time, the emission factor approach is recognized by regulatory agencies as an accepted method.

The emission rates for existing facilities that are adopted in the air quality model represent typical normal operating conditions. Short-term fluctuations because of production variation or upset conditions are not included in the model predictions but are included in the ambient air quality measurements. This can make comparisons between model predictions difficult.

The effects assessment using air emissions dispersion modelling usually leaves out the smaller or more local emission sources such as traffic, communities, or biogenic emissions. Emissions from industrial point sources are better understood, and their magnitude is much larger.

Reliance on a three-year assessment period reduces uncertainty. Additionally, reference to the U.S. EPA air quality standards requires a three-year assessment period.

8.3 Meteorological Uncertainty

Meteorological conditions vary systematically and randomly from year to year, with season, and with time of day. In addition, meteorological conditions at any given time can vary with location because of the presence of local tree canopy or terrain influences. It is important to include a wide range of possible meteorological conditions in the assessment. The application of three years of meteorological data provides the opportunity to include a wide range of conditions that can affect dispersion of air emissions. Uncertainty in meteorological conditions included in the air quality modelling arises from assumptions made in the meteorological model and the quantity and quality of observed data used for model initialization.

8.4 Modelling Methods: Rio Tinto Alcan Kitimat Modernization Project versus the LNG Canada Export Terminal Base Case

Air quality assessments for both the RTA KMP project and the Project use CALMET Version 6.334 and CALPUFF Version 6.42 for dispersion modelling of their respective emission scenarios. Therefore, a comparison can be made between the SO_2 predictions of the STAR (RTA 2013) and those for the Project base case (Table 8.4-1).

The Project base case predictions are higher than those in STAR (RTA 2013); however, the results are within expected uncertainties. Both sets of SO_2 predictions show exceedances of the same general magnitude that are directly attributable to the RTA facility SO_2 emissions. A comparison of isopleth maps for each study indicates that most of the exceedances occur in the same general area concentrated to the west of both facilities and where the terrain is rising rapidly. The Project base case predictions for the Kitimat residential areas to the northeast are much lower than the predictions for the RTA facility emissions.

Table 8.4-1: Comparison of Maximum Predicted SO_2 Concentrations for RTA Kitimat Modernization Project and the Project Base Case

Averaging Period	Maximum Predicted Concentrations (µg/m^3)			
	RTA Modelling Grid: Offsite (outside RTA facility property line)[a]	Project Modelling Grid: Offsite (outside the RTA fenceline)[b]	RTA Modelling Grid: Residential[c]	Project Modelling Grid: Residential[d]
1-hour	2,630	3,390	1,918	735
3-hour	1,122	2,170	874	382
24-hour	261	573	191	85.0
Annual	35.0	32.5	16.0	9.0

NOTES:

[a] RTA offsite gridded receptors refers to page 77 of draft STAR Volume 3 - Appendices. RTA modelled concentrations include a background concentration appropriate to the averaging period. Background concentrations are based on monitoring data at the nearby Kitamaat Village monitoring station, as follows: 1.5 ppb (3.9 µg/m^3) for the 1-hour and 3-hour averaging periods, 1.2 ppb (3.1 µg/m^3) for the 24-hour averaging period, and 0.4 ppb (1.0 µg/m^3) for the annual averaging period. These background concentrations were not added to the LNG Canada results.

[b] LNG Canada offsite gridded receptors refers to Figure 6.3-2.

[c] RTA residential area receptors refers to page 77 draft STAR Volume 3 - Appendices.pdf.

[d] LNG Canada residential area receptors refers to Figure 6.3-2.

The discrepancies between the RTA and LNG Canada results are attributable to the ways in which the models are implemented. The assessment for LNG Canada strove to remain consistent with the RTA methods and used many of the same input files to characterize the facility. The LNG Canada air assessment team discovered that the RTA team used methods inconsistent with the Guidelines (BCMOE 2008) or good modelling practice. The differences in model implementations are discussed below and summarized in Table Table 8.4-2:

1. **Meso-meteorological data used**: RTA facility modelling used output from the MM5 model for the years 2006, 2008, and 2009. LNG Canada modelling used output from the WRF model for the years 2008 to 2010. The WRF model replaces the MM5 model; the MM5 model was unsupported by the developer after October 2008. More details are available in Appendix E.
2. **Geophysical characterization**: Information contained in the GEO.DAT file characterizes the surface conditions within the modelling domain. For example, surface conditions change with time and some have a pronounced annual cycle. For example, snow cover is much more extensive in winter than in summer. RTA modelling used one set of characteristics for all seasons, whereas LNG Canada modelling uses a distinct set for each season. As well, the parameters setting the characteristic were based on the TRC CALMET guide (Scire et al. 2000a) rather than the Guidelines (BCMOE 2008). There are major differences between the two datasets. More details are available in Appendix E.

3. **Upper-air data used**: The RTA modelling used upper-air data from the upper-air stations located at Annette Island and Port Hardy to supplement the upper-air modelling. LNG Canada modelling does not use these datasets because of excessive missing data within the three-year simulation period. Also, these two stations are far from the near-field domain. The Guidelines (BCMOE 2008) recommend using sounding data only when a project site is very near the upper-air stations and located at approximately the same elevation.
4. **CALPUFF chemistry option**: RTA modelling used the MESOPUFF option, whereas LNG Canada modelling uses the more sophisticated RIVAD/ARM option. The RIVAD/ARM option treats the NO to NO_2 conversion process internal to CALPUFF, leading to more realistic nitrate transformation rates.
5. **CALPUFF MSHEAR setting**: MSHEAR turns on the vertical wind shear above a stack top. RTA modelled with the MSHEAR option on, whereas LNG Canada modelling does not use this option. The Guidelines (BCMOE 2008) recommend that this option be turned off. However, CALPUFF sensitivity runs with MSHEAR turned on or off did not predict any substantial differences.
6. **Use of a subgrid-scale coastal boundary data file, COASTLN.DAT**: RTA modelling included the use of information in a COASTLN.DAT file, but LNG Canada modelling does not. The Kitimat coast is quite far inland from the Pacific coast, so the effects of a subgrid-scale coastal boundary data file would not be felt.
7. **RSA ozone**: RTA modelled CALPUFF assuming a constant O_3 level of 80 ppb in the modelling domain. LNG Canada modelling uses hourly values taken from measurements at the Smithers St. Joseph's monitoring station.
8. **Building Downwash**: RTA modelling included downwash effects at the RTA facility. Because downwash affects dispersion only in the very near field and stacks for the modernized facility were designed to minimize downwash, LNG Canada modelling does not include downwash effects for the RTA facility.
9. **Other sources added**: RTA modelling only included the effects from the RTA facility. LNG Canada modelling includes the emissions from the KLNG project, located much further south. However, it is expected that there are minimal overlapping effects between the RTA facility emissions and the emissions attributable to KLNG.
10. **Receptor grid concurrence with BCMOE Guidelines:** LNG Canada's modelling protocol conformed with the receptor grid protocol recommended in Section 6.2 of the Guidelines (BCMOE 2008). The Project fenceline grid resolution is 20 m. The grid resolution for the nearby area (Figure 6.3-1) and over the residential areas (Figure 6.3-2) is also 50 m. RTA modelling used a resolution of 500 m throughout their domain except for over the residential areas where 100 m was used. A finer grid resolution can affect predictions because the maximum point of impingement will most likely fall between the widely spaced grid points of a coarser grid.

Table 8.4-2: Comparison of RTA STAR and the Project Air Quality Modelling System Methods

Item	Model Element	RTA STAR Modelling Approach	LNG Canada Modelling Approach
1	Meso-meteorological data used	MM5-derived; years 2006, 2008, 2009	WRF-derived, years 2008, 2009, 2010
2	Geophysical characterization	One GEO.DAT file for all seasons. Surface parameter values selected based on TRC CALMET guide only. Not consistent with BCMOE Guidelines	Four seasonal GEO.DAT files and all surface parameter values selected based on BCMOE Guideline and TRC CALMET guide. Consistent with BCMOE Guidelines
3	Upper-air data used	Used two upper air station data: Annette Island, Port Hardy	Not used
4	Chemistry option	MESOPUFF	RIVAD/ARM
5	MSHEAR	Yes	No (default)
6	Use of a subgrid-scale coastal boundary data file, COASTLN.DAT	Yes	No
7	RSA ozone	Monthly average 80 ppb	Hourly measurements
8	Building downwash	Yes	No
9	Other sources added	No	Yes
10	Receptor grid conforms to BCMOE Guidelines	No	Yes

Of these, the key difference is the meso-meteorological data used to develop the CALMET input files, which drive CALPUFF. It appears to be almost entirely responsible for lower predictions in the far-field and higher predictions in the near-field compared to RTA (2013). LNG Canada independently developed a meso-meteorological dataset, with two of three years coinciding with the RTA dataset. The data used to drive the LNG Canada assessment is arguably more advanced, robust, and appropriate than the dated approach taken in the RTA (2013) work. The differences between both works are within expected uncertainties, and they are both suitable for consideration by decision makers.

8.5 Quality Assurance and Quality Control

A numerical air quality simulation model is one of the more powerful tools available to estimate the effect of air emissions on ambient air quality. The air quality assessment required the preparation of a large amount of numerical data required for model input and the processing of a large amount of numerical data taken from the model output. A number of quality assurance and quality control checks were undertaken for all components of the assessment.

These included the following:

- **Emissions inventory**: The Project emissions inventory was constructed using standard methodologies based on all available engineering information. The air emissions inventories for other facilities were based on information taken from recent publications. The information contained in these publications has already been reviewed and approved by stakeholders, including regulatory agencies. The locations of the emission sources were confirmed by using mapping tools such as latitudes and longitudes of facilities reporting to the National Pollutant Release Inventory available through Environment Canada, satellite imagery to confirm project locations, and maps presented in other applications. The emission inventory (Appendix D) was reviewed for logical consistency to confirm values, such as emission rates, stack heights, diameters, exhaust temperatures, and velocities, were within the range of typical values for each source type.
- **Meteorology:** The output of the CALMET model was compared with observations to confirm consistency. Wind direction, wind speed, temperature, mixing height, stability, and precipitation plots were prepared (see Appendix E) for multiple locations for comparison to measured data and to confirm reasonable model performance.
- **Model application:** CALPUFF concentration predictions were rationalized against the emission inventory information to verify that model concentration predictions are logically consistent with the source emission inventory (e.g., high concentrations occur where expected). During post-processing, unexpected model results were investigated and rationalized in detail to confirm consistency with model input.

The air quality assessment was undertaken by the air assessment team working together under the direction of the air discipline lead. Critical components of the quality assurance/quality control process were numerous progressive reviews and ongoing communication among team members.

8.6 Model Prediction Confidence

Uncertainty associated with dispersion model predictions stems from two main areas (U.S. EPA 2005):

- **Reducible uncertainty—**results from uncertainties associated with the input values and with the limitations of the model physics and formulations. Reducible uncertainty can be reduced by better (i.e., more accurate and representative) measurements and improved model physics.
- **Inherent uncertainty**—associated with the stochastic nature of the atmosphere and its representation. Models predict concentrations that represent an ensemble average of numerous repetitions for the same nominal event. An individual observed value can deviate significantly from the ensemble value. This uncertainty may be responsible for a ±50% deviation from the measured values.

Predictions for a specific site and time are often poorly correlated with observed values. This poor correlation can often be related to errors in wind direction. For example, an uncertainty of 5º to 10º in wind direction can produce a concentration error in the 20% to 70% range (U.S. EPA 2005).

The U.S.EPA (2005) provides guidance to decision makers relative to model uncertainty. Specifically, it recommends that model predictions be accepted as a “best estimate,” until sufficient technical progress has been made to meaningfully implement concepts dealing with uncertainty.

9 KEY RESULTS AND FINDINGS

The AIR for the Project identified air quality as a VC. To evaluate Project effects on air quality, emissions of CACs were estimated for both the construction and operation phases.

Construction CAC emissions are intermittent, transient, and small when compared with Project operation emissions, so the effects of the construction emissions were deemed insubstantial and were not included in the dispersion modelling assessment.

As determined by comparison with the AAQO developed by Canada and BC, the primary effects of Project-alone air emissions will be a moderate increase in the nearby area of ground-level concentrations of SOI. Four modelling scenarios are evaluated: base case (existing and approved sources), Project-alone case (Project emissions in isolation), application case (base and Project-alone cases), and cumulative case (application and future sources). Key findings are as follows:

- For the Project-alone case, there are no predicted exceedances of the existing and interim AAQO.
- For the base case, SO_2 concentrations at levels greater than the applicable and the interim AAQO are predicted primarily to the west of the RTA facility. These levels are a direct result of the SO_2 emissions from the RTA facility. There are no predicted concentrations in excess of the AAQO for any of the other SOI modelled.
- The overall findings from the application and cumulative cases are the same as for the base case. The RTA facility is by far the dominant contributor of SO_2 in the RSA, and it accounts for a large portion of the predicted SO_2 concentrations.

Based on the findings of this assessment, it is concluded that air quality in the facility RSA will not change appreciably from base case conditions when the Project is fully operational. Air quality in the District of Kitimat is already compromised by SO_2 emissions from the operation of the RTA facility. The Project adds a very small increment to the effects predicted for the RTA facility alone.

10 CLOSURE

This report has been prepared for the sole benefit of LNG Canada Development Inc. and their representatives. The report may not be relied upon by any other person or entity without the express written consent of Stantec and LNG Canada Development Inc.

Any use which a third party makes of this report, or any reliance on decisions made based on it, is the responsibility of such third parties. Stantec accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

Should additional information become available which differs substantially from our understanding of conditions presented in this report, we request that this information be brought to our attention so that we may reassess the conclusions provided herein.

This report was prepared by a number of Stantec staff, identified in the Authorship section preceding the Executive Summary. We trust that the above information meets with your present requirements. Should you have any questions or require further information, please contact Peter Reid directly at (403) 781-4142.

Respectfully submitted,
Stantec Consulting Ltd.

Original signed by:

Peter Reid, Principal
[Discipline Lead]

Original signed by:

Michael Schroeder, Senior Air Quality Scientist
[Senior Reviewer]

11 REFERENCES

11.1 Literature Cited and Internet Sites

British Columbia Ministry of Environment (BCMOE). 2008. *Guidelines for Air Quality Dispersion Modelling in British Columbia*. British Columbia Ministry of Environment, Environmental Protection Division, Environmental Quality Branch, Air Protection Section. March 2008.

British Columbia Ministry of Environment (BCMOE). 2013a. *Provincial Air Quality Objective Information Sheet*. Updated August 12, 2013. Available at: http://www.bcairquality.ca/reports/pdfs/aqotable.pdf. Accessed: April 2014.

British Columbia Ministry of Environment (BCMOE). 2013b. *Annual Statistical Analysis System Summary Reports for Ambient Air Quality Data.* Dataset compiled by Robert Gibson, BCMOE Air Quality Data Interpretation Specialist, Victoria, BC.

British Columbia Ministry of Environment (BCMOE). 2014. *BC Air Data Archive.* Available at: http://envistaweb.env.gov.bc.ca/. Accessed: January 2014.

Enbridge. 2010. *Volume 6: Environmental and Socio-Economic Assessment Atmospheric Environment, Enbridge Northern Gateway Pipelines Project*. May 2010. Environmental Assessment Section, including Appended Technical Data Report. Available at: http://gatewaypanel.review-examen.gc.ca/clf-nsi/hm-eng.html.

Environment Canada. 2013. *Canadian Ambient Air Quality Standards.* Available at: http://ec.gc.ca/default.asp?lang=En&n=976258C6-1&news=A4B2C28A-2DFB-4BF4-8777-ADF29B4360BD. Accessed: April 2014.

Environment Canada. 2014. *National Climate Data and Information Archive*. *Canadian Climate Normals*. Available at: http://www.climate.weatheroffice.ec.gc.ca/climate_normals/index_e.html. Accessed: January 2014.

ESSA, 2014. Kitimat Airshed Emissions Effects Assessment, ESSA Technologies, J. Laurence, Risk Sciences International, Trent University, and Trinity Consultants. 2014. Report prepared for BC Ministry of Environment, Smithers, BC. 205 pp. + appendices.

GeoBase. 2013. *Canadian Digital Elevation Data*. Available at: http://www.geobase.ca/geobase/en/index.html;jsessionid=FBC8E4097F3D49C98CAFA4921EC07F23.geobase2. Accessed: June 2014.

Kitimat LNG Terminal Project (KLNG). 2005. *Application for an Environmental Assessment Certificate for the Kitimat LNG Terminal Project submitted by Kitimat LNG Inc. to John Bones (EAO) on June 6, 2005.* Environmental Assessment Section, including Appended Technical Data Report. Available at: http://a100.gov.bc.ca/appsdata/epic/html/deploy/epic_document_244_20404.html

MARPOL. 2008*. International Convention for the Prevention of Pollution from Ships. Annex VI. North American Emission Control Area.*

Rio Tinto Alcan (RTA). 2013. *Sulphur Dioxide Technical Assessment Report in Support of the 2013 Application to Amend the P2-00001 Multimedia Permit, Kitimat Modernization Project.* Prepared for: Rio Tinto Alcan, Kitimat, BC, Canada. Prepared by: ESSA Technologies Ltd. Vancouver, BC, Canada . Includes Volume 1: Executive Summary; Volume 2: Technical Report; and Volume 3: Appendices. February 18, 2013.

Stantec Consulting Ltd. (Stantec). 2013a. *Scoping of Photochemical Oxidants for the LNG Canada Project*. Memorandum from Peter Reid to Russell Morrison, LNG Canada Development Inc. August 7, 2013

Stantec. 2013b. *Scoping of Photochemical Oxidants for the LNG Canada Project*. Memorandum from Peter Reid to Russell Morrison, LNG Canada Development Inc. September 19, 2013

Scire J.S., F.R. Robe, M. E. Ferneau, and R.J. Yamartino. 2000a, *A User's Guide for the CALMET Meteorological Model.* Earth Tech Inc., Jan. 2000, p 332.

Scire, J.S., D.G. Strimaitis, and R.J. Yamartino. 2000b. *A User's Guide for the CALPUFF Dispersion Model (Version 5).* Earth Tech, Inc., Concord, MA.

Tang, H., Burns, Yang, L. and F. Apon, 2011. *AMEC Multigas Passive Sampler: A Green Product for Cost-Effectively Monitoring Air Pollution Indoors and Outdoors*. Transactions of the Wessex Institute. Paper DOI: 10.2495/AIR110131.

United States Western Regional Air Partnership (U.S. WRAP). 2012. *Western Regional Air Partnership (WRAP) West-wide Jump Start Air Quality Modeling Study (WestJumpAQMS) WRF Application/Evaluation.* Prepared by ENVIRON International Corporation, Alpine Geophysics, LLC and the University of North Carolina (February 29, 2012).

United States Environmental Protection Agency (U.S. EPA). 1995. *SCREEN3 Model User's Guide*. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Emissions, Monitoring, and Analysis Division. September, 1995. EPA-454/B-95-004

United States Environmental Protection Agency (U.S. EPA). 2005. *Appendix W to Part 51, Revision to the Guideline on Air Quality Models: Adoption of a Preferred General Purpose (Flat and Complex Terrain) Dispersion Model and Other Revisions; Final Rule*. (November 9, 2005 Edition).

United States Environmental Protection Agency (U.S. EPA). 2012. *National Ambient Air Quality Standards*. Available at: http://www.epa.gov/air/criteria.html. Accessed: June 2014.

United States Environmental Protection Agency (U.S. EPA). 2014. *Health Effects of Ozone in the General Population.* Available at: http://www.epa.gov/apti/ozonehealth/population.html. Accessed: June 2014.

Wayne, R.P. 1991. *Chemistry of Atmospheres*. *2nd Edition*. Oxford University Press. New York, NY.

World Health Organization (WHO). 2006. *Air Quality Guidelines. Global Update 2005. Particulate Matter, Ozone, Nitrogen Dioxide and Sulphur Dioxide*. World Health Organization. Geneva, Switzerland. ISBN 92 890 2192 6.

11.2 Personal Communications

Bailey, S. 2014. Executive Project Director. BC Environmental Assessment Office, Victoria, BC. E-mail. February 12, 2014.

APPENDIX A

Baseline Climate

A.1 Introduction

The following tables contain climate normals for three regional meteorological stations: the Kitimat 2, Kitimat townsite, and Terrace Airport observing stations. The normals data, which are based on 30 years of records (1981 to 2010), provide information on average and extreme weather conditions for each location. Tables A-1 through A-3 were compiled from data provided by Environment Canada (2014).

Table A-1: Climate Normals and Extremes for the Kitimat 2 Station (1981 to 2010)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Temperature													
Daily Average (°C)	-0.9	0.9	3.8	7.3	11.2	14.9	17.1	17.1	13.2	7.9	2.4	-0.2	7.9
Daily Maximum (°C)	1.4	3.7	7.4	12.0	16.5	19.8	22.0	21.9	17.3	10.8	4.7	2.0	11.6
Daily Minimum (°C)	-3.3	-2.0	0.2	2.6	5.9	9.8	12.2	12.2	9.0	4.9	0.1	-2.4	4.1
Extreme Maximum (°C)	11.0	12.0	19.5	29.0	35.5	36.0	36.0	36.7	33.3	22.0	15.5	12.5	
Date (yyyy/dd)	2003/05	1990/27	1994/28	2005/26	1983/29	2004/18	1998/26	1977/18	1974/01	1993/03	1980/20	1980/14	
Extreme Minimum (°C)	-23.3	-18.9	-17.0	-7.8	-2.2	0.5	2.8	2.8	0.0	-12.5	-23.0	-26.0	
Date (yyyy/dd)	1969/28	1975/12	2003/08	1966/12	1972/14	1988/01	1976/03	1969/17	1976/18	1984/31	1985/26	1995/08	
Precipitation													
Rainfall (mm)	304.3	209.0	194.7	164.6	103.6	81.6	61.3	100.6	210.9	391.3	356.3	294.7	2,472.8
Snowfall (cm)	86.3	48.8	22.1	4.3	0.6	0.0	0.0	0.0	0.0	2.5	50.8	86.9	302.3
Precipitation (mm)	390.6	257.8	216.8	168.9	104.2	81.6	61.3	100.6	210.9	393.8	407.1	381.1	2,774.6
Extreme Daily Rainfall (mm)	152.9	169.0	118.9	82.0	61.5	61.0	58.4	74.9	148.0	179.4	150.0	154.4	
Date (yyyy/dd)	1973/22	1993/27	1966/28	1986/07	1972/12	1987/11	1998/16	1978/05	1988/28	1978/31	1978/05	1984/05	
Extreme Daily Snowfall (cm)	82.6	76.2	53.6	28.4	14.0	0.0	0.0	0.0	0.0	12.0	60.0	59.0	
Date (yyyy/dd)	1974/17	1972/07	1972/08	1996/02	2001/18	1966/01	1966/01	1966/01	1966/01	1992/17	1999/28	1990/02	
Extreme Daily Precipitation (mm)	152.9	169.6	118.9	83.0	61.5	61.0	58.4	74.9	148.0	179.4	150.0	158.0	

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Date (yyyy/dd)	1973/22	1993/27	1966/28	1986/07	1972/12	1987/11	1998/16	1978/05	1988/28	1978/31	1978/05	1984/05	
Extreme Snow Depth (cm)	93	127	32	12	0	0	0	0	0	8	52	135	
Date (yyyy/dd)	1982/10	1999/13	2002/11	2002/06	1981/01	1981/01	1981/01	1980/01	1981/01	1984/30	2006/30	2001/20	
Days with Precipitation ≥0.2 mm	15.7	12.9	18.3	17.4	16.7	15.3	14.1	14.2	17.3	22.4	20.7	16.4	201.2
Wind													
Maximum Hourly Speed (km/h)	40	34	40	32	35	32	31	29	35	37	35	39	

Table A-2: Climate Normals and Extremes for the Kitimat Townsite Station (1981 to 2010)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Temperature													
Daily Average (°C)	-1.7	0.3	3.2	7.1	11.0	14.5	16.7	16.5	12.6	7.2	1.8	-0.8	7.4
Daily Maximum (°C)	0.5	3.1	6.7	11.7	16.2	19.5	21.6	21.4	16.8	10.1	3.9	1.2	11.1
Daily Minimum (°C)	-4.0	-2.5	-0.3	2.4	5.7	9.5	11.7	11.5	8.3	4.3	-0.3	-2.8	3.6
Extreme Maximum (°C)	12.2	13.0	18.0	27.5	32.8	37.0	36.1	36.0	33.3	25.0	13.3	10.0	
Date (yyyy/dd)	1963/06	2005/28	1994/28	2005/26	1963/21	2004/20	1958/27	1990/11	1974/01	2003/01	1970/01	1957/02	
Extreme Minimum (°C)	-25.0	-23.9	-19.4	-10.0	-6.7	-0.6	3.9	2.0	-2.0	-13.0	-24.0	-25.0	
Date (yyyy/dd)	1979/03	1978/03	1955/03	1966/12	1975/18	1978/01	1976/01	1979/17	1979/25	1984/31	1985/26	1964/25	
Precipitation													
Rainfall (mm)	195.7	133.6	134.5	123.0	88.7	73.1	62.4	95.7	190.2	319.9	266.6	202.7	1,886.1
Snowfall (cm)	92.7	53.2	26.3	5.4	0.8	0.0	0.0	0.0	0.0	3.5	53.7	89.1	324.6
Precipitation (mm)	288.4	186.8	160.7	128.3	89.5	73.1	62.4	95.7	190.2	323.5	320.3	291.8	2,210.7
Extreme Daily Rainfall (mm)	95.8	86.6	108	71.6	57.2	46.6	49	57.4	130	144.8	110	129.4	
Date (yyyy/dd)	1973/22	1961/05	1966/28	1972/18	1972/12	1987/11	1998/16	1978/05	1992/28	1976/26	1978/05	1979/26	
Extreme Daily Snowfall (cm)	106.9	112.3	58.4	28.2	17	0	0	0	0	33	78.7	57.2	
Date (yyyy/dd)	1973/19	1972/18	1976/11	1972/04	2001/18	1954/01	1954/01	1954/01	1954/01	1964/28	1975/11	1967/22	
Extreme Daily Precipitation (mm)	106.9	112.3	108.0	71.6	57.2	46.6	49.0	57.4	130.0	144.8	110.0	129.4	

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Date (yyyy/dd)	1973/19	1972/18	1966/28	1972/18	1972/12	1987/11	1998/16	1978/05	1992/28	1976/26	1978/05	1979/26	
Extreme Snow Depth (cm)	90	140	65	33	0	0	0	0	0	1	86	122	
Date (yyyy/dd)	1993/24	1999/12	2002/01	2002/01	1981/01	1981/01	1981/01	1980/01	1981/01	1991/28	1994/30	1994/11	
Days with Precipitation ≥0.2 mm	14.5	12.0	16.7	17.0	15.8	14.8	13.2	13.7	16.9	21.9	18.8	14.8	190.1
Wind													
Prevailing Wind Direction	N	N	SE	SE	SE	SE	SE	SE	SE	SE	N	N	
Maximum Hourly Speed (km/h)	55	55	42	37	37	35	35	31	39	42	56	55	

Table A-3: Climate Normals and Extremes for the Terrace Airport Station (1981 to 2010)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Temperature													
Daily Average (°C)	-3.0	-0.9	2.4	6.3	10.6	14.2	16.5	16.3	12.1	6.4	0.7	-2.6	6.6
Daily Maximum (°C)	-1.1	1.7	5.8	10.8	15.7	19.1	21.4	21.1	16.0	9.0	2.6	-0.8	10.1
Daily Minimum (°C)	-5.0	-3.4	-1.1	1.7	5.5	9.2	11.6	11.5	8.2	3.7	-1.1	-4.5	3.0
Extreme Maximum (°C)	9.4	12.7	16.9	26	34.6	36.5	37.3	36.2	32.2	21.4	13.4	11.3	
Date (yyyy/dd)	1962/30	2005/28	1994/28	2005/26	1983/29	2004/20	2009/29	1990/11	1974/01	1993/02	1980/05	1980/15	
Extreme Minimum (°C)	-25.0	-25.0	-19.4	-8.3	-2.2	0.6	3.3	2.8	-1.4	-13.5	-25.3	-26.7	
Date (yyyy/dd)	1969/01	1956/15	2003/08	1966/12	1964/13	1960/04	1955/01	1973/31	1983/28	1984/31	1985/26	1964/16	
Precipitation													
Rainfall (mm)	91.7	61.8	58.8	64.7	55.7	50.8	52.8	61.2	111.5	185.2	132.2	99.0	1,025.3
Snowfall (cm)	88.4	51.9	34.3	8.5	0.4	0.0	0.0	0.0	0.0	4.8	56.0	87.1	331.5
Precipitation (mm)	173.5	110.6	92.3	73.7	56.4	50.8	52.8	61.2	111.5	190.3	187.1	180.9	1,340.8
Extreme Daily Rainfall (mm)	115.0	79.0	42.7	43.4	39.6	35.4	39.4	71.8	106.6	114.8	93.0	111.4	
Date (yyyy/dd)	2007/24	1961/05	1960/16	2001/24	1985/03	1993/22	1966/19	1978/06	1988/28	1978/31	1956/02	1990/07	
Extreme Daily Snowfall (cm)	99.1	113.4	44.2	49.6	6.1	0	0	0	0.3	21.3	39.4	82.8	
Date (yyyy/dd)	1974/17	1999/11	2007/28	1981/04	1965/03	1954/01	1954/01	1953/01	1972/27	1956/31	2003/27	1990/03	
Extreme Daily Precipitation (mm)	115.0	99.7	53.2	59.2	39.6	35.4	39.4	71.8	106.6	114.8	95.8	142.0	

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Date (yyyy/dd)	2007/24	1999/11	2007/28	1981/04	1985/03	1993/22	1966/19	1978/06	1988/28	1978/31	1956/02	1991/20	
Extreme Snow Depth (cm)	165	191	165	48	3	0	0	0	0	23	56	160	
Date (yyyy/dd)	1974/18	1972/20	1972/10	1971/01	1965/03	1955/01	1955/01	1955/01	1955/01	1964/29	1975/26	1957/29	
Days with Precipitation ≥0.2 mm	20.6	15.3	17.5	15.4	14.8	14.7	14.1	13.4	16.6	21.8	21.9	20.9	206.8
Wind													
Prevailing Wind Direction	N	N	S	S	S	S	S	S	S	S	N	N	
Maximum Hourly Speed (km/h)	72	80	89	93	68	80	64	95	68	69	80	80	

A.2 References

Environment Canada. 2014*. National Climate Data and Information Archive.* Canadian Climate Normals. Available at: http://www.climate.weatheroffice.ec.gc.ca/climate_normals/index_e.html. Accessed: January 2014.

APPENDIX B

Background Air Quality Data

Table B-1: North Coast Passive Monitoring Results for Sulphur Dioxide

SO_2(µg/m3)																
Station Name / Month	Jul-13	Aug-13	Sep-13	Oct-13	Nov-13	Dec-13	Jan-14	Feb-14	Mar-14	Apr-14	May-14	Jun-14	Jul-14	Average	Maximum	Minimum
Lakelse Lake 1	2.36	0.26	0.26	0.79	2.36	0.52	0.26	1.31	0.52	0.26	0.52	0.52	0.52	0.81	2.36	0.26
Lakelse Lake 2	1.05	0.26	1.05	0.52	2.10	0.26	1.05	1.83	0.52	0.26	0.52	0.79	0.79	0.85	2.10	0.26
Kitimat Haul Road 1	4.98	3.93	7.07	6.29	5.50	1.05	23.84	9.95	24.10	6.55	14.14	11.00	14.41	10.22	24.10	1.05
Kitimat Haul Road 2	10.48	6.55	5.24	7.07	4.71	0.79	22.27	4.71	10.74	3.67	9.69	22.79	15.45	9.55	22.79	0.79
Kitamaat Village 1	1.31	0.79	0.79	0.79	1.05	13.10	1.05	1.57	0.52	0.26	0.52	0.52	0.52	1.75	13.10	0.26
Kitamaat Village 2	1.05	0.26	2.10	1.57	6.02	14.41	0.52	2.10	0.52	0.79	0.26	0.52	0.26	2.34	14.41	0.26
Terrace 1-1			0.26	0.26	1.57	0.26	0.52	1.05	0.52	0.26	0.26	0.26	0.52	0.52	1.57	0.26
Terrace 1-2			0.26	1.05	0.52	0.26	0.52	0.26	0.26	0.26	0.52	0.26	0.26	0.40	1.05	0.26
Old Town 1				2.62	1.83	0.26		8.12	0.79	0.26	0.26	0.52	0.26	1.66	8.12	0.26
Old Town 2				3.14	3.14	0.26		5.24	0.79	0.26	0.26	0.79	0.26	1.57	5.24	0.26
Gil Island 1				1.83	1.05	0.26		2.10	0.26	0.26	0.26	0.26	0.26	0.73	2.10	0.26
Gil Island 2				1.83	1.57	0.26		1.31	0.26	0.26	0.26	0.26	0.26	0.70	1.83	0.26
Promise Island 1				2.36	1.31	2.36		3.41	0.52	0.26	0.26	0.26	0.26	1.22	3.41	0.26
Promise Island 2				2.88	3.93	0.52		2.62	0.79	0.26	0.26	0.26	0.26	1.31	3.93	0.26
Terrace 2-1					0.26	0.79	0.26	2.62	0.52	0.26	0.26	0.26	0.26	0.61	2.62	0.26
Terrace 2-2					0.26	0.79	0.52	1.05	0.26	0.26	0.26	0.52	0.26	0.47	1.05	0.26
Gitaus 1						0.52	0.79	0.26	0.52	0.26	0.79	0.26	0.26	0.46	0.79	0.26
Gitaus 2						1.05	0.79	0.26	0.26	0.26	0.52	0.26	0.26	0.46	1.05	0.26
Metlakatla 1							1.57	2.62	0.52		0.26	0.26	0.26	0.92	2.62	0.26
Metlakatla 2							1.31	1.57	0.52		0.26	0.26	0.26	0.70	1.57	0.26
McCauley Island 1								0.26	0.79	0.26	0.26	0.26	0.26	0.35	0.79	0.26
McCauley Island 1								2.88	0.52	0.26	0.26	0.26	0.26	0.74	2.88	0.26
Dolphin Island 1								3.41		0.79	0.26	0.26	0.26	1.00	3.41	0.26
Dolphin Island 2								0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26
Kitsumkalum Lake 1								0.26	0.52	0.79	0.26	0.26	0.26	0.39	0.79	0.26
Kitsumkalum Lake 2								1.05	0.26	0.26	0.52	0.26	0.26	0.44	1.05	0.26
Average	3.54	2.01	2.13	2.36	2.32	2.10	3.95	2.39	1.84	0.73	1.24	1.63	1.44	2.13	3.95	0.73
Maximum	10.48	6.55	7.07	7.07	6.02	14.41	23.84	9.95	24.10	6.55	14.14	22.79	15.45	12.96	24.10	6.02
Minimum	1.05	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.32	1.05	0.26

Table B-2: North Coast Passive Monitoring Results for Nitrogen Dioxide

NO_2(µg/m3)																
Station Name / Month	Jul-13	Aug-13	Sep-13	Oct-13	Nov-13	Dec-13	Jan-14	Feb-14	Mar-14	Apr-14	May-14	Jun-14	Jul-14	Average	Maximum	Minimum
Lakelse Lake 1	0.19	0.19	0.19		3.39	7.90	38.00	0.94	8.84	0.94	0.75	1.13	1.13	5.30	38.00	0.19
Lakelse Lake 2	0.19			1.50	4.70	8.09		0.38	4.33	1.88	1.69	1.32	1.50	2.56	8.09	0.19
Kitimat Haul Road 1	1.88	3.39	6.02	1.32	12.04	1.32	8.28	5.83	22.76	7.90	7.71	9.03	15.05	7.89	22.76	1.32
Kitimat Haul Road 2	3.76		4.70		12.60	3.20	9.78	4.51	17.12	8.84	9.40	9.03	8.84	8.34	17.12	3.20
Kitamaat Village 1	0.19	1.88	0.19		2.07	14.48	3.01	0.38	6.02	1.50	1.88	1.69	1.32	2.88	14.48	0.19
Kitamaat Village 2	0.19	2.07	2.45	1.13	3.76	9.03	3.01	0.94	7.15	2.07	1.50		2.26	2.96	9.03	0.19
Terrace 1-1			2.26	1.50	7.15	0.38	6.96	1.50	6.96	5.27	3.57	3.95		3.95	7.15	0.38
Terrace 1-2			3.39		3.57	0.75	13.92	2.63	5.27	5.27	3.76	5.27		4.87	13.92	0.75
Old Town 1				0.56	5.45			3.20	2.07	1.69	1.13	1.69	2.26	2.26	5.45	0.56
Old Town 2				1.32	0.94	4.33		4.70	3.01	3.39	2.07	3.76	2.26	2.86	4.70	0.94
Gil Island 1				0.19	0.56	1.88		7.15	3.20	1.50	0.56	1.50	6.96	2.61	7.15	0.19
Gil Island 2					0.38	3.57		2.07	4.51	0.94	0.75	1.32	3.57	2.14	4.51	0.38
Promise Island 1				0.56	3.39	1.50		11.85	2.26	1.50	1.32	4.51	7.34	3.80	11.85	0.56
Promise Island 2					2.26	1.88		3.01	3.57		1.50	12.04	1.69	3.71	12.04	1.50
Terrace 2-1					2.45	7.52		0.75	3.76	4.51	3.95	3.95	3.20	3.76	7.52	0.75
Terrace 2-2					1.88	11.10	23.32	0.56	5.27	3.76	3.20	4.33	8.46	6.88	23.32	0.56
Gitaus 1						0.94	2.07	2.45	10.72	3.57	3.01	3.01	2.45	3.53	10.72	0.94
Gitaus 2						2.45	1.69	2.45	4.33		3.20	3.01	2.07	2.74	4.33	1.69
Metlakatla 1							5.83	1.32	3.76		3.95	4.14	6.02	4.17	6.02	1.32
Metlakatla 2							6.77	1.32	2.63		3.57	3.95	3.57	3.64	6.77	1.32
McCauley Island 1								0.75	0.75	1.13	1.32	1.13	2.26	1.22	2.26	0.75
McCauley Island 1								0.94	0.56	1.69	0.94	1.88	2.26	1.38	2.26	0.56
Dolphin Island 1								0.94	1.69	0.56	1.50	1.13	1.32	1.19	1.69	0.56
Dolphin Island 2								1.50	0.75	3.39	1.13	1.32	1.88	1.66	3.39	0.75
Kitsumkalum Lake 1								0.94	2.07	0.94	0.75	0.56	1.50	1.13	2.07	0.56
Kitsumkalum Lake 2								2.07	1.32	0.56	1.32	0.75	1.32	1.22	2.07	0.56
Average	1.07	1.88	2.74	1.01	4.16	4.72	10.22	2.50	5.18	2.86	2.52	3.42	3.77	3.54	10.22	1.01
Maximum	3.76	3.39	6.02	1.50	12.60	14.48	38.00	11.85	22.76	8.84	9.40	12.04	15.05	12.28	38.00	1.50
Minimum	0.19	0.19	0.19	0.19	0.38	0.38	1.69	0.38	0.56	0.56	0.56	0.56	1.13	0.54	1.69	0.19

Table B-3: North Coast Passive Monitoring Results for Hydrogen Sulphide

H_2S ($\mu g/m^3$)																
Station Name / Month	Jul-13	Aug-13	Sep-13	Oct-13	Nov-13	Dec-13	Jan-14	Feb-14	Mar-14	Apr-14	May-14	Jun-14	Jul-14	Average	Maximum	Minimum
Lakelse Lake 1	0.18	0.06	0.15	0.11	0.04	0.10	0.28	0.13	0.07	0.15	0.04	0.06	0.13	0.11	0.28	0.04
Lakelse Lake 2	0.15	0.04	0.15	0.13	0.04	0.17	0.28	0.13	0.06	0.21	0.04	0.08	0.11	0.12	0.28	0.04
Kitimat Haul Road 1	1.98	0.77	0.84	1.59	0.33	2.42	0.99	0.38	0.64	0.21	0.57	0.47	0.64	0.91	2.42	0.21
Kitimat Haul Road 2	1.95	0.59	0.95	1.60	0.35	2.01	1.05	0.45		0.21	0.60	0.82	0.54	0.93	2.01	0.21
Kitamaat Village 1	1.10	0.74	0.67	0.38	0.07	0.50	0.63	0.14	0.06	0.22	0.26	0.79	0.77	0.49	1.10	0.06
Kitamaat Village 2	1.06	0.93	0.61	0.40	0.07	0.46	0.42	0.14	0.04	0.22	0.29	0.91	0.61	0.47	1.06	0.04
Terrace 1-1			0.22	0.13	0.04	0.15	0.17	0.14	0.06	0.22	0.04	0.15	0.25	0.14	0.25	0.04
Terrace 1-2			0.24	0.14	0.04	0.24	0.06	0.14	0.06	0.22	0.06	0.07	0.18	0.13	0.24	0.04
Old Town 1				0.36	0.07	0.46		0.60	0.06	0.22	0.08	0.14	0.13	0.24	0.60	0.06
Old Town 2				0.36	0.07	0.45		0.64	0.06	0.22	0.11	0.13	0.14	0.24	0.64	0.06
Gil Island 1				0.26	0.04	0.21		0.40	0.07	0.22	0.06	0.08	0.08	0.16	0.40	0.04
Gil Island 2				0.20	0.04	0.18		0.15	0.06	0.24	0.04	0.10	0.15	0.13	0.24	0.04
Promise Island 1				0.31	0.08	0.39		0.24	0.06	0.24	0.06	0.14	0.07	0.17	0.39	0.06
Promise Island 2				0.29	0.10	0.33		0.39	0.06	0.24	0.06	0.13	0.15	0.19	0.39	0.06
Terrace 2-1					0.03	0.14	0.15	0.11	0.06	0.24	0.06	0.14	0.13	0.12	0.24	0.03
Terrace 2-2					0.03	0.18	0.13	0.11	0.06	0.24	0.04	0.11	0.14	0.11	0.24	0.03
Gitaus 1						0.11	0.03	0.11	0.06	0.24	0.07	0.13	0.10	0.10	0.24	0.03
Gitaus 2						0.13	0.11	0.11	0.06	0.24	0.06	0.11	0.11	0.11	0.24	0.06
Metlakatla 1							0.11	0.13	0.06		0.11	0.15	0.18	0.12	0.18	0.06
Metlakatla 2							0.11	0.13	0.07		0.15	0.26	0.18	0.15	0.26	0.07
McCauley Island 1								0.13	0.06	0.25	0.07	0.24	0.13	0.14	0.25	0.06
McCauley Island 1								0.13	0.06	0.25	0.06	0.32	0.04	0.14	0.32	0.04
Dolphin Island 1								0.11	0.06	0.25	0.04	0.07	0.10	0.10	0.25	0.04
Dolphin Island 2								0.13	0.06	0.25	0.04	0.08	0.13	0.11	0.25	0.04
Kitsumkalum Lake 1								0.11		0.25	0.10	0.15	0.13	0.15	0.25	0.10
Kitsumkalum Lake 2								0.13	0.06	0.25	0.13	0.18	0.11	0.14	0.25	0.06
Average	1.07	0.52	0.48	0.45	0.09	0.48	0.32	0.21	0.08	0.23	0.12	0.23	0.21	0.35	1.07	0.08
Maximum	1.98	0.93	0.95	1.60	0.35	2.42	1.05	0.64	0.64	0.25	0.60	0.91	0.77	1.01	2.42	0.25
Minimum	0.15	0.04	0.15	0.11	0.03	0.10	0.03	0.11	0.04	0.15	0.04	0.06	0.04	0.08	0.15	0.03

APPENDIX C

Detailed Dispersion Modelling Plan

Detailed Modelling Plan

Detailed Air Quality Modelling Plan for the Proposed LNG Canada Project

Prepared for:
LNG Canada Development Inc.
Calgary, Alberta

Prepared by:
Stantec Consulting Ltd.
Calgary, Alberta

FINAL

December 17, 2013

Sign-off Sheet

This document entitled Detailed Modelling Plan was prepared by Stantec Inc. for the account of Shell-LNG Canada. The material in it reflects Stantec's best judgment in light of the information available to it at the time of preparation. Any use which a third party makes of this report, or any reliance on or decisions made based on it, are the responsibilities of such third parties. Stantec Inc. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

Prepared by _____
(signature)

Katelyn Wells, B.Sc

Prepared by _____
(signature)

John Spagnol, Ph.D.

Reviewed by _____
(signature)

Peter Reid, M.A.

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Abbreviations

ARM	ambient ration method
BC MOE	British Columbia Ministry of Environment
BSCFD	billion standard cubic feet per day
CAAQS	Canadian Ambient Air Quality Standards
CAC	criteria air contaminants
CCNS	Canadian Climate Normal Station
CDED	Canadian Digital Elevation Data
CMS	Canadian Meteorological Service
CO	carbon monoxide
CO_2	carbon dioxide
DWT	dead weight tonnes
EA	Environmental Assessment
EAO	BC Environmental Assessment Office
ECA	North American Emission Control Area
H_2S	hydrogen sulphide
ha	hectares
IMO	International Marine Organization
LNG	liquefied natural gas
MARPOL	International Convention for the Prevention of Pollution from Ships
masl	metres above sea level
MM5	The Fifth-Generation Penn State University / National Center for Atmospheric Research mesoscale model
MSCMD	million standard cubic meters per day
MTPA	million tonnes per annum
MW	megawatt
NCAR	National Center for Atmospheric Research
NGL	natural gas liquid
NO_2	nitrogen dioxide
NO_X	total oxides of nitrogen
OLM	ozone limiting method
PAI	Potential Acid Input
$PM_{2.5}$	fine particulate matter
QA/QC	quality assurance and quality control
SO_2	sulphur dioxide
SOC	substances of concern
TDR	Technical Data Report

USGS	US Geological Survey
UTM	Universal Transverse Mercator coordinate system
VOC	volatile organic compound
WRF	Weather Research and Forecasting

1.0 Introduction

1.1 THE LNG CANADA PROJECT

The LNG Canada Project ("the Project") is a proposed natural gas liquefaction plant and marine terminal facility designed for the export of liquefied natural gas (LNG). The Project will be located in the District of Kitimat, British Columbia. LNG Canada Development Inc. (LNG Canada), joint venture consisting of Shell Canada Energy, Diamond LNG Canada Ltd, Kogas Canada LNG Ltd and Phoenix Energy Holdings Ltd, is proposing the development of the Project.

It is anticipated that the Project will be constructed in two or three phases with the first phase having a design capacity of approximately 12 million tonnes per annum (MTPA) of LNG and a further 12 MTPA of design capacity to be added in one or two subsequent phases. The financial investment decision is anticipated to be made mid-decade followed by four to five years of construction with the commissioning of the first phase to follow. Subsequent phase(s) will be developed as market demand requires. At full build-out, the proposed Project will process approximately 96 million standard cubic metres per day (MSCMD) or 3.4 billion standard cubic feet per day (BSCFD) of natural gas supplied by a third-party-owned and operated pipeline and will ship approximately 24 MTPA of LNG to global markets.

1.2 REGULATORY SETTING

The proposed Project will constitute a reviewable Energy Project under Part 4 of the *Reviewable Projects Regulation* (BC Reg.370/2002) since the design capacity will process natural gas at a rate greater or equal to 5.634 MSCMD. The Project is also a "designated project" under the Regulations Designating Physical Activities pursuant to Canadian Environmental Assessment Agency (CEAA) 2012 as amended by the Regulations Amending the Regulations Designating Physical Activities (CEAA 2012).

In addition to the requirement to obtain a BC Environmental Assessment Office (EAO) Environmental Assessment (EA) Certificate, LNG Canada will require a number of Provincial permits before construction of the Project can begin. To complete the Environmental Assessment and secure a permit authorizing air emissions, LNG Canada must conduct an air quality assessment consistent with the *Guidelines for Air Quality Dispersion Modelling in British Columbia* (BC MOE 2008). The *Guidelines* (BC MOE 2008) recommend the development and regulatory approval of a Detailed Model Plan which is the focus of this report. The air quality assessment of the dispersion modelling findings and the resultant Air Quality Technical Data Report (TDR) are integral parts of the both the EA and the process for an air emissions permit application under the *Environmental Management Act (Waste Discharge Regulation).*

1.3 LEVEL OF ASSESSMENT

This air quality assessment considers effects in two distinct regions: the region around the District of Kitimat, and confined shipping channels that connect Kitimat to the Pacific Ocean.

This air quality assessment is primarily intended to evaluate the effects of air emissions from a large industrial development in Kitimat, including vessels at the marine terminal. The predicted concentrations will be compared to the applicable Canada and BC air quality objectives. As Kitimat has many existing industrial emission sources the assessment also evaluates the consequences of cumulative air emissions from multiple sources at multiple facilities. This work also provides information to support human health and ecological studies. As such, Section 2.2.3 of the *Guidelines* (BC MOE, 2008) indicates that a Level 3 or detailed air quality assessment is appropriate.

The secondary purpose of this air quality assessment is to evaluate the effects of air emissions from marine vessel traffic in the confined shipping channels outside Kitimat that are a consequence of industrial development in Kitimat. This work will evaluate a source that may need further analysis if it contributes to ambient concentrations in excess of short-term air quality objectives. Marine vessels can be modelled as a single point source, and their effects occur in a remote setting. As such, Section 2.2.1 of the *Guideline* (BC MOE 2008) indicates that a Level 1 screening assessment is appropriate for modelling emissions from marine vessel in confined shipping channels outside Kitimat.

1.4 CONTENTS OF THIS DOCUMENT

This document describes a dispersion modelling methodology consistent with both Level 3 and Level 1 in the *Guideline* (BC MOE, 2008). It considers the following aspects of the work: the effects of project, regional, and future air emissions (Section 2), a description of the regional setting (Section 3), modelling methodology (Section 4), the TDR data presentation (Section 5), the quality management program (Section 6), and the review by regulatory agencies (Section 7).

2.0 Emission Sources

2.1 PROJECT OVERVIEW

The Project will consist of the following major components, all located in the Kitimat area of BC:

- a natural gas receiving and LNG production facility
- a marine terminal able to accommodate two LNG carriers each with a capacity between 130,000 cubic metres (approximately 64,000 dead weight tonnes, or DWT) and 265,000 cubic metres (approximately 122,000 DWT) and a materials offloading area
- supporting infrastructure and facilities including power supply and handling, water supply and handling, and waste collection and treatment
- temporary infrastructure and facilities (located outside of the facility plant boundary).

The project will be supplied with gas from throughout Western Canada Sedimentary Basin including northeast BC. The sales gas specification feed gas will contain known levels of carbon dioxide (CO_2), as well as trace amounts of hydrogen sulphide (H_2S), water, natural gas liquids (NGLs), and other components that may not meet LNG process specifications. Acid gas incinerators, gas dehydration units, mercury guard beds, and NGL extraction units will remove the other components that do not meet the LNG process specifications. The sales quality natural gas will be compressed and cooled resulting in LNG. The LNG will be loaded into LNG carriers that are assisted by tugboats for berthing and de-berthing.

In summary, during regular Project operation, the following key activities will occur:

- natural gas receiving
- gas treatment
- gas liquefaction
- storage of the LNG in tanks
- storage of the NGLs in tanks
- maintenance
- NGL rail car staging
- LNG and NGL loading.

2.2 PROJECT EMISSIONS SOURCES

The following substances of concern (SOCs) emitted from Project emission sources will be included in dispersion modelling. The results of the modelling (e.g. predicted concentrations) will be compared to the applicable ambient air quality objectives. The SOCs include the following criteria air contaminants (CACs):

- Sulphur dioxide (SO_2)
- Total oxides of nitrogen (NO_X) including nitric oxide (NO) and nitrogen dioxide (NO_2)
- Carbon monoxide (CO)
- Fine particulate matter ($PM_{2.5}$)
- Hydrogen Sulphide (H_2S), and
- Volatile Organic Carbon species (VOCs)

The effects of the water vapour emissions from the cooling towers (specifically fogging and icing) will also be assessed.

Presently, marine vessels must be compliant with the International Marine Organization (IMO) North American Emission Control Area (ECA) that was adopted under Annex VI to the International Convention for the Prevention of Pollution from Ships (MARPOL). Vessels off North American coasts will be required to meet the new emissions targets of SO_2, with the further benefits of reduced NO_X and PM emissions. Presently, vessels operating in the ECA will be required to use fuel with a maximum sulphur target of 1.0 wt%. Beginning in 2015, the sulphur limit will drop further to 0.1 wt%, hence SO_2 emissions from carrier ships are expected to be insubstantial.

Table 1 lists the primary equipment that comprises the main emission sources for the Project. The main emissions source types are the compressor turbines and incinerators. Thermal oxidizers and the flare stacks are also included in the list of primary combustion sources.

Table 1 Primary Emission Sources

Equipment Name	Location	Type	Quality	Substances of Concern
Compressor turbine	Trains 1-4	LMS 100	2 per train = 8	SO_2, NO_x, CO, $PM_{2.5}$, H_2S, VOC
Thermal oxidizer	Trains 1-4	Acid gas incinerator	1 per train = 4	SO_2, NO_x, CO, $PM_{2.5}$, H_2S, VOC
Warm flare	South of Trains 1 & 2 inside Flare Derrick	Flare stack	1	SO_2, NO_x, CO, $PM_{2.5}$, H_2S, VOC
Cold flare	South of Trains 1 & 2 inside Flare Derrick	Flare stack	1	SO_2, NO_x, CO, $PM_{2.5}$, H_2S, VOC
Spare flare	South of Trains 1 & 2 inside Flare Derrick	Startup flare stack	1	SO_2, NO_x, CO, $PM_{2.5}$, H_2S, VOC
Operation flare	South of Trains 1 & 2 inside Flare Derrick	Emergency flare stack	1	SO_2, NO_x, CO, $PM_{2.5}$, H_2S, VOC
Emergency flare for tanks and tankers	South of Trains 1 & 2 inside Flare Derrick	Emergency flare stack	1	SO_2, NO_x, CO, $PM_{2.5}$, H_2S, VOC
Carrier vessel engines	Marine terminal	120,000 m^3 to 265,000 m^3 capacity	1 or 2	SO_2, NO_x, CO, $PM_{2.5}$, H_2S, VOC
Assist tugboat engines	Marine terminal	-	1 or 2	SO_2, NO_x, CO, $PM_{2.5}$, H_2S, VOC

2.3 EMISSION INVENTORY

2.3.1 Baseline Emissions

The regional emission sources making up the base case dispersion modelling scenario include:

- The RTA Aluminum Smelter and modernization facility with the emissions scenario for after KMP, maximum case. The SOCs associated with the RTA project are SO_2, NO_x, and $PM_{2.5}$.
- Existing marine traffic including any vessels equivalent to or larger than BC ferry vessels, including tugs. The SOCs from the existing marine traffic are SO_2, NO_x, CO, $PM_{2.5}$, H_2S and VOCs.
- Kitimat LNG Terminal Project, and all of the SOCs considered therein.

Marine air emissions from carriers, ferries, tankers, tugs, and government vessels and warships will be estimated. Because of the new MARPOL regulations for marine fuel sulphur content, SO_2 emissions from the baseline sources will decrease from previous estimates.

2.3.2 Project Emissions

The estimated Project emissions associated with the equipment listed in Table 1 are quantified in Table 2. The emission rates are based on the equipment manufacturer specifications, US EPA AP-42 emission factors as well as information supplied by LNG Canada.

Table 2 Project Emissions

Emission Source[1]	Total Number of Units	SO_2 Emission Rates[5] (t/yr)	NO_x Emission Rates (t/yr)	$PM_{2.5}$ Emission Rates (t/yr)	CO Emission Rates (t/yr)	VOC Emission Rates (t/yr)
Land Emissions						
LMS 100	8	18	1,321	163	2,466	52
Flare Pilot Light	5	Emission information pending				
Thermal Oxidizer (Fuel Burning)[2]	4	1.2	170	12.9	143	9.3
Thermal Oxidizer (Incineration)[3]		1,095 to 2,190	760	-	-	-
Marine Emissions						
LNG Carrier [4]	350	15.6	324	5.6	33.9	15.9
Assist Tugs	700	0.32	35.9	3.23	4.02	1.38
Total		**1,130 to 2,225**	**2,611**	**184**	**2,647**	**78.6**

NOTE:

1. Emissions rates presented are totals for the total number of units.
2. These emission rates represent the result of the combustion of sales-quality natural gas only in all fired equipment.
3. These SO_2 emission rates represent the combustion of reduced sulphur compounds (RSC) in the acid gas stripped from the inlet gas stream only, as a single line item for clarity. They are expressed as a range, and are based on assumptions of both 6 ppm RSC (3 t/d) and 12 ppm RSC (6 t/d) expressed as SO_2.
4. Assumed 350 LNG carrier visits per year and 1 assist tug from Triple Island and 2 assist tugs for berthing, plus one at the berth for firefighting. It is assumed 2-hour berthing and 2-hour un-berthing. The loading time for each visit is assumed to be 18-22 hours base on the size of the carrier. 0.1 wt% sulphur content for the fuel is assumed.
5. The H_2S emission rate will be based on combustion efficiencies of the various pieces of fired equipment, and expressed as a representative fraction of the SO_2 emissions rate.

- = information pending

2.3.2.1 Flaring

There will be five flares on site, these are:

- warm flare
- cold flare
- spare flare
- operational flare, and
- storage and loading flare.

The warm flare is for when the back end of the facility goes down. The cold flare is for when the cold end of the facility goes down. The spare flare is used only when the warm or cold flare is not available. Therefore, the warm, cold and spare flares are used infrequently; in start-up and for emergencies.

The operational flare is for routine maintenance of any of the other flares, and is therefore is not a continuous emission source. The storage and loading flare is used only when the boil off gas compressor goes down during the loading of a carrier.

During normal operations all flares will have a continuous purge of nitrogen for safety reasons. There is no routine purge of natural gas in the flare system. Each flare will also have a series of lit pilot lights. The emissions from the pilot lights will be quantified for this assessment. The potential emissions from the main flare stacks will be represented as a number of flaring cases for planned and unplanned events.

2.3.3 Future Emissions

Planned projects with air emission sources include the following:

- Enbridge Northern Gateway Project (ENGP), and all of the SOCs considered therein.
- Douglas Channel LNG Project.

The pertinent ENGP emissions will be modelled as presented in the recently-filed Environmental Impact Assessment (EIA).

Emission and other details sufficient to drive a modelling exercise have not been made available publicly for the Douglas Channel LNG Project. The emissions for this facility will be estimated based on professional judgment assuming similarity with comparable sized facilities.

3.0 Regional Setting

3.1 SITE DESCRIPTIONS

The LNG facility will be located on approximately 300–350 hectares (ha) within the District of Kitimat. Approximately 10% of the LNG facility site was previously developed for methanol production, storage, and transshipment (former Methanex Corporation facility), and for condensate transshipment (Cenovus Energy Inc.). The former Methanex site is now owned by Shell on behalf of the joint venture partners.

3.2 TOPOGRAPHY

The elevation of the LNG production facility is at approximately 20 metres above sea level (masl) and the marine terminal at or near sea level. The Project facility areas are bounded by rapidly rising terrain on each side with the narrow Douglas Channel extending to the south and the narrow Kitimat valley extending to the north.

3.3 BACKGROUND AIR QUALITY

3.3.1 Continuous Monitors

Background air quality data allows for an understanding of the existing conditions and helps establish a link between emissions and potential changes in air quality. Local ambient air quality data are available from existing and historic air quality monitoring stations in Kitimat.

In addition there will be Project-specific passive ambient monitoring stations providing background air quality data in areas not covered by the existing network.

Consistent with the *Guidelines* (BC MOE, 2008), background concentrations for selected substances were established based on data from the four existing monitoring stations in Kitimat (Kitimat Rail, Kitimat Haul Road, Kitimat Riverlodge, and Kitimat Whitesail).

In the CALPUFF modelling exercise these background data (see Table 3) *will not* be added to the predicted maximum values obtained through dispersion modelling. Normally this is done to account for background concentrations resulting from air emissions on a local, regional and global scale. However in the CALPUFF modelling exercise the Base (or existing) case sources will be accounted for through modelling. Adding background to the Application (Base + Project) case would imply double counting of these existing facilities.

In the SCREEN3 exercise for marine vessel emissions, background values will be added. A background value for the short-term exposure intervals will be conservatively assigned taking into account both continuous monitoring data collected in Kitimat and the (monthly) results of the passive monitoring stations.

Table 3 Background Values for Substances of Concern

Location	Averaging Period	Concentration [a] (µg/m³)
SO_2	One-hour	36.7
	Three-hour	31.7
	24-hour	20.0
	Annual	5.8
NO_X	One-hour	31.2
	24-hour	15.4
	Annual	3.2
NO_2	One-hour	30.6
	24-hour	17.4
	Annual	6.7
CO [b]	One-hour	3,092
	8-hour	2,281
$PM_{2.5}$ [c]	24-hour	9.7
	Annual	-
H_2S	One-hour	2.3
	24-hour	1.3

NOTES:

[a] Representative values are based on all available monitoring data in Kitimat area for January 2000–March 2008. Values are the 98th percentile of monitored concentrations (excepting annual averages) and are consistent with the *Guidelines* (BC MOE 2008).

[b] Ambient CO data are not measured locally. Suitable background data was obtained from the nearest, most representative station (Smithers, BC).

[c] $PM_{2.5}$ monitoring period is from April 2002 - March 2008.

SOURCE: Data obtained from the British Columbia Air Data Acquisition and Management System (ADAMS) database (Government of British Columbia 2008, Internet site).

These existing background concentrations are representative of the period January 2000 to March 2008. They are in need of updating to include an additional station (Kitimaat Village) and more current measurements at the other stations. It is not expected that the values expressed in the table will change substantially but will be updated and included in the air quality assessment.

3.3.2 Passive Monitors

Nine or more project-specific passive ambient monitoring stations will augment the existing background air quality data. This program will employ a Multigas Passive Sampler (Tang 2011). This passive technology is a simple means of reliably characterizing background air quality (see Figure 1). These exposure-type monitors require no power to yield monthly average concentration measurements.

Each station measures a comprehensive suite of substances of interest including SO_2, NO_2, NO_X, VOCs, hydrogen sulphide (H_2S), and ozone (O_3). Although H_2S and O_3 are not in the Project list of SOCs, they are included out of general interest.

Figure 1 Rain Shelter and Multigas Passive Sampler on Gil Island

The monitoring program will employ duplicate monthly passive measurements at each site. Once the stations are established this involves swapping out two small Teflon discs containing the sample media each month, and returning the exposed sample media to the laboratory in Edmonton, Alberta.

The four to six month-long program of monthly sampling intervals will cover late winter to early summer, 2013/2014. Given the low seasonal climatic variation, this limited program will adequately characterize both monthly and longer-term (annual average) conditions.

The passive ambient air monitoring data will be used to establish representative background concentrations that can be added to the dispersion modelling results, particularly in the more remote

regions. The station locations and substances of interest measured are summarized in Table 4, and described further below.

Table 4 Passive Ambient Air Monitoring Station Information

Station Number	Station Name	Station Type	Substances of Interest Measured	Date of Installation
1	Lakelse lake	Measurement	SO_2, NO_2, NO_X, VOC, H_2S, and O_3	Jul. 4, 2013
2	Kitimat (Haul Road)	Reference	SO_2, NO_2, NO_X, VOC, H_2S, and O_3	Jul. 17, 2013
3	Kitimaat Village	Reference	SO_2, NO_2, NO_X, VOC, H_2S, and O_3	Jul. 4, 2013
4	Terrace 1	Measurement	SO_2, NO_2, NO_X, VOC, H_2S, and O_3	Sep. 4, 2013
5	Old Town (Gitga'at First Nations)	Measurement	SO_2, NO_2, NO_X, VOC, H_2S, and O_3	Oct. 1, 2013
6	Gil Island	Measurement	SO_2, NO_2, NO_X, VOC, H_2S, and O_3	Oct. 1, 2013
7	Promise Island	Measurement	SO_2, NO_2, NO_X, VOC, H_2S, and O_3	Oct. 1, 2013
8	Terrace 2	Measurement	SO_2, NO_2, NO_X, VOC, H_2S, and O_3	Nov. 6, 2013
9	Gitaus	Measurement	SO_2, NO_2, NO_X, VOC, H_2S, and O_3	Nov. 28, 2013

The nine passive ambient air monitoring sites are described below:

1. **Lakelse lake**: A station was established on the west side of Lakelse Lake at the already-established wet deposition monitoring site for Rio Tinto Alcan. This will provide a full suite of CACs for the settlement, validated through the technology's performance in Kitimat and Kitimaat Village.
2. **Kitimat (Haul Road):** A station was established in the District of Kitimat, co-located with one of the existing continuous monitoring stations located there. This provides a point of reference against known measurements in an industrial setting and validates the technology. It also includes parameters not routinely measured in Kitimat (VOCs for example).
3. **Kitimaat Village:** A station was established in Kitimaat Village, co-located with the new continuous monitoring station located there. This provides a point of reference against known measurements in a residential setting and validates the technology. It also includes parameters not routinely measured in Kitimaat Village (VOCs for example).
4. **Terrace 1:** A station was established in Terrace, on the Kitselas First Nations land. This will provide a full suite of CACs for the settlement, validated through the technology's performance in Kitimat and Kitimaat Village.
5. **Old Town (Gitga'at First Nations):** A station was established in an uninhabited location called "Old Town" located mid-way between Kitimat and Hartley Bay. This will provide a full suite of CACs for the settlement, validated through the technology's performance in Kitimat and Kitimaat Village.
6. **Gil Island:** A station was established on Gil Island (uninhabited, but near Hartley Bay). This will provide a full suite of CACs for the area, validated through the technology's performance in Kitimat and Kitimaat Village.
7. **Promise Island:** A station was established on Promise Island (uninhabited and remote). This will provide a full suite of CACs for the area, validated through the technology's performance in Kitimat and Kitimaat Village.

8. **Terrace 2:** A station was established in Kitsumkalum, just outside Terrace. This will provide a full suite of CACs for the settlement, validated through the technology's performance in Kitimat and Kitimaat Village.
9. **Gitaus:** A station was established in the Gitaus subdivision, east Terrace. This will provide a full suite of CACs for the subdivision, validated through the technology's performance in Kitimat and Kitimaat Village.

4.0 Modelling Methodology

4.1 SELECTED MODELS

As per Section 2.3 of the *Guidelines* (BC MOE, 2008) and specifically Section 2.3.2.4, the following models and versions will be used for the Level 3 assessment of the Project effects within the assessment area:

- CALMET Version 6.334 Level 110325, a diagnostic 3-dimensional meteorological model
- CALPUFF Version 6.42 Level 110421, an air quality dispersion model.

As per Section 2.1 of the *Guidelines* (BC MOE 2008) and specifically Section 2.3.1.1, the SCREEN3 dispersion model will be used for the Level 1 assessment of the marine traffic effects within the confined shipping channels outside of the Kitimat area.

Non-guideline models or beta-test versions are not planned for use. There are no modifications to any of the models planned.

4.2 CALMET METEOROLOGICAL MODELLING

4.2.1 CALMET Configuration

There are various switches within CALMET that have specific status settings determined by the *Guidelines* (BC MOE 2008). All of the switches recommended in the *Guidelines* will be applied. The *Guidelines* also suggests a one to five year period of meteorological conditions to support the dispersion modelling. The Canadian Ambient Air Quality Standards (CAAQS) for $PM_{2.5}$ require three consecutive years of predictions to be compared to the CAAQS. For this reason, years 2008-2010 will be modeled.

4.2.2 Meteorological Model

There are reliable and long-term surface and upper data in the immediate vicinity of the Project site, however meteorological model data will be used to provide spatially and temporally varying wind and temperature fields across the study area. These models can be categorized as either prognostic or diagnostic models.

The Fifth-Generation Penn State University / National Center for Atmospheric Research mesoscale model (commonly referred to as MM5) is a frequently-used meteorological model for historical episodes. It is a limited-area, nonhydrostatic, terrain-following sigma-coordinate model designed to simulate or predict mesoscale and regional-scale atmospheric circulations. As a community model it is continuously being improved by contributions from multiple users.

The Weather Research and Forecasting (WRF) Model is a next-generation mesoscale numerical weather prediction system designed to serve both operational forecasting and atmospheric research needs. This state-of-the-art system will serve as an update to MM5. It is designed to be a flexible atmospheric

simulation system that is portable and efficient on available parallel computing platforms. WRF is suitable for use in a broad range of applications across scales ranging from metres to thousands of kilometres and will also be community-based.

Diagnostic models use interpolation schemes that can rely on empirical relationships to account for topographical or other influences that can occur between the observing sites. The CALMET model is an example of a diagnostic model. The CALMET model can be applied on a finer scale to the WRF or MM5 model output in order to resolve more local-scale terrain influences. In this assessment, the WRF resolution will be 4km and the CALMET model will be applied on a 500m grid

Historically MM5 model was widely used in air quality modeling community. However, it was officially phased out by the National Center for Atmospheric Research (NCAR) in 2008. On October 31, 2008, NCAR (NCAR 2008) announced that all technical support for the MM5 model has been discontinued and all users are strongly encouraged to utilize the new WRF model which is fully supported by NCAR. WRF provides better numerical prediction schemes, better handling of topography and better programming than MM5 and includes all new features and options developed by Mesoscale & Microscale Meteorology Division at NCAR in the recent years. Many studies have already proven that WRF has met the requirements for the transition from MM5 and outperforms MM5 in overall model prediction accuracy.

Considering the advantage of using a new generation model, the WRF model will be selected as the prognostic model for this assessment. The National Center for Environmental Prediction (NCEP) 32 km resolution North American Regional Reanalysis (NARR) gridded analysis data will be used as input to the most recent version 3 of WRF model to produce a 3-year (2008-2010) meteorological dataset on a 4 km grid resolution using the Stantec high performance computing cluster. The 4 km grid resolution WRF model output will be used as an initial guess field and the CALMET model will adjust the initial guess field for the kinematic effects of terrain, slope flows, and terrain blocking effects using the finer scaled terrain data to produce a modified wind field. This approach has become the standard for air quality assessments.

4.2.3 CALMET Domain

There will be two CALMET modelling domains created for the CALPUFF dispersion modelling. A near-field domain will be selected to predict Project air emission effects and the effects of cumulative sources. The far field domain will be used to predict acidification and eutrophication effects. Table 5 shows he dimensions of the near field and far field CALMET domains.

Table 5 CALMET Modelling Domains

Domain	Dimensions	Resolution
Small – near field	40 km x 40 km	500 m
Large – far field	352 km x 352 km	4.0 km

4.2.4 TERRAIN, LAND USE, AND GEOPHYSICAL INPUTS

Terrain and land use are used to create geophysical input files to characterize the CALMET surface conditions. A geophysical data file contains dominant land use for each grid cell and also computes weighted surface parameters such as surface roughness, albedo, and Bowen ratio. The Project is located in northern BC where each season (summer, fall, winter, and spring) contributes to the characteristics of the land surface. Sections 9.3.2 and 9.3.3 of the *Guidelines* (BC MOE 2008) state that modelling should include seasonal variations in surface roughness, albedo and Bowen ratios. For this reason a different geophysical data file for each of the four seasons will be used.

Terrain and land use data will be selected following Sections 8.1 and 8.2 of the *Guidelines* (BC MOE 2008) as follows:

- Terrain data: Canadian Digital Elevation Data (CDED) for a 1:50,000 map scale
- Land use: US Geological Survey (USGS) Global land use characterization data at a 1 km grid resolution
- Values of the geophysical parameters will be selected with corresponding values in Tables 9.3, 9.4, and 9.5 of the *Guidelines* (BC MOE 2008).

4.2.5 Meteorological Measurements

The CALMET model uses the WRF meteorological fields as a first guess and adjusts the meteorological fields to reflect the higher terrain and land use conditions. The resulting meteorological fields are enhanced by directly incorporating observations into the CALMET simulations. The meteorological stations and locations in the domain are summarized in Table 6.

Table 6 Surface Stations and Parameters used in CALMET Simulations

Station Type	Station Name	Station ID	Elevation (masl)	UTM NAD 83 Zone 9		Data Range	Data Reference
				Easting (m)	Northing (m)		
-	Kitimat Whitesail	-	119.0	523547	5991092	Jan 01, 2008 - Dec 31, 2010	1
-	Kitimat Haul Road	-	2.0	519546	5986867	Jan 01, 2008 - Dec 31, 2010	1
-	Kitimat Eurocan Dock	-	0	521197	5982823	Jan 01, 2008 - Dec 31, 2010	1
-	Kitimat 2	1064321	16.8	519333	5984644	Jan 01, 2008 - Dec 31, 2010	3
-	Kitimat 3	1064322	137	523507	5990782	Jan 01, 2008 - Dec 31, 2010	3
-	Kitimat Hatchery	106D289	13	520808	5988421	Jan 01, 2008 - Dec 31, 2010	3
-	Kitimat Townsite	1064320	128	523949	5989548	Jan 01, 2008 - Dec 31, 2010	3
Buoy	Nanakwa Shoal Buoy	46181	0	511078	5964992	Nov 22, 1988 - Current	2
-	Terrace Access Centre	-	510.0	526055	6041265	Jan 01, 2008 - Dec 31, 2010	1
-	Telkwa	-	80.0	625384	6062156	Jan 01, 2008 - Dec 31, 2010	1
-	Smithers St Josephs	-	481.0	617204	6072167	Jan 01, 2008 - Dec 31, 2010	1
-	New Hazelton School	-	321.0	589890	6122989	Jan 01, 2008 - Dec 31, 2010	1
-	Kitwanga School	-	253	562773	6108276	Jan 01, 2008 - Dec 31, 2010	1
-	Houston Firehall	-	594	652882	6030271	Nov 21, 1994- Current	1
Buoy	North Hecate Strait Buoy	46183	0	360763	5942933	May 15, 1991 - Current	2
-	Bonilla Island	1060902	16.2	391348	5928339	Jan 01, 2008 - Dec 31, 2010	3
-	Bonilla Island (Aut)	1060R0K	14.9	391661	5929135	Jan 01, 2008 - Dec 31, 2010	3
CMS	Holland Rock	1063496	5	411170	6003570	Jan 01, 2007 - June 10, 2013	3
-	Lucy Island Lightstation	1064728	26.2	387655	6024787	Jan 01, 2008 - Dec 31, 2010	3
CCNS	Prince Rupert AWOS	1066483	35.4	405953	6016318	Jan 01, 2007 - May 08, 2012	3
-	Prince Rupert Mont Circ	1066488	60	416094	6019924	Jan 01, 2008 - Dec 31, 2010	3
-	Smithers Airport	1077500	521.8	616743	6076862	Jan 01, 2008 - Dec 31, 2010	3
-	Terrace Airport	1068130	217.3	527384	6035497	Jan 01, 2008 - Dec 31, 2010	3

Table 6 Surface Stations and Parameters used in CALMET Simulations

Station Type	Station Name	Station ID	Elevation (masl)	UTM NAD 83 Zone 9		Data Range	Data Reference
				Easting (m)	Northing (m)		
-	Terrace PCC	1068131	58.2	524302	6039435	Jan 01, 2008 - Dec 31, 2010	3
-	Kemano	1064020	87	570004	5935459	Jan 01, 2008 - Dec 31, 2010	3
-	Grey Islet (Aut)	1063303	8.2	390267	6049409	Jan 01, 2008 - Dec 31, 2010	3

References:

1. Data Retrieved from British Columbia Envista Web on July 30 ,2013. Website location (http://envistaweb.env.gov.bc.ca/) .
2. Data Retrieved from Environment Canada, Department of Fisheries and Oceans, on July 30 ,2013. Website location (http://www.meds-sdmm.dfo-mpo.gc.ca/isdm-gdsi/waves-vagues/search-recherche/index-eng.asp).
3. Data received from Environment Canada, Meteorological Services of Canada, on July 25 2013.

4.3 CALPUFF DISPERSION MODELLING

4.3.1 CALPUFF Domain and Receptor Grids

There will be two CALPUFF modelling domains (See Figure 2 and Figure 3). The near field CALPUFF domains is sized to capture all values of interest (e.g. predicted concentrations greater than 10% of the applicable ambient air quality objective) as per the *Guidelines* (BC MOE 2008). The far field domain is sized to capture the areas potentially affected by acidification. As well, the far-field will capture any sensitive receptors not included in the near-field domain.

The near field domain is also sized to encompass the project sources, existing and planned industrial sources, and nearby marine terminals. This includes the shipping channel in mid-Douglas Channel, and maneuvering areas adjacent to both the approved Kitimat LNG Project jetty and the proposed Enbridge Northern Gateway Project jetty.

CDED terrain elevations will be applied to all receptors used in the dispersion modelling.

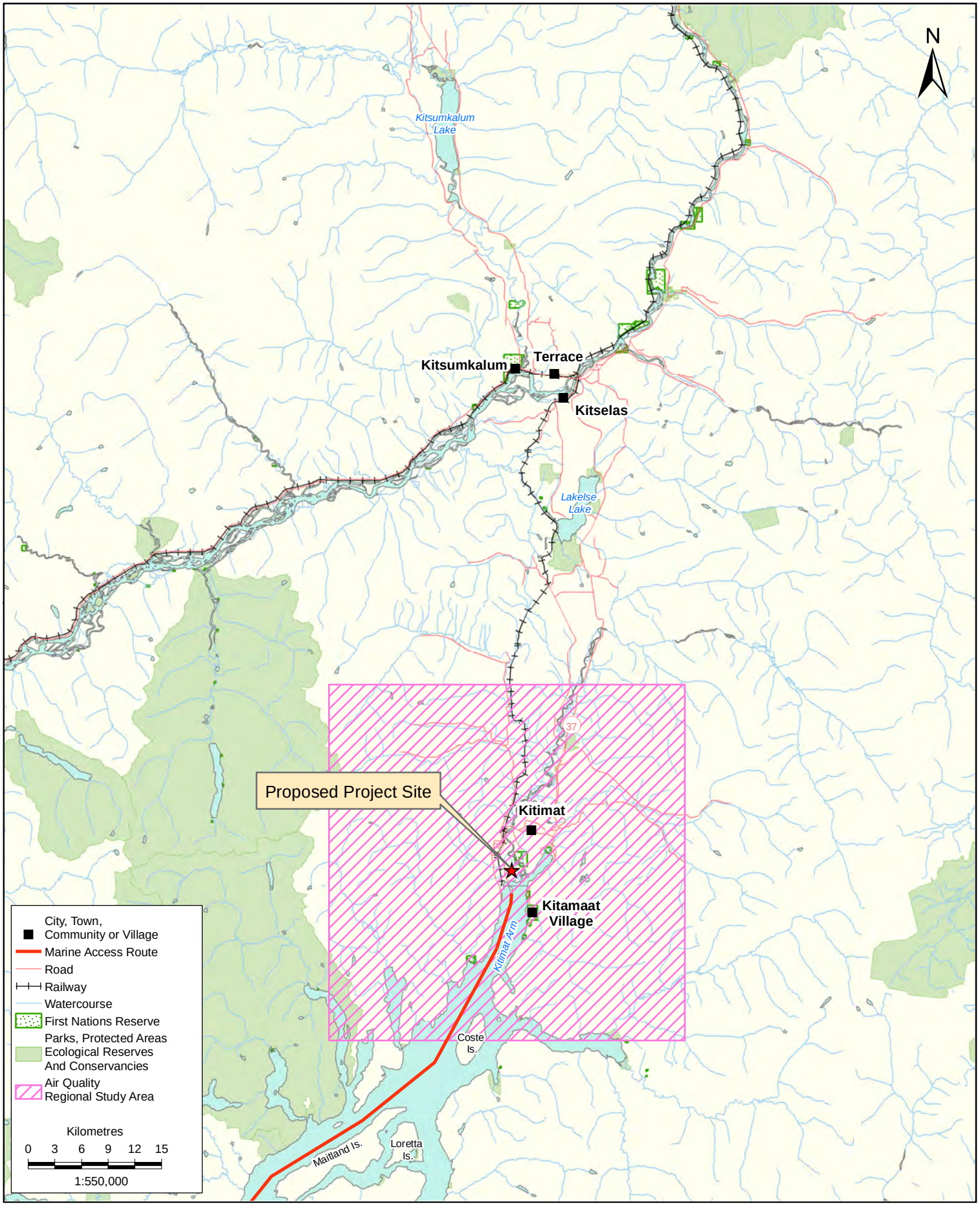
4.3.2 Near Field

The near-field domain size is 40 km by 40 km centered on the project. Section 6.2 of the Guidelines (BC MOE 2008) describes the receptor spacing recommended for modelling. The recommended grid spacing is denser around the maximum point of impingement. The following is the suggested starting point for receptor spacing:

- 20 m receptor spacing along the plant boundary
- 50 m spacing within 500 m of sources
- 250 m spacing within 2 km of sources
- 500 m spacing within 5 km of sources
- 1,000 m spacing beyond 5 km of sources.

After a tentative location of the predicted maximum concentrations is determined, the CALPUFF grid will be provided with a finer receptor resolution around that point to ensure that the maximum is resolved.

A recommendation of the *Guidelines* (BC MOE 2008) is to identify and create discrete receptors at specific points such as individual residences, residential areas, schools, hospitals, campgrounds, parks, recreational areas, commercial day care and seniors' centres, sensitive ecosystems, etc. Also included as discrete receptors are passive monitoring sites, ambient monitoring sites, deposition monitoring sites, and stream sampling sites. These discrete receptors will be identified and added to the receptor grid. Sensitive areas, including the nearby settlements, will be provided with 50 m receptor spacing.



Stantec	LNGCANADA	*MODEL PLAN* **NEAR FIELD CALPUFF DOMAIN** LNG CANADA KITIMAT, BRITISH COLUMBIA	PROJECTION: UTM9	DRAWN BY: SHS
			DATUM: NAD 83	CHECKED BY: SW
			DATE: 12-DEC-13	FIGURE NO.: **2**

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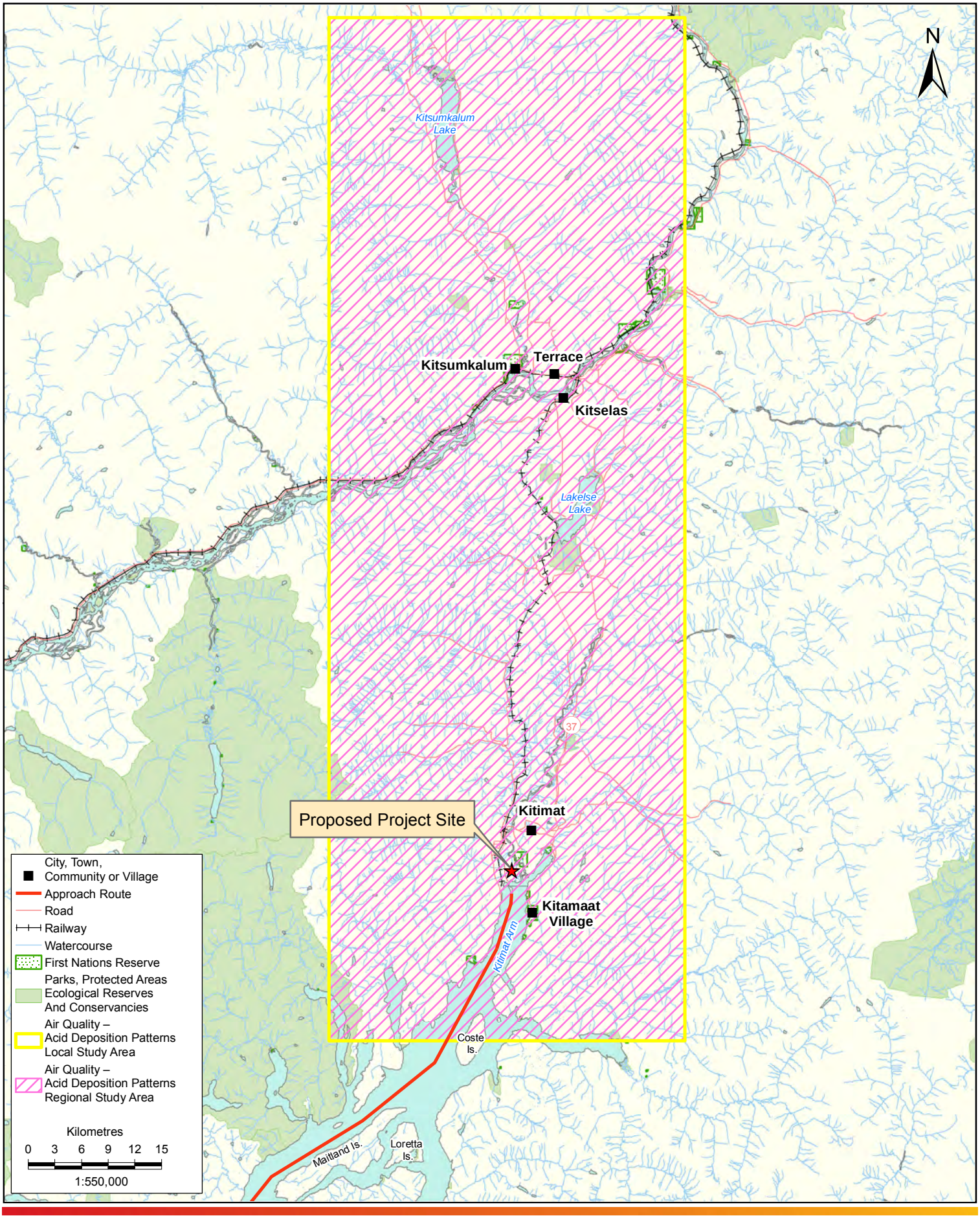

Stantec

LNGCANADA

MODEL PLAN

FAR FIELD CALPUFF DOMAIN

LNG CANADA
KITIMAT, BRITISH COLUMBIA

PROJECTION	DRAWN BY
UTM9	SHS
DATUM	CHECKED BY
NAD 83	SW
DATE	FIGURE NO.
02-DEC-13	3

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4.3.3 Far Field

The purpose of the far field CALPUFF receptor domain is to capture the effects of the Project emissions on acidification and eutrophication effects in a large region surrounding the project.

The far field CALPUFF receptor grid will have the capacity to cover portions or the entire 352 km x 352 km CALMET domain starting with a grid of 40km by 115 km (Figure 3). The grid spacing will be determined based on the location, with a denser grid over populated areas. This larger selective domain will allow for a better understanding of the Project effects on regional acidification and eutrophication.

4.3.4 CALPUFF Settings

All of the required and recommended switch settings outlined in Section 9.4 of the *Guidelines* (BC MOE 2008) will be used.

CALPUFF employs several chemical transformation schemes. Two of these are the MESOPUFF II and the RIVAD/ARM3 (Regional Impact in Visibility and Acid Deposition/Acid Rain Mountain Mesoscale Model) schemes. The RIVAD/ARM3 chemical transformation scheme will be used as it is considered more robust for a rural setting. The RIVAD/ARM3 chemistry scheme treats the NO and NO_2 oxidation process in addition to the NO_2 to ammonium nitrate and SO_2 to ammonium sulphate chemical transformations, with equilibrium between gaseous nitric acid and ammonium nitrate (Scire et al. 2000) aerosol. The CALPUFF deposition options will be turned on to enable the prediction and deposition of NO_x, SO_2, nitrates and sulfates to be used in the acid deposition analysis.

A separate document (the "Acidification Plan") has been developed with stakeholders that will address how the effects of acidic wet and dry deposition (and Potential Acid Input or PAI) will be assessed. This acidic deposition is a result SO_2 and NO_x emissions, and their evolution to sulphates and nitrates, and ultimately sulphuric and nitric acids. The predicted deposition of substances containing sulphur and nitrogen will be developed by dispersion modelling and then used by other disciplines (including human health, water quality, vegetation, and soils) to assess the acidification issue.

4.3.5 NO to NO_2 Conversion

Section 11.4 of the *Guidelines* (BC MOE 2008) will be followed. The conversion methods to be considered, in order, are:

- 100% conversion: if the maximum NO_X concentrations are less than the ambient objective for NO_2, then the predicted results for NO_x will be report as NO_2.
- RIVAD/ARM3 NO to NO_2 conversion
- Ozone limiting method (OLM)
- Ambient ratio method (ARM).

4.3.6 Building Downwash Effects

Building downwash effects will be incorporated using the BPIP-Prime model. All of the buildings within the facility boundary will be considered in building downwash effects. If the Prime model method causes CALPUFF computing issues, then the ISC downwash option will be used (as allowed by the *Guidelines*). This option is allowed and has been approved by MOE for other projects.

4.3.7 Fogging and Icing Effects

The effects of cooling tower plumes will be assessed in terms of their potential for condensed plumes to reach ground-level. Two cases will be considered: condensed plumes with air temperatures >°0 C (fogging) and condensed plumes with air temperatures 0 <°C (icing). These two cases are considered as reduced visibility and icing conditions on roadways are a safety concern.

CALPUFF post processers will be used to predict the extents and frequencies of fogging and icing due to the cooling tower emissions. Two CALPUFF post processers operate on the fog plume-mode output to characterize visible plume height and length statistics. Another operates on the fog receptor-mode output to characterize the frequency of possible fogging and icing events at specific locations. An analysis of the predictions from both modes will be assessed.

Since all instances of cooling tower emission induced fogging and icing may occur near the Project site, this assessment will focus on a smaller area (e.g. 5 km by 5 km area) centered on the Project. Periods when the relative humidity are greater than 98% will be excluded from the simulation as fog is likely to occur naturally under these conditions.

The design of the cooling towers is such that the vapour coming out of the cooling towers is super-heated and has high buoyancy. The result of this design is that the vapour is lifted to cloud level before it condenses. This type of technology is expected to greatly reduce the potential for fogging from the cooling towers at ground level.

4.4 SCREEN3 DISPERSION MODELLING

To evaluate the air quality effects of marine vessel traffic in confined shipping channels outside Kitimat SCREEN3 will be employed.

SCREEN3 is a single-source Gaussian plume model that provides maximum ground-level concentration predictions for point, area, flare, and volume sources. SCREEN3 is able to account for a variety of effects including: building downwash for the near-wake and far-wake regions, cavity recirculation, and flare releases. This model can incorporate the effects of terrain below stack height on maximum concentrations and can also estimate 24-hour average concentrations due to point-source plume impaction on terrain above stack height.

Marine vessels can be modelled as a single point source in the confined channel as they tend to travel singly. The effects occur in a remote setting, and the terrain in the immediate vicinity of the vessels is flat, simplifying the exercise. Exceedances of short-term air quality objectives are the prime concern.

SCREEN3 is therefore ideally suited to characterizing the potential effects of marine vessel traffic in the confined shipping channels.

SCREEN3 modelling will portray the relationship between emissions from the worst-case (highest emitting) marine vessel and distance from the source under all possible conditions of dispersion. A worst-case event would be two vessels with two assist tugs passing in mid channel. The time the two vessels and tugs coincide, and their entire transit of any shore-based receptors in general, are brief. For that reason, the assumption of the worst-case being one vessel remaining stationary for 1-hour in the channel is considered conservative.

While the short-term objectives will be the focus of this assessment, insight into longer averaging intervals can be gained by employing power law relationships documented in the SCREEN3 Model User's Guide (US EPA 1995).

The SCREEN3 modelling will consider all SOCs emitted by marine vessels (see Section 2). The project case emissions will be consistent with the MARPOL Annex VI amendment regarding low sulphur fuel, as well as ongoing actions respecting the North American Emission Control Areas.

Marine vessel emissions consistent with both the existing emissions and the project emissions will be considered by modelling the worst-case vessel emissions for each case. The vessels will be modelled as stationary continuous point source. This is a conservative assumption given the vessel is a mobile source, and is proximate to the community for a brief portion of any given hour. Topography will not be considered as these emission scenarios are occurring over the flat ocean surface. The resultant predictions will be a function of distance from the source.

Three communities will be considered in the SCREEN3 modelling, plus a number of other receptors designated through consultation. Figure 4 shows the relation of these communities to the shipping route.

Settlements:

- **Hartley Bay:** LNG and other vessels travelling to and from Kitimat move along a narrow shipping lane in Douglas channel just east of Hartley Bay. Just south of Hartley Bay in Grenville Channel there is existing marine vessel traffic (BC Ferries, freighter traffic and other vessels). Larger vessels like LNG carriers are unlikely to travel in Grenville Channel, instead preferring Principae Channel when travelling north. Hartley Bay is 2.5 and 8 km from the marine vessel traffic in Douglas Channel and Grenville Channel respectively.

- **Kitkatla:** This settlement is more removed from marine vessel traffic originating in Kitimat than Hartley Bay. Grenville Channel lies to the north (25 km) and Principae Channel lies to the south (13 km). More local marine traffic includes smaller vessels plying Ogden Channel to and from Kitkatla itself. Despite the distances involved it is possible to predict, with a high degree of conservativeness with SCREEN3, the effect of LNG vessels traversing to the south of Kitkatla in Principae Channel.

- **Metlakatla Village:** This settlement is also more removed from the marine vessel traffic but their traditional areas extend out from the coast, including Triple Island. Predictions of the effect of LNG vessels traversing near Triple Island will be assessed at distances from this island to the Metalakatla Village.

Other Receptors

- **Pitt Island – southwest**: This receptor is on the southwest of the island in Monckton Nii Luutiksm Conservancy
- **Banks Island – north end:** This receptor is on the north end of the island in Banks Nii Luutiksm Conservancy
- **McCauley Island – north:** This receptor is on McCauley Island
- **Dolphin Island:** This receptor is on Dolphin Island 1 Indian Reserve
- **Porcher Island:** This receptor is in Gitxaala Nii Luutiksm Kitkatla Conservancy
- **Stephens Island:** This receptor is in the K'sgaxl/Stephens Islands Conservancy

Other sensitive receptors will be added as appropriate. Sensitive receptors considered include passive monitoring sites that lie adjacent to the marine vessel route (See section 3.3.2).

If the Level 1 assessment indicates marine vessel traffic need further analysis a Level 3 assessment will be conducted.

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LNGCANADA

MODEL PLAN

MARINE ACCESS ROUTE TO THE LNG CANADA PROPOSED PROJECT SITE

LNG CANADA
KITIMAT, BRITISH COLUMBIA

PROJECTION	DRAWN BY
UTM9	NP
DATUM	CHECKED BY
NAD 83	WP
DATE	FIGURE NO.
02-DEC-13	4

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DETAILED MODELLING PLAN

Modelling Methodology
December 17, 2013

5.0 Data Presentation

5.1 TABLES

Maximum predicted concentrations of each CAC will be tabulated and compared to the applicable air quality objectives. Background concentrations will be included in the tables for comparison. Potential fogging and icing events and frequency will be presented in tabular format.

5.2 FIGURES

Maximum predicted concentrations of each CAC will be presented graphically as isopleths without the background concentrations added. Spatial distribution maps for short-term and long-term averaging period over the 40 km by 40 km CALPUFF domain will be included. All areas where fogging and icing potential is predicted to occur will be shown graphically.

DETAILED MODELLING PLAN

Data Presentation
December 17, 2013

6.0 Quality Management Program

For all levels of the assessment, quality assurance and quality control (QA/QC) procedures will be employed to confirm the accuracy of the source inputs, receptors, meteorological data, and the proper behavior of the models. Both input and output files will be subjected to rigorous examination to ensure that they are free of errors. The model output will be studied to ensure that the concentration values and geographic distribution is consistent with expectations. The general approach provided in Section 10.2.1 of the *Guidelines* (BC MOE, 2008) will be followed.

In addition, the standard Stantec Quality Management System will be followed in all aspects of this work. This includes file and version management protocols to avoid erroneous substitution of superseded files, and a series of documented technical and senior reviews by personnel not involved in the day-to-day project work.

DETAILED MODELLING PLAN

Quality Management Program
December 17, 2013

7.0 Review by Regulatory Agencies

The draft Detailed Model Plan was provided to the BC MOE on December 3rd 2013. The BC MOE review was completed and comments transmitted to LNG Canada via e-mail on December 5th 2013. Revisions were undertaken in response to the BC MOE comments.

The final Detailed Model Plan was finished on December 17th 2013 and transmitted to the BC MOE shortly thereafter.

8.0 References

BC MOE. 2008. Guidelines for Air Quality Dispersion Modelling in British Columbia. British Columbia Ministry of Environment, Environmental Protection Division, Environmental Quality Branch, Air Protection Section. March 2008.

Government of Canada, 2012. Canadian Environmental Assessment Act, 2012. Available at: http://www.ceaa-acee.gc.ca/default.asp?lang=en&n=16254939-1

NCAR. 2008. National Center for Atmospheric Research. October 31, 2008. Available at: http://www.mmm.ucar.edu/mm5/support/consult.html

Scire, J.S., D.G. Strimaitis, and R.J. Yamartino. 2000. A User's Guide for the CALPUFF Dispersion Model (Version 5). Earth Tech, Inc., Concord, MA.

Tang, H., Burns, Yang, L. and F. Apon, 2011. AMEC Multigas Passive Sampler: A Green Product for Cost-Effectively Monitoring Air Pollution Indoors and Outdoors. Transactions of the Wessex Institute. Paper DOI: 10.2495/AIR110131

US EPA, 1995 SCREEN3 Model User's Guide U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Emissions, Monitoring, and Analysis Division, Research Triangle Park, North Carolina 27711, EPA-454/B-95-004

9.0 Closure

We trust that this meets your needs at this time. If you have any questions or concerns, please do not hesitate to contact the undersigned.

Respectfully Submitted,

STANTEC CONSULTING LTD.

Original signed by

Peter D. Reid, M.A
Principal
Tel: 403 781-4142
Fax: 403 269-5245
peter.reid@stantec.com

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DETAILED MODELLING PLAN

Closure
December 17, 2013

APPENDIX D

Emissions Inventory

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D.1 Introduction

This Appendix details estimation methods and results of air emission inventories from regional sources, construction activities for the LNG Export Terminal Project (the Project), Project operation, and reasonably foreseeable future projects. The substances inventoried include criteria air contaminants (CACs) for which ambient air quality objectives have been established. The CACs considered in the assessment include sulphur dioxide (SO_2), oxides of nitrogen (NO_X), carbon monoxide (CO), fine particulate matter ($PM_{2.5}$), and hydrogen sulphide (H_2S). Total volatile organic compounds (VOCs) are also inventoried.

D.2 Regional Sources

Two regional sources, the existing Rio Tinto Alcan Primary Metal BC Aluminum Smelter (RTA) and the proposed Kitimat LNG export terminal (KLNG), are included in the dispersion modelling assessment for the base case scenario. RTA emissions are based on the technical document supporting its permit application for the Kitimat Modernization Project (RTA 2013), which was provided by the British Columbia Ministry of Environment (BC MOE). In the technical document, three emission scenarios are presented for different post-project emission rates, which are based on different sulphur content in the raw material. The scenario with the highest SO_2 emission rates is used in the dispersion modelling assessment for the LNG Canada Project. RTA imports alumina from Australia using bulk carriers and exports aluminum on general cargo vessels. Emissions from those marine vessels are estimated based on an average of 40 to 50 vessel visits per year to the RTA terminal.

Emissions from the proposed and approved KLNG terminal are also considered in this assessment. In 2008, the project description for the KLNG terminal was revised such that the originally proposed import configuration was changed to an export configuration, resulting in a decrease in its air emissions from original design. The KLNG emissions are calculated based on the previously published document (Kitimat LNG 2008) and on updated operating information of adding four new gas turbines for power generation. This information also was provided by BC MOE.

Emissions and emission parameters for the regional existing and proposed sources are summarized in Table D.2-1.

D.3 Construction Emission Estimates

Project construction activities will result in CAC emissions, most likely engine exhaust from off-road equipment, marine vessels, and on-road vehicles. Fugitive dust associated with vehicle movements and site preparations is expected to be negligible because of high year-round precipitation in the Kitimat area and is not included in the emission inventory. The construction phases are planned to be 84 months long (Q1 2016 to Q1 2023), which includes site preparation; mechanical, electrical, and instrumental installation for the full build-out scenario (four trains); transportation of construction personnel and material; and marine terminal construction. The following subsections summarize the methods and assumptions used to estimate CACs emissions from off-road equipment, marine vessels, and on-road vehicles.

D.3.1 Off-Road Equipment

All equipment is assumed to be powered with diesel fuel. The engine type, number of units, power rating, and total operating hours of all the equipment are assumed based on construction schedule, manufacturer specifications, and experience with similar projects.

The load factors considered in this assessment are a ratio of actual engine output relative to maximum rated output and are based on the United States Environmental Protection Agency (U.S. EPA) NONROAD 2008a model (U.S. EPA 2010a). This is the standard model used in Canada to estimate emissions from off-road equipment.

Off-road diesel equipment that will be used for Project construction is listed in Table D.3-1. The main types of equipment are loaders, excavators, dozers, and cranes.

Emission standards for off-road engines vary with model year because of changing regulations. Canada has adopted the U.S. EPA off-road standards. Before 1996, off-road engines were not regulated (referred to as Tier 0). The first emission standards, known as Tier 1 standards, began to be phased in by horsepower rating in 1996. Tier 2 standards began in 2001, and Tier 3 standards began in 2006. For this assessment, it is assumed that most equipment has Tier 3 engines. All equipment is assumed to be manufactured in 2008 or later. Some highly specialized equipment, such as a crane, might have been manufactured before 2008. However, it is assumed the emissions sources, such as equipment motors, have been replaced or retrofitted with more recent parts.

Table D.2-1 Regional Emissions and Emission Parameters Included in Plume Dispersion Modelling

Facility	Source		Location (UTM NAD83)				Stack Parameters				Emissions (g/s)					
	Description	Type	mE	mN	Zone	Base Elevation (m)	Height (m)	Diameter (m)	Exit Velocity (m/s)	Exit Temperature (K)	SO_2	NOx	CO	$PM_{2.5}$	H_2S	VOCs
RTA	Pyro Scrubber	Point Source	519779	5983565	9	8.6	46.5	2.57	22.0	1,208	87.0	8.57	NA	3.60	NA	NA
	Calciner Cooler	Point Source	519721	5983607	9	11.9	15.2	0.71	20.4	374	2.32	0.000	NA	0.640	NA	NA
	Casting DC 4 (B) Furnace 41	Point Source	519717	5985286	9	16.7	34.1	0.89	23.4	608	0.000	0.083	NA	0.894	NA	NA
	Casting DC 4 (B) Furnace 42	Point Source	519722	5985287	9	16.6	34.1	0.89	23.4	608	0.000	0.083	NA	0.894	NA	NA
	Casting C Furnace 1	Point Source	519710	5985421	9	16.0	25.0	1.30	7.00	573	0.000	0.083	NA	0.180	NA	NA
	Casting C Furnace 2/3	Point Source	519675	5985414	9	16.0	25.0	1.30	7.00	573	0.000	0.083	NA	0.180	NA	NA
	Gas Treatment Centre Stack 1	Point Source	519560	5985240	9	17.0	60.0	7.00	17.0	373	184	0.000	NA	2.25	NA	NA
	Gas Treatment Centre Stack 2	Point Source	519442	5985218	9	17.0	60.0	7.00	17.0	373	184	0.000	NA	2.25	NA	NA
	Fume Treatment Centre Stack	Point Source	519242	5985386	9	18.0	50.0	2.00	14.0	373	20.0	0.644	NA	0.240	NA	NA
	Paste Plant	Point Source	519784	5983754	9	9.2	50.0	1.23	14.0	286	0.000	0.000	NA	0.198	NA	NA
	Bath Dust Collector	Point Source	519261	5985456	9	18.0	40.0	1.12	14.0	301	0.000	0.000	NA	0.133	NA	NA
	Bulk Carrier	Point Source	520439	5983111	9	0.0	30.0	1.50	37.6	558	0.018	0.447	0.039	0.007	0.000	0.016
	Tug 1	Point Source	520370	5983048	9	0.0	10.0	0.75	14.5	558	0.001	0.071	0.008	0.005	0.000	0.004
	Tug 2	Point Source	520365	5983190	9	0.0	10.0	0.75	14.5	558	0.001	0.071	0.008	0.005	0.000	0.004
	Potline A North	Line Source	519622.21	5985120.2	9	15.5	23.5	-	-	-	0.937	0.000	NA	0.583	NA	NA
			519566.2	5985402.2	9											
	Potline A South	Line Source	519678.21	5984810.2	9	14.1	23.5	-	-	-	0.937	0.000	NA	0.583	NA	NA
			519626.21	5985098.2	9											
	Potline B North	Line Source	519553.2	5985108.2	9	16.0	23.5	-	-	-	0.937	0.000	NA	0.583	NA	NA
			519498.2	5985390.2	9											
	Potline B South	Line Source	519609.2	5984798.2	9	15.0	23.5	-	-	-	0.937	0.000	NA	0.583	NA	NA
			519557.2	5985086.2	9											
	Potline C North	Line Source	519504.2	5985099.2	9	16.5	23.5	-	-	-	0.937	0.000	NA	0.583	NA	NA
			519448.2	5985381.2	9											
	Potline C South	Line Source	519560.2	5984789.2	9	15.5	23.5	-	-	-	0.937	0.000	NA	0.583	NA	NA
			519508.2	5985077.2	9											
	Potline D North	Line Source	519435.2	5985087.2	9	16.0	23.5	-	-	-	0.937	0.000	NA	0.583	NA	NA
			519380.2	5985369.2	9											
	Potline D South	Line Source	519491.2	5984777.2	9	14.4	23.5	-	-	-	0.937	0.000	NA	0.583	NA	NA
			519439.2	5985065.2	9											
RTA emissions totals (g/s)											485	10.1	0.06	16.1	0.00	0.02
RTA emissions totals (t/y)											15,290	320	1.74	509	0.00	0.75

Facility	Source		Location (UTM NAD83)				Stack Parameters				Emissions (g/s)					
	Description	Type	mE	mN	Zone	Base Elevation (m)	Height (m)	Diameter (m)	Exit Velocity (m/s)	Exit Temperature (K)	SO_2	NOx	CO	$PM_{2.5}$	H_2S	VOCs
KLNG	Compressor Exhaust 1a	KM_STC1a	516765	5975140	9	26.1	30.0	4.00	27.6	686	0.000	6.33	7.71	0.458	0.000	0.146
	Compressor Exhaust 1b	KM_STC1b	516785	5975130	9	21.1	30.0	4.00	27.6	686	0.000	6.33	7.71	0.458	0.000	0.146
	Compressor Exhaust 2a	KM_STC2a	516825	5975110	9	10.9	30.0	4.00	27.6	686	0.000	6.33	7.71	0.458	0.000	0.146
	Compressor Exhaust 2b	KM_STC2b	516845	5975100	9	6.0	30.0	4.00	27.6	686	0.000	6.33	7.71	0.458	0.000	0.146
	Heaters	KM_STH	516905	5975070	9	7.0	10.0	1.05	8.00	303	0.067	1.50	3.10	0.281	0.000	0.203
	Flare	KM_SFE	516685	5975450	9	10.6	54.0	0.80	20.0	1,273	0.000	0.100	0.478	0.000	0.000	0.000
	LNG Carrier	KM_STV	516758	5974504	9	0.0	40.0	2.00	3.50	573	0.785	0.540	0.155	0.069	0.000	0.022
	Tug Boat 1	KM_STB1	516855	5974925	9	0.0	10.0	0.50	6.30	773	0.003	0.060	0.005	0.002	0.000	0.002
	Tug Boat 2	KM_STB2	516845	5974635	9	0.0	10.0	0.50	6.30	773	0.003	0.060	0.005	0.002	0.000	0.002
KLNG emissions totals (g/s)											1	28	35	2	0.000	1
KLNG emissions totals (t/y)											27.1	870	1,090	68.9	0.000	25.6

NOTE:
NA – data not available
- – not applicable

Table D.3-1: Off-Road Diesel Equipment List

Equipment	Number of Equipment	Engine Power (hp)	Load Factor (%)	BSFC[a] (lb/hp*h)
Site Preparation				
Compactor	5	100	43.0	0.408
Dozer, 450 KW Class	5	600	59.0	0.367
Loader, 6 m^3	6	275	59.0	0.367
Grader	3	530	59.0	0.367
Excavator	6	335	59.0	0.367
Track Drill	4	425	43.0	0.367
Instrumental Installation				
Welding Rig	12	40	21.0	0.408
Gene Boom Manlift	6	60	21.0	0.408
Crane, 120 tonnes	1	469	43.0	0.367
Crane, 90 tonnes	1	339	43.0	0.367
Crane, 60 tonnes	1	229	43.0	0.367
Crane, 30 tonnes	1	179	43.0	0.367
Compressor	2	475	43.0	0.367
Marine Terminal Construction				
Piling Driver	2	235	43.0	0.367
Dozer , 200 KW Class	3	275	59.0	0.367
Medium Crane , 22 tonnes	3	160	43.0	0.367
Drill Rig, 12.5 tonnes	3	196	43.0	0.367
Large Crane, 100 tonnes	2	390	43.0	0.367
Off-road Trucking				
P/U Truck	5	225	59.0	0.367
Water Truck, 15 kgal	2	750	59.0	0.367
Dump Truck, 10 m^3	10	325	59.0	0.367
Dump Truck, 20 m^3	12	511	59.0	0.367
Fitter Truck	5	202	59.0	0.367
Aggregate Haul Truck	10	375	59.0	0.367
Cement Truck	10	350	59.0	0.367
X-ray Truck	1	325	59.0	0.367

NOTE:
[a] BSFC – brake specific fuel consumption

The U.S. EPA NONROAD 2008a model accounts for the degradation of an engine's performance over its lifetime resulting from normal use or misuse (i.e., tampering or negligence). Engine deterioration increases exhaust emissions, which usually leads to reduced combustion efficiency and can increase exhaust and non-exhaust emissions. The model also accounts for variation in emissions resulting from transient operation of engines. Emission factors for off-road engines are primarily determined with steady-state tests, which might not represent real-world conditions. A transient adjustment factor is included in the model because actual emissions might be greater as a result of differences in load, engine speed, and other differences attributable to transient demand.

The emission factors are adjusted from the zero-hour, steady state emission factors by accounting for transient adjustment and deterioration as follows:

$$EF_{adj(HC,CO,NO_x)} = EF_{ss} \times TAF \times DF$$

$$EF_{adj(PM)} = (EF_{ss} \times TAF \times DF) - S_{PMadj}$$

$$EF_{adj(BSFC)} = EF_{ss} \times TAF$$

where:

EF_{adj} = final emission factor used in model, after adjustment to account for transient operation and deterioration (g/hp-h);

EF_{ss} = zero-hour, steady-state emission factor (g/hp-h);

TAF = transient adjustment factor (unitless);

DF = deterioration factor (unitless); and

S_{PMadj} = adjustment to PM emission factor to account for variation in fuel sulphur content (g/hp-h).

Deterioration factors affect emissions of hydrocarbons (HCs), CO, NO_x, and PM, and are calculated from age factors:

$$DF = 1 + A \times (Age\ Factor)^b \text{ for age factor } \leq 1$$

$$DF = 1 + A \text{ for age factor } > 1$$

where:

$$Age\ Factor = \frac{Cumulative\ Activity\ (h)\ \times Load\ Factor}{Median\ Life\ at\ Full\ Load\ (h)}$$

and:

A and b less than or equal to 1 are constants for a given pollutant/technology type.

S_{PMadj} corrects PM emissions from the default fuel sulphur level to the episodic fuel sulphur level and is calculated using the following equation:

$$S_{PMadj} = BSFC \times 453.6 \times 7.0 \times soxcnv \times 0.01 \times (soxbas - soxdsl)$$

where:

BSFC = the in-use adjusted brake specific fuel consumption (lb/hp-h);

SO_xcnv = the fraction of fuel sulphur converted to direct PM;

SO_xbas = default certification fuel sulphur weight percent; and

SO_xdsl = the episodic weight percent of sulphur in off-road diesel fuel.

The emission factor for SO_x is calculated based on brake-specific fuel consumption:

$$EF_{SO_x} = (BSFC\ \times 453.6 \times (1 - SO_x cnv) - HC) \times 0.01 \times SO_x dsl \times 2$$

where:

HC = the in-use adjusted hydrocarbon emissions (g/hp-h).

The model year of all equipment in this study is assumed to be 2008 or later and the equipment usage year is assumed to be 2016. The sulphur content for off-road diesel is assumed to be 15 ppm based on ultra-low sulphur diesel limit (Environment Canada 2002). In the NONROAD model, all PM emissions are assumed to be smaller than 10 microns (PM_{10}), and 97% of PM_{10} emissions are assumed to be $PM_{2.5}$.

The equipment-specific adjusted emission factors for the Project are listed in Table D.3-2.

Table D.3-2: Construction Off-Road Diesel Equipment Emission Factors

Equipment	Calculated Adjusted Emission Factor (g/hp*h)					
	SO_2	NO_X	CO	PM_{10}	$PM_{2.5}$	HC
Site Preparation						
Compactor	0.0054	3.0086	2.4929	0.2196	0.2130	0.1854
Dozer, 450 KW Class	0.0049	2.6126	1.4070	0.2312	0.2243	0.1781
Loader, 6 m^3	0.0057	3.0492	2.2112	0.4623	0.4485	0.4318
Grader	0.0049	2.6135	1.4153	0.2357	0.2286	0.1783
Excavator	0.0049	2.6153	1.4323	0.2448	0.2375	0.1787
Track Drill	0.0049	2.5046	0.8716	0.1143	0.1108	0.1679
Instrumental Installation						
Welding Rig	0.0064	5.7405	4.1950	0.9507	0.9222	0.6461
Gene Boom Manlift	0.0064	5.6933	6.2062	0.5893	0.5717	0.8440
Crane, 120 tonnes	0.0049	2.5097	0.9044	0.1325	0.1286	0.1691
Crane, 90 tonnes	0.0049	2.5097	0.9044	0.1325	0.1286	0.1691
Crane, 60 tonnes	0.0049	2.5146	0.8299	0.1498	0.1453	0.1872
Crane, 30 tonnes	0.0049	2.5146	0.8299	0.1498	0.1453	0.1872
Compressor	0.0049	2.5080	0.8935	0.1264	0.1226	0.1687
Marine Terminal Construction						
Piling Driver	0.0049	2.5069	0.7863	0.1224	0.1187	0.1853
Dozer, 200 KW Class	0.0049	2.6189	1.3007	0.2628	0.2549	0.1975
Medium Crane, 22 tonnes	0.0049	2.5146	0.9622	0.2440	0.2366	0.1872
Drill Rig, 12.5 tonnes	0.0049	2.5069	0.7863	0.1224	0.1187	0.1853
Large Crane, 100 tonnes	0.0049	2.5097	0.9044	0.1325	0.1286	0.1691
Off-road Trucking						
P/U Truck	0.0049	2.6208	1.3164	0.2723	0.2641	0.1980
Water Truck, 15 kgal	0.0049	2.6208	2.3372	0.2723	0.2641	0.1800
Dump Truck, 10 m^3	0.0049	2.6208	1.4837	0.2723	0.2641	0.1800
Dump Truck, 20 m^3	0.0049	2.6208	1.4837	0.2723	0.2641	0.1800
Fitter Truck	0.0049	2.6208	1.3164	0.2723	0.2641	0.1980
Aggregate Haul Truck	0.0049	2.6208	1.4837	0.2723	0.2641	0.1800
Cement Truck	0.0049	2.6208	1.4837	0.2723	0.2641	0.1800
X-ray Truck	0.0049	2.6208	1.4837	0.2723	0.2641	0.1800

Total emissions were determined using the following equation.

$$Emissions\ (t) = Operating\ Time\ (h) \times Maximum\ Engine\ Power\ (hp) \times Emission\ Factor\ \left(\frac{g}{hp\ h}\right) \times Unit\ Conversion\ \left(\frac{t}{10^6 g}\right)$$

The HC emission factors were converted to VOC using conversion factor, 1.053 (VOC and HC), which is based on the U.S. EPA report, *Conversion Factors for Hydrocarbon Emission Components* (U.S. EPA 2010b).

Estimated CACs from off-road diesel equipment during Project construction are listed in Table D.3-3.

Table D.3-3: Off-Road Diesel Equipment Emissions for Project Construction

Equipment	Emissions (tonnes)					
	SO_2	NO_X	CO	PM_{10}	$PM_{2.5}$	VOC
Site Preparation						
Compactor	0.007	3.959	3.280	0.289	0.280	0.262
Dozer, 450 KW Class	0.053	28.301	15.241	2.505	2.430	2.072
Loader, 6 m^3	0.034	18.167	13.174	2.754	2.672	2.763
Grader	0.028	15.005	8.125	1.353	1.312	1.100
Excavator	0.036	18.981	10.396	1.777	1.723	1.393
Track Drill	0.022	11.205	3.899	0.511	0.496	0.807
Instrumental Installation						
Welding Rig	0.008	6.855	5.009	1.135	1.101	0.829
Gene Boom Manlift	0.006	5.099	5.558	0.528	0.512	0.812
Crane, 120 tonnes	0.012	5.996	2.161	0.317	0.307	0.434
Crane, 90 tonnes	0.008	4.334	1.562	0.229	0.222	0.314
Crane, 60 tonnes	0.006	2.933	0.968	0.175	0.169	0.235
Crane, 30 tonnes	0.004	2.293	0.757	0.137	0.132	0.183
Compressor	0.024	12.137	4.324	0.612	0.594	0.877
Marine Terminal Construction						
Piling Driver	0.004	2.219	0.696	0.108	0.105	0.176
Dozer, 200 KW Class	0.006	3.059	1.519	0.307	0.298	0.248
Medium Crane, 22 tonnes	0.002	1.246	0.477	0.121	0.117	0.100
Drill Rig, 12.5 tonnes	0.003	1.521	0.477	0.074	0.072	0.121
Large Crane, 100 tonnes	0.004	2.020	0.728	0.107	0.103	0.146
Off-road Trucking						
P/U Truck	0.000	0.250	0.126	0.026	0.025	0.020
Water Truck, 15 kgal	0.001	0.334	0.298	0.035	0.034	0.025
Dump Truck, 10 m^3	0.001	0.724	0.410	0.075	0.073	0.053
Dump Truck, 20 m^3	0.003	1.365	0.773	0.142	0.138	0.101
Fitter Truck	0.000	0.225	0.113	0.023	0.023	0.018
Aggregate Haul Truck	0.002	0.835	0.473	0.087	0.084	0.062
Cement Truck	0.001	0.779	0.441	0.081	0.079	0.057
X-ray Truck	0.000	0.072	0.041	0.008	0.007	0.005

D.3.2 Marine Vessels

Marine vessels will be used for dredging and shipping during Project construction. The shipping activities involve carriers and their assistant tugs travelling along the marine access route from open sea to the Project construction site/port. Travelling speed is assumed to be 12 knots (22.2 km/h), with a total of 13 hours travelling time along the marine access route. The specifications and operation hours for each vessel are provided by LNG Canada Development Inc. (LNG Canada). Construction and shipping vessels that will be used for the Project are listed in Table D.3-4. The main types of vessels are general carriers, dredgers, and tugs.

The method to calculate emissions from construction vessels uses energy-based emission factors together with activity profiles for each vessel. These emissions are determined using the following equation.

$$Emissions\ (t) = Maximum\ Continuous\ Rating\ Power\ (kW) \times Load\ Factor\ (percent\ of\ vessel's\ total\ power\ in\ use) \times Operating\ Time\ (h) \times Emission\ Factor\ \left(\frac{g}{kW\ h}\right) \times Unit\ Conversion\ \left(\frac{t}{10^6 g}\right)$$

Starting January 2015, vessels travelling or operating in the North American Emission Control Area (ECA) will be required to use fuel with a maximum sulphur limit of 0.1 wt% (MARPOL 2008). The emission factors used for marine vessels in this inventory are taken from a report prepared for U.S. EPA (ICF 2009), which use this new fuel requirement (0.1 % sulphur). In addition, NO_X adjustment factors for each of main and auxiliary engines are applied to account for the changes imposed by the MARPOL fuel oil requirement (ICF 2009). Emission factors are in units of emissions per units of energy from the engines and are listed in Table D.3-5. Each emission factor is multiplied by the power needed to move the vessel in a particular activity. Estimated CAC emissions from construction vessels are listed in Table D.3-6.

Table D.3-4: Vessels for Project Construction

Construction Vessel	Manufacturer/ Owner	Model	Main Engine Power	Auxiliary Engine Power	Total Operating Hours	Number of Carrier Visits	Operating Hours per Carrier Visit		
			(kW)	(kW)			Travelling along Channel	Berthing / Unberthing	Loading
Sea-Floor Preparation									
Dredge vessel	Jan De Nul	Jan De Nul	1,909	–	4,800	–	–	–	–
Tug boat w/ material barge	Hornbeck Offshore	Supply Vessel	746	–	9,600	–	–	–	–
Shipping – Module Carriers									
Module carriers	Bigroll	MC Class	8,775	1,000	–	70	13	3	168
Tug boat w/ material barge	Seaspan	Cavalier	1,268	–	–	175	–	3	–
Shipping – Break Bulk Carriers									
Break bulk carriers	Austral Asia Line	A-Class	11,620	975	–	130	13	2	72
Tug boat w/ material barge	Seaspan	Cavalier	1,268	–	–	325	–	2	–

NOTE:
– - not applicable

Table D.3-5: Construction and Shipping Vessels Emission Factors

Substance	SO_2	NO_X	CO	$PM_{2.5}$	VOC
Emission factor (g/kW h) for construction vessel	1.3	13.2	1.1	0.7	0.5
Emission factor (g/kW h) for main engine	0.36	17.0	1.4	0.17	0.6
Emission factor (g/kW h) for aux engine	0.42	13.9	1.1	0.17	0.4
Emission factor (g/kW h) for tug	0.09	9.8	1.1	0.64	0.5

Table D.3-6: Marine Vessel Emissions for Project Construction

Category	Emissions (t)				
	SO_2	NO_X	CO	$PM_{2.5}$	VOC
Dredging	5.57	56	5	3	3
Shipping	7.85	208	29	4	12

D.3.3 On-road vehicles

During construction, most on-road vehicles will be buses and pickup trucks. Regular shuttle bus service is planned from Terrace Airport to the workforce accommodation centre(s) and also from the workforce accommodation centre to the construction site. The number of daily movements of each shuttle service and onsite pickup trucks was provided by LNG Canada:

- bus movements (between airport and workforce accommodation centre(s)): 10 to 60 per day
- bus movements (between workforce accommodation centre and site): 200 to 700 per day, and
- small vehicle (pickup, SUV, car, and van) movements: 200 to 1,000 per day.

Emission factors for on-road vehicles are determined using the MOBILE6.2C model, which is the Canadian version of the U.S. EPA MOBILE6 model, developed by Environment Canada. It is the standard model used in Canada to estimate emissions from on-road vehicles.

MOBILE6.2C is a computer program that estimates emission factors for emissions from gasoline and diesel highway motor vehicles. The MOBILE6.2C derived emission factors are estimated assuming the vehicles are between the 2005 to 2010 model years, and vehicle age is assumed to be evenly distributed between these years. Similar to the NONROAD model, MOBILE6.2C estimates vehicle class-specific emission factors using a database developed from emission tests conducted under standardized conditions for temperature, fuel, and driving cycle. Environmental and age factors are incorporated into

the model to account for deterioration in engine performance with age and the effects of climate on exhaust and non-exhaust emissions.

Each Project vehicle is classified corresponding to the MOBILE6.2C vehicle classifications. The emission factors for CACs from on-road diesel equipment for construction are listed in Table D.3-7. The estimated CACs from on-road diesel equipment during the construction are calculated using the following equation:

$$Emissions\ (t) = Emission\ Factor\ \left(\frac{g}{mile}\right) \times Total\ Distance\ Travelled\ (mile) \times Unit\ Conversion\ \left(\frac{t}{10^6 g}\right)$$

Table D.3-7: On-road Diesel Vehicle Emission Factors

Equipment	Vehicle Type	GVWR[a] (lb)	Emission Factors (g/mile)				
			SO_2	CO	NO_X	PM_{10}	$PM_{2.5}$
Bus	HDDBS	14,050	0.0151	0.268	2.744	0.0639	0.0285
Truck, Crew Cab 4x4	HDDV2b	9,200	0.0073	0.096	1.013	0.0269	0.0132

NOTE:
[a] GVWR – gross vehicle weight rating

Estimated CACs from on-road diesel equipment during construction are listed in Table D.3-8.

Table D.3-8 Overall Construction Emissions for On-road Equipment

Vehicle Type	Emissions (tonnes)				
	SO_2	CO	NO_X	PM_{10}	$PM_{2.5}$
Buses	0.14	2.40	24.5	0.57	0.25
Pickup Trucks	0.04	0.49	5.18	0.14	0.07

D.3.4 Overall Construction Emission Summary

Construction emissions include site preparation; mechanical, electrical, and instrumental installation; and marine terminal construction. The emissions from shipping activities using marine vessels are also included in the inventory. Overall construction emissions are summarized in Table D.3-9.

Table D.3-9: Overall Construction Emissions

Category	Emissions (t)				
	SO_2	NO_X	CO	$PM_{2.5}$	VOC
Site Preparation	0.19	98.3	55.7	9.18	8.60
Instrumental Installation (Phase 1)	0.07	41.6	21.4	3.23	3.83
Instrumental Installation (Phase 2 and 3)	0.07	41.6	21.4	3.23	3.83
Marine Terminal Construction (Phase 1)	5.57	66.4	8.60	3.69	2.93
Marine Terminal Construction (Phase 2 and 3)	5.57	66.4	8.60	3.69	2.93
Marine Shipping (inbound)	7.85	208	28.6	4.42	12.0
Marine Shipping (outbound)	7.85	208	28.6	4.42	12.0
Shuttle Bus Service	0.12	21.0	2.05	0.22	0.00
Onsite Pickup Trucks	0.03	4.44	0.42	0.06	0.00
Total	27.3	756	175	32.1	46.1

D.4 Operation Emissions

Major sources of CAC emissions during Project operation activities include gas turbines, acid gas removal unit (AGRU), flares, and marine-based sources, including LNG carriers and tug boats. The following subsections describe CAC emission calculations for each source.

D.4.1 Gas Turbine

The GE LMS 100 gas turbine equipped with dry low NO_X emissions (DLE) combustors will be used as the mechanical drive for the refrigerant compressors. There are two parallel identical compressor strings for each refrigerant circuit (train), and each string is driven by one gas turbine. A total of eight LMS 100 gas turbines are needed for the full built-out of four trains. Air emissions from the gas turbines comprise primarily NO_X and CO, with small amounts of $PM_{2.5}$, SO_2, and VOCs.

The main source of fuel gas for gas turbines is Boil Off Gas (BOG) from the LNG storage tanks (90%), with the remainder from feed gas (10%). LNG Canada provided the data for the constituents of fuel gas listed in Table D.4-1, with each constituent represented as percentage of one mole of gas.

Table D.4-1: Fuel Gas Composition

Substance	Chemical Formula	Mole Percentage (%)
Nitrogen	N_2	3.991
Carbon Dioxide	CO_2	0.1999
Methane	CH_4	95.272
Ethane	C_2H_6	0.4072
Propane	C_3H_8	0.094
i-Butane	C_4H_{10i}	0.014
n-Butane	C_4H_{10n}	0.015
i-Pentane	C_5H_{12i}	0.004
n-Pentane	C_5H_{12n}	0.004
n-Hexane	C_6H_{14n}	0.003
n-Heptane	C_7H_{16n}	0.002
Benzene	C_6H_6	0.00013
Toluene	C_7H_8	0.00011
Hydrogen Sulphide	H_2S	0.00002
Ethyl Mercaptan	C_2H_5 SH	0.00004
Carbonyl Sulphide	COS	0.000006

NOTE:
This turbine fuel gas composition was provided by LNG Canada for the purposes of Project air contaminant emission calculations and differs slightly from a later updated gas composition provided by LNG Canada for the greenhouse gas calculations.

Estimates of NO_X emissions are based on manufacturer performance data with stack emission concentration as low as 25 ppm. Carbon monoxide emissions are calculated based on Canadian Council of Ministers of the Environment (CCME) *National Emission Guidelines for Stationary Combustion Turbines* with exhaust emission limit at 50 ppm (CCME 1992). Emissions of $PM_{2.5}$ and VOCs from turbines are calculated as 0.0066 lb/MMBtu and 0.0021 lb/MMBtu, respectively, using fuel input emission factors based on U.S. EPA AP 42 chapter 3.1 for stationary gas turbines (U.S. EPA 1995). Sulphur dioxide emissions are calculated using overall sulphur balance of approximately 0.66 ppm of total sulphur (including H_2S, mercaptans, and carbonyl sulphide) in the fuel gas.

Stack and emission parameters associated with the gas turbine source included in plume dispersion modelling are summarized in Table D.4-2. The emission rate for each CAC is based on a single equipment type, and the location of the stacks associated with each of the eight gas turbines is listed in Table D.4-3.

Table D.4-2: Stack and Emission Parameters Associated with Gas Turbines

Source Identification		LMS 100
Number of unit		8
Unit name		Gas Turbine
Source Type		Point
Capacity (Power Output)	MMBtu/h	319
	MW	93.4
Capacity (Fuel Input based on HHV[a])	MMBtu/h	881
	MW	258
Fuel Type		90% of BOG and 10% of Feed Gas
Fuel Consumption	m^3/h at 15°C and 101.325 kPa	25,586
Stack Dimensions		
Stack Height	m	35
Stack Inside Diameter	m	3.9
Exhaust Parameters		
Exit Velocity	m/s	25.1
Exit Temperature	°C	196
	K	469
CACs Emission Rate		
NO_x	kg/h	32.1
SO_2	kg/h	0.05
CO	kg/h	39.1
$PM_{2.5}$	kg/h	2.64
VOC	kg/h	0.84

NOTE:
[a] HHV = Higher Heating Value

Table D.4-3: Source Location Associated with Gas Turbines

Stack Name	Stack Code	Location (UTM NAD 83)		
		UTM Zone	Easting (m)	Northing (m)
Compressor Exhaust 1a	STC1a	9	520946	5986069
Compressor Exhaust 1b	STC1b	9	520954	5985976
Compressor Exhaust 2a	STC2a	9	520734	5986050
Compressor Exhaust 2b	STC2b	9	520742	5985957
Compressor Exhaust 3a	STC3a	9	520475	5986377
Compressor Exhaust 3b	STC3b	9	520482	5986284
Compressor Exhaust 4a	STC4a	9	520263	5986358
Compressor Exhaust 4b	STC4b	9	520271	5986265

Table D.4-4 lists the overall emissions from all eight gas turbines under normal conditions at 100% capacity.

Table D.4-4 Emissions for Full Build-out Facility

Substance	Emissions	
	(tonnes/day)	(tonnes/year)
SO_2	0.009	3.20
NO_x	6.162	2,249
CO	7.501	2,738
$PM_{2.5}$	0.507	185
VOC	0.161	58.6

D.4.2 Acid Gas Removal Unit

Feed gas from the upstream facility is sent to the AGRU, where acid gases (predominantly CO_2 and sulphur compounds) are removed to meet product specification and to prevent freezing in the liquefaction process. The acid gases are then incinerated before being discharged to the atmosphere. One AGRU is required for each processing train, with four units for the full built-out facility. The CAC emissions from the AGRU comprise primarily SO_2 with small amounts of NO_X, CO, $PM_{2.5}$, and VOCs.

SO_2 emission rates are estimated using overall sulphur balance methods based on total sulphur at 9 mg per cubic metres in the feed gas (data provided by LNG Canada) as normal case. Conservatively, it is assumed that 0.1% of sulphur compounds, present as H_2S, are going to be unburnt and emitted to the air.

Emissions of NO_X, CO, $PM_{2.5}$, and VOCs from the incinerator are calculated using fuel input emission factors based on U.S. EPA AP 42 chapter 1.4 for uncontrolled natural gas combustion (U.S. EPA 1995) shown in Table D.4-5.

Table D.4-5: Emission Factors for Natural Gas Combustion – Uncontrolled

Substance	EF (lb/mmscf)	EF (lb/MMBtu)	EF (g/GJ)
NO_X	190	0.1863	80.08
CO	84	0.0824	35.41
$PM_{2.5}$	7.6	0.0075	3.20
VOC	5.5	0.0054	2.32

Stack and emission parameters associated with the AGRU source included in plume dispersion modelling are summarized in Table D.4-6. The emission rate for each CAC is based on a single equipment type, and the location of the stacks associated with each AGRU is listed in Table D.4-7.

Table D.4-6: Stack and Emission Parameters Associated with Acid Gas Removal Unit

Source Identification		AGRU
Number of unit		4
Unit name		Incinerator
Source Type		Point
Capacity (Power Output)	MMBtu/h	112
	MW	29.8
Stack Dimensions		
Stack Height	m	65
Stack Inside Diameter	m	2.6
Exhaust Parameters		
Exit Velocity	m/s	15.7
Exit Temperature	°C	960
	K	1,233
CACs Emission Rate		
NO_x	kg/h	9.46
SO_2	kg/h	19.9
H_2S	kg/h	0.01
CO	kg/h	4.18
$PM_{2.5}$	kg/h	0.38
VOC	kg/h	0.27

Table D.4-7: Source Location Associated with Acid Gas Removal Units

Stack Name	Stack Code	Location (UTM NAD 83)		
		UTM Zone	Easting (m)	Northing (m)
Incinerator Exhaust 1	STI1	9	521031	5986232
Incinerator Exhaust 2	STI2	9	520819	5986213
Incinerator Exhaust 3	STI3	9	520559	5986540
Incinerator Exhaust 4	STI4	9	520348	5986521

Table D.4-8 lists the overall emissions from all four AGRUs under normal conditions at 100% capacity.

Table D.4-8: Emissions Summary from Acid Gas Removal Units

Substance	Emissions	
	(tonnes/day)	(tonnes/year)
SO_2	6.36	697
NO_x	0.908	331
CO	0.402	147
$PM_{2.5}$	0.036	13.2
H_2S	0.003	0.37
VOC	0.026	9.60

D.4.3 Flares

The flares act as a vapor relief system and will be used to collect and dispose of hydrocarbon (HC)-containing streams, which are typically released during start-up and shutdown, but also during upset and emergency conditions. Five flares will be operated in the facility: warm, cold, spare, operational, and storage and loading. The warm flare will dispose of warm/wet HC streams from the front end of the LNG train. The cold flare will handle cold/dry HC streams from the liquefaction and refrigeration processes. The operational flare will handle either warm/wet or cold/dry HC releases during the start-up of the train. The storage and loading flare will dispose of HC streams resulting from BOG compressor failure. The spare flare will be the backup flare if other flares fail.

During normal operations, venting HC streams are not routed to the flares, and they are operated by small volumes of purge gas and pilot gas. Nitrogen is selected as purge gas to prevent air ingress and enable burning of the HCs into the flare header in case of emergency. Fuel gas is used as pilot gas so that the pilot flame is on continuously. Air emissions associated with the pilot light flares were estimated based on the pilot rate at 7.5 kg/h, and a 100% conversion efficiency of H_2S to SO_2 is assumed during

normal operations. The pilot gas constituents, provided by LNG Canada, are listed in Table D.4-9, with each constituent represented as percentage of one mole of gas.

Table D.4-9: Pilot Gas Compositions for Flares

Substance	Chemical Formula	Mole Percentage (%)
Nitrogen	N_2	0.313
Carbon Dioxide	CO_2	2.005
Methane	CH_4	92.350
Ethane	C_2H_6	3.978
Propane	C_3H_8	0.940
i-Butane	C_4H_{10i}	0.140
n-Butane	C_4H_{10n}	0.148
i-Pentane	C_5H_{12i}	0.041
n-Pentane	C_5H_{12n}	0.039
n-Hexane	C_6H_{14n}	0.028
n-Heptane	C_7H_{16n}	0.017

The CAC emissions from flares at normal operating conditions are calculated using emission factors from U.S. EPA AP 42 (U.S. EPA 1995) and also follow the BC dispersion modelling guideline (BC MOE 2008).

Stack and emission parameters associated with the flares during normal operations included in plume dispersion modelling are summarized in Table D.4-10. The emission rate for each CAC is based on a single equipment type, and the locations for each flare stack are presented in Table D.4-11.

Table D.4-10: Stack and Emission Parameters Associated with Flares

Source Identification		Flares
Number of unit		5
Unit name		Flares
Source Type		Point
Heat Release Rate	GJ/h	0.129
Purge Rate	kg/h	400
Pilot Rate	kg/h	7.5
Stack Dimensions		
Stack Height	m	125
Stack Inside Diameter	m	1.6
Exhaust Parameters		
Exit Velocity	m/s	20
Exit Temperature	°C	1000

Source Identification		Flares
	K	1273
CACs Emission Rate		
NO_x	kg/h	0.0021
SO_2	kg/h	0
H_2S	kg/h	0
CO	kg/h	0.0025
$PM_{2.5}$	kg/h	0.0008
VOC	kg/h	0.0077

Table D.4-11 Source Location Associated with Flares

Stack Name	Stack Code	Location (UTM NAD 83)		
		UTM Zone	Easting (m)	Northing (m)
Warm flare	SFW	9	520960	5985542
Cold flare	SFC	9	520968	5985543
Spare flare	SFS	9	520976	5985544
Operational flare	SFO	9	520983	5985545
Storage and loading flare	SFT	9	520990	5985546

The principle function of the flare system is to dispose of excess gases safely by controlled combustion in the event of an upset or during plant maintenance. The flare emissions during upset or maintenance conditions are considered to be non-routine operations and have been assessed in isolation at the facility.

During an emergency, it is likely that the LNG processing trains will be shut down and the remaining vapours will be routed to either the cold or warm gas flare and the storage and loading flare to reduce the pressure in the plant. It might be unlikely for the dry or wet gas flare and the storage and loading flare to operate simultaneously, but conservatively, the worst-case emergency scenario for a release from all of three flares is considered.

Air emissions associated with a flare blow-down event are estimated based on a release rate of 400 kg/s for the cold and warm flares and a peak release rate is 30 kg/s for the storage and loading flare. The blow-down event is assumed to last one hour with the above release rates conservatively considered. The release gas compositions to the cold or warm gas flare, and storage and loading flare, provided by LNG Canada, are listed in Table D.4-12, with each constituent represented as percentage of one mole of gas.

Table D.4-12: Release Gas Composition for the Flares

Substance	Chemical Formula	Mole Percentage (%)		
		Warm Flare	Cold Flare	Storage Flare
Nitrogen	N_2	0.313		4.4
Carbon Dioxide	CO_2	2.005		
Methane	CH_4	92.350	0.9	95.6
Ethane	C_2H_6	3.978	62.1	
Propane	C_3H_8	0.940	37.0	
i-Butane	C_4H_{10i}	0.140		
n-Butane	C_4H_{10n}	0.148		
i-Pentane	C_5H_{12i}	0.041		
n-Pentane	C_5H_{12n}	0.039		
n-Hexane	C_6H_{14n}	0.028		
n-Heptane	C_7H_{16n}	0.017		

The CAC emissions from flares during emergency conditions are calculated using emission factors from U.S. EPA AP 42 (U.S.EPA 1995) and also follow the BC dispersion modelling guideline. The stack and emission parameters associated with the flares during upset operations are summarized in Table D.4-13.

Table D.4-13: Emission Parameters Associated with Flares in Normal and Emergency Conditions

Source Identification		Flares		
Unit name		Warm Flare	Cold Flare	Storage Flare
Source Type		Point	Point	Point
Pilot Rate	kg/h	7.5	7.5	7.5
Emergency Release Rate	kg/s	400	400	30
Stack Dimensions				
Stack Height	m	125	125	125
Stack Inside Diameter	m	1.6	1.6	1.6
Exhaust Parameters				
Exit Velocity	m/s	20	20	20
Exit Temperature	°C	1,000	1,000	1,000
	K	1,273	1,273	1,273
CACs Emission Rate at Normal Condition (t/y)				
SO_2		0.000	0.000	0.000
NO_x		0.093	0.093	0.093
CO		0.110	0.110	0.110
$PM_{2.5}$		0.036	0.036	0.036
H_2S		0.000	0.000	0.000

Source Identification	Flares		
VOC	0.339	0.339	0.339
CACs Emission Rate at Emergency Condition (tonnes per event)			
SO_2	0.036	0.000	0.000
NO_x	0.410	1.222	0.092
CO	0.484	1.442	0.109
$PM_{2.5}$	0.158	0.470	0.035
H_2S	0.000	0.000	0.000
VOC	1.489	4.440	0.334

D.4.4 Marine Vessels

The Project includes a marine terminal that is able to accommodate LNG carriers ranging in capacity between 140,000 m^3 to 266,000 m^3. The marine facility will be designed to have two berths facilitating two LNG carriers safely approaching, berthing, loading, and departing simultaneously. The world fleet of LNG carriers comprise vessels ranging in capacity from 50,000 m^3 to 266,000 m^3. Q-Flex vessels range from 210,000 m^3 to 216,000 m^3 and the largest vessels, Q-Max, range from 250,000 m^3 to 266,000 m^3. Conservatively, all LNG carriers calling to the port are assumed to be Q-Max equivalent carriers.

Based on information provided by LNG Canada, it is estimated that a total of 350 LNG carriers will visit the terminal per year at full build-out. Tugs will escort the carriers and assist them in berthing and loading. During berthing, three tugs are required to support the operation. Only one tug will remain onsite for assistance when the LNG carrier is loading product. During a typical port-of-call, each LNG carrier will require about three hours to maneuver in/off the berth and 15 hours to load the vessel.

Characteristics of the vessels are listed in Table D.4-14.

Table D.4-14: Marine Vessel Characteristics

Feature	Vessel Class	
	LNG Carrier	Tug
Vessel Length (m)	345	36
Cargo Capacity (m^3)	265,000	–
Main Engine Power Rating (kW)	37,980	1,342
Auxiliary Engine Power Rating (kW)	8,020	–
Number of LNG carrier visits per year	350	–
Number of vessel in Port at one time	1–2	1–4
Total time of maneuvering per visit (h)	3	–

Feature	Vessel Class	
	LNG Carrier	Tug
Total time of loading per visit (h)	15	–
Fuel type	Marine Gas Oil (MGO)	Diesel

NOTE:
– - not applicable

The LNG carriers and their assistant tugs will travel along the marine access route from open sea to the LNG Canada terminal. The travelling speed is controlled by the reduced speed zone and assumed at 12 knots (22.2 km/h), with a total of 13 hours travelling time along the marine access route. The method to calculate emissions from marine vessels is to use energy-based emission factors together with activity profiles for each vessel. These emissions were determined using the following equation.

$$Emissions\ (t) = Maximum\ Continuous\ Rating\ Power\ (kW) \times Load\ Factor\ (percent\ of\ vessel's\ total\ power\ in\ use) \times Operating\ Time\ (h) \times Emission\ Factor\ \left(\frac{g}{kW\ h}\right) \times Unit\ Conversion\ \left(\frac{t}{10^6 g}\right)$$

The load factors are expressed as a percent of the vessel's total propulsion power and can be calculated using the following equation.

$LF = (AS/MS)^3$

Where LF = Load Factor (percent)

AS = Actual Speed (knots)

MS = Maximum Speed (knots)

The emission factors are in units of emissions per unit of energy from the engine and are listed in Table D.4-15. The emission factor is multiplied by the power needed to move the vessel in a particular activity (operating hours). Starting January 2015, vessels travelling in the North American ECA will be required to use fuel with a maximum sulphur limit of 0.1 wt% (MARPOL 2008). The emission factors used for marine vessels in this inventory are taken from a report prepared for U.S. EPA (ICF 2009), which are based on this new fuel requirement (0.1% sulphur). In addition, NO_X adjustment factors for each of the main and auxiliary engines are applied to account for the changes imposed by the MARPOL fuel oil requirement (ICF 2009).

Emissions associated with the operations of LNG carriers at the marine terminal during berthing, unberthing, and loading are estimated for the short-term (hourly/daily) and long-term (annual) operating scenario. The short-term emissions assume one LNG carrier is hotelling and loading, while the second carrier is maneuvering to/off the dock area. These emissions are assumed to represent hourly and daily

conditions. The long-term emissions reflect average annual LNG carrier emissions with a total of 350 visits per year.

Table D.4-15: Marine Vessel Emission Factors

Substance	SO_2	NO_x	CO	$PM_{2.5}$	VOC
Emission factor (g/kW h) for main engine	0.36	17.0	1.4	0.17	0.6
Emission factor (g/kW h) for aux engine	0.42	13.9	1.1	0.17	0.4
Emission factor (g/kW h) for boiler	0.57	2.0	0.2	0.15	0.1
Emission factor (g/kW h) for tug	0.09	9.8	1.1	0.64	0.5

Stack and emission parameters associated with the marine source included in plume dispersion modelling are summarized in Table D.4-16. The location of the stacks associated with each vessel is listed in Table D.4–17.

Table D.4-16: Stack and Emission Parameters Associated with Marine Vessels

Source Identification		Marine Vessels	
Unit name		LNG Carrier	Tug Boat
Source Type		Point	Point
Stack Dimensions			
Stack Height	m	75	10
Stack Inside Diameter	m	1.5	0.75
Exhaust Parameters			
Exit Velocity	m/s	37.58	14.53
Exit Temperature	°C	285	285
	K	558	558
CACs Emission Rate (Short-term)			
SO_2	kg/h	2.59	0.04
NO_x	kg/h	40.23	4.08
CO	kg/h	7.9	0.46
$PM_{2.5}$	kg/h	1.03	0.26
VOC	kg/h	4.17	0.21
CACs Emission Rate (Long-term)			
SO_2	kg/h	0.92	0.01
NO_x	kg/h	10.24	0.97
CO	kg/h	1.63	0.11
$PM_{2.5}$	kg/h	0.31	0.06
VOC	kg/h	0.78	0.05

Table D.4-17: Source Location Associated with Marine Vessels

Stack Name	Stack Code	Location (UTM NAD 83)		
		UTM Zone	Easting (m)	Northing (m)
LNG Carrier South	STV1	9	520952	5982973
LNG Carrier North	STV2	9	520800	5983403
Tug Boat 1	STB1	9	520899	5982873
Tug Boat 2	STB2	9	520872	5983073
Tug Boat 1	STB3	9	520768	5983326
Tug Boat 2	STB4	9	520757	5983487

Emissions associated with the operation of LNG carriers in confined shipping channels outside the marine terminal are estimated, assuming one LNG carrier is travelling with reduced speed at 12 knots. These emissions are listed in Table D.4-18.

Table D.4-18: Emission Parameters Associated with Marine Vessel Shipping

Source Identification		Marine Vessels	
Unit name		LNG Carrier	Tug Boat
Source Type		Point	Point
Stack Dimensions			
Stack Height	m	75	10
Stack Inside Diameter	m	1.5	0.75
Exhaust Parameters			
Exit Velocity	m/s	37.58	14.53
Exit Temperature	°C	285	285
	K	558	558
CACs Emission Rate (Shipping at reduced speed zone)			
SO_2	kg/h	3.83	0.04
NO_x	kg/h	98.04	4.08
CO	kg/h	13.82	0.46
$PM_{2.5}$	kg/h	1.74	0.26
VOC	kg/h	5.73	0.21

D.4.5 Overall Emissions Summary from Project Operation

Annual CACs emissions during Project operation are summarized in Table D.4-19.

Table D.4-19: Overall Operation Emissions

Source	Emissions (t/y)					
	SO_2	NO_X	CO	$PM_{2.5}$	H_2S	VOC
8 Gas Turbines	3.20	2,249	2,738	185	0.00	58.6
4 Incinerators	697	331	147	13.2	0.37	9.60
5 Flares	0.00	0.09	0.11	0.04	0.00	0.34
Total Land Based	**700**	**2,581**	**2,885**	**198**	**0.37**	**68.5**
LNG Carriers (berthing/loading)	16.1	179	28.6	5.50	0.00	13.7
Tugs (berthing/loading)	0.30	34.0	3.82	2.21	0.00	1.74
LNG Carriers (shipping inbound)	17.4	446	62.9	7.92	0.00	26.1
Tugs (shipping inbound)	0.16	18.6	2.08	1.20	0.00	0.95
LNG Carriers (shipping outbound)	17.4	446	62.9	7.92	0.00	26.1
Tugs (shipping outbound)	0.16	18.6	2.08	1.20	0.00	0.95
Total Marine Based	**51.6**	**1,143**	**162**	**26.0**	0.00	**69.5**
Total from Project Operation	**752**	**3,723**	**3,047**	**224**	**0.37**	**138**

D.5 Future Projects

Reasonable foreseeable future projects located in the regional study area include the Enbridge Northern Gateway project and Kitimat Clean refinery project. Air emissions from the Enbridge Northern Gateway project were obtained from previously published documents (Stantec 2010), and BC MOE provided detailed emission rates from the proposed Kitimat Clean refinery project (BC MOE 2014).

Emissions and emission parameters for these reasonably foreseeable future sources are summarized in Table D.5-1.

Table D.5-1: Reasonably Foreseeable Future Emissions and Emission Parameters Included in Plume Dispersion Modelling

Facility	Source		Location (UTM NAD83)				Stack Parameters				Emissions (g/s)					
	Description	Type	mE	mN	Zone	Base Elevation (m)	Height (m)	Diameter (m)	Exit Velocity (m/s)	Exit Temperature (K)	SO_2	NO_X	CO	$PM_{2.5}$	H_2S	VOCs
Enbridge Northern Gateway	Synthetic Oil Tanks 1	Volume Source	517787	5977722	9	186.4	18.3	73.80	-	-	0.000	0.000	0.000	0.000	0.000	0.075
	Synthetic Oil Tanks 2	Volume Source	518060	5977715	9	194.8	18.3	73.80	-	-	0.000	0.000	0.000	0.000	0.000	0.075
	Synthetic Oil Tanks 3	Volume Source	517967	5977780	9	198.4	18.3	73.80	-	-	0.000	0.000	0.000	0.000	0.000	0.075
	Synthetic Oil Tanks 4	Volume Source	517873	5977845	9	194.2	18.3	73.80	-	-	0.000	0.000	0.000	0.000	0.000	0.075
	Synthetic Oil Tanks 5	Volume Source	518189	5977836	9	201.5	18.3	73.80	-	-	0.000	0.000	0.000	0.000	0.000	0.075
	Synthetic Oil Tanks 6	Volume Source	518096	5977902	9	196.5	18.3	73.80	-	-	0.000	0.000	0.000	0.000	0.000	0.075
	Diluted Bitumen Tanks 1	Volume Source	518002	5977967	9	194.4	18.3	73.80	-	-	0.000	0.000	0.000	0.000	0.000	0.177
	Diluted Bitumen Tanks 2	Volume Source	517895	5978030	9	189.9	18.3	73.80	-	-	0.000	0.000	0.000	0.000	0.000	0.177
	Diluted Bitumen Tanks 3	Volume Source	517989	5977964	9	195.1	18.3	73.80	-	-	0.000	0.000	0.000	0.000	0.000	0.177
	Diluted Bitumen Tanks 4	Volume Source	518081	5977899	9	195.5	18.3	73.80	-	-	0.000	0.000	0.000	0.000	0.000	0.177
	Diluted Bitumen Tanks 5	Volume Source	518178	5977832	9	202.5	18.3	73.80	-	-	0.000	0.000	0.000	0.000	0.000	0.177
	Diluted Bitumen Tanks 6	Volume Source	517889	5977822	9	195.4	18.3	73.80	-	-	0.000	0.000	0.000	0.000	0.000	0.177
	Condensate Tanks 1	Volume Source	518366	5978152	9	198.5	18.3	73.80	-	-	0.000	0.000	0.000	0.000	0.000	0.157
	Condensate Tanks 2	Volume Source	518273	5978217	9	192.4	18.3	73.80	-	-	0.000	0.000	0.000	0.000	0.000	0.157
	Condensate Tanks 3	Volume Source	518179	5978283	9	185.9	18.3	73.80	-	-	0.000	0.000	0.000	0.000	0.000	0.157
	Condensate Tanks 4	Volume Source	518265	5978406	9	188.3	18.3	73.80	-	-	0.000	0.000	0.000	0.000	0.000	0.157
	VLCC Tanker	Point Source	519038	5977801	9	0.0	45.0	1.50	7.20	773	0.108	3.168	0.288	0.043	0.000	0.116
	Suezmax and Aframax Tankers	Point Source	518965	5977289	9	0.0	36.0	1.50	22.80	773	0.403	5.440	0.530	0.127	0.000	0.230
	Tug Boat 1	Point Source	519034	5977858	9	0.0	10.0	0.50	6.30	773	0.001	0.103	0.012	0.007	0.000	0.005
	Tug Boat 2	Point Source	518992	5977455	9	0.0	10.0	0.50	6.30	773	0.001	0.103	0.012	0.007	0.000	0.005
	Tug Boat 3	Point Source	518985	5977356	9	0.0	10.0	0.50	6.30	773	0.001	0.103	0.012	0.007	0.000	0.005
	Tug Boat 4	Point Source	518852	5976962	9	0.0	10.0	0.50	6.30	773	0.001	0.103	0.012	0.007	0.000	0.005
	Tug Boat 5	Point Source	519003	5977144	9	0.0	10.0	0.50	6.3	773	0.001	0.103	0.012	0.007	0.000	0.005
	Tug Boat 6	Point Source	519098	5977665	9	0.0	10.0	0.50	6.30	773	0.001	0.103	0.012	0.007	0.000	0.005
Enbridge Northern Gateway emissions totals (g/s)											1	9	0.887	0		2.517
Enbridge Northern Gateway emissions totals (t/y)											16.3	291	28.0	6.61		79.4
Kitimat Clean West Coast Refinery	Diluted Bitumen 1001	Volume Source	524366	6016492	524366	212.0	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.016
	Diluted Bitumen 1002	Volume Source	524384	6016365	524384	212.0	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.016
	Diluted Bitumen 1003	Volume Source	524366	6016185	524366	210.3	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.016
	Diluted Bitumen 1004	Volume Source	524330	6016040	524330	211.0	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.016
	Diluted Bitumen 1005	Volume Source	524330	6015824	524330	208.1	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.016

Facility	Source		Location (UTM NAD83)				Stack Parameters				Emissions (g/s)					
	Description	Type	mE	mN	Zone	Base Elevation (m)	Height (m)	Diameter (m)	Exit Velocity (m/s)	Exit Temperature (K)	SO_2	NO_X	CO	$PM_{2.5}$	H_2S	VOCs
	Diluted Bitumen 1006	Volume Source	524312	6015716	524312	208.0	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.016
	Asphalter Feed 1029	Volume Source	524312	6015517	524312	206.7	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.000
	Asphalter Feed 1030	Volume Source	524330	6015355	524330	206.0	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.000
	Asphalter Feed 1031	Volume Source	524312	6015156	524312	206.0	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.000
	Light Naphtha 2001	Volume Source	524294	6014994	524294	205.0	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.014
	Light Naphtha 2002	Volume Source	524276	6014813	524276	205.0	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.014
	Hydrocracker Naphtha 2003	Volume Source	524258	6014669	524258	205.0	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.014
	Hydrocracker Naphtha 2004	Volume Source	524240	6014470	524240	203.0	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.014
	Refomate 2005	Volume Source	524222	6014254	524222	201.6	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.003
	Refomate 2006	Volume Source	524204	6014073	524204	183.2	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.003
	Iso-Octane 2007	Volume Source	524204	6013929	524204	169.1	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.001
	Iso-Octane 2008	Volume Source	524222	6013748	524222	198.8	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.001
	Gasoline 2009	Volume Source	524240	6013604	524240	198.0	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.075
	Gasoline 2010	Volume Source	524168	6013423	524168	197.0	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.075
	Gasoline 2011	Volume Source	524168	6013189	524168	194.2	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.075
	Gasoline 2012	Volume Source	524637	6016510	524637	213.7	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.075
	Gasoline Day Tanks 2013	Volume Source	524637	6016311	524637	211.0	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.008
	Gasoline Day Tanks 2014	Volume Source	524655	6016113	524655	212.0	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.008
	DHT Kerosene 2020	Volume Source	524655	6015986	524655	210.4	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.004
	DHT Kerosene 2021	Volume Source	524637	6015824	524637	210.8	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.004
	DHT Kerosene 2022	Volume Source	524637	6015607	524637	209.0	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.004
	Hydrocraker Kero 2023	Volume Source	524637	6015445	524637	209.0	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.004
	Hydrocraker Kero 2024	Volume Source	524619	6015264	524619	208.6	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.004
	Hydrocraker Kero 2025	Volume Source	524619	6015030	524619	205.8	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.004
	DHT Diesel 2030	Volume Source	524601	6014831	524601	206.1	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.003
	DHT Diesel 2031	Volume Source	524601	6014705	524601	205.3	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.003
	DHT Diesel 2032	Volume Source	524619	6014542	524619	204.5	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.003
	Hydrocracker Diesel 2033	Volume Source	524601	6014272	524601	201.0	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.003
	Hydrocracker Diesel 2034	Volume Source	524583	6014055	524583	203.0	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.003

Facility	Source		Location (UTM NAD83)				Stack Parameters				Emissions (g/s)					
	Description	Type	mE	mN	Zone	Base Elevation (m)	Height (m)	Diameter (m)	Exit Velocity (m/s)	Exit Temperature (K)	SO_2	NO_X	CO	$PM_{2.5}$	H_2S	VOCs
	Hydrocracker Diesel 2035	Volume Source	524583	6013893	524583	201.0	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.003
	Diluent 3001	Volume Source	524547	6013676	524547	176.3	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.053
	Diluent 3002	Volume Source	524547	6013514	524547	182.4	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.053
	Diluent 3003	Volume Source	524583	6013333	524583	198.0	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.053
	Straight Run Napphtha 3004	Volume Source	524583	6013153	524583	197.0	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.026
	Straight Run Napphtha 3005	Volume Source	524998	6016546	524998	212.0	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.026
	Coker Naphtha 3006	Volume Source	524998	6016311	524998	211.0	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.026
	Coker Naphtha 3007	Volume Source	524998	6016113	524998	209.0	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.026
	Straight Run Distillate 3008	Volume Source	524980	6015986	524980	209.0	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.006
	Straight Run Distillate 3009	Volume Source	524980	6015770	524980	206.0	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.006
	Straight Run Distillate 3010	Volume Source	524980	6015625	524980	206.0	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.006
	Coker Distillate 3011	Volume Source	524944	6015463	524944	206.0	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.006
	Coker Distillate 3012	Volume Source	524980	6015300	524980	205.1	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.006
	Coker Distillate 3013	Volume Source	524980	6015156	524980	205.6	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.006
	Hydrocracker Feed 3014	Volume Source	524980	6014994	524980	205.8	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.001
	Hydrocracker Feed 3015	Volume Source	524926	6014849	524926	205.0	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.001
	Hydrocracker Feed 3016	Volume Source	524926	6014615	524926	201.8	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.001
	Hydrocracker Feed 3017	Volume Source	524944	6014434	524944	202.2	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.001
	Hydrocracker Feed 3018	Volume Source	524944	6014290	524944	203.4	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.001
	Hydrocracker Feed 3019	Volume Source	524926	6014109	524926	202.0	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.001
	Reformer Feed 3020	Volume Source	524926	6013965	524926	201.0	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.004
	Reformer Feed 3021	Volume Source	524962	6013802	524962	199.4	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.004
	Reformer Feed 3022	Volume Source	524962	6013640	524962	199.3	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.004
	Isom Feed 3023	Volume Source	524926	6013495	524926	199.0	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.021
	Isom Feed 3024	Volume Source	524926	6013333	524926	195.0	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.021
	Straight Run Slop 3025	Volume Source	524908	6013134	524908	196.1	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.065
	Straight Run Slop 3026	Volume Source	525323	6016510	525323	211.0	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.065
	Cracked Slop 3027	Volume Source	525323	6016347	525323	209.9	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.065
	Cracked Slop 3028	Volume Source	525323	6016149	525323	209.0	50.0	100.00	-	-	0.000	0.000	0.000	0.000	0.000	0.065

Facility	Source		Location (UTM NAD83)				Stack Parameters				Emissions (g/s)					
	Description	Type	mE	mN	Zone	Base Elevation (m)	Height (m)	Diameter (m)	Exit Velocity (m/s)	Exit Temperature (K)	SO_2	NO_X	CO	$PM_{2.5}$	H_2S	VOCs
	Crude Heater 21 - Train 1	Point Source	526821	6016780	526821	207.0	20.0	0.75	11.00	500	0.187	0.731	1.053	0.437	0.014	0.233
	Vacuum Heater 21 - Train 1	Point Source	526803	6016474	526803	205.8	20.0	0.75	11.00	500	0.167	0.656	0.944	0.394	0.012	0.210
	Stripper Reboiler - Train 1	Point Source	526749	6016076	526749	206.4	20.0	0.75	11.00	500	0.037	0.152	0.219	0.092	0.003	0.049
	HDS Heater 25 - Train 1	Point Source	526749	6015752	526749	205.0	20.0	0.75	11.00	500	0.009	0.081	0.043	0.017	0.000	0.009
	HDS Charge 24 - Train 1	Point Source	526731	6015463	526731	203.0	20.0	0.75	11.00	500	0.009	0.089	0.049	0.020	0.000	0.012
	HDS Reboiler 24 - Train 1	Point Source	526695	6015192	526695	203.0	20.0	0.75	11.00	500	0.040	0.155	0.224	0.092	0.003	0.049
	Hydrocracker Charge 23 - Train 1	Point Source	526749	6014903	526749	200.6	20.0	0.75	11.00	500	0.069	0.273	0.394	0.164	0.006	0.086
	Hydrocracker Frac 23 - Train 1	Point Source	527200	6016798	527200	199.0	20.0	0.75	11.00	500	0.210	0.820	1.182	0.492	0.014	0.262
	CCR Heater 28 - Train 1	Point Source	527182	6016492	527182	206.9	20.0	0.75	11.00	500	0.104	0.406	0.587	0.245	0.006	0.129
	CCR Reboiler 28 - Train 1	Point Source	527146	6016058	527146	206.0	20.0	0.75	11.00	500	0.006	0.058	0.032	0.012	0.000	0.006
	InAlk Heaters 29 - Train 1	Point Source	527146	6015752	527146	204.0	20.0	0.75	11.00	500	0.043	0.170	0.245	0.101	0.003	0.055
	InAlk Reboiler 29 - Train 1	Point Source	527128	6015445	527128	202.0	20.0	0.75	11.00	500	0.017	0.193	0.104	0.043	0.000	0.023
	Hydrogen Reformer 30 - Train 1	Point Source	527128	6015174	527128	202.0	20.0	0.75	11.00	500	0.337	1.318	1.896	0.791	0.029	0.423
	Crude Heater 21 - Train 2	Point Source	527669	6016780	527669	210.2	20.0	0.75	11.00	500	0.187	0.731	1.053	0.437	0.014	0.233
	Vacuum Heater 21 - Train 2	Point Source	527669	6016510	527669	200.3	20.0	0.75	11.00	500	0.167	0.656	0.944	0.394	0.012	0.210
	Stripper Reboiler - Train 2	Point Source	527669	6016167	527669	205.5	20.0	0.75	11.00	500	0.037	0.152	0.219	0.092	0.003	0.049
	HDS Heater 25 - Train 2	Point Source	527669	6015824	527669	203.0	20.0	0.75	11.00	500	0.009	0.081	0.043	0.017	0.000	0.009
	HDS Charge 24 - Train 2	Point Source	527687	6015463	527687	201.2	20.0	0.75	11.00	500	0.009	0.089	0.049	0.020	0.000	0.012
	HDS Reboiler 24 - Train 2	Point Source	527687	6015138	527687	200.8	20.0	0.75	11.00	500	0.040	0.155	0.224	0.092	0.003	0.049
	Hydrocracker Charge 23 - Train 2	Point Source	527651	6014795	527651	200.0	20.0	0.75	11.00	500	0.069	0.273	0.394	0.164	0.006	0.086
	Hydrocracker Frac 23 - Train 2	Point Source	528103	6016762	528103	205.6	20.0	0.75	11.00	500	0.210	0.820	1.182	0.492	0.014	0.262
	CCR Heater 28 - Train 2	Point Source	528121	6016456	528121	202.3	20.0	0.75	11.00	500	0.104	0.406	0.587	0.245	0.006	0.129
	CCR Reboiler 28 - Train 2	Point Source	528121	6016131	528121	203.8	20.0	0.75	11.00	500	0.006	0.058	0.032	0.012	0.000	0.006
	InAlk Heaters 29 - Train 2	Point Source	528085	6015788	528085	203.0	20.0	0.75	11.00	500	0.043	0.170	0.245	0.101	0.003	0.055
	InAlk Reboiler 29 - Train 2	Point Source	528085	6015427	528085	195.0	20.0	0.75	11.00	500	0.017	0.193	0.104	0.043	0.000	0.023
	Hydrogen Reformer 30 - Train 2	Point Source	528067	6015120	528067	197.9	20.0	0.75	11.00	500	0.337	1.318	1.896	0.791	0.029	0.423
	Backup Boiler #1	Point Source	528825	6016275	528825	208.4	20.0	0.75	11.00	500	0.014	1.280	0.851	0.319	0.014	0.170
	Backup Boiler #2	Point Source	528861	6015968	528861	210.0	20.0	0.75	11.00	500	0.014	1.280	0.851	0.319	0.014	0.170
	Backup Turbine #1	Point Source	528861	6015679	528861	203.7	20.0	0.75	11.00	500	0.009	0.190	0.342	0.181	0.009	0.066

Facility	Source		Location (UTM NAD83)				Stack Parameters				Emissions (g/s)					
	Description	Type	mE	mN	Zone	Base Elevation (m)	Height (m)	Diameter (m)	Exit Velocity (m/s)	Exit Temperature (K)	SO_2	NO_X	CO	$PM_{2.5}$	H_2S	VOCs
	Backup Turbine #2	Point Source	528843	6015355	528843	205.0	20.0	0.75	11.00	500	0.009	0.190	0.342	0.181	0.009	0.066
	SRU Thermal Converter #1	Point Source	528843	6015048	528843	204.0	20.0	0.75	11.00	500	12.565	0.362	0.242	0.000	0.242	0.000
	SRU Thermal Converter #2	Point Source	528879	6014669	528879	197.8	20.0	0.75	11.00	500	12.565	0.362	0.242	0.000	0.242	0.000
	Train 1 Crude Flare	Point Source	529312	6016293	529312	213.0	50.0	0.75	20.00	500	0.000	0.017	0.089	0.000	0.000	0.017
	Train 1 Conversion Flare	Point Source	529258	6015968	529258	210.5	50.0	0.75	20.00	500	0.000	0.017	0.089	0.000	0.000	0.017
	Train 2 Crude Flare	Point Source	529294	6015679	529294	209.3	50.0	0.75	20.00	500	0.000	0.017	0.089	0.000	0.000	0.017
	Train 2 Conversion Flare	Point Source	529276	6015318	529276	207.0	50.0	0.75	20.00	500	0.000	0.017	0.089	0.000	0.000	0.017
	Waste Water Thermal Converter	Point Source	529312	6014994	529312	200.0	20.0	0.75	11.00	500	0.000	0.003	0.003	0.000	0.000	1.933
Kitimat Clean West Coast Refinery emissions totals (g/s)											28	14	17	6.8	0.7	6.7
Kitimat Clean West Coast Refinery emissions totals (t/y)											872	440	541	214	22.3	211

NOTE:
- – not applicable

D.6 References

British Columbia Ministry of Environment (BC MOE). 2008. Guidelines for Air Quality Dispersion Modelling in British Columbia. March 2008.

British Columbia Ministry of Environment (BC MOE). 2014. *Kitimat Clean Refinery Background Information*. February 2014.

Canadian Council of Ministers of the Environment (CCME). 1992. National Emission Guidelines for Stationary Combustion Turbines. December 1992.

Environment Canada. 2002. Sulphur in Diesel Fuel Regulations, SOR/2002-253. July 2002

ICF International (ICF). 2009. *Current Methodologies in Preparing Mobile Source Port-Related Emission Inventories, Final Report*. April 2009.

Kitimat LNG 2008. *Kitimat LNG Terminal Revised Project Description*. October 2008.

MARPOL. 2008. International Convention for the Prevention of Pollution from Ships. Annex VI. North American Emission Control Area. September 2008.

Rio Tinto Alcan (RTA). 2013. RTA S*ulphur Dioxide Techincal Assessment Report in Support of the 2013 Application to Amend the P2-00001 Multimedia Permit – Kitimat Modernization Project*. February 2013.

Stantec Consulting Ltd. (Stantec). 2010. *Stantec Atmospheric Environment Techinical Data Report for Enbridge Northern Gateway Project*. May 2010.

U.S. EPA, 1995. *AP 42, Compilation of Air Pollutant Emission Factors. Volume 1: Stationary Point and Area Sources, Fifth Edition*. U.S. Environmental Protection Agency. January 1995. http://www.epa.gov/ttn/chief/ap42/

U.S. Environmental Protection Agency (US EPA). 2004a. *Exhaust and Crankcase Emission Factors for Nonroad Engine Modeling- Compression-Ignition*. April 2004. Available at: http://www.epa.gov/OMS/models /nonrdmdl/nonrdmdl2004/420p04009.pdf

U.S. Environmental Protection Agency (US EPA). 2004b. *Final Regulatory Analysis: Control of Emissions from Nonroad Diesel Engines*. May 2004. Available at: http://www.epa.gov/nonroad-diesel/2004fr/420r04007.pdf

US Environmental Protection Agency (US EPA). 2010a. *Median Life, Annual Activity, and Load Factor Values for Nonroad Engine Emissions Modeling*. Available at: http://www.epa.gov/oms/models/nonrdmdl/nonrdmdl2010/420r10016.pdf

US Environmental Protection Agency (US EPA). 2010b. *Conversion Factors for Hydrocarbon Emission Components*. Available at: http://www.epa.gov/otaq/models/nonrdmdl/nonrdmdl2010/420r10015.pdf

APPENDIX E

CALMET

TABLE OF CONTENTS

List of Tables

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E.1 Introduction

This appendix provides technical details of the CALMET meteorological model, which was used as part of the CALPUFF dispersion modelling system for the proposed LNG Canada Export Terminal (the Project). An overview of CALMET predictions for the assessment area is also provided.

Meteorology determines the transport and dispersion of industrial emissions; consequently, it plays a significant role in determining air quality downwind of emission sources. For this air quality assessment, meteorological data for a three-year period (January 1, 2008 to December 31, 2010) were used to define transport and dispersion parameters. The selection of a three-year period is consistent with the *Guidelines for Air Quality Dispersion Modelling in British Columbia* (BC MOE 2008), which require data for at least a one-year period when using data from a meteorological model.

Meteorological characteristics vary with time (e.g., season and time of day) and location (e.g., elevation, terrain exposure, and land cover). Historically, meteorological data measured at one location have been applied via extrapolation to represent conditions over the full model domain. For large model domains, this approach fails to recognize that meteorological conditions for any given hour can vary from one location to another because of terrain and geophysical differences. Curvilinear airflow can also result from meso-scale and synoptic-scale weather effects.

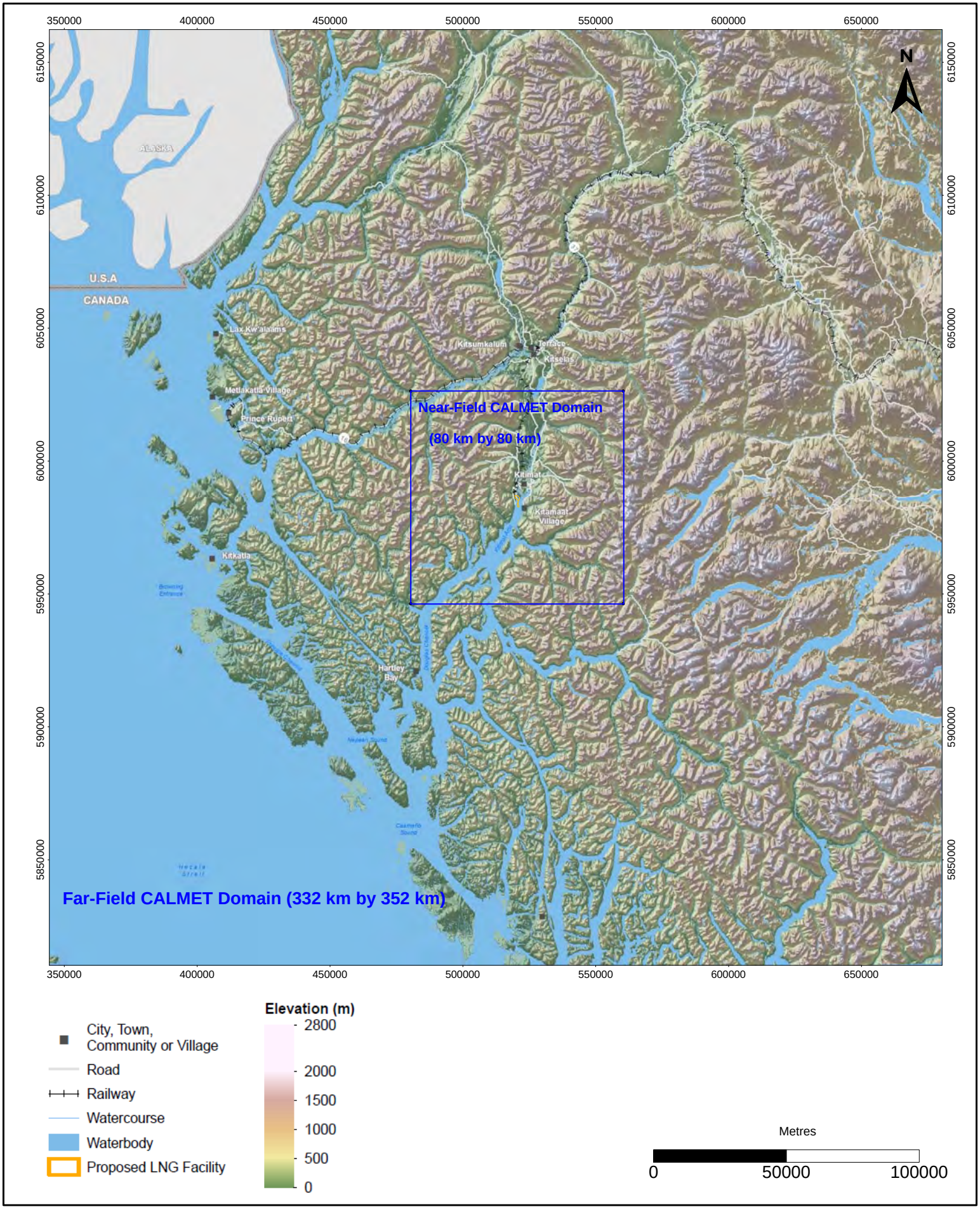
More recently, meteorological models have been used to provide spatially and temporally varying wind and temperature fields across the model domain to overcome the limitations associated with use of single-station measurements. For this assessment, the CALMET meteorological pre-processing program was used to provide temporally and spatially varying meteorological parameters as required by the CALPUFF model.

E.2 Model Domain

E.2.1 Boundaries

Two CALMET model domains were adopted for this assessment: the far-field and near-field domains. Figure E.2-1 shows both model domains.

The far-field model domain extends from approximately 52.4208° N to 55.5733° N, resulting in a north-south extent of 352 km, and from 131.2888° W to 126.1391° W, resulting in an east-west extent of 332 km (Figure E.2-1). The far-field domain covers an area of 116,864 square kilometres (km^2) (Table E.2-1). The meteorological grid spacing is 4 km, resulting in 84 grid points in the X direction and 88 grid points in the Y direction.



Stantec	LNG CANADA Opportunity for British Columbia. Energy for the world	*AIR QUALITY TECHNICAL DATA REPORT* Terrain in the Far-Field and Near-Field Model Domains LNG CANADA EXPORT TERMINAL KITIMAT, BRITISH COLUMBIA	PROJECTION: UTM9	DRAWN BY: YS
			DATUM: NAD 83	CHECKED BY: JG
			DATE: 3-APR-14	FIGURE NO.: E.2-1

Table E.2-1: Coordinates of the Far-Field CALMET Domain (332 km by 352 km)

Domain Corner	Location (UTM NAD 83, Zone 9)	
	East (m)	North (m)
Southwest	344360	5810310
Northwest	344360	6162310
Northeast	680360	6162310
Southeast	680360	5810310

For assessment of Project effects in the regional study area (RSA), a finer meteorological grid is required. The near-field model domain is defined as an 80 km by 80 km area, centred on the LNG facility. The near-field domain has grid spacing of 500 m, resulting in 160 grid points in the X direction and 160 grid points in the Y direction. The near-field domain covers an area of 6,400 km^2 (Table E.2-2).

Table E.2-2: Coordinates of the Near-Field CALMET Domain (80 km by 80 km)

Domain Corner	Location (UTM NAD 83, Zone 9)	
	East (m)	North (m)
Southwest	480360	5946310
Northwest	480360	6026310
Northeast	560360	6026310
Southeast	560360	5946310

The near-field domain includes the communities of Kitimat and Kitamaat Village near the centre of the domain and extends north to Lakelse Lake and south to cover Kitimat Arm and part of Douglas Channel. The far-field domain includes Smithers to the east and the Prince Rupert area to the west.

E.2.2 Topography

The valleys and elevated terrain features in the meteorological domain can affect surface wind flow patterns. The terrain data used to define these features were obtained from Canadian Digital Elevation Data (CDED; GeoBase 2013). The source data for CDED at scales of 1:50,000 (~30 m horizontal resolution) and 1:250,000 (~90 m horizontal resolution) were extracted from the hypsographic and hydrographic elements of the National Topographic Data Base and from various scaled positional data acquired from the provinces and territories. The 1:50,000 scale dataset does not cover the western portion of the far-field model domain. Therefore, 1:50,000 and 1:250,000 scale datasets were applied in the near-field CALMET model run and far-field CALMET model run, respectively.

Terrain in the near-field domain is shown in Figure E.2-2. In the middle portion of the far-field and near-field domains, a predominantly flat valley more than 5 km wide connects Kitimat to Terrace, 60 km to the north.

Major water features in the near-field domain include:

- **Douglas Channel** is located in the south and southwest portions of the domain.
- **Kitimat Arm** and **Minette Bay** are located in the middle portion of the domain.
- **Kitimat River** is located in the north portion of the domain. It flows from the mountains south of Terrace into Douglas Channel.
- **Lakelse Lake** is located in the northern portion of the domain.

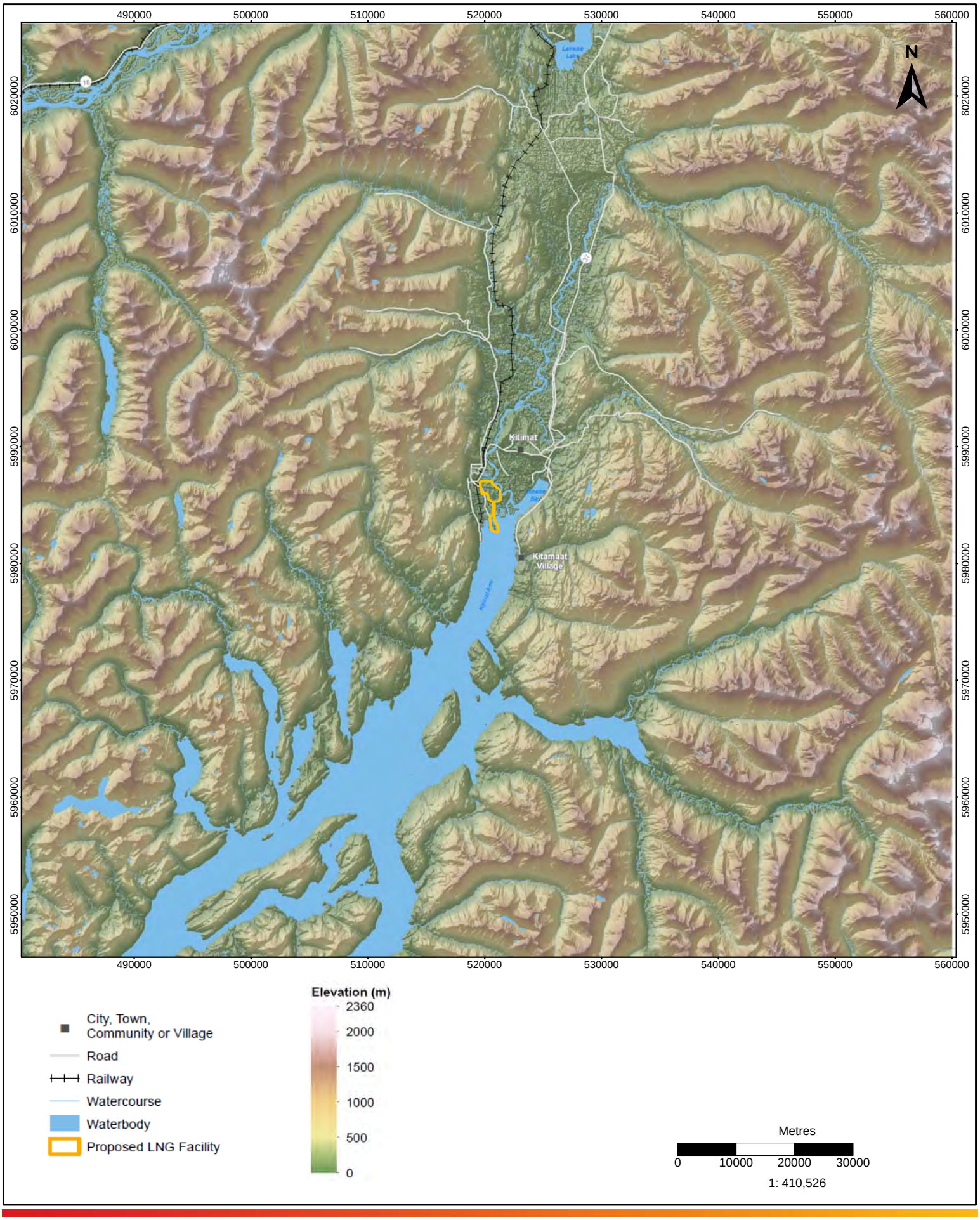
Broadly speaking, the higher elevations are towards the west and east portions of the near-field domain and the lowest elevations are near the middle and southwest portions of the domain. Major elevated features in the near-field domain include:

- **Kitimat Ranges** rise behind Kitimat and across the entire near-field domain. The Kitimat Ranges comprise one of the three main subdivisions of the Coast Mountains in British Columbia (BC).
- **Mount Holt**, **Mount Temple**, and **Mount Light** are located in the northwestern portion of the near-field domain and rise to an elevation of over 1,650 m above mean sea level (asl).

These terrain features can influence the transport and dispersion of air emissions as they are transported by the wind from their source locations.

E.2.3 Land-Cover Types

In addition to terrain elevation data, the CALMET model uses surface parameters such as surface roughness length, albedo, Bowen ratio, leaf area index (LAI), soil heat flux, and anthropogenic heat flux to provide input to important subroutines which, in turn, estimate parameters such as surface heat flux and mechanical turbulence.



Stantec	LNG CANADA Opportunity for British Columbia. Energy for the world	*AIR QUALITY TECHNICAL DATA REPORT* **Terrain in the Near-Field CALMET Model Domain (80 km by 80 km)** LNG CANADA EXPORT TERMINAL KITIMAT, BRITISH COLUMBIA	PROJECTION: UTM9 DATUM: NAD 83 DATE: 3-APR-14	DRAWN BY: YS CHECKED BY: JG FIGURE NO.: E.2-2

For this assessment, the North American land-cover dataset (CEC 2010) was used to initialize land-use categories in the CALMET model. The 2005 North American land-cover dataset was produced as part of the North American Land Change Monitoring System (NALCMS), a trilateral effort between the Canada Centre for Remote Sensing, the United States Geological Survey, and three Mexican organizations, including the National Institute of Statistics and Geography, National Commission for the Knowledge and Use of the Biodiversity, and the National Forestry Commission of Mexico. The 2005 North American land-cover dataset is at a resolution of 250 m. This land-cover information was then converted into the fractional land-use format accepted by the CALMET MAKEGEO pre-processor. This conversion was accomplished by mapping the dominant NALCMS land-cover category for each 500 m grid cell into one of the land-cover categories typically used in the CALMET model. Tables E.2-3 to E.2-6 list the seasonal values for surface roughness (z_0), albedo, Bowen ratio, soil heat flux, anthropogenic heat flux, and LAI, defined according to the BC MOE Guidelines (BC MOE 2008) and the CALMET User's Guide (Scire et al. 2000).

Land-use in the CALMET domain is mixed. Figures E.2-3a and E.2-3b show the land-cover data on a 4 km resolution basis and 500 m resolution basis, respectively. Based on the 500 m grid resolution data, the near-field domain comprises 56.4% evergreen forest, 10.1% shrub rangeland, 7.8% barren land, 7% deciduous forest, 5.9% water, 5.2% perennial snow or ice, 3% mixed forest, 2.7% rangeland, 1.1% tundra and 0.6% wetland.

Table E.2-3: Land-use Characterization and Associated Geophysical Parameters for the Winter Season (November to March)

NALCMS Code	Surface Roughness (m)	Albedo	Bowen Ratio	Soil Heat Flux (fraction)	Anthropogenic Heat Flux (W/m^2)	Leaf Area Index	CALMET Code	CALMET Land Cover Type
1	1.3	0.35	1.5	0.15	0	7.0	42	Evergreen Forest Land
2	1.3	0.35	1.5	0.15	0	7.0	42	Evergreen Forest Land
3	1.3	0.35	1.5	0.15	0	7.0	42	Evergreen Forest Land
4	0.5	0.5	1.5	0.15	0	7.0	41	Deciduous Forest Land
5	0.5	0.5	1.5	0.15	0	7.0	41	Deciduous Forest Land
6	1.0	0.1	1.0	0.15	0	7.0	43	Mixed Forest Land
7	0.05	0.25	1.0	0.15	0	0.5	32	Shrub Rangeland
8	0.05	0.25	1.0	0.15	0	0.5	32	Shrub Rangeland
9	0.001	0.6	1.5	0.15	0	0.5	30	Rangeland
10	0.001	0.6	1.5	0.15	0	0.5	30	Rangeland
11	0.2	0.3	0.5	0.15	0	0.0	80	Tundra
12	0.2	0.3	0.5	0.15	0	0.0	80	Tundra
13	0.2	0.3	0.5	0.15	0	0.0	80	Tundra
14	0.05	0.3	1.5	0.25	0	2.0	60	Wet Land
15	0.01	0.6	1.5	0.15	0	3.0	20	Agricultural Land
16	0.15	0.45	6.0	0.15	0	0.05	70	Barren Land
17	1.0	0.35	1.5	0.25	0	0.2	10	Urban or Build-up
18	0.0001	0.2	1.5	1.00	0	0.0	50	Water
19	0.2	0.7	0.5	0.15	0	0.0	90	Snow or Ice

NOTES:
W/m^2 = watts per square metre.

Table E.2-4: Land-use Characterization and Associated Geophysical Parameters for the Spring Season (April and May)

NALCMS Code	Surface Roughness (m)	Albedo	Bowen Ratio	Soil Heat Flux (fraction)	Anthropogenic Heat Flux (W/m^2)	Leaf Area Index	CALMET Code	CALMET Land Cover Type
1	1.3	0.12	0.7	0.15	0	7.0	42	Evergreen Forest Land
2	1.3	0.12	0.7	0.15	0	7.0	42	Evergreen Forest Land
3	1.3	0.12	0.7	0.15	0	7.0	42	Evergreen Forest Land
4	1.0	0.12	0.7	0.15	0	7.0	41	Deciduous Forest Land
5	1.0	0.12	0.7	0.15	0	7.0	41	Deciduous Forest Land
6	1.0	0.10	1.0	0.15	0	7.0	43	Mixed Forest Land
7	0.05	0.25	1.0	0.15	0	0.5	32	Shrub Rangeland
8	0.05	0.25	1.0	0.15	0	0.5	32	Shrub Rangeland
9	0.05	0.18	0.4	0.15	0	0.5	30	Rangeland
10	0.05	0.18	0.4	0.15	0	0.5	30	Rangeland
11	0.2	0.30	0.5	0.15	0	0.0	80	Tundra
12	0.2	0.30	0.5	0.15	0	0.0	80	Tundra
13	0.2	0.30	0.5	0.15	0	0.0	80	Tundra
14	0.2	0.12	0.1	0.25	0	2.0	60	Wet Land
15	0.03	0.14	0.3	0.15	0	3.0	20	Agricultural Land
16	0.3	0.30	3.0	0.15	0	0.05	70	Barren Land
17	1.0	0.14	1.0	0.25	0	0.20	10	Urban or Build-up
18	0.0001	0.12	0.1	1.00	0	0.0	50	Water
19	0.2	0.70	0.5	0.15	0	0.0	90	Snow or Ice

NOTES:
W/m^2 = watts per square metre.

Table E.2-5: Land-use Characterization and Associated Geophysical Parameters for the Summer Season (June to August)

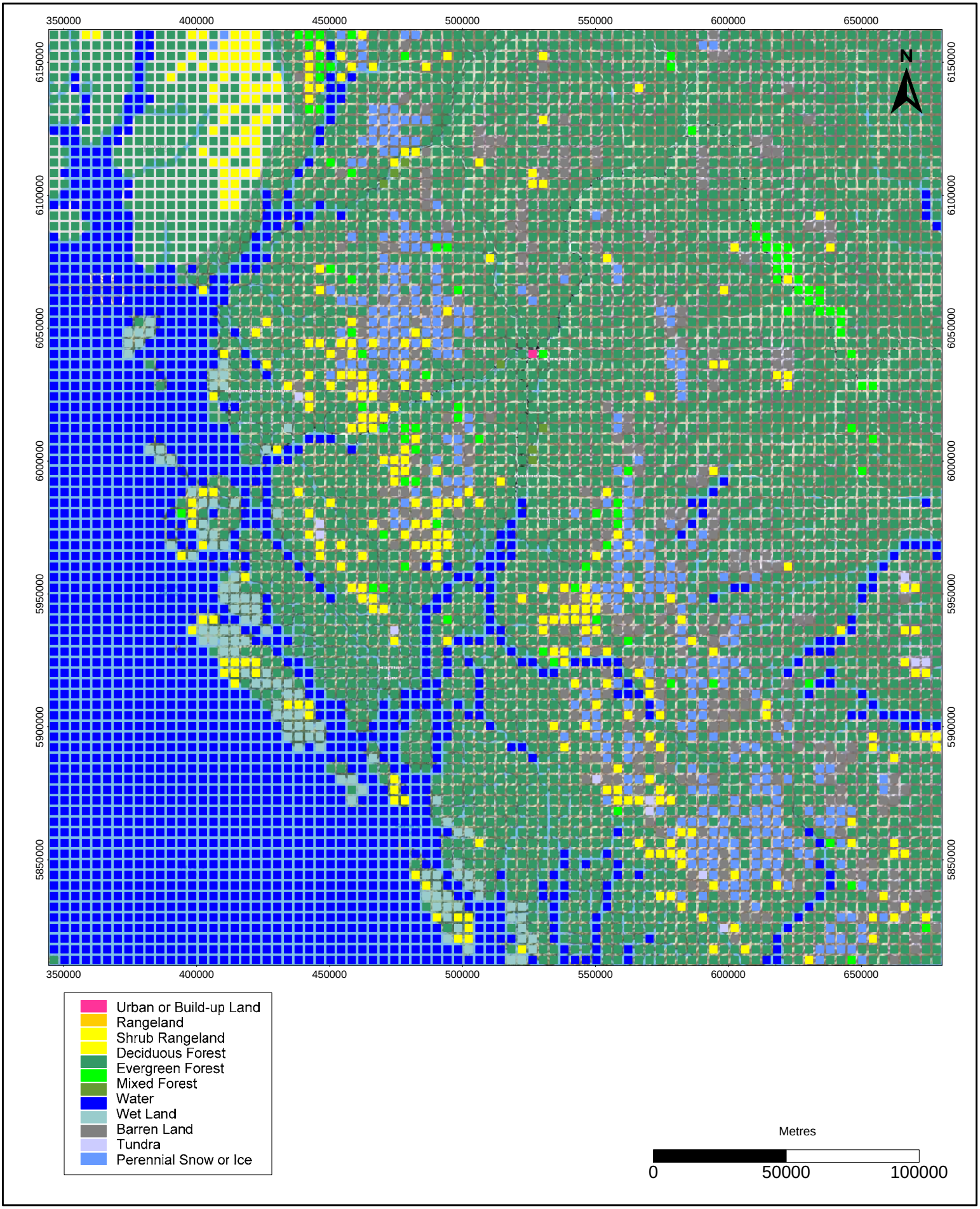
NALCMS Code	Surface Roughness (m)	Albedo	Bowen Ratio	Soil Heat Flux (fraction)	Anthropogenic Heat Flux (W/m^2)	Leaf Area Index	CALMET Code	CALMET Land Cover Type
1	1.3	0.12	0.3	0.15	0	7.0	42	Evergreen Forest Land
2	1.3	0.12	0.3	0.15	0	7.0	42	Evergreen Forest Land
3	1.3	0.12	0.3	0.15	0	7.0	42	Evergreen Forest Land
4	1.3	0.12	0.3	0.15	0	7.0	41	Deciduous Forest Land
5	1.3	0.12	0.3	0.15	0	7.0	41	Deciduous Forest Land
6	1.0	0.10	1.0	0.15	0	7.0	43	Mixed Forest Land
7	0.05	0.25	1.0	0.15	0	0.5	32	Shrub Rangeland
8	0.05	0.25	1.0	0.15	0	0.5	32	Shrub Rangeland
9	0.1	0.18	0.8	0.15	0	0.5	30	Rangeland
10	0.1	0.18	0.8	0.15	0	0.5	30	Rangeland
11	0.2	0.30	0.5	0.15	0	0.0	80	Tundra
12	0.2	0.30	0.5	0.15	0	0.0	80	Tundra
13	0.2	0.30	0.5	0.15	0	0.0	80	Tundra
14	0.2	0.14	0.1	0.25	0	2.0	60	Wet Land
15	0.2	0.20	0.5	0.15	0	3.0	20	Agricultural Land
16	0.3	0.28	4.0	0.15	0	0.05	70	Barren Land
17	1.0	0.16	2.0	0.25	0	0.2	10	Urban or Build-up
18	0.0001	0.10	0.1	100	0	0.0	50	Water
19	0.2	0.70	0.5	0.15	0	0.0	90	Snow or Ice

NOTES:
W/m^2 = watts per square metre.

Table E.2-6: Land-use Characterization and Associated Geophysical Parameters for the Fall Season (September and October)

NALCMS Code	Surface Roughness (m)	Albedo	Bowen Ratio	Soil Heat Flux (fraction)	Anthropogenic Heat Flux (W/m^2)	Leaf Area Index	CALMET Code	CALMET Land Cover Type
1	1.3	0.12	0.8	0.15	0	7.0	42	Evergreen Forest Land
2	1.3	0.12	0.8	0.15	0	7.0	42	Evergreen Forest Land
3	1.3	0.12	0.8	0.15	0	7.0	42	Evergreen Forest Land
4	0.8	0.12	1.0	0.15	0	7.0	41	Deciduous Forest Land
5	0.8	0.12	1.0	0.15	0	7.0	41	Deciduous Forest Land
6	1.0	0.10	1.0	0.15	0	7.0	43	Mixed Forest Land
7	0.05	0.25	1.0	0.15	0	0.5	32	Shrub Rangeland
8	0.05	0.25	1.0	0.15	0	0.5	32	Shrub Rangeland
9	0.01	0.20	1.0	0.15	0	0.5	30	Rangeland
10	0.01	0.20	1.0	0.15	0	0.5	30	Rangeland
11	0.2	0.30	0.5	0.15	0	0.0	80	Tundra
12	0.2	0.30	0.5	0.15	0	0.0	80	Tundra
13	0.2	0.30	0.5	0.15	0	0.0	80	Tundra
14	0.2	0.16	0.1	0.25	0	2.0	60	Wet Land
15	0.05	0.18	0.7	0.15	0	3.0	20	Agricultural Land
16	0.3	0.28	6.0	0.15	0	0.05	70	Barren Land
17	1.0	0.18	2.0	0.25	0	0.2	10	Urban or Build-up
18	0.0001	0.14	0.1	1.00	0	0.0	50	Water
19	0.2	0.70	0.5	0.15	0	0.0	90	Snow or Ice

NOTES:
W/m^2 = watts per square metre.



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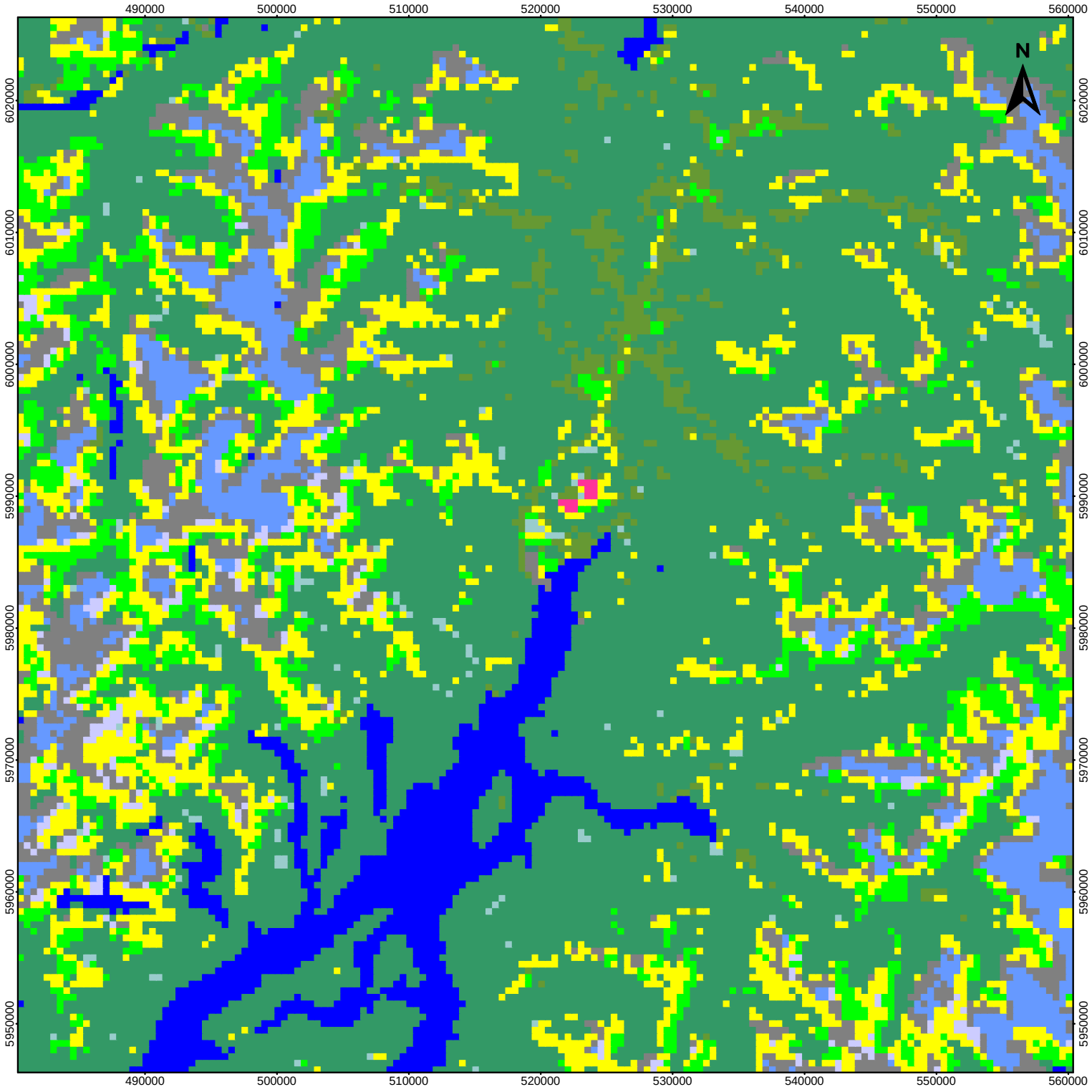
AIR QUALITY TECHNICAL DATA REPORT

Land-Cover Classes (4 km resolution) within Far-Field CALMET Model Domain

LNG CANADA EXPORT TERMINAL
KITIMAT, BRITISH COLUMBIA

PROJECTION	DRAWN BY
UTM9	YS
DATUM	CHECKED BY
NAD 83	JG
DATE	FIGURE NO.
3-APR-14	E.2-3a



- Urban or Build-up Land
- Rangeland
- Shrub Rangeland
- Deciduous Forest
- Evergreen Forest
- Mixed Forest
- Water
- Wet Land
- Barren Land
- Tundra
- Perennial Snow or Ice

Metres

0 5000 10000 15000

1: 410,526

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LNG CANADA
Opportunity for British Columbia. Energy for the world

AIR QUALITY TECHNICAL DATA REPORT

Land-Cover Classes (500 m resolution) within Near-Field CALMET Model Domain

LNG CANADA EXPORT TERMINAL
KITIMAT, BRITISH COLUMBIA

PROJECTION: UTM9	DRAWN BY: YS
DATUM: NAD 83	CHECKED BY: JG
DATE: 3-APR-14	FIGURE NO.: E.2-3b

E.2.4 Meteorological Stations

The CALMET meteorological dataset was developed for the years 2008, 2009, and 2010 using a prognostic weather model (see Section E.4), surface weather station observations, and Fisheries and Oceans Canada (DFO) buoy station observations.

Surface Meteorological Stations

The locations of the surface meteorological stations in the domain are summarized in Table E.2-7 and shown in Figure E.2-4. These stations include:

- Environment Canada (EC) airports: Terrace Airport, Prince Rupert Airport, and Smithers Airport (Environment Canada 2014).
- Other EC stations: Holland Rock, Grey Islet (automated), Bonilla Island (automated), and Lucy Island Lightstation. For the most part, the meteorological measurements at these stations are limited to dry bulb temperature, wind speed, and wind direction.
- BC Ministry of Environment (BC MOE) monitoring stations: Kitimat Whitesail, Kitimat Haul Road, Kitimat Eurocan Dock, Terrace Access Centre, Telkwa, Smithers St. Josephs, and New Hazelton School.

Although there are a number of locations where meteorological measurements are taken, the spatial coverage is not uniform across the domain. There are only four stations located in the 80 km by 80 km near-field domain. The nearest meteorological station to the Project is Kitimat Haul Road, which is less than 1 km from the Project site.

Buoy Meteorological Stations

The locations of the buoy meteorological stations in the domain are summarized in Table E.2-7 and shown in Figure E.2-4. These stations include:

- Fisheries and Oceans Canada (DFO) buoy stations Nanakwa Shoal and North Hecate Strait. Data from these two stations were included in the CALMET dataset. No adjustments were made.

Table E.2-7: Coordinates of Meteorological Surface Stations in the Model Domain

Source	Station Name	Latitude (degree N)	Longitude (degree W)	Elevation (m asl)	UTM NAD 83		
					km East	km North	Zone
MOE	Terrace Access Centre	54.5183	-128.5975	510	526.055	6041.265	9
MOE	Telkwa	54.6911	-127.0547	80	625.384	6062.156	9
BC MOE	Smithers St Josephs	54.7830	-127.1775	481	617.204	6072.167	9
BC MOE	New Hazelton School	55.2452	-127.5861	321	589.890	6122.989	9
BC MOE	Kitimat Whitesail	54.0675	-128.6402	119	523.547	5991.092	9
BC MOE	Kitimat Haul Road	54.0297	-128.7016	2	519.546	5986.867	9
BC MOE	Kitimat Eurocan Dock	53.9933	-128.6767	0	521.197	5982.823	9
EC	Holland Rock	54.1725	-130.3608	5	411.170	6003.570	9
	Prince Rupert AWOS	54.2861	-130.4447	35	405.953	6016.318	9
BC MOE	Kitwanga School	55.1172	-128.0158	253	562.773	6108.276	9
	Houston Firehall	54.3972	-126.6450	594	652.882	6030.271	9
EC	Smithers Airport	54.8247	-127.1828	522	616.743	6076.862	9
	Terrace Airport	54.4664	-128.5775	217	527.384	6035.497	9
	Grey Islet (automated)	54.5803	-130.6978	8	390.267	6049.409	9
	Bonilla Island (automated)	53.5000	-130.6333	15	391.661	5929.135	9
	Lucy Island Lightstation	54.3585	-130.7289	26	387.655	6024.787	9
DFO	Nanakwa Shoal Buoy	53.8333	-128.8317	0	511.078	5964.992	9
	North Hecate Strait Buoy	53.6167	-131.1050	0	360.763	5942.933	9

Stantec	LNG CANADA Opportunity for British Columbia. Energy for the world	*AIR QUALITY TECHNICAL DATA REPORT* **Surface Meteorological Stations in the CALMET Model Domains** LNG CANADA EXPORT TERMINAL KITIMAT, BRITISH COLUMBIA	PROJECTION: UTM9 / DRAWN BY: YS DATUM: NAD 83 / CHECKED BY: JG DATE: 3-APR-14 / FIGURE NO.: E.2-4	

Upper Air Stations

Two upper air stations exist in the far-field model domain (outside the near-field domain), located near the western and eastern boundaries of the domain: Annette Island, Alaska (55.03° N and 131.57° W), and Port Hardy, BC (50.683 N° and 127.367° W). However, these stations have significant data gaps (up to 50%) for the time period included in the modelling. Although CALMET allows missing values of wind speed, wind direction, and temperature at intermediate vertical levels and will fill in missing data by assuming a straight-line interpolation between valid levels, the *CALPUFF Modeling System Version 6 User Instructions* (TRC 2011) indicate that whenever this assumption is questionable, the upper air data should not be used with the model. Therefore, due to the amount of missing data, upper air data from these stations were not used in this assessment.

E.3 Meteorological Measurements

Meteorological data from observing stations in the model domain were used to characterize the existing climate. Selected parameters were reviewed to evaluate whether meteorological data from 2008 to 2010 were representative of long-term means. Section 4.2.1 of the Air Quality Technical Data Report summarizes regional temperature and precipitation data. Appendix A provides climate normals from Environment Canada for the 1981 to 2010 period for Kitimat Townsite, Kitimat 2, and Terrace Airport stations. Information on visibility and wind are provided below.

E.3.1 Visibility

Figure E.3-1 shows the mean number of hours for each month from 1981 to 2010 when reported visibility was less than 1 km and when visibility was between 1 km and 9 km. Visibility is recorded at the Terrace Airport. Reduced visibility at Terrace was most common during the fall and winter months and least common during the summer.

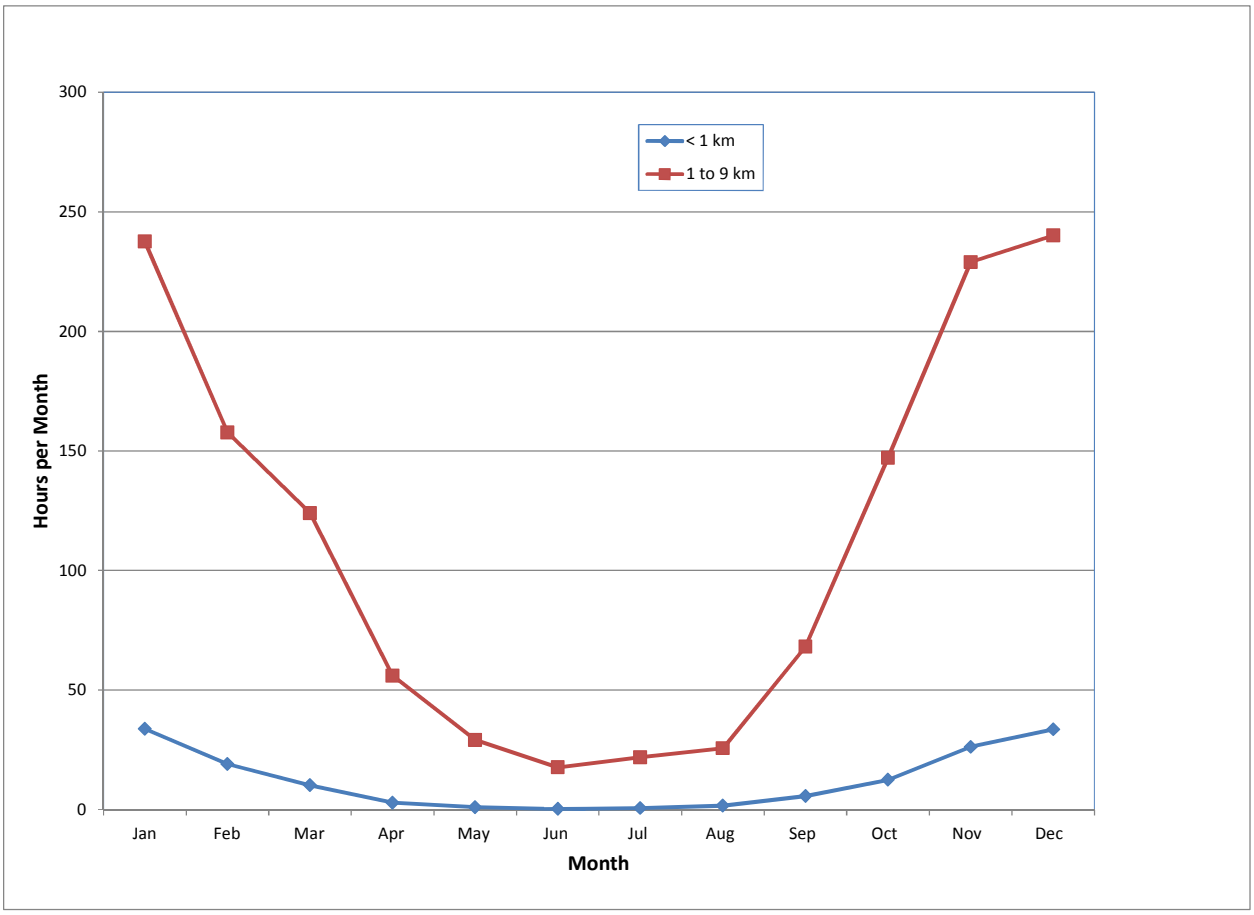


Figure E.3-1: Mean Number of Hours per Month with Reduced Visibility at Terrace Airport (1981 to 2010)

E.3.2 Surface Winds

Wind speed and direction are measured at Environment Canada meteorological stations and some BC MOE stations. Wind data are commonly displayed using a “wind rose,” which is a histogram plotted in polar coordinates. The histogram is comprised of 16 bars whose lengths represent the frequency that the wind blows from one of the 16 cardinal compass points (e.g., N, NNE, NE). The bar is segmented to represent different wind speed classes. To characterize wind conditions in the model domain, wind roses were prepared from data collected at various monitoring locations in the domain.

E.3.2.1 Wind Direction

Figure E.3-2 shows wind roses for three BC MOE surface stations in Kitimat (Kitimat Haul Road, Kitimat Whitesail, and Kitimat Eurocan Dock) for the three-year period 2008 to 2010. The prevailing wind direction at the Kitimat Haul Road station is from the southeast, whereas winds at the Whitesail and Eurocan Dock stations exhibit a more north-south orientation. These differences are likely attributable to the local topography near each of the stations. For instance, winds at the Kitimat Whitesail station are influenced by proximity to the Kitimat River valley, which has a north-south orientation.

Figure E.3-3 shows wind roses from two stations in Terrace (Terrace Airport and Terrace Access Centre). Prevailing winds at Terrace Airport are oriented north-south along the Lakelse valley, whereas at the Terrace Access Centre winds show more directional variety, likely due to greater influence of the Skeena River valley.

In addition to terrain influences, observed winds can be influenced by the presence and orientation of nearby tree canopies. Therefore, wind information from the location where it was measured may not reflect conditions at another nearby location. Winds at the Project site are expected to be strongly influenced by local topography and land cover.

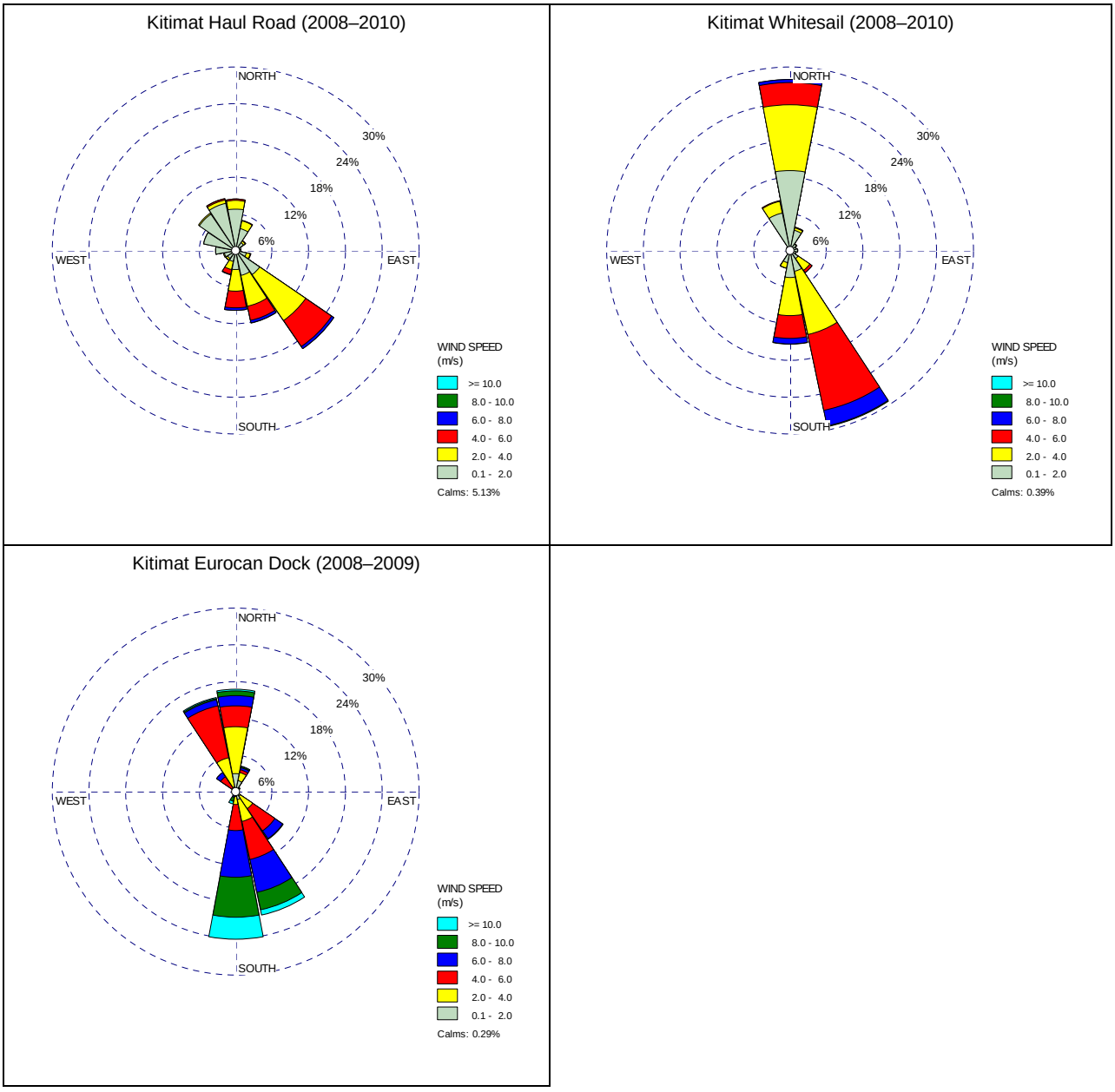


Figure E.3-2: Wind Roses for Three Meteorological Stations in the Kitimat Area (2008 to 2010)

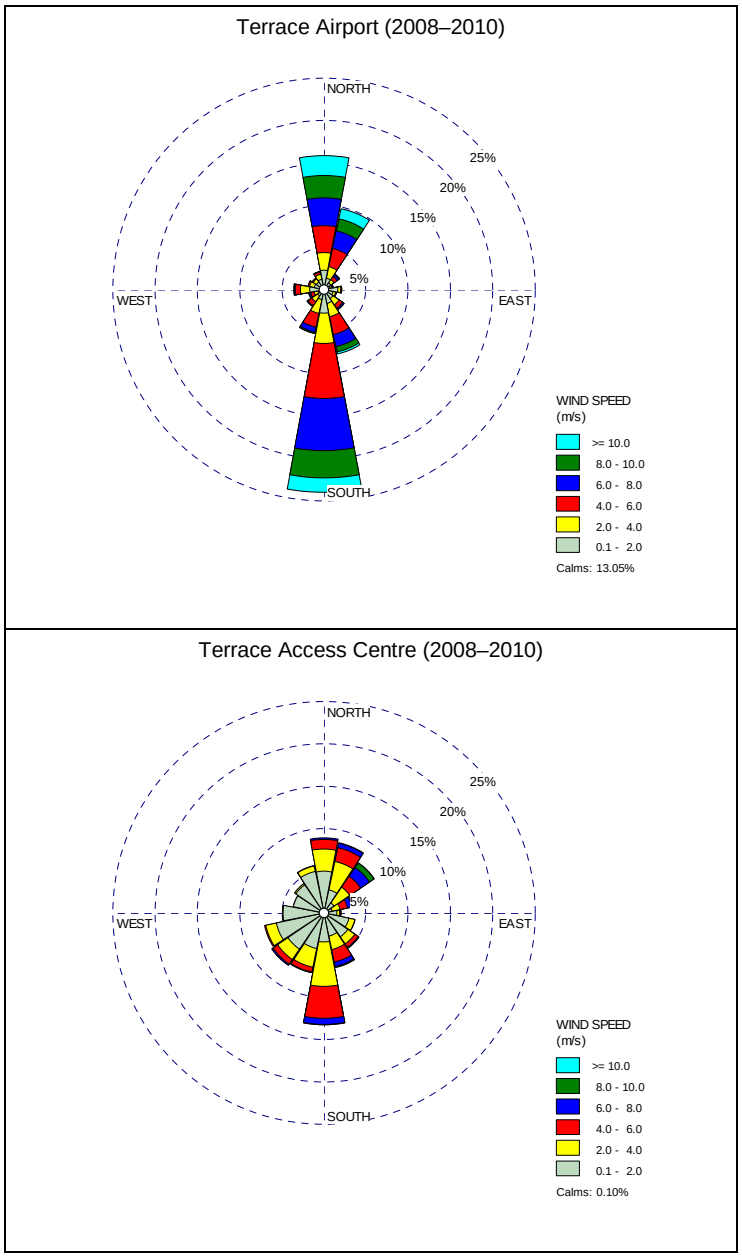


Figure E.3-3: Wind Roses for Two Meteorological Stations in the Terrace Area (2008 to 2010)

E.3.2.2 Wind Speed

Table E.3-1 provides wind speed statistics (based on hourly averages) for three Kitimat meteorological stations in the near-field CALMET domain. Average wind speeds for the 2008 to 2010 period ranged from 1.8 metres per second (m/s) at Kitimat Haul Road to 5.2 m/s at Kitimat Eurocan Dock. These differences are likely attributable to the relative wind sensor exposures associated with the different sites. In addition, year-to-year variation in average wind speed may occur because of meteorological differences or land cover changes (e.g., clearing).

Table E.3-1 Measured Wind Speeds at Three Locations in the Kitimat Area

Station Name	Period	Average Wind Speed (m/s)	Maximum Wind Speed (m/s)
Kitimat Whitesail	2008–2010	2.7	9.6
Kitimat Haul Road	2008–2010	1.8	9.4
Kitimat Eurocan Dock	2008–2009	5.2	16.5

E.4 Meteorological Predictions

E.4.1 Meteorological Models

Because of limited meteorological data in a large domain and uncertainty about whether the measured data are representative of the larger region, meteorological models were used to provide spatially and temporally varying wind and temperature fields across the model domains. These models can be categorized as either prognostic or diagnostic models.

- Prognostic models use meteorological measurements and fundamental equations of atmospheric motion to determine how the meteorological conditions will behave between the observing stations.

  The Fifth-Generation Penn State University/National Center for Atmospheric Research (NCAR) mesoscale model (commonly referred to as MM5) is a frequently-used meteorological model for historical episodes. It is a limited-area, nonhydrostatic, terrain-following sigma-coordinate model designed to simulate or predict mesoscale and regional-scale atmospheric circulations. As a community model, it is continuously being improved by contributions from multiple users.

  The Weather Research and Forecasting (WRF) Model is a next-generation mesoscale numerical weather prediction system designed to serve both operational forecasting and atmospheric research needs. This state-of-the-art system serves as an update to the MM5. It is designed to be a flexible atmospheric simulation system that is portable and efficient on parallel computing platforms. The WRF model is suitable for use in a broad range of

applications across scales ranging from metres to thousands of kilometres and is community-based.

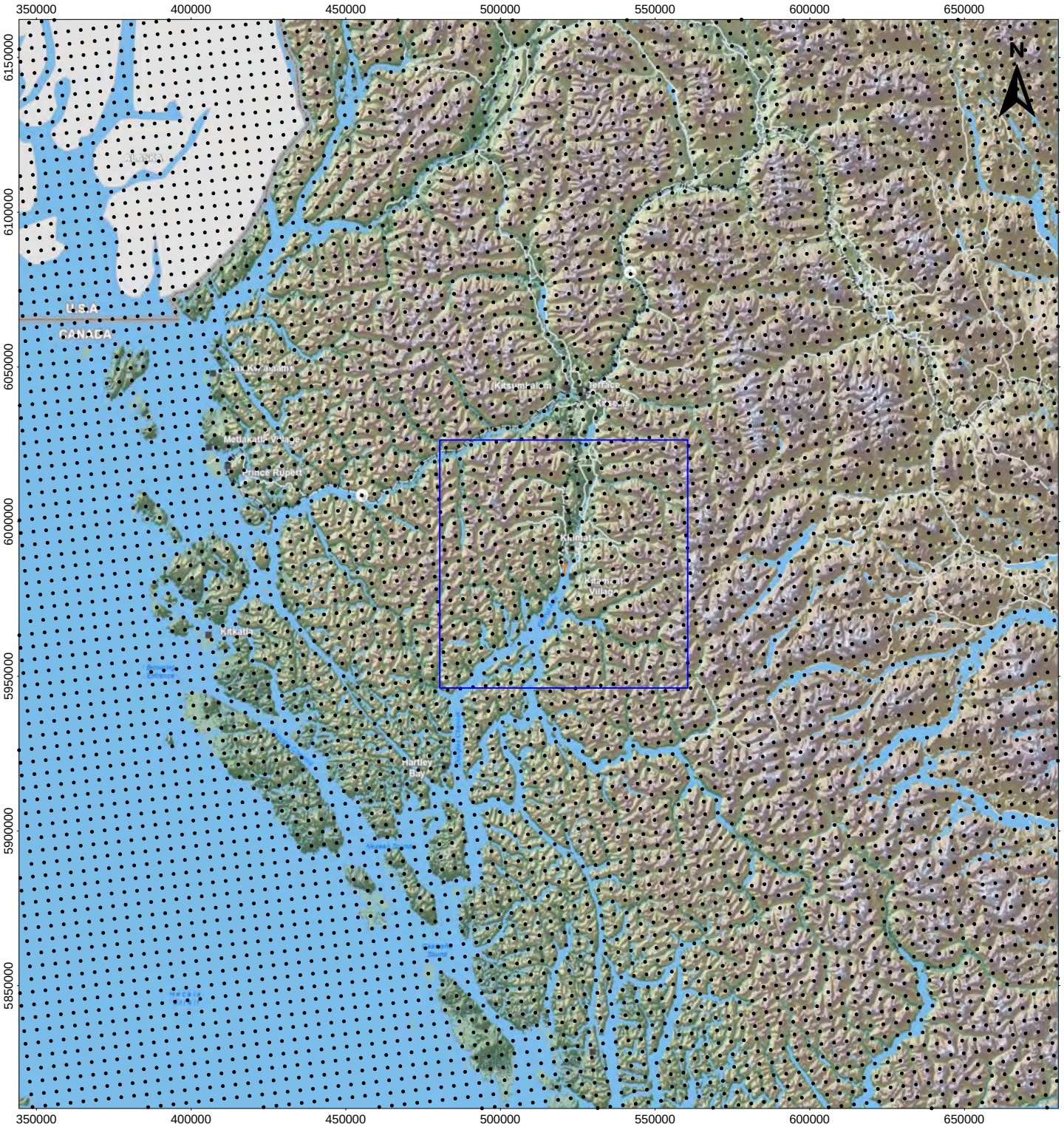
- Diagnostic models use interpolation schemes that rely on empirical relationships to account for topographical or other influences that can occur between the observing sites. The CALMET model is an example of a diagnostic model (Scire et al. 2000). The CALMET model can be applied on a finer scale to the WRF or MM5 model output in order to resolve more local-scale terrain influences.

E.4.2 Selection of Prognostic Model

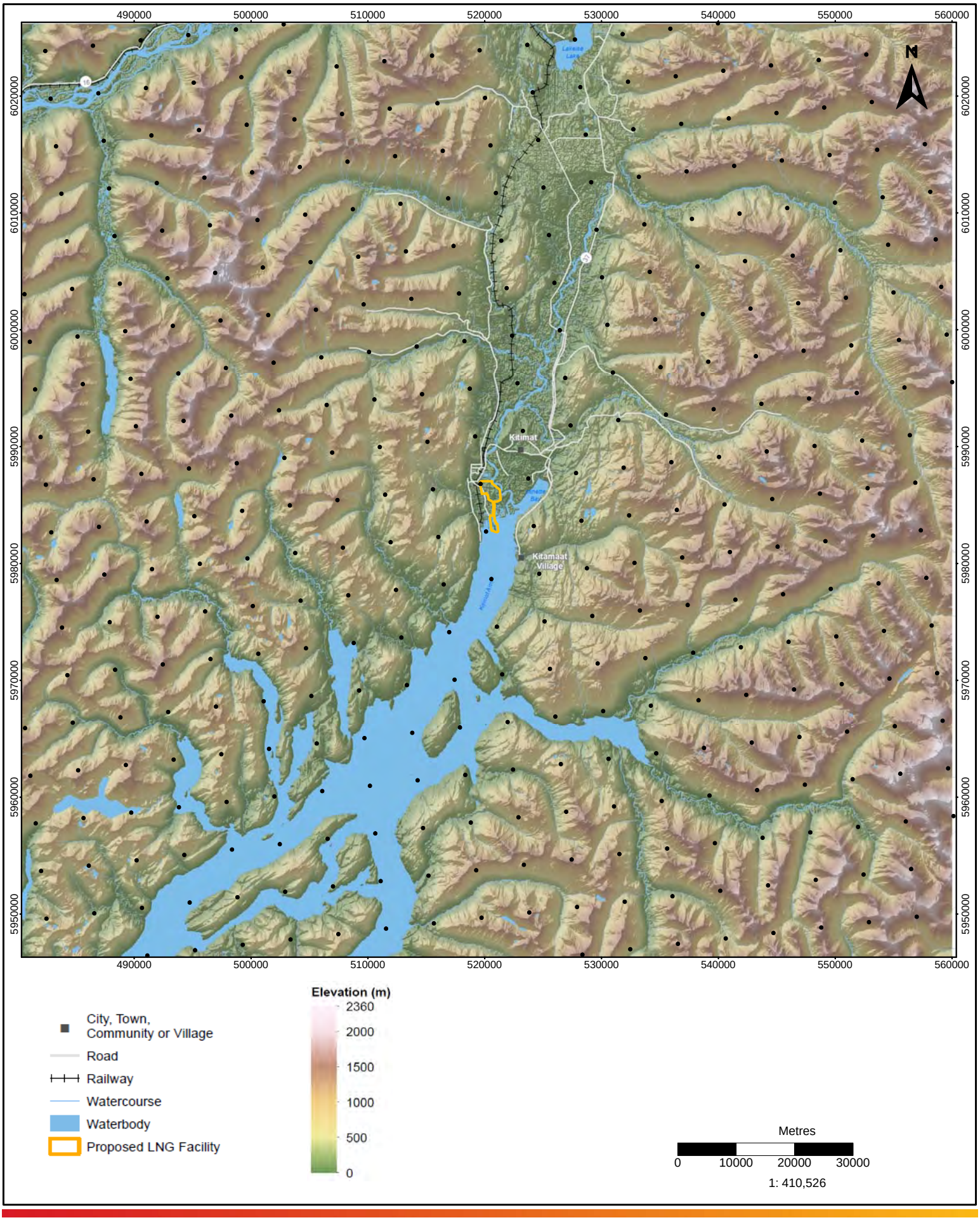
Historically, the MM5 model was widely used in the air quality modeling community. However, it has been officially phased out by NCAR in 2008. On October 31, 2008, NCAR announced that all technical support for the MM5 model was discontinued and users were encouraged to transition to the new WRF model, which is fully supported by NCAR (NCAR 2008). The WRF model provides better algorithms, better handling of topography, and better programming than the MM5 model. The WRF model also includes all new features and options developed by the Mesoscale and Microscale Meteorology Division at NCAR in recent years. The WRF model has been shown to meet the requirements for transitioning from the MM5 model, and it outperforms the MM5 model in overall model accuracy (U.S. EPA 2010).

Considering the advantages of the WRF model, it was selected as the prognostic model for this assessment. The National Centers for Environmental Prediction 32 km resolution North American Regional Reanalysis gridded analysis data were used as input to Version 3 of the WRF model to produce a three-year (2008 to 2010) meteorological dataset on a 4 km grid resolution using the Stantec Consulting Ltd. (Stantec) high performance computing cluster. The 4 km grid resolution WRF model output was used as an initial guess field for the CALMET model, which then adjusted the initial guess field for the kinematic effects of terrain, slope flows, and terrain blocking effects using the finer-scaled CALMET terrain data to produce a modified wind field.

Figures E.4-1 and E.4-2 provide the WRF grid point locations based on the 4 km grid resolution within the far-field model domain and near-field model domain, respectively. Although the grid points provide a much greater and more uniform density across the domain than the locations where meteorological parameters are measured (see Figure E.2-4), WRF provides interpolated/predicted data at these receptors.



Stantec	LNG CANADA Opportunity for British Columbia. Energy for the world	*AIR QUALITY TECHNICAL DATA REPORT* **WRF 4 km Grid Points in the Far-Field Model Domain** LNG CANADA EXPORT TERMINAL KITIMAT, BRITISH COLUMBIA	PROJECTION: UTM9 DATUM: NAD 83 DATE: 3-APR-14	DRAWN BY: YS CHECKED BY: JG FIGURE NO.: E.4-1



Stantec	LNG CANADA Opportunity for British Columbia. Energy for the world	*AIR QUALITY TECHNICAL DATA REPORT* **WRF 4 km Grid Points in the Near-Field Model Domain** LNG CANADA EXPORT TERMINAL KITIMAT, BRITISH COLUMBIA	PROJECTION: UTM9 DATUM: NAD 83 DATE: 3-APR-14	DRAWN BY: YS CHECKED BY: JG FIGURE NO.: E.4-2

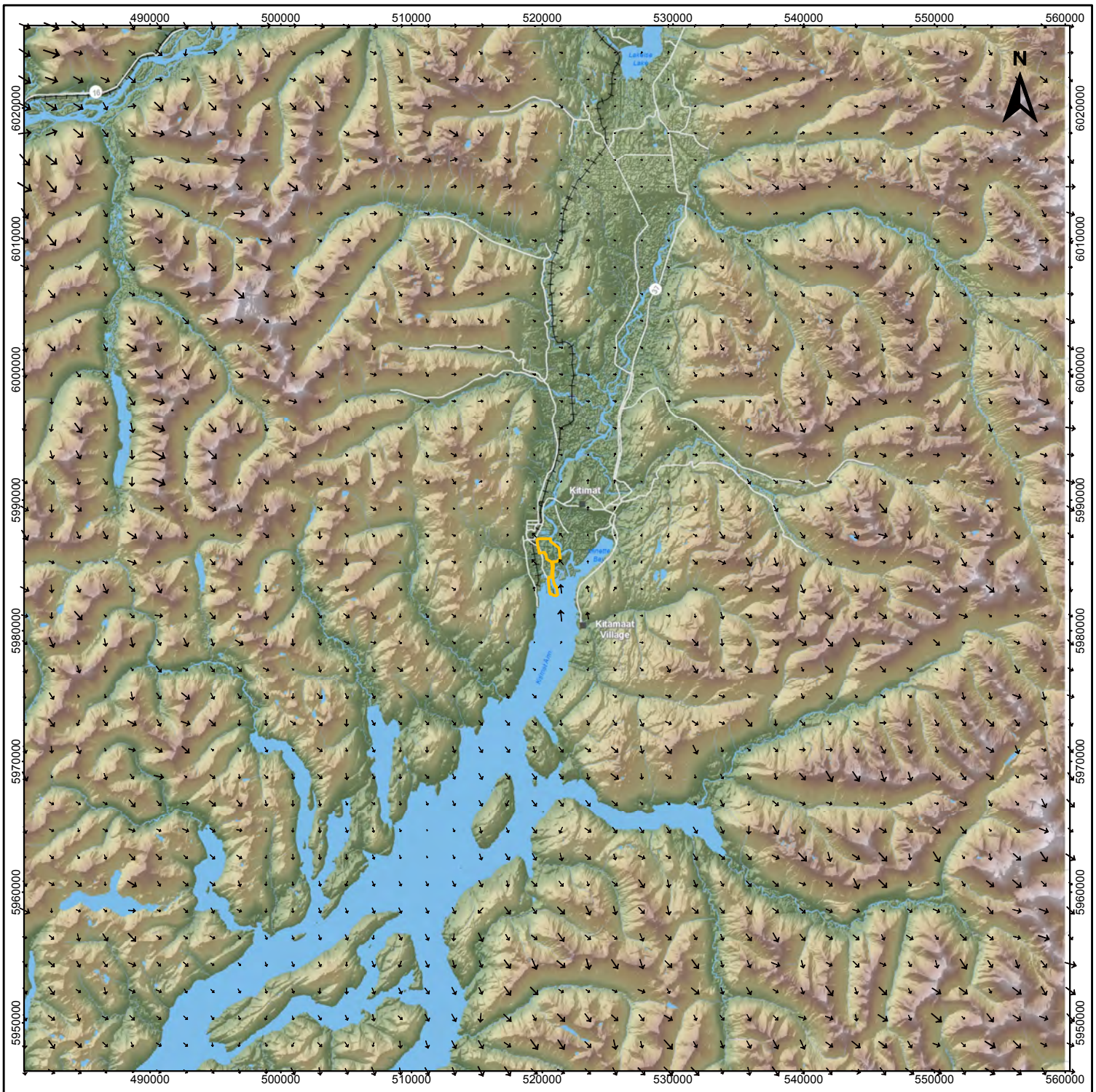
E.4.3 Regional Scale Winds

E.4.3.1 Surface Wind Vector Plots (2008)

The CALMET model can provide surface wind vector plots for all the grid points across a model domain. Three plots were generated to represent unstable, stable, and neutral conditions for the near-field model domain. Atmospheric stability is categorized by the Pasquill Gifford (PG) stability class scheme (see Section E.4.5). The three sample wind vector plots are described below:

- Figure E.4-3 shows the wind field as a vector plot at 1300 LST on July 15, 2008, for convective (i.e., unstable) conditions (PG class B). Winds in the centre of the domain tend to be lighter than winds in other parts of the domain. In the areas with light winds, the airflow is less organized. The predicted wind at the Project site is from the southeast with a wind speed of 2.1 m/s. The measured data at the Kitimat Haul Road surface station show winds from the southeast with a wind speed of 3.7 m/s.
- Figure E.4-4 shows the wind field as a vector plot at 0800 LST on January 4, 2008, for stable conditions (PG class F). The winds in the southern part of the domain tend to be southerly, whereas those in the middle of the domain tend to be lighter and from the east. The predicted wind at the Project site is from the east with a wind speed of 0.4 m/s. The measured data at the Kitimat Haul Road surface station show winds from the northwest with a wind speed of 0.4 m/s.
- Figure E.4-5 shows the wind field as a vector plot at 1900 LST on November 15, 2008, for high wind speed (i.e., neutral) conditions. Under these conditions, winds are from the north or east across most of the domain. The predicted wind at the Project site is from the north with a wind speed of 2.3 m/s. The measured data at the Kitimat Haul Road surface station show winds from the north with a wind speed of 1.5 m/s.

The vector plots were not selected to represent a specific meteorological condition; they are provided to show the variability of the airflow that can occur over the 80 km by 80 km area during any given hour. Departures of the predicted vector plots from the actual wind field for a given hour are to be expected given the nature of modelling and the relatively low density of actual observations across the region. The predicted values, however, are preferable to assuming a homogeneous wind field across the domain for each hour, based on the local terrain influences that are reflected in the measured data.



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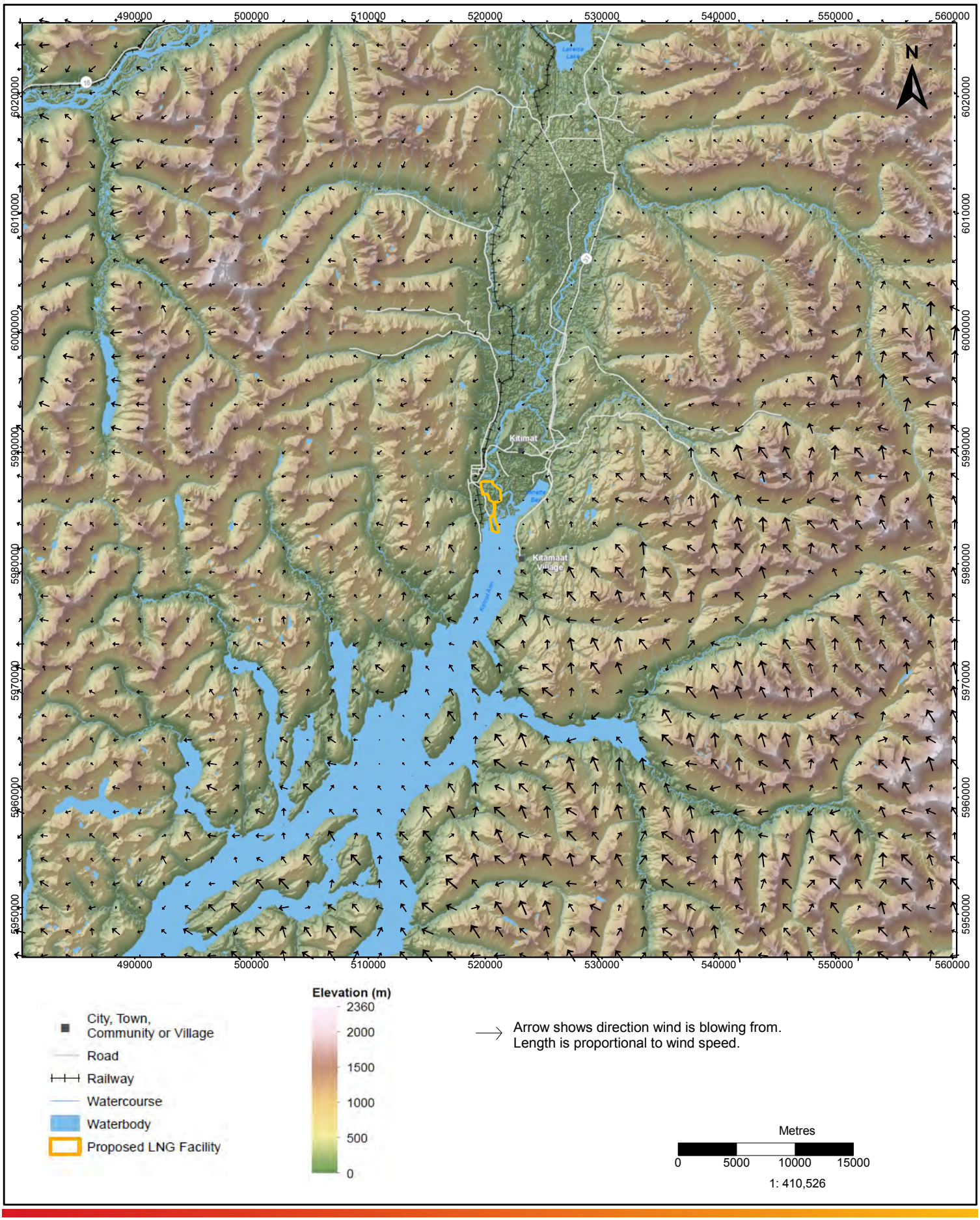
AIR QUALITY TECHNICAL DATA REPORT

Predicted Surface Wind Field for Unstable Conditions (1300 LST July 15, 2008)

LNG CANADA EXPORT TERMINAL
KITIMAT, BRITISH COLUMBIA

PROJECTION: UTM9	DRAWN BY: YS
DATUM: NAD 83	CHECKED BY: JG
DATE: 3-APR-14	FIGURE NO.: E.4-3



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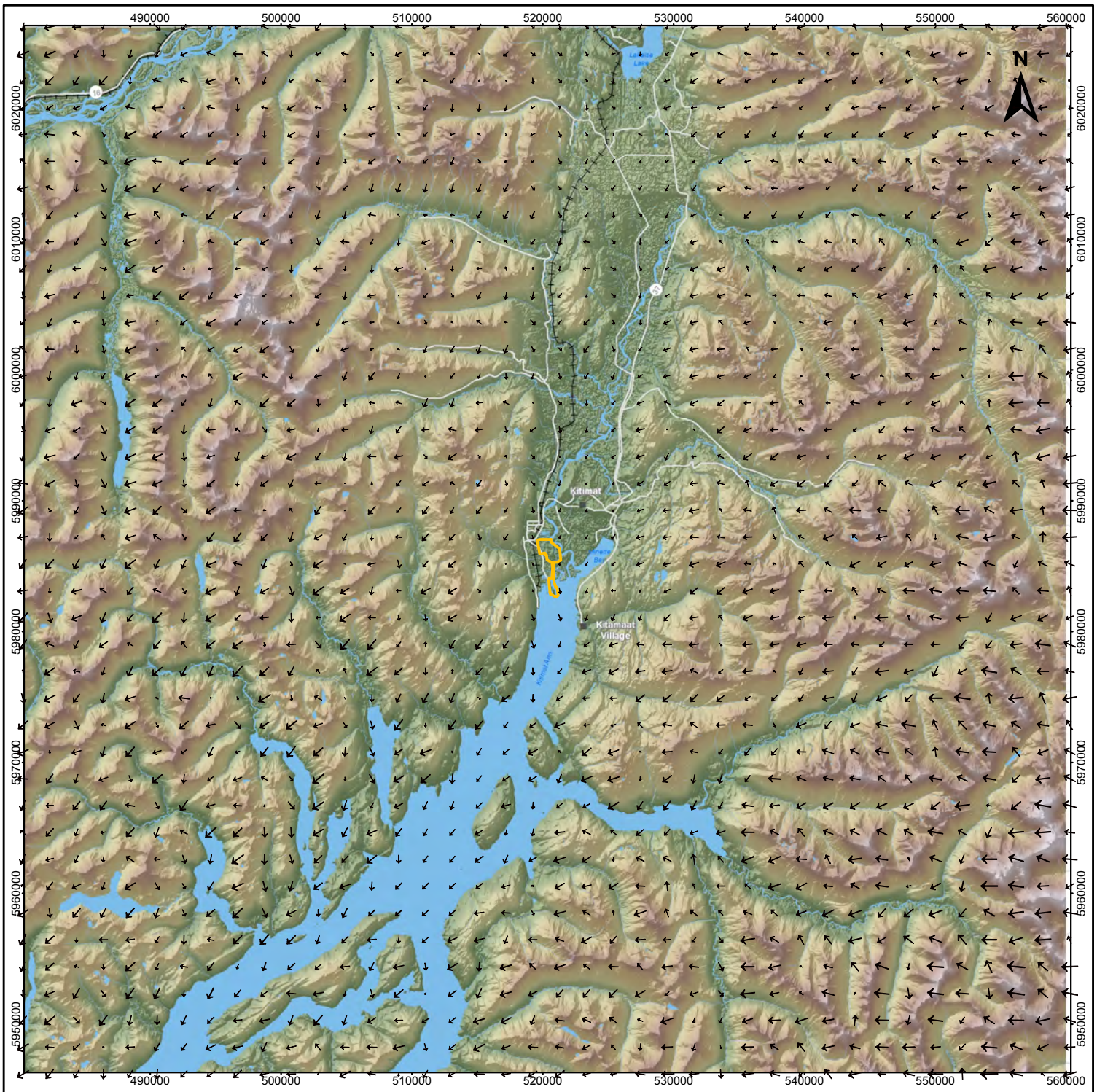
LNG CANADA
Opportunity for British Columbia. Energy for the world

AIR QUALITY TECHNICAL DATA REPORT

Predicted Surface Wind Field for Stable Conditions (0800 LST January 4, 2008)

LNG CANADA EXPORT TERMINAL
KITIMAT, BRITISH COLUMBIA

PROJECTION	DRAWN BY
UTM9	YS
DATUM	CHECKED BY
NAD 83	JG
DATE	FIGURE NO.
3-APR-14	E.4-4



Stantec	LNG CANADA Opportunity for British Columbia. Energy for the world	*AIR QUALITY TECHNICAL DATA REPORT* **Predicted Surface Wind Field for Neutral Conditions (1900 LST November 15, 2008)** LNG CANADA EXPORT TERMINAL KITIMAT, BRITISH COLUMBIA	PROJECTION: UTM9 DATUM: NAD 83 DATE: 3-APR-14	DRAWN BY: YS CHECKED BY: JG FIGURE NO.: E.4-5

E.4.3.2 Predicted Elevated Winds (2008 to 2010)

Figure E.4-6 shows the wind roses predicted by CALMET for the Project site at various elevations (10 m, 60 m, 120 m, and 240 m) above the ground. The results indicate a tendency for more southerly winds and an increase in wind speed, with increasing height above the ground.

Figure E.4-7 shows the annual wind roses predicted by CALMET for the Project site at 10 m above the ground. Little annual variation in the dominant winds is evident at this site.

E.4.4 Predicted Mixing Heights

The presence of an elevated inversion can trap effluents discharged into the atmosphere in the layer between the surface and the base of the inversion layer, which can increase ground-level ambient concentrations relative to the absence of an inversion layer. Mixing heights are usually the highest (e.g., in the 1,000 m to 2,000 m range) during daytime periods that are characterized by strong solar heating and lowest (about 100 m) during the night. High wind speeds can also produce well-mixed layers. Mixing heights are typically determined by analyzing vertical temperature profiles, which are not directly measured on a routine basis. Daily maximum values are suppressed by the site's coastal location, remaining below 800 m for all but a few days (Van der Kamp and McKendry 2010)

For this assessment, the CALMET post-processor was used to extract mixing heights from CALMET output files. Mean mixing height predictions for the Project site are shown in Figure E.4-8. Mean diurnal maximum values for each season are approximately:

- winter: 580 m at 1300 LST
- spring: 850 m at 1400 LST
- summer: 870 m at 1500 LST, and
- fall: 640 m at 1400 LST.

Minimum values for each season are predicted to occur at night. At night, the mixing height tends to be determined by mechanical mixing, with higher wind speeds resulting in a deeper mixed layer. This explains why the winter season has the highest nighttime mixing heights. The convective mixing process dominates during the day, leading to maximum mixed layer depths during the afternoon. The CALMET model, as applied, sets the minimum mixing height to 50 m.

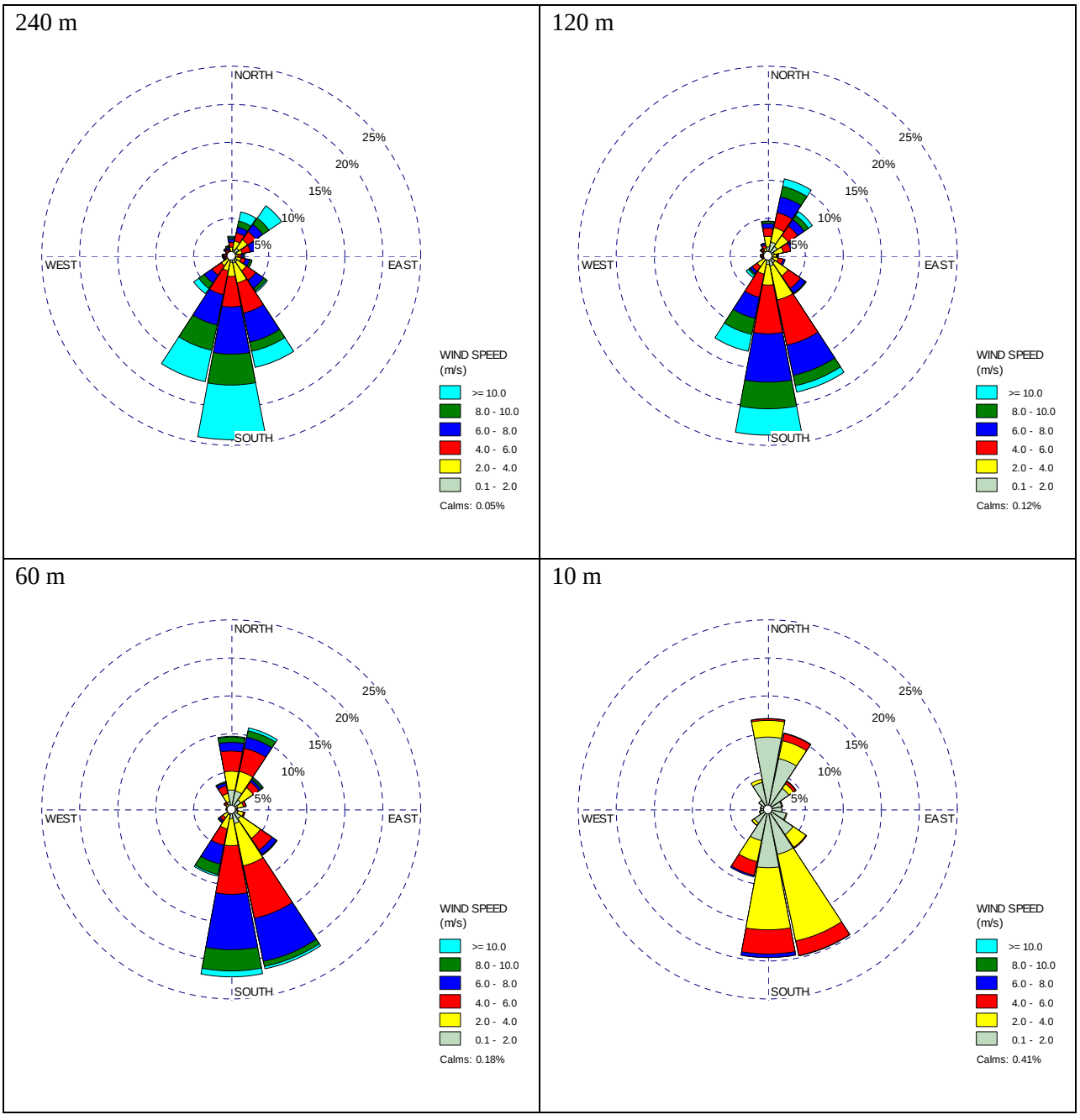


Figure E.4-6: Predicted (CALMET) Project Site Wind Roses at Four Levels (2008 to 2010)

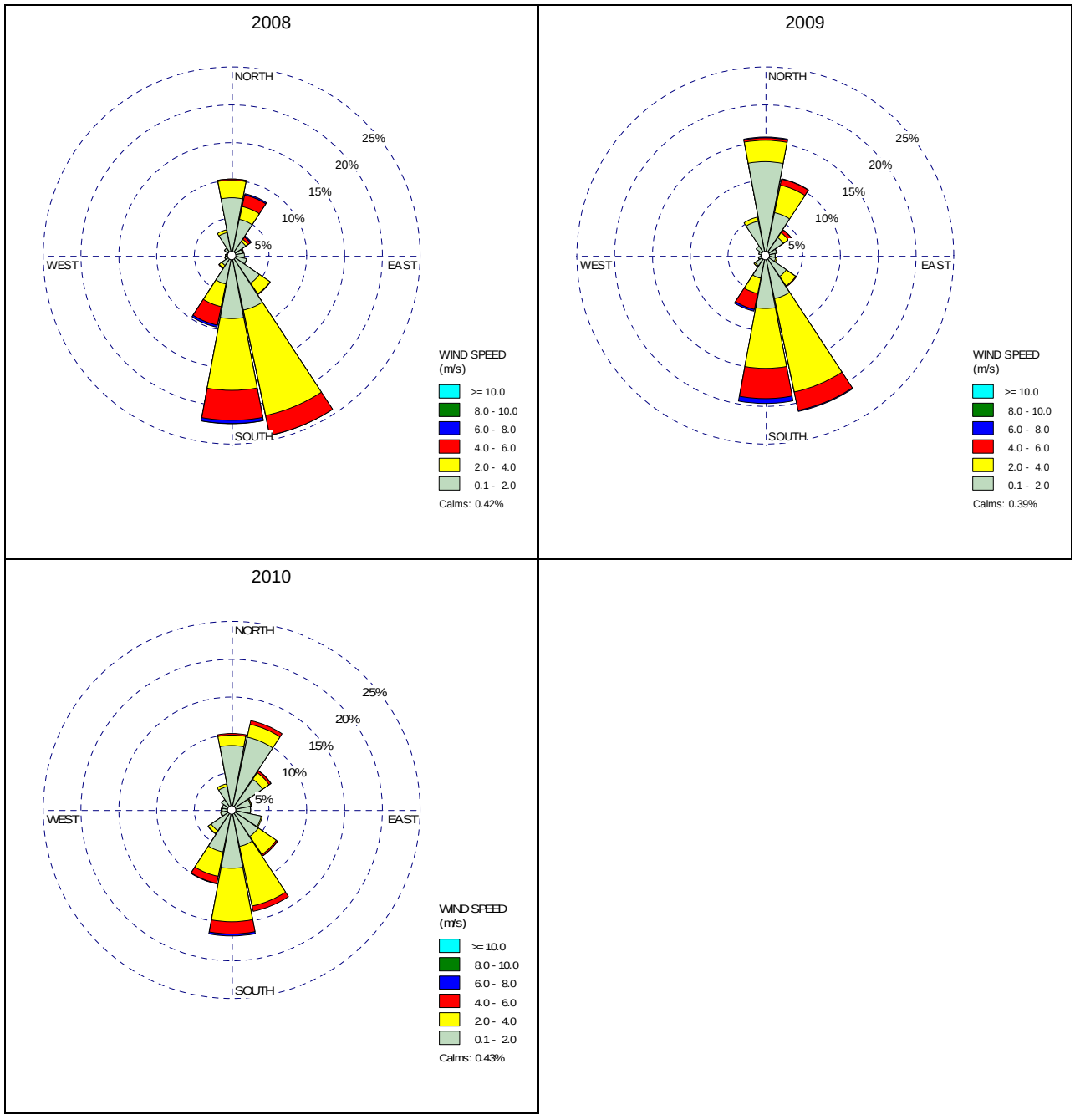


Figure E.4-7: Predicted (CALMET) Project Site Wind Roses at the 10 m Level for Individual Years 2008 to 2010

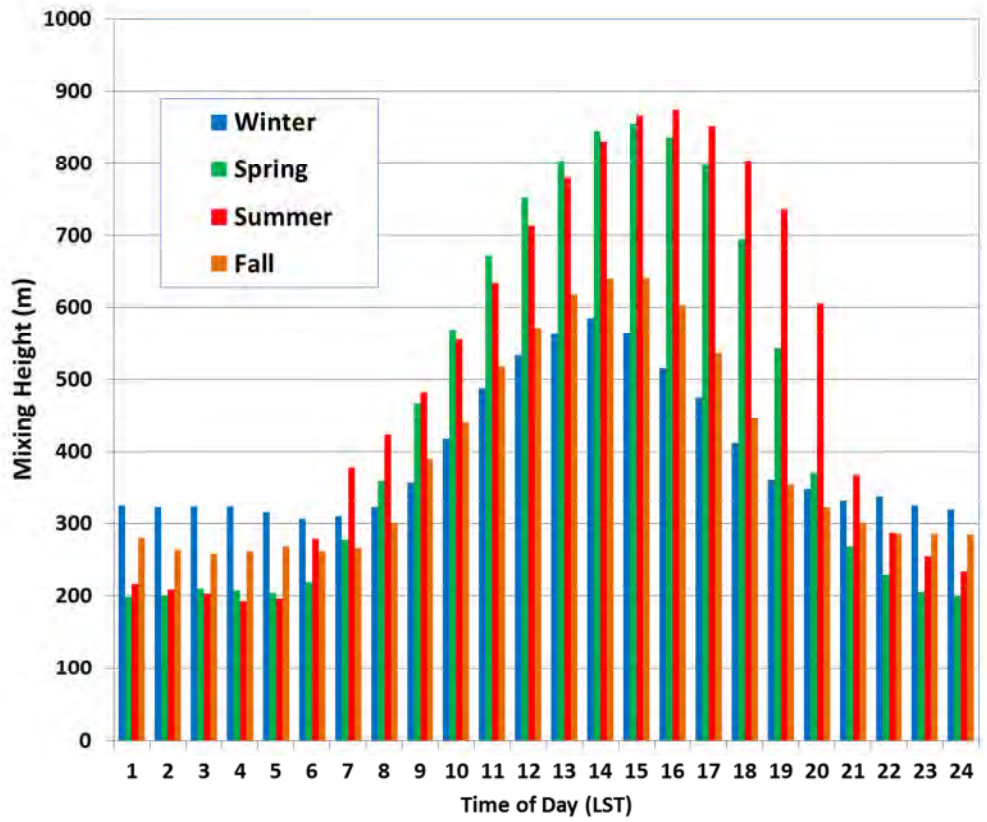


Figure E.4-8: CALMET Predicted Mixing Heights for Different Seasons and Times of Day at the Project Site (2008 to 2010)

E.4.5 Predicted Atmospheric Stability Class

Atmospheric dispersion results from turbulence, which is related to wind shear and atmospheric stability. The six PG stability classes are described below:

- Stability classes A, B, and C occur during the day when the earth is heated by solar radiation. The air near the surface is heated and become buoyant, enhancing vertical motion. This is referred to as an unstable atmosphere.
- Stability classes E and F occur during the night when the earth cools due to long-wave radiation losses. The air near the surface cools, suppressing vertical motions. This is referred to as a stable atmosphere.
- Stability class D is associated with completely overcast conditions (day or night) when there is no net heating or cooling of the earth, transitional periods between stable and unstable conditions, or during high wind speed periods (winds greater than 6 m/s [or 22 km/h]). This is referred to as a neutral atmosphere.

Atmospheric stability exhibits significant diurnal and seasonal variation (Figure E.4-9). Stability classes can be determined from routine airport observations using the method devised by Turner (1963). A stability classification algorithm is also included in the CALMET model; this approach is also based on the Turner method, using wind speed and cloud cover information for each grid point in the domain.

Table E.4-1 provides the stability class frequency distributions based on the CALMET model predictions for the Project site. Figure E.4-9 shows the frequency distributions of predicted seasonal PG stability classes at the Project site on a diurnal basis. Unstable conditions are more frequent during the summer and during daytime periods. Stable conditions are more frequent during nighttime periods. Neutral conditions are most frequent during the fall and winter, during both day and night. This is due to the combination of high winds and persistent cloud cover, which are present in the area during the fall and winter storm season.

Table E.4-1: Stability Class Frequency Distributions at the Project Site (2008 to 2010)

Pasquill Gifford Class	Frequency at Project Site (%)
A	0.6
B	8.0
C	15.2
D	47.6
E	6.1
F	22.5
Total	**100.0**

NOTES:

Winter: December, January, and February

Spring: March, April, and May.

Summer: June, July, and August.

Fall: September, October, and November.

Figure E.4-9: Frequency of Predicted PG Stability Class at the Project Site (2008 to 2010)

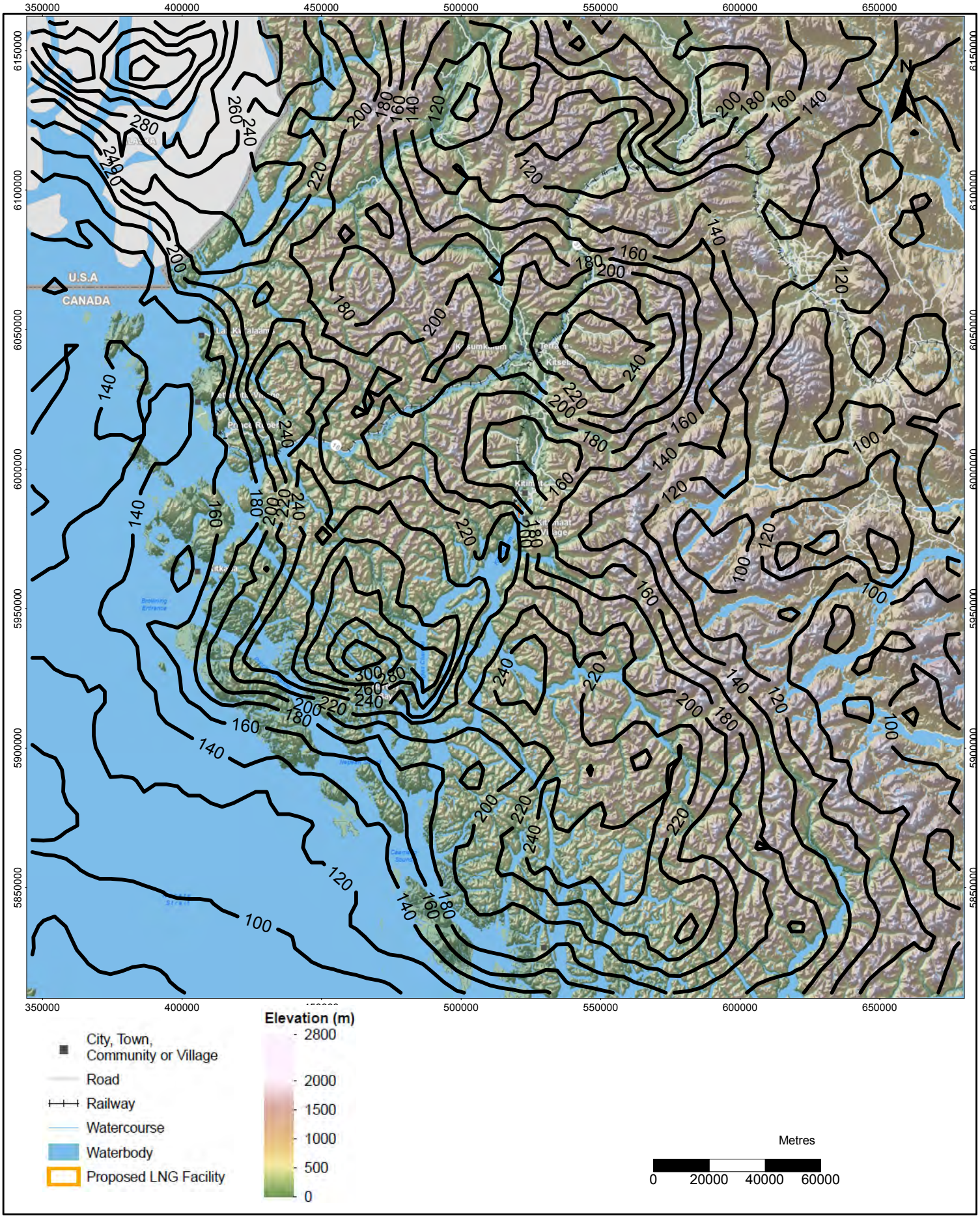
E.4.6 Predicted Precipitation

Table E.4-2 compares the annual total precipitation measured at the Kitimat Townsite and Terrace Airport observing stations for the 2008 to 2010 period with the associated predictions based on the CALMET and WRF models. In general, the predicted values are greater than the measured values by 25% to 104% for individual years. The middle of the model domain shows closer agreement between measurements and predictions at the Kitimat Town Site station. The largest over-predictions are observed for the Terrace Airport station.

Figure E.4-10 shows the July 2008 monthly total precipitation for the far-field domain. Relatively large variation occurs along the Kitimat Ranges, Douglas Channel, and Kitimat River valley. Greater precipitation occurs at high-elevation sites, and less precipitation occurs in the river valley and other low-elevation sites. Gridded meteorological model precipitation output provides better spatial variation than limited precipitation measurements from observing stations.

Table E.4-2 Comparison of Measured and Predicted Annual Total Precipitation at Kitimat Town Site station and Terrace Airport (2008 to 2010)

Year	Measured Total Precipitation (mm)	Predicted Total Precipitation (mm)	Over/Under Prediction (mm)	Over/Under Prediction (%)
Kitimat Town Site				
2008	2,062	2,640	578	28
2009	1,771	2,219	448	25
2010	1,825	2,450	625	34
Average	1,886	2,436	550	29
Terrace Airport				
2008	1,213	2,479	1,266	104
2009	1,031	2,087	1,056	102
2010	1,329	2,298	969	73
Average	1,191	2,288	1,097	93



Stantec	LNG CANADA Opportunity for British Columbia. Energy for the world	*AIR QUALITY TECHNICAL DATA REPORT* **C**ALMET Predicted July 2008 Monthly Total Precipitation (mm) in the Far-field Model Domain LNG CANADA EXPORT TERMINAL KITIMAT, BRITISH COLUMBIA	PROJECTION: UTM9 DATUM: NAD 83 DATE: 3-APR-14	DRAWN BY: YS CHECKED BY: JG FIGURE NO.: E.4-10

E.4.7 Advantages of a Meteorological Model

Given the large model domain, the sparseness of meteorological measurements within the domain, and the demonstrated terrain influences on regional air flow, the WRF and CALMET models provide the most representative possible meteorological data for the CALPUFF model (discussed in Appendix F). Key advantages of these models include:

- The WRF model data used in this assessment are for a 4 km resolution, which should allow terrain effects on air flow to be better resolved.
- The models allow the meteorological data to vary spatially across the model domain in response to synoptic airflow patterns (based on the WRF model), terrain influences (based on CALMET), and land-cover properties (based on CALMET). The CALMET model supplements the WRF data with regional surface winds and temperatures.
- The models provide hourly meteorological predictions that account for systematic daily and seasonal variation in combination with spatial influences.
- The models show the north to south wind direction bias at the Project site as well as the tendency for the winds to become more southerly at higher elevations.
- The predicted mixing heights show the expected seasonal and diurnal variation, and the values are consistent with the limited measurements in the region.
- The predicted PG classes show that unstable conditions are more frequent during the summer and daytime. Stable conditions are more frequent during nighttime. Neutral conditions are most frequent during fall and winter.
- Two options are available for precipitation data: one uses monitoring station meteorological data and the other uses predicted data from the WRF model. The WRF approach was used because it allows the precipitation field to vary across the domain and provides higher values that are more consistent with the increased precipitation that occurs over elevated terrain.

Application of the CALMET model with mesoscale model data has been used to provide input data for the CALPUFF model for over a decade. Applications of the CALMET model since 2009 have typically used meteorological model data to provide more robust model predictions. While the goal of using more sophisticated models and more data is to improve model predictions, the application as described cannot resolve detailed microscale influences within valleys. The approach, however, is an improvement over using data from a single station.

E.5 CALMET Application

The CALMET pre-processor is available from the model developer's (i.e., the Atmospheric Studies Group at TRC) website (http://www.src.com/calpuff/calpuff1.htm). The current U.S. EPA version of CALMET is Version 5.8, level 070623. A more recent version, Version 6.334, level 110421 was used in this assessment.

To simulate transport and dispersion processes, it is also important to simulate the representative vertical profiles of wind direction, wind speed, temperature, and turbulence intensity within the atmospheric boundary layer (i.e., the layer within about 2,000 m above the earth's surface). To capture this vertical structure, ten vertical layers were selected. CALMET defines a vertical layer as the midpoint between two faces (i.e., 11 faces corresponds to ten layers, with the lowest layer always being ground level or 10 m). The vertical faces used in this study are 0 m, 20 m, 40 m, 80 m, 160 m, 320 m, 640 m, 1,200 m, 2,000 m, 3,000 m, and 4,000 m.

The CALMET model was applied using 2008 to 2010 meteorological data (26,303 hours). The model requires surface and upper air information. The gridded three-dimensional meteorological dataset produced by the WRF model was used as an initial guess field (Klausmann et al. 2003). The WRF mesoscale dataset was prepared by Stantec and was used to generate vertical wind and temperature profiles across entire study domain on a 4 km grid resolution for the year 2008 to 2010.

The CALMET model adjusted the initial guess field for the kinematic effects of terrain, slope flows, and terrain blocking using the finer-scaled CALMET terrain data to produce a modified wind field. The CALMET model used concurrent surface station measurements. The input parameters for the CALMET control file used in the modelling assessment are provided in Tables E.5-1 to E.5-8.

Table E.5-1: Input Groups in the CALMET Control File

Input Group	Description	Applicable to Project
0	Input and output file names	Yes
1	General run control parameters	Yes
2	Grid control parameters	Yes
3	Output options	Yes
4	Meteorological data options	Yes
5	Wind field options and parameters	Yes
6	Mixing height, temperature, and precipitation parameters	Yes
7	Surface meteorological station parameters	Yes
8	Upper air meteorological station parameters	No
9	Precipitation parameters	No

Table E.5-2: CALMET Model Options Groups 0 and 1

Parameter	Default	Project	Comment
Input Group 0: Input and output file names			
NUSTA	-	0	Number of upper air stations
NOWSTA	-	0	Number of overwater met stations
MM3D	-	36	Number of MM4/MM5/3D.DAT files (one for each month)
NIGF	-	0	Number of IGF-CALMET.DAT files
Input Group 1: General run control parameters			
IBYR	-	2008	Starting year
IBMO	-	1	Starting month
IBDY	-	1	Starting day
IBHR	-	0	Starting hour
IBSEC	-	0	Starting second
IEYR	-	2011	Ending year
IEMO	-	1	Ending month
IEDY	-	1	Ending day
IEHR	-	0	Ending hour
IESEC	-	0	Ending second
ABTZ	-	UTC-0800	UTC time zone
NSECDT	3,600	3,600	Length of modelling time-step (seconds)
IRTYPE	1	1	Run type
LCALGRD	T	T	Special data fields
ITEST	2	2	Flag to stop run after SETUP phase

Table E.5-3: CALMET Model Options Group 2: Grid Control Parameters

Parameter	Default	Project	Comment
PMAP	UTM	UTM	Map projection
IUTMZN	-	9	UTM zone
UTMHEM	N	N	Hemisphere for UTM projection
DATUM	WGS-84	NAR-C	NORTH AMERICAN 1983 GRS 80 spheroid used for output coordinate in consistent with the applied CDED terrain data
NX	-	84 (far-field) 160 (near-field)	No. X grid cells
NY	-	88 (far-field) 160 (near-field)	No. Y grid cells
DGRIDKM	-	4.(far-field) 0.5 (near-field)	Grid spacing (km)
XORIGKM	-	344.36 (far-field) 480.36 (near-field)	Reference coordinate of SW corner of grid cell (1,1) -X coordinate (km)
YORIGKM	-	5810.31 (far-field) 5946.31 (near-field)	Reference coordinate of SW corner of grid cell (1,1) -Y coordinate (km)
NZ	-	10	Vertical grid definition: Number of vertical layers
ZFACE	-	0.,20.,40.,80.,160.,320.,640.,1200.,2000.,3000.,4000.	Vertical grid definition: Cell face heights in arbitrary vertical grid (m)

Table E.5-4: CALMET Model Options Group 3: Output Options

Parameter	Default	Project	Comment
Disk Output:			
LSAVE	T	T	Save meteorological fields in the unformatted output files
IFORMO	1	1	Type of unformatted output file
Line printer output:			
LPRINT	F	F	Print meteorological fields every 4 hours
IPRINF	1	4	Print intervals (hours) Meteorological fields are printed
IUVOUT (NZ)	0	10*0	Specify which layers of U,V wind component to print
IWOUT (NZ)	0	10*0	Specify which level of the w wind component to print
ITOUT (NZ)	0	10*0	Specify which levels of the 3-D temperature field to print
Meteorological fields to print:			
Variable	**Print? 0 = no print 1 = print**		**Comment**
STABILITY	0		PGT stability
USTAR	0		Friction velocity
MONIN	0		Monin-Obukhov length
MIXHT	0		Mixing height
WSTAR	0		Convective velocity scale
PRECIP	1		Precipitation rate
SENSHEAT	0		Sensible heat flux
CONVZI	0		Convective mixing height
Testing and debug print options for micrometeorological module:			
LDB	F	F	Print input meteorological data and internal variables
NN1	1	1	First time step for which debug data are printed
NN2	1	1	Last time step for which debug data are printed
LDBCST	F	F	Print distance to land internal variables
Testing and debug print options for wind field module:			
IOUTD	0	0	Control variable for writing the test/debug wind fields to disk files
NZPRN2	1	0	Number of levels, starting at surface, to print
IPR0	0	0	Print the interpolated wind components
IPR1	0	0	Print the terrain adjusted surface wind components
IPR2	0	0	Print the smoothed wind components and the initial divergence fields
IPR3	0	0	Print the final wind speed and direction
IPR4	0	0	Print the final divergence fields
IPR5	0	0	Print the winds after kinematic effects are added
IPR6	0	0	Print the winds after the Froude number adjustment is made
IPR7	0	0	Print the winds after slope flows are added
IPR8	0	0	Print the final wind field components

Table E.5-5: CALMET Model Options Group 4: Meteorological Data Options

Parameter	Default	Project	Comment
NOOBS	0	1	Use surface and overwater stations; Use MM4/MM5/3D.DAT for upper air data
Number of Surface & Precipitation Meteorological Stations:			
NSSTA	-	16	Number of surface stations
NPSTA	-	-1	Precipitation observation not used
Cloud Data Options:			
ICLOUD	0	0	Gridded clouds not used; Airport cloud data was used
File Formats:			
IFORMS	2	2	Used free-formatted surface meteorological data file
IFORMP	2	Not applicable	Precipitation data file format
IFORMC	2	Not applicable	Cloud data file format

Table E.5-6: CALMET Model Option Group 5: Wind Field Options and Parameters

Parameter	Default	Project	Comment
Wind Field Model Options:			
IWFCOD	1	1	Model selection variables
IFRADJ	1	1	Compute Froude number adjustment
IKINE	0	0	Compute kinematic effects
IOBR	0	0	Use O'Brien procedure for adjustment of the vertical velocity
ISLOPE	1	1	Compute slope flow effects
IEXTRP	-4	-4	Extrapolate surface wind observations to upper layers (similarity theory used with layer 1 data at upper air stations ignored)
ICALM	0	0	Extrapolate surface winds even if calm
BIAS	0	10*0	Layer-dependent biases modifying the weights of surface and upper air stations BIAS= -1 reduces the weight of upper air station by 100%
RMIN2	4	-1.0	Minimum distance from nearest upper air station to surface station for which extrapolation of surface winds at surface station will be allowed Set to -1 where all surface stations should be extrapolated
IPROG	0	14	Use gridded prognostic wind field model output fields as input to the diagnostic wind field model Set to 14 as WRF gridded model data was used as the main input to CALMET model for this assessment
ISTEPPGS	3,600	3,600	Time step (seconds) of the prognostic model input data
IGFMET	0	0	Use coarse CALMET fields as initial guess fields
Radius of Influence Parameters:			
LVARY	F	T	Use varying radius of influence

Parameter	Default	Project	Comment
RMAX1	-	10	Maximum radius of influence over land in the surface layer (km)
RMAX2	-	40	Maximum radius of influence over land aloft (km)
RMAX3	-	Not applicable	Maximum radius of influence over water
Other wind field input parameters:			
RMIN	0.1	0.1	Minimum radius of influence used in the wind field interpolation (km)
TERRAD	-	15	Radius of influence of terrain features (km)
R1	-	2	Relative weighting of the first guess field and observations in the surface layer (km)
R2	-	Not applicable	Relative weighting of the first guess field and observations in the layers aloft (km)
RPROG	-	0	Relative weighting parameter of the prognostic wind field data (km)
DIVLIM	5.0E-6	5.0E-6	Maximum acceptable divergence in the divergence minimization procedure
NITER	50	50	Maximum number of iterations in the divergence minimization procedure
NSMTH (NZ)	2, (mxnz-1) *4	2, 9*4	Number of passes in the smoothing procedure For NZ level 1, the CALMET default value 2 was used for the Project. For other levels, value 4 was used as CALMET input 4 km WRF data already provided high resolution spatial wind fields
NINTR2	99	10*99	Maximum number of stations used in each layer for the interpolation of data to a grid point
CRITFN	1.0	1.0	Critical Froude number
ALPHA	0.1	0.1	Empirical factor controlling the influence of kinematic effects
FEXTR2(NZ)	0.0	10*0.	Multiplicative scaling factor for extrapolation of surface observations to upper layers
Barrier Information:			
NBAR	0	0	Number of barriers to interpolation of the wind fields (The barrier option was not used)
KBAR	NZ	10	Level (1 to NZ) up to which barriers apply For this project, NZ = 8
XBBAR	-	0	X coordinate of beginning of each barrier
YBBAR	-	0	Y coordinate of beginning of each barrier
XEBAR	-	0	X coordinate of ending of each barrier
YEBAR	-	0	Y coordinate of ending of each barrier
Diagnostic module data input options:			
IDIOPT1	0	0	Surface temperature (0 = compute internally from hourly surface observation)
ISURFT	-	-1	use 2-D spatially varying surface temperatures
IDIOPT2	0	0	Domain-averaged temperature lapse (0 = compute internally from hourly surface observation)
IUPT	-	Not applicable	Upper air station not used
ZUPT	200	200	Depth through which the domain-scale lapse rate is computed (m)

Parameter	Default	Project	Comment
IDIOPT3	0	0	Domain-averaged wind components
IUPWND	-1	Not applicable	Upper air station not used
ZUPWND	1., 1000	Not applicable	Bottom and top of layer through which domain-scale winds are computed (m). Not applied for the Project, used only if IDIOPT3 = 0, NOOBS >0, and IUPWND >0
IDIOPT4	0	0	Observed surface wind components for wind field module
IDIOPT5	0	Not applicable	Observed upper air wind components for wind field module
Lake breeze information:			
LLBREZE	F	F	Lake breeze module was not used
NBOX	-	0	Number of lake breeze regions
XG1	-	0	X Grid line 1 defining the region of interest
XG2	-	0	X Grid line 2 defining the region of interest
YG1	-	0	Y Grid line 1 defining the region of interest
YG2	-	0	Y Grid line 2 defining the region of interest
XBCST	-	0	X Point defining the coastline in kilometres (Straight line)
YBCST	-	0	Y Point defining the coastline in kilometres (Straight line)
XECST	-	0	X Point defining the coastline in kilometres (Straight line)
YECST	-	0	Y Point defining the coastline in kilometres (Straight line)
NLB	-	0	Number of stations in the region
METBXID	-	0	Station IDs in the region

Table E.5-7: CALMET Model Option Group 6: Mixing Height, Temperature, and Precipitation Parameters

Parameter	Default	Project	Comment
Empirical mixing height constants:			
CONSTB	1.41	1.41	Neutral, mechanical equation
CONSTE	0.15	0.15	Convective mixing height equation
CONSTN	2400	2400	Stable mixing height equation
CONSTW	0.16	0.16	Over water mixing height equation
FCORIO	1.0E-4	1.0E-04	Absolute value of Coriolis (s^{-1})
Spatial averaging of mixing heights:			
IAVEZI	1	1	Conduct spatial averaging
MNMDAV	1	1	Maximum search radius in averaging (grid cells)
HAFANG	30	30	Half-angle of upwind looking cone for averaging
ILEVZI	1	1	Layer of winds used in upwind averaging
Convective mixing height options:			
IMIXH	1	1	Method to compute the convective mixing height (Maul-Carson)
THRESHL	0.05	0.05	Threshold buoyancy flux required to sustain convective mixing height growth overland (W/m^3)
THRESHW	0.05	0.05	Threshold buoyancy flux required to sustain convective mixing height growth overwater (W/m^3)
ITWPROG	0	0	Option for overwater lapse rates used in convective mixing height growth (1 = use prognostic lapse rates)
ILUOC3D	16	16	Land use category ocean in 3D.DAT datasets
Other mixing height variables:			
DPTMIN	0.001	0.001	Minimum potential temperature lapse rate in the stable layer above the current convective mixing height (K/m)
DZZI	200	200	Depth of layer above current convective mixing height through which lapse rate is computed (m)
ZIMIN	50	50	Minimum overland mixing height (m)
ZIMAX	3000	4000	Maximum overland mixing height (m)
ZIMINW	50	50	Minimum overwater mixing height (m)
ZIMAXW	3,000	4,000	Maximum overwater mixing height (m)
Overwater surface fluxes method and parameters:			
ICOARE	10	10	Overwater surface fluxes method Set to 10 means COARE with no wave parameterization
DSHELF	0	0	Coastal/Shallow water length scale (km)
IWARM	0	0	COARE warm layer computation
ICOOL	0	0	COARE cool skin layer computation

Parameter	Default	Project	Comment
Relative humidity parameters:			
IRHPROG	0	1	3D relative humidity from WRF 4 km grid resolution prognostic data for the Project
Temperature parameters:			
ITPROG	0	1	3D temperature from WRF 4 km grid resolution prognostic data for the Project
IRAD	1	1	Interpolation type
TRADKM	500	500	Radius of influence for temperature interpolation (km)
NUMTS	5	15	Maximum number of stations to include in temperature interpolation
IAVET	1	1	Conduct spatial averaging of temperatures (1 = yes)
TGDEFB	-0.0098	-0.0098	Default temperature gradient below the mixing height over water (K/m)
TGDEFA	-0.0045	-0.0045	Default temperature gradient above the mixing height over water (K/m)
JWAT1	-	55	Beginning land use categories for temperature interpolation over water
JWAT2	-	55	Ending land use categories for temperature interpolation over water
Precipitation interpolation parameters:			
NFLAGP	2	2	Method of interpolation
SIGMAP	100	Not applicable	Radius of Influence (km) Not applicable for the Project as no precipitation station data was used
CUTP	0.01	0.01	Minimum precipitation rate cut-off (mm/h)

Table E.5-8: CALMET Model Option Group 7: Surface Meteorological Station Parameters

Name	ID	X Coordinate (km)	Y Coordinate (km)	Time zone	Anemometer Height
Ter_Acce	99981	526.055	6041.265		
Telkwa	99982	625.384	6062.156	8	10
Smit_St	99983	617.204	6072.167	8	10
New_Haz	99984	589.890	6122.989	8	10
Kit_Whit	99985	523.547	5991.092	8	10
Kit_Haul	99986	519.546	5986.867	8	10
Kit_Euro	99987	521.197	5982.823	8	10
Hol_Rock	99988	411.170	6003.570	8	10
Pri_Rupe	99989	405.953	6016.318	8	10
Kitwanga	99990	562.773	6108.276	8	10
Hou_Fire	99991	652.882	6030.271	8	10
Smit_Air	99992	616.743	6076.862	8	10
Terr_Air	99993	527.384	6035.497	8	10
Grey_Isl	99994	390.267	6049.409	8	10
Boni_Isl	99995	391.661	5929.135	8	10
Lucy_Isl	99996	387.655	6024.787	8	10

NOTE:
The sites are shown for the 2008–2010 simulation and include:

Ter_Acce	Terrace Access Centre
Telkwa	Telkwa
Smit_St	Smithers St. Josephs
New_Haz	New Hazelton School
Kit_Whit	Kitimat Whitesail
Kit_Haul	Kitimat Haul Road
Kit_Euro	Kitimat Eurocan Dock
Hol_Rock	Holland Rock
Pri_Rupe	Prince Rupert AWOS
Kitwanga	Kitwanga School
Hou_Fire	Houston Firehall
Smit_Air	Smithers Airport
Terr_Air	Terrace Airport
Grey_Isl	Grey Islet (automated)
Boni_Isl	Bonilla Island (automated)
Lucy_Isl	Lucy Island Lightstation

E.6 References

British Columbia Ministry of Environment (BC MOE). 2008. *Guidelines for Air Quality Dispersion Modelling in British Columbia*. Environmental Protection Division, Environmental Quality Branch, Air Protection Section. Victoria, BC.

Commission for Environmental Cooperation (CEC). 2010. *North American Land Change Monitoring System (NALCMS).* North American Land Cover Data. Available at: http://www.cec.org/Page.asp?PageID=924&ContentID=2819. Accessed: January 2014.

Environment Canada. 2014. *National Climate Data and Information Archive*. *Canadian Climate Normals*. Available at: http://www.climate.weatheroffice.ec.gc.ca/climate_normals/index_e.html. Accessed: January 2014.

GeoBase. 2013. *Canadian Digital Elevation Data*. Available at: http://www.geobase.ca/geobase/en/index.html;jsessionid=FBC8E4097F3D49C98CAFA4921EC07F23.geobase2. Accessed: June 2014.

Klausmann, M., M. Phadnis and J. Scire. 2003. *The Application of MM5/WRF Models to Air Quality Assessments*. Thirteenth PSU/NCAR Mesoscale Model Users' Workshop, Boulder, U.S.A., June 2003.

National Center for Atmospheric Research (NCAR). 2008. *Consultation for the MM5 Modeling System.* Available at: http://www.mmm.ucar.edu/mm5/support/consult.html. Accessed: April 2014.

Scire, J.S., F.R. Robe, M.E. Ferneau, and R.J. Yamartino. 2000. *A User's Guide for the CALMET Meteorological Model*. Earth Tech Inc. Concord, MA.

TRC. 2011. *CALPUFF Modeling System Version 6 User Instructions*. Available at: http://www.src.com/calpuff/download/download.htm. Accessed: January 2014.

Turner, D.B. 1963. A diffusion model for an urban area. *Journal of Applied Meteorology* 3(1):83–91.

United States Environmental Protection Agency (U.S. EPA). 2010. *Multiscale Meteorological Modeling for Air Quality.* Atmospheric Modeling and Analysis Division. Available at: http://www.epa.gov/AMD/Research/Air/meteorologicalModeling.html. Accessed: June 2014.

Van der Kamp, D. and I.G. McKendry. 2010. Diurnal and seasonal trends in convective mixed-layer heights estimated from two years of continuous ceilometer observations in Vancouver, BC. *Boundary-Layer Meteorology* 137(3): 459–475.

APPENDIX F

CALPUFF

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F.1 Introduction

Ambient air quality models are used to predict changes in air quality (i.e., changes in ambient concentrations or deposition) associated with current and future emission scenarios. This appendix discusses the selection and application of the primary dispersion model that is used for the LNG Canada Export Terminal (the Project) air quality assessment.

F.1.1 Model Types

Air quality dispersion models provide a scientific means of relating industrial and community emissions to changes in air quality using mathematical equations to simulate transport, dispersion, transformation, and deposition processes in the atmosphere. Dispersion models can address a wide range of distance scales (hundreds of metres to thousands of kilometres) and time scales (minutes to years). There are two levels of modelling effort:

- **Screening models** estimate maximum short-term (1-hour) average concentrations for a wide range of pre-selected meteorological conditions. These models are typically limited to single sources and downwind distances of less than 10 km (e.g., the United States Environmental Protection Agency [U.S. EPA] SCREEN3 model).
- **Refined models** use sequential hourly meteorological data for a one to three year period (8,760 hours to 26,280 hours, respectively). These models can address multiple sources and can predict hourly average concentrations for all source, meteorology, and receptor combinations. The hourly concentrations can be used to predict concentrations for averaging periods that are factors of 24 (i.e., 2, 3, 4, 6, 8, or 12 hours) or for longer periods (i.e., seasonal or annual). Some refined models can also account for chemical transformation and deposition processes.

Regulatory agencies rely on dispersion models as part of the approval process for projects requiring environmental review. Numerous models are available to predict ambient air quality changes, and the appropriate selection depends on project-specific circumstances. In response to the regulatory use of these models, formal guidelines regarding the selection and application of these models have been developed, such as the *Guidelines for Air Quality Dispersion Modelling in British Columbia* (BC MOE 2008).

F.1.2 Model Input and Output Files

The application of a dispersion model requires the preparation of input files and the analysis of output files. Input files include the following:

- control/option information to identify the model run, to select the available technical features, and to control the output options specific to the selected model
- source data that identify the locations, emission characteristics (e.g., stack height), and emission rates (e.g., nitrogen oxides [NO_X] emission rate) for each source
- terrain elevations and surface characteristics to account for terrain influences on airflow and turbulence
- surface characteristics to provide the deposition properties for the vegetation canopy, and
- hourly meteorological data to characterize airflow, temperature, precipitation, humidity, mixing height and turbulence in the region.

The output files can include:

- a summary file to identify the model run and to provide an overview of the run
- hourly concentration files for each receptor and meteorological combination, and
- hourly deposition files for each receptor and meteorological combination.

Presentation software is used to reformat the model predictions and to provide concentrations and deposition contour plots that can be superimposed over base maps.

F.2 Model Selection

F.2.1 Model Requirements

For this assessment, the selected model must have the ability to account for:

- multiple point, line and area sources
- flat and elevated terrain features
- secondary particulate matter ($PM_{2.5}$) formation
- sulphur dioxide (SO_2) to sulphate (SO_4^{2-}), and nitrogen oxides (NO_x) to nitrate (NO_3^-) conversion, and
- wet, dry, gaseous, and particulate deposition processes.

These features are required to predict ambient concentrations and potential acid input.

F.2.2 Candidate Models

Table F.2–1 describes the dispersion models outlined in the British Columbia Ministry of Environment (BC MOE) modelling guidelines (BC MOE 2008). Of these models, only the CALPUFF model can be used to predict secondary $PM_{2.5}$ formation, chemical transformation, and deposition of acidifying compounds.

The CALPUFF model was therefore selected as the preferred model for this assessment. CALPUFF has two options with respect to meteorological data:

- The simple mode assumes a uniform meteorological field over the model domain (defined in Appendix E) during a given hour. While this approach is consistent with the AERMOD model, CALPUFF has the advantage of allowing the plume trajectories to vary from hour-to-hour in a systematic manner as the wind direction varies from hour-to-hour. This becomes more important to include when the model is applied to larger domains.
- The CALMET model allows for three-dimensionally varying meteorological fields over the model domain during a given hour.

For this assessment, the CALPUFF model with the three-dimensional CALMET wind field was used (see Appendix E). The CALPUFF and CALMET models and documentation are available online at http://www.src.com/calpuff/calpuff1.htm.

The SCREEN3 model is applied to the marine vessels travelling along the marine access route outside the Kitimat area to evaluate air quality effects from marine shipping activity. The SCREEN3 model and corresponding documentation are available from the United States Support Centre for Regulatory Air Models website: http://www.epa.gov/ttn/scram.

Table F.2–1: Dispersion Models Identified in the BC MOE Air Quality Modelling Guidelines

The **SCREEN3** (U.S. EPA 1995) model is a Gaussian plume model that provides maximum ground-level concentration predictions for point, area, flare, and volume sources. SCREEN3 is able to account for a variety of effects, including: building downwash for the near-wake and far-wake regions, cavity recirculation, and flare releases. This model can incorporate the effects of terrain below stack height on maximum concentrations and can also estimate 24-hour average concentrations resulting from point-source plume impaction on terrain above stack height.
AERMOD (U.S. EPA 2004) is a straight-line, steady-state plume model that is an improvement over ISC-PRIME in that it incorporates recent boundary layer theory and advanced methods for handling terrain. AERMOD has some Gaussian plume characteristics but also contains new or improved algorithms for dispersion under stable and unstable conditions; plume rise and buoyancy; plume penetration into elevated inversions; treatment of elevated, near-surface, and surface level sources; computation of vertical profiles of wind, turbulence, and temperature; terrain effects on plume behaviour. AERMOD also includes the PRIME building downwash algorithms.
The **CALPUFF** (Scire et al. 2000) model is a multi-layer, multi-species, non-steady state puff dispersion model that can simulate the effects of time and space-varying meteorological conditions on substance transport, transformation, and removal. CALPUFF can use the three-dimensional meteorological fields developed by the CALMET model or simple, single station winds in a format consistent with the meteorological files used to drive the ISCST3 steady-state Gaussian models.

F.2.3 CALPUFF Model

CALPUFF contains algorithms for near-source effects, such as building downwash, transitional plume rise, and partial plume penetration, as well as longer-range effects, such as chemical transformation and pollutant removal (wet scavenging and dry deposition). It can accommodate arbitrarily varying point source and area source emissions. Most of the algorithms contain options to treat physical processes at differing levels of detail depending on the requirements for the particular model application:

- **Atmospheric Dispersion:** Several options are provided in CALPUFF for the computation of dispersion coefficients:
  - similarity theory to estimate σ_v and σ_w from surface heat and momentum fluxes provided by CALMET
  - Pasquill-Gifford (PG) dispersion coefficients
  - dispersion equations based on the Complex Terrain Dispersion Model (CTDM), and
  - hourly values of direct turbulence measurements (σ_v and σ_w).
- **Chemical Transformation:** CALPUFF includes options to parameterize chemical transformation effects using the five species scheme (SO_2, SO_4^{2-}, NO_X, HNO_3, and NO_3^-) employed in the MESOPUFF II model, a modified six-species scheme (SO_2, SO_4^{2-}, NO, NO_2, HNO_3, and NO_3^-) adapted from the RIVAD/ARM3 method, or a set of user-specified, diurnally-varying transformation rates (Scire et al. 2000).
- **Dry Deposition:** A full resistance model is provided to calculate dry deposition rates of gases and particulate matter as a function of geophysical parameters, meteorological conditions, and substance properties. Options are provided to allow user-specified, diurnally varying deposition velocities to be used for one or more pollutants instead of the resistance model (e.g., for sensitivity testing) or to bypass the dry deposition model completely.
- **Wet Deposition:** An empirical scavenging coefficient approach is used in CALPUFF to compute the depletion and wet deposition fluxes attributable to precipitation scavenging. The scavenging coefficients are specified as a function of the pollutant and precipitation type (i.e., frozen vs. liquid precipitation).

The following section describes the application of the CALPUFF model specific to this assessment.

F.3 Model Application

F.3.1 Model Domain

The CALPUFF model requires the user to define a domain where emission sources are identified, meteorological conditions are characterized, and locations where changes in air quality are to be predicted. Two CALPUFF modelling domains—the near-field and far-field computational domains—are used for the Project:

- The near-field domain is sized to encompass the Project sources, existing and planned industrial sources, and nearby marine terminals. It captures all values of interest (e.g., predicted concentrations greater than 10% of the applicable ambient air quality objective) as per the modelling guidelines (BC MOE 2008). The domain area is 78 kilometres (km) by 78 km, centred on the liquefied natural gas (LNG) facility.
- The far-field domain is comprised of a 320 km by 320 km area centred on the LNG facility. The far-field domain is sized to capture the areas potentially affected by acidification and eutrophication as well as any sensitive receptors not included in the near-field domain.

Boundary coordinates of the two model domains are provided in Table F.3–1.

Table F.3–1: CALPUFF Study Area Coordinates (UTM Zone 9, NAD 83)

	Easting (m)	Northing (m)
Near-Field Modelling Domain		
Southwest Corner	480410	5946860
Southeast Corner	558410	5946860
Northwest Corner	480410	6024860
Northeast Corner	558410	6024860
Far-Field Modelling Domain		
Southwest Corner	352410	5824860
Southeast Corner	672410	5824860
Northwest Corner	352410	6144860
Northeast Corner	672410	6144860

F.3.2 Receptor Locations

Four types of receptors in the model domain are defined: nested Cartesian near-field gridded points, nested Cartesian far-field gridded points, selected sensitive receptors, and gridded points for human health assessment areas.

F.3.2.1 Gridded Near-Field Receptors

The nested receptor points that are used to provide an understanding of the spatial concentration and deposition patterns due to Project emissions are shown in Figure F.3–1. The receptors are based on the following spacing:

- 20 m spacing along the Project boundary, including the marine terminal
- 50 m spacing within 2.8 km by 5.4 km of the facility (**Grid E**)
- 50 m spacing within a 2.5 km by 3.5 km area centred at the Project-alone case maximum point of impingement (**Grid E**)
- 50 m spacing along other industrial fencelines
- 250 m spacing within 5.75 km by 8.5 km of the facility (**Grid D**)
- 500 m spacing within 12 km by 15 km of the facility (**Grid C**)
- 1,000 m spacing within 40 km by 40 km of the facility (**Grid B**), and
- 2,000 m spacing beyond 40 km of the facility (**Grid A**).

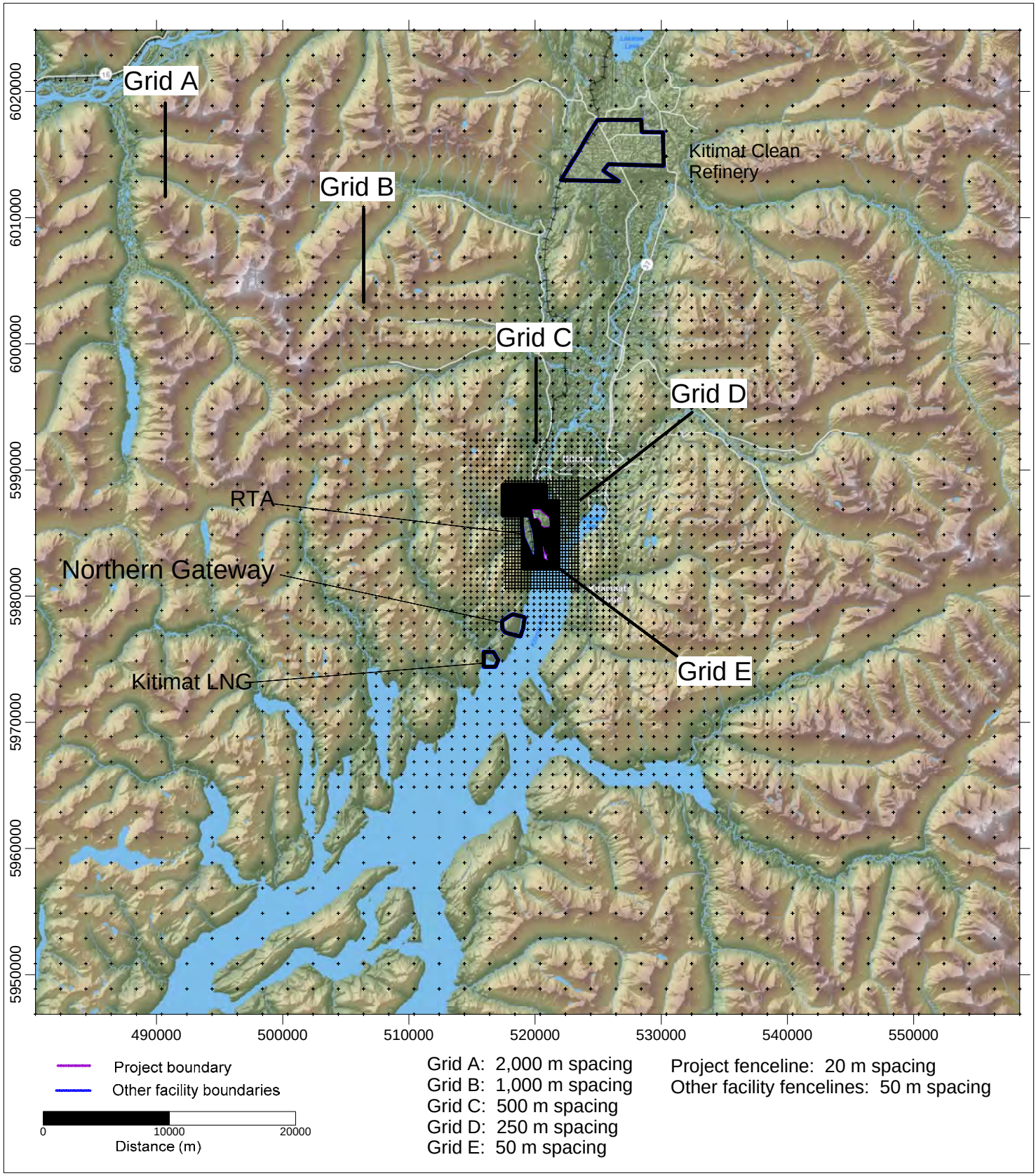
The grid density is greatest near the LNG facility to allow the assessment to focus on the effects of Project emissions. More distant from the LNG facility, the resolution is sufficient to determine the additive effects of Project emissions with emissions from other sources. The density of the receptor grid is based on recommendations in the modelling guidelines (BC MOE 2008).

F.3.2.2 Gridded Far-Field Receptors

The nested far-field receptor points (see Figure F.3-2) were created on the 320 km by 320 km CALPUFF modelling domain with the following spacing:

- 1,000 m spacing within a 44 km by 117 km area covering the Kitimat and Terrace regions, and
- 4,000 m spacing beyond the 44 km by 117 km area.

These receptors are sufficient to provide predictions of the magnitude and spatial variations of depositions attributable to Project emissions for the acidification and eutrophication assessment.



+ Discrete Receptor

- 20 m spacing along Project boundary
- 50 m spacing within 2.8 km by 5.4 km of the facility
- 50 m spacing within a 2.5 km by 3.5 km area centred at the Project alone case maximum point of impingement
- 50 m spacing along other industrial fencelines
- 250 m spacing within 5.75 km by 8.5 km of the facility
- 500 m spacing within 12 km by 15 km of the facility
- 1,000 m spacing within 40 km by 40 km of the facility
- 2,000 m spacing beyond 40 km of the facility

LNG Canada

CALPUFF Near-Field Receptor Grid
(78 km by 78 km)

Sources: Natural Resources Canada.

Although there is no reason to believe that there are any errors associated with the data used to generate this product or in the product itself, users of these data are advised that errors in the data may be present

DATE:	27 - Feb - 2014	PROJECTION:	UTM - ZONE 9
FIGURE ID:	fig_receptor_grid	DATUM:	NAD 83
DRAWN BY:	J. WANG	CHECKED BY:	J. SPAGNOL

PREPARED BY: Stantec

PREPARED FOR: LNGCANADA

FIGURE NO: F.3-1

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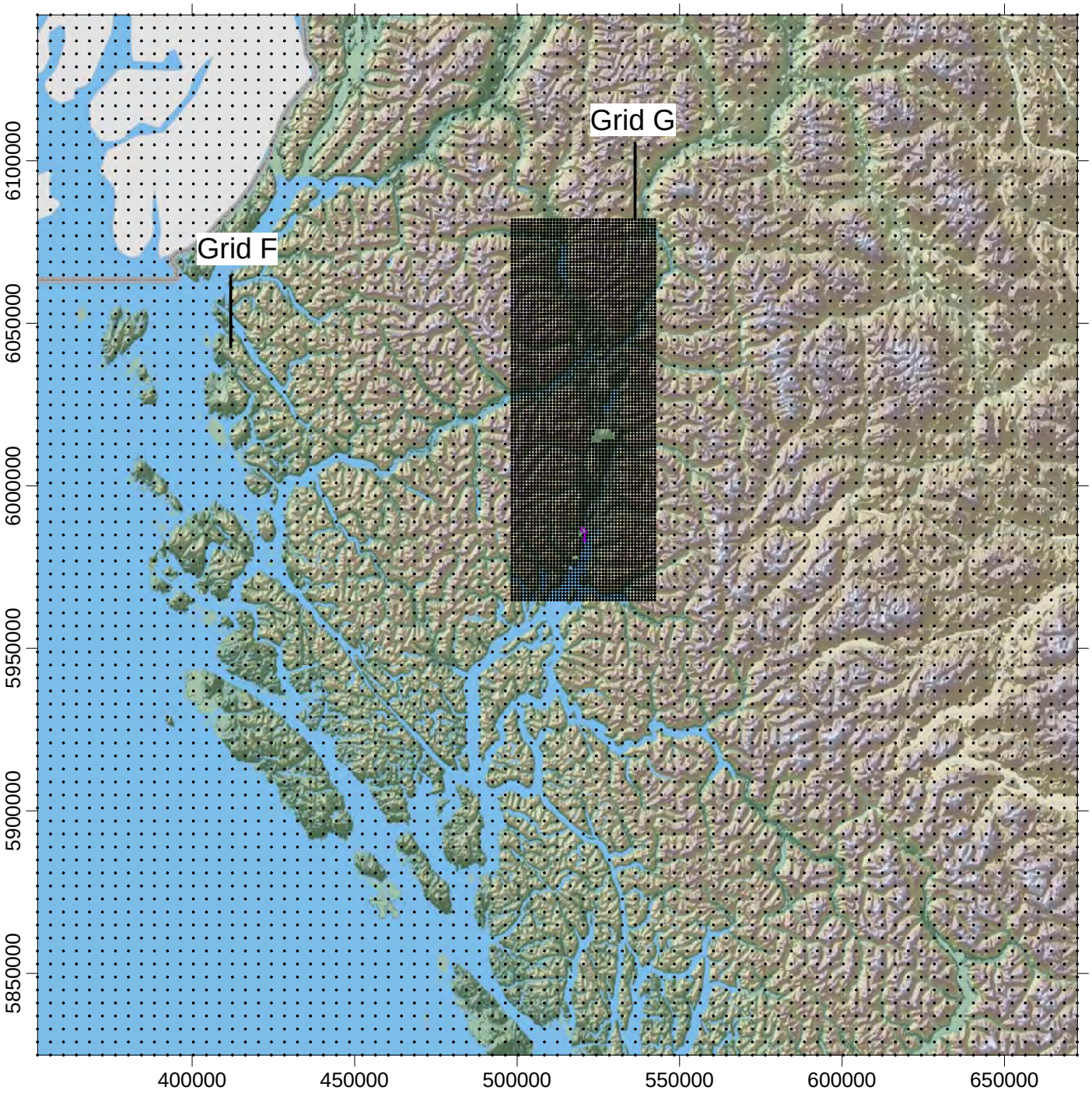


+ Discrete Receptor

- 1,000 m spacing within 44 km by 117 km area covering the Kitimat and Terrace region
- 4,000 m spacing beyond the 44 km by 117 km area

LNG Canada

CALPUFF Far-Field Receptor Grid
(320 km by 320 km)

Sources: Natural Resources Canada.

Although there is no reason to believe that there are any errors associated with the data used to generate this product or in the product itself, users of these data are advised that errors in the data may be present

DATE:	14 - March - 2014	PROJECTION:	UTM - ZONE 9
FIGURE ID:	fig_contours	DATUM:	NAD 83
DRAWN BY:	B. ZHANG	CHECKED BY:	J. SPAGNOL

PREPARED BY: Stantec

PREPARED FOR: LNGCANADA

FIGURE NO: F.3-2

F.3.2.3 Sensitive Receptors

In addition to the gridded receptor points, 112 discrete locations corresponding to specific sites of interest are included in the assessment. Table F.3-2 identifies the names and associated coordinates of these sensitive receptors. These receptors are broadly grouped as follows:

- 83 sensitive receptors correspond to selected lakes, creeks, and rivers for the aquatics assessment, and
- 29 human health sensitive receptors correspond to schools, daycare centres, health care facilities, and residential areas.

Locations of the sensitive receptors are shown in Figure F.3-3.

F.3.2.4 Gridded Human Health Assessment Receptors

Five selected human health assessment areas (shown in Figure F.3-3) are defined with 50 m grid point spacing to provide an understanding of the spatial deposition patterns attributable to Project emissions over the Kitimat area. The human health assessment grid is comprised of 7,684 receptor points.

Table F.3-2: Names and Locations of Sensitive Receptors

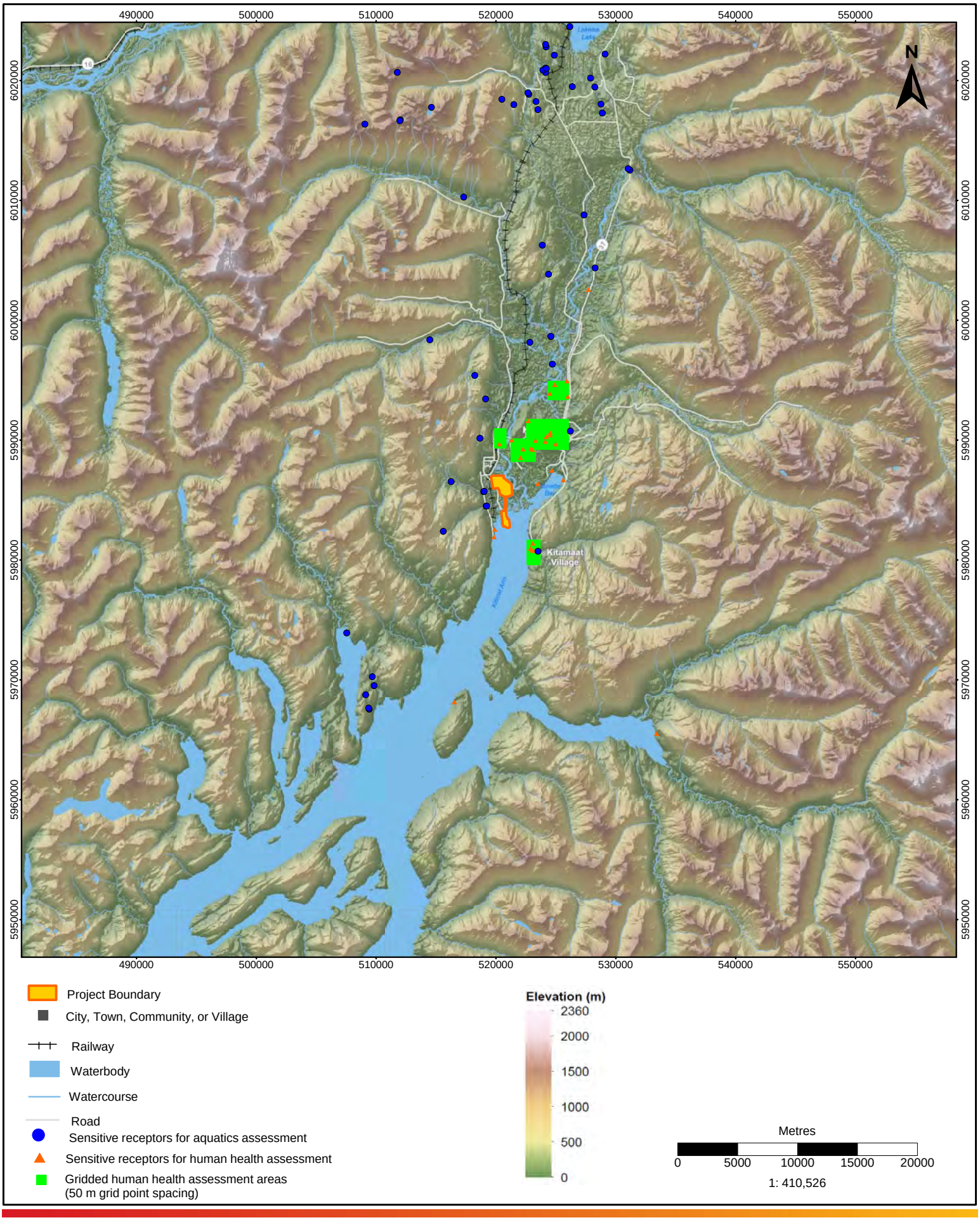
Receptor ID	Receptor Name	UTM Zone	UTM Easting (m)	UTM Northing (m)
LAK 01	Hai Lake	9	524902	6030031
LAK 02	Herman Lake	9	526167	6029625
LAK 03	Herman Lake	9	523872	6006261
LAK 04	Herman Lake	9	521495	6017989
LAK 05	Herman Lake	9	523496	6017571
LAK 06	End Lake	9	524155	6020661
LAK 07	Clearwater Lakes	9	528771	6018028
LAK 08	Clearwater Lakes	9	526372	6019486
LAK 11	Clearwater Lakes	9	520497	6018425
LAK 12	Clearwater Lakes	9	524145	6021028
LAK 13	Clearwater Lakes	9	528030	6029449
LAK 14	Ena Lake	9	524874	6022115
LAK 15	Ena Lake	9	524389	6003837
LAK 16	Ena Lake	9	523347	6018243
LAK 17	Ena Lake	9	527352	6008780
LAK 18	Clearwater Lakes	9	528877	6017283
LAK 22	Clearwater Lakes	9	524185	6022796
LAK 23	West Lake	9	522750	6018850
LAK 24	Lakelse Lake	9	529485	6027587
LAK 27	Bowbyes Lake	9	518232	5995394

Receptor ID	Receptor Name	UTM Zone	UTM Easting (m)	UTM Northing (m)
LAK 28	Bowbyes Lake	9	519139	5993425
LAK 30	Bowbyes Lake	9	518664	5990153
LAK 32	Bowbyes Lake	9	521235	6047108
LAK 34	Bowbyes Lake	9	525386	6049589
LAK 35	Bowbyes Lake	9	532929	6048155
LAK 37	Bowbyes Lake	9	529805	6047783
LAK 38	Bowbyes Lake	9	531275	6047088
LAK 39	Bowbyes Lake	9	530899	6048213
LAK 41	Bowbyes Lake	9	510173	6048579
LAK 42	Bowbyes Lake	9	520911	6048362
LAK 44	Bowbyes Lake	9	522541	6050321
LAK 45	Bowbyes Lake	9	509063	6016350
LAK 47	Bowbyes Lake	9	512026	6016712
LAK 49	Bowbyes Lake	9	514619	6017762
LAK 50	Bowbyes Lake	9	511772	6020675
LAK 51	Bowbyes Lake	9	513427	6030393
LAK 53	Jesse Lake	9	507548	5973909
LAK 54	Jesse Lake	9	509425	5967551
LAK 55	Jesse Lake	9	509678	5970261
LAK 56	Jesse Lake	9	509126	5968749
LAK 57	Jesse Lake	9	509833	5969514
STR 01	Anderson Creek u/s	9	516262	5986538
STR 02	Anderson Creek d/s	9	518978	5985696
STR 03	Clearwater Creek	9	528251	6019455
STR 04	Furlong Creek	9	531506	6028178
STR 05	Hatchery Creek	9	530637	6025347
STR 06	Hirsch Creek	9	526210	5990748
STR 07	Humphrys Creek	9	528275	6004359
STR 08	Kitimat River u/s	9	531185	6012512
STR 09	Kitimat River d/s	9	524711	5996333
STR 10	Lakelse River u/s	9	520838	6030544
STR 11	Lakelse River d/s	9	515370	6032863
STR 12	Little Wedeene River u/s	9	514480	5998366
STR 13	Little Wedeene River d/s	9	522827	5998156
STR 14	Moore Creek u/s	9	515607	5982383
STR 15	Moore Creek d/s	9	519186	5984492
STR 16	Schulbuckhand Creek	9	529109	6022205

Receptor ID	Receptor Name	UTM Zone	UTM Easting (m)	UTM Northing (m)
STR 17	Wedeene River u/s	9	517313	6010274
STR 18	Wedeene River d/s	9	524585	5998646
STR 19	Williams Creek	9	533988	6032904
STR 20	Wathl Creek	9	523506	5980726
REF 01	Wathl Creek	9	518039	6052028
REF 02	Wathl Creek	9	519975	6051301
Lakelse inlet	Lakelse Lake	9	529936	6027821
Lakelse outlet	Lakelse Lake	9	526166	6024493
Lakelse middle	Lakelse Lake	9	528853	6026718
LAK 51 - S	Lakelse Lake	9	513356	6030313
STR 15 - S	Moore Creek d/s	9	519220	5984496
STR 02 - S	Anderson Creek	9	519018	5985724
STR 18 - S	Wedeene River	9	524585	5998657
STR 08 - S	Kitimat River	9	531026	6012640
STR 03 - S	Clearwater Creek	9	527899	6020199
STR 11 - S	Lakelse River, d/s	9	515283	6032676
STR 10 - S	Lakelse River u/s	9	520829	6030555
STR 05 - S	Hatchery Creek	9	530775	6025442
LAK 06 - S	End Lake	9	523917	6020863
LAK 12 - S	End Lake	9	524199	6020996
LAK 22 - S	End Lake	9	524142	6023003
LAK 23 - S	West Lake	9	522673	6018972
LAK 42 - S	West Lake	9	520904	6048413
LAK 44 - S	West Lake	9	522602	6050387
LAK 47 - S	West Lake	9	511976	6016644
LAK 04 - S	West Lake	9	509376	5967643
HHERA1	Mt. Elizabeth Secondary High School	9	524512	5990357
HHERA2	Nechako Elementary School	9	524114	5989809
HHERA3	Kildala Elementary School	9	522251	5989177
HHERA4	St Anthony's Catholic Elementary School	9	524975	5989606
HHERA5	Kitimat City High School	9	523302	5989884
HHERA6	Haisla Community School	9	523150	5980708
HHERA7	C'Imo'Ca Child Care Centre	9	523016	5980749
HHERA8	Kitimat Child Development Centre	9	524529	5990549
HHERA9	Stepping Stones Preschool	9	524198	5990214
HHERA10	Kitimat General Hospital and Health Centre	9	523067	5989132
HHERA11	Haisla Recovery Centre - Kitamaat Village	9	522881	5980891

Receptor ID	Receptor Name	UTM Zone	UTM Easting (m)	UTM Northing (m)
HHERA12	Nearest resident - Kitamaat Village (Haisla)	9	523078	5981322
HHERA13	Nearest resident - Kitimat town	9	522056	5988463
HHERA14	Kitimat residence2	9	521314	5989938
HHERA15	SE residence	9	523502	5986309
HHERA16	Kitimat residenceN	9	522694	5991544
HHERA17	N Kitimat (SW)	9	524485	5993829
HHERA18	N Kitimat (NW)	9	524907	5994564
HHERA19	N Kitimat (NE)	9	525922	5994860
HHERA20	N Kitimat (SE)	9	526001	5993572
HHERA21	Kiwanis Senior Society	9	522929	5989229
HHERA22	Coste Island	9	516535	5968079
HHERA23	SW dockyard	9	519911	5982474
HHERA24	Half Moon Bay	9	519840	5981852
HHERA25	Minette Bay1	9	525621	5986610
HHERA26	Minette Bay Lodge	9	524665	5987418
HHERA27	Kitimat Service Area	9	520279	5989605
HHERA28	Kitimat Airport	9	527723	6002502
HHERA29	Kildala Beach	9	533408	5965438

NOTE:
u/s – upstream
d/s – downstream



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AIR QUALITY TECHNICAL DATA REPORT

CALPUFF Human Health Receptor Grid and Sensitive Receptor Locations

LNG CANADA EXPORT TERMINAL
KITIMAT, BRITISH COLUMBIA

PROJECTION: UTM9	DRAWN BY: JW
DATUM: NAD 83	CHECKED BY: JS
DATE: 6-MAY-14	FIGURE NO.: F.3-3

F.3.3 Meteorology

The CALMET diagnostic wind field module was used to provide representative wind, temperature, and turbulence fields (see Appendix E). Three years (2008 to 2010) of hourly CALMET input files are included in the assessment. The meteorology inputs for each year reflect seasonal variation in the land-cover properties (see Appendix E).

F.3.4 Model Options

The CALPUFF model offers a number of execution options. Table F.3-3 provides a detailed listing of all CALPUFF model user options selected for one of the CALPUFF simulations done for this assessment. Recommendations from the British Columbia (BC) modelling guidelines (BC MOE 2008) were fully applied. Model default values, as recommended by U.S. EPA, are presented for comparative purposes. In most cases, these default values were used.

Table F.3-3: CALPUFF Options Used for the Assessment

Input Group	Parameter	U.S. EPA Default	LNG Canada	Description
Group 1: General Run Control Parameters	METRUN	0	0	Run all period in met file
	IBYR	-	2008	Starting year
	IBMO	-	1	Starting month
	IBDY	-	1	Starting day
	IBHR	-	0	Starting hour
	IBMIN	-	0	Starting minute
	IBSEC	-	0	Starting second
	IEYR	-	2011	Starting year
	IEMO	-	1	Starting month
	IEDY	-	1	Starting day
	IEHR	-	0	Starting hour
	IEMIN	-	0	Starting minute
	IESEC	-	0	Starting second
	ABTZ	-	UTC-0800	Time zone, Pacific Standard Time
	NSECDT	3,600	3,600	Length of modelling time-step (s)
	NSPEC	5	11	Number of chemical species modelled
	NSE	3	8	Number of chemical species emitted
	ITEST	2	2	Continue with model execution after setup
	MRESTART	0	0	Do not write a restart file
	NRESPD	0	0	Write restart file only at last period
	METFM	1	1	CALMET binary file (CALMET.MET)
	MPRFFM	1	1	CTDM plus tower file (PROFILE.DAT)

Input Group	Parameter	U.S. EPA Default	LNG Canada	Description
	AVET	60	60	Averaging time is 60 minutes
	PGTIME	60	60	PG averaging time is 60 minutes
	IOUTU	1	1	Mass unit applied – g/m^3 or $g/m^2/s$
	IOVERS	2	2	Dataset Version 2.2 applied
Group 2: Technical Options	MGAUSS	1	1	Gaussian distribution used in the near field
	MCTADJ	3	3	Partial Plume Path Adjustment Method of terrain adjustment
	MCTSG	0	0	Subgrid-scale complex terrain not modelled
	MSLUG	0	0	Near-field puffs not elongated
	MTRANS	1	1	Transitional plume rise computed
	MTIP	1	1	Stack tip downwash applied
	MBDW	1	2	PRIME method is applied
	MRISE	1	1	Briggs plume rise used
	MSHEAR	0	0	Vertical wind shear not modelled
	MSPLIT	0	0	No puff splitting allowed
	MCHEM	1	3	Transformation rates computed internally (RIVAD/ARM3 scheme)
	MAQCHEM	0	0	Aqueous phase transformation not modelled
	MLWC	1	1	Gridded cloud water data read from CALMET data file
	MWET	1	1	Wet removal modelled
	MDRY	1	1	Dry removal modelled
	MTILT	0	0	Gravitational setting is not modelled
	MDISP	3	2	Dispersion coefficients calculated from micrometeorological variables
	MTURBVW	3	3	Use direct turbulence measurements to estimate dispersion
	MDISP2	3	3	Use PG coefficients when turbulence measurements not available
	MTAULY	0	0	Draxler default 617.284s
	MTAUADV	0	0	No turbulence advection is applied
	MCTURB	1	1	Standard CALPUFF subroutines is applied
	MROUGH	0	0	Sigma Y and Z are not adjusted for roughness
	MPARTL	1	1	Model partial plume penetration of elevated inversion applied for point sources
	MPARTLBA	1	1	Model partial plume penetration of elevated inversion applied for buoyant area sources
	MTINV	0	0	Strength of temperature inversion is computed from default gradients
	MPDF	0	1	Use PDF to compute near-field dispersion under convective conditions

Input Group	Parameter	U.S. EPA Default	LNG Canada	Description
	MSGTIBL	0	0	Sub-grid TIBL module is not used
	MBCON	0	0	Boundary conditions are not modelled
	MSOURCE	0	0	Individual source contributions are not saved
	MFOG	0	0	Not configured for fog model output
	MREG	1	0	Do not test options against defaults
Group 3: Species List	CSPEC	SO_2, SO_4, NO, NO_2, HNO_3, NO_3, $PM_{2.5}$, CO, NO_X, H_2S, VOC		List of chemical species
	-	SO_2		Modelled, Emitted, Dry deposited
	-	SO_4		Modelled, Dry deposited
		NO		Modelled, Emitted, Dry deposited
		NO_2		Modelled, Emitted, Dry deposited
		HNO_3		Modelled, Dry deposited
	-	NO_3		Modelled, Dry deposited
	-	$PM_{2.5}$		Modelled, Emitted, Dry deposited
	-	CO		Modelled, Emitted
		NO_X		Modelled, Emitted
	-	H_2S		Modelled, Emitted
	-	VOC		Modelled, Emitted
Group 4: Grid Control Parameters	PMAP	UTM	UTM	Universal Transverse Mercator for Projection of all X, Y
	FEAST	0	0	False Easting (Not Used)
	FNORTH	0	0	False Northing (Not Used)
	IUTMZN	-	9	UTM Zone
	UTMHEM	N	N	Northern Hemisphere
	RLAT0	-	40N	Latitude of Projection Origin
	RLON0	-	90W	Longitude of Projection Origin
	XLAT1	-	30N	Latitude of 1st Parallel
	XLAT2	-	60N	Latitude of 2nd Parallel
	DATUM	WGS-84	NAR-C	North American 1983 GRS 80 Spheriod, Mean for Conus, NAD83
	NX	-	160	Number of X grid cells
	NY	-	160	Number of Y grid cells
	NZ	-	10	Number of vertical grid cells
	DGRIDKM	-	0.5	Grid spacing in X and Y directions (km)
	ZFACE	-	0, 20, 40, 80, 160, 320, 640, 1200, 2000, 3000, 4000	Vertical cell face heights of the NZ vertical layers

Input Group	Parameter	U.S. EPA Default	LNG Canada	Description
	XORIGKM	-	480.36	Reference Easting of SW corner of SW grid cell in UTM (km)
	YORIGKM	-	5946.31	Reference Northing of SW corner of SW grid cell in UTM (km)
	IBCOMP	-	1	X index of lower left grid cell for computation
	JBCOMP	-	1	Y index of lower left grid cell for computation
	IECOMP	-	160	X index of upper right grid cell for computation
	JECOMP	-	160	Y index of upper right grid cell for computation
	LSAMP	T	F	Sampling grid is not used
	IBSAMP	-	0	X index of lower left grid cell for sampling
	JBSAMP	-	0	Y index of lower left grid cell for sampling
	IESAMP	-	0	X index of upper right grid cell for sampling
	JESAMP	-	0	Y index of upper right grid cell for sampling
	MESHDN	1	1	Nesting factor of sampling grid
Group 5: Output Options	ICON	1	1	Create binary concentration output file
	IDRY	1	1	Binary dry flux output file is created
	IWET	1	1	Binary wet flux output file is created
	IT2D	0	0	Output file containing 2D temperature is not created
	IRHO	0	0	Output file containing 2D density is not created
	IVIS	1	0	Output file containing relative humidity is not created
	LCOMPRS	T	T	Use data compression
	IQAPLOT	1	1	Create a standard series of output files suitable for plotting
	IPFTRAK	0	0	No puff locations reported
	IMFLX	0	0	Diagnostic mass flux option not applied
	IMBAL	0	0	Do not report hourly mass balance for each species
	INRISE	0	0	File with plume properties for rise increment
	ICPRT	0	0	Do not print concentrations to list file
	IDPRT	0	0	Do not print dry fluxes to list file
	IWPRT	0	0	Do not print wet fluxes to list file
	ICFRQ	1	24	Concentration print interval in hours
	IDFRQ	1	24	Dry flux print interval in hours
	IWFRQ	1	24	Wet flux print interval in hours
	IPRTU	1	3	Output units are µg m^{-3} for concentration and µg m^{-2} s^{-1} for fluxes
	IMESG	2	2	Track progress of run on screen
	-	SO_2		Concentrations, dry fluxes, and wet fluxes are saved on disk.
	-	SO_4		

Input Group	Parameter	U.S. EPA Default	LNG Canada	Description	
	-	NO			
	-	NO_2			
	-	HNO_3			
		NO_3			
		$PM_{2.5}$			
		CO			
		NO_X			
		H_2S			
		VOC			
	LDEBUG	F	F	Do not print debug data	
	IPFDEB	1	1	Debug options - First puff to track	
	NPFDEB	1	1	Debug options - Number of puffs to track	
	NN1	1	1	Debug options - Met period to start output	
	NN2	10	10	Debug options - Met period to end output	
Group 6: Subgrid Scale Complex Terrain Inputs	NHILL	0	0	Number of terrain features	
	NCTREC	0	0	Number of complex terrain receptors	
	MHILL	-	2	Hill data created by OPTHILL and input below in Subgroup (6b); Receptor data in Subgroup (6c)	
	XHILL2M	1	1	Horizontal conversion factor to meters	
	ZHILL2M	1	1	Vertical conversion factor to metres	
	XCTDMKM	-	0	CTDM X origin relative to CALPUFF grid	
	YCTDMKM	-	0	CTDM Y origin relative to CALPUFF grid	
Group 7: Chemical Parameters for Dry Deposition of Gases	Diffusivity	Alpha Star	Reactivity	Mesophyll Resistance	Henry's Law Coefficient
SO_2	0.1509	1000	8.0	0	0.04
NO	0.1345	1	2.0	25	18.0
NO_2	0.1656	1	8.0	5	3.5
HNO_3	0.1628	1	18.0	0	0.00000008
Group 8: Size Parameters for Dry Deposition of Particles		Geometric Mass Mean (microns)		Geometric Standard Deviation (microns)	
	SO_4	0.48		2.0	
	NO_3	0.48		2.0	
	$PM_{2.5}$	0.12		1.0	
Group 9: Miscellaneous Dry Deposition	RCUTR	30	30	Reference cuticle resistance	
	RGR	10	10	Reference ground resistance	
	REACTR	8	8	Reference pollutant reactivity	

Input Group	Parameter	U.S. EPA Default	LNG Canada	Description
Parameters	NINT	9	9	Number of particle size intervals used to evaluate effective particle deposition velocity
	IVEG	1	1	Vegetation in non-irrigated areas is active and unstressed
Group 10: Wet Deposition Parameters		Liquid Precip Coef.		Frozen Precip Coef.
	SO_2	0.00003		0
	SO_4	0.0001		0.00003
	NO	0.000029		0
	NO_2	0.000051		0
	HNO_3	0.00006		0
	NO_3	0.0001		0.00003
	$PM_{2.5}$	0.0001		0.00003
Group 11: Chemistry Parameters	MOZ	1	1	Hourly ozone values are used in chemistry
	MNH_3	0	0	Monthly ammonia (NH_3) values are used in chemistry
	$BCKNH_3$	12*10	12*0.5	Constant background monthly NH_3 concentration in ppb
	RNITE1	0.2	0.2	Nighttime SO_2 loss rate (% per hour) (Not Used)
	RNITE2	2	2	Night time NO_X loss rate (% per hour) (Not Used)
	RNITE3	2	2	Night time HNO_3 formation rate (% per hour) (Not Used)
	$BCKH_2O_2$	12*1	12*1	Background H_2O_2 (Not Used)
	BCKPMF	12*1	12*1	Background fine particulate matter (Not Used)
	OFRAC	12*0.20	0.15, 0.15, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.20, 0.15	Organic fraction of fine particulate matter (Not Used)
	VCNX	12*50	12*50	VOC/NO_X ratio for chemistry (Not Used)
Group 12: Miscellaneous Dispersion and Computational Parameters	SYTDEP	550	550	Horizontal size of puff (m) beyond which Heffer dispersion is applied
	MHFTSZ	0	0	Do not use Heffer formulas for sigma Z
	JSUP	5	5	Stability class used to determine plume growth rates for puff above the boundary layer
	CONK1	0.01	0.01	Vertical dispersion constant for stable conditions
	CONK2	0.1	0.1	Vertical dispersion constant for neutral/unstable conditions
	TBD	0.5	0.5	ISC Transition-point
	IURB1	10	10	Lower range of land use categories for which urban dispersion is assumed

Input Group	Parameter	U.S. EPA Default	LNG Canada	Description
	IURB2	19	19	Upper range of land use categories for which urban dispersion is assumed
	ILANDUIN	20	20	Land use category for modelling domain
	ZOIN	0.25	0.25	Roughness length (m) for domain
	XLAIIN	3	3	Leaf area index for domain
	ELEVIN	0	0	Elevation (m asl)
	XLATIN	-999	-999	Latitude of met location in degrees
	XLONIN	-999	-999	Longitude of met location in degrees
	ANEMHT	10	10	Anemometer height (m)
	ISIGMAV	1	1	Read sigma-v from profile file
	IMIXCTDM	0	0	Predicted mixing heights are used (Not Used)
	XMXLEN	1	1	Maximum slug length
	XSAMLEN	1	1	Maximum travel distance of a puff in grid units during one sampling step
Group 12: Miscellaneous Dispersion and Computational Parameters	MXNEW	99	99	Maximum number of puffs released from one source during one sampling step
	MXSAM	99	99	Maximum number of sampling steps during one time step for a puff
	NCOUNT	2	2	Number of iterations used when computing the transport wind for a sampling step that includes transitional plume rise
	SYMIN	1	1	Minimum sigma Y (m) for a new puff
	SZMIN	1	1	Minimum sigma Z (m) for a new puff
	SZCAP_M	5.0E06	5.0E06	Maximum sigma Z (m)
	SVMIN	0.5, 0.5, 0.5, 0.5, 0.5, 0.5	0.5,0.5,0.5, 0.5, 0.5, 0.5	Default minimum turbulence velocities for each stability class (Sigma-V)
	SWMIN	0.2,0.12, 0.08, 0.06, 0.03, 0.016	0.2, 0.12, 0.08, 0.06, 0.03, 0.016	Default minimum turbulence velocities for each stability class (Sigma-W)
	CDIV	0, 0	0, 0	Divergence criteria for dw dz^{-1} (m)
	NLUTIBL	4	4	Search radius for nearest land/water cells
	WSCALM	0.5	0.5	Minimum wind speed allowed for non-calm conditions in m s^{-1}
	XMAXZI	3,000	3,000	Maximum mixing height (m)
	XMINZI	50	50	Minimum mixing height (m)
	WSCAT	1.54, 3.09, 5.14, 8.23, 10.8	1.54, 3.09, 5.14, 8.23, 10.8	Default wind speed classes - 5 upper bounds (m s^{-1}) are entered; the sixth class has no upper limit
	PLX0	.07, .07, .10, .15, .35, .55	.07, .07, .10, .15, .35, .55	Wind speed profile power-law exponents for stabilities 1 to 6 for 10 cm roughness length

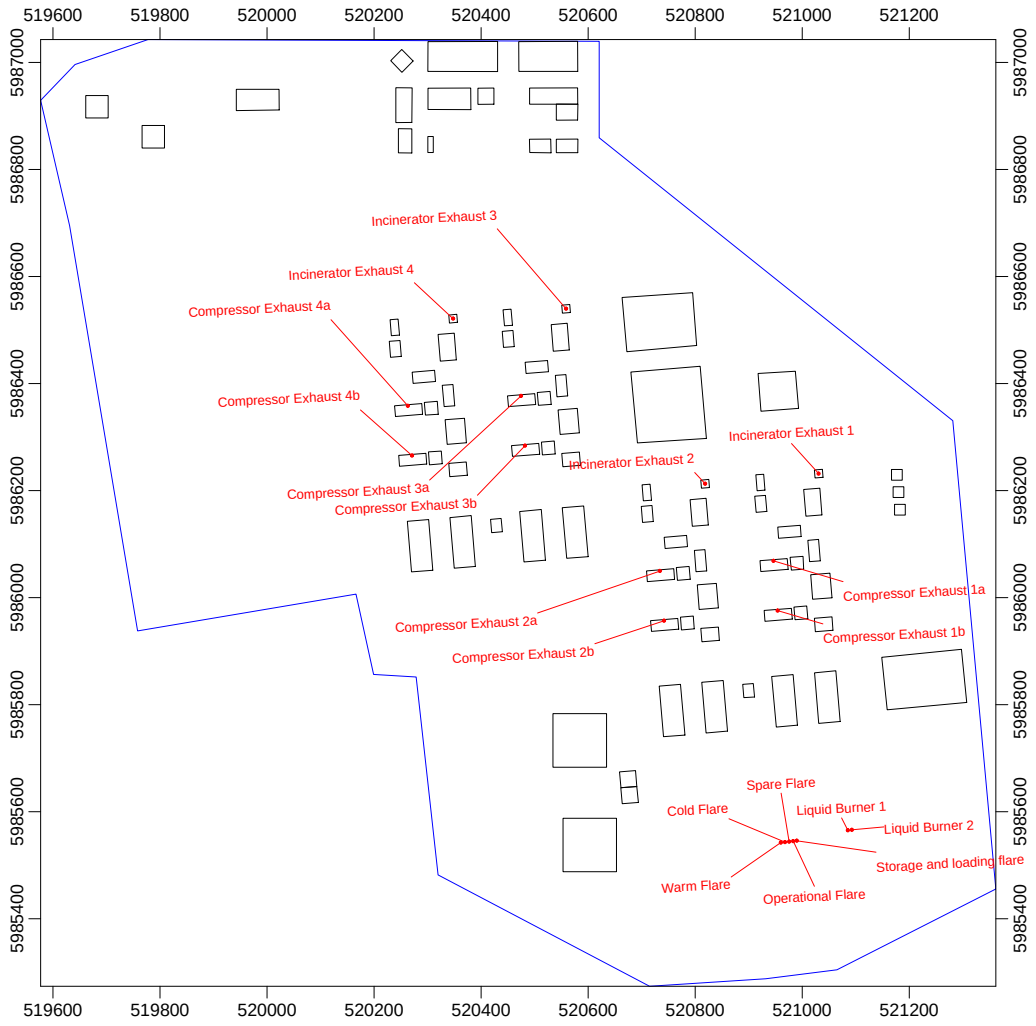
Input Group	Parameter	U.S. EPA Default	LNG Canada	Description
	PTG0	0.02, 0.035	0.02, 0.035	Potential temperature gradient for stable classes
	PPC	0.5, 0.5, 0.5, 0.5, 0.35, 0.35	0.5, 0.5, 0.5, 0.5, 0.35, 0.35	Plume path coefficients for partial plume path adjustment terrain method.
	SL2PF	10	10	Slug to puff transition factor (Not used)
	NSPLIT	3	3	Number of puffs that result every time a puff is split (Not used)
	IRESPLIT	0,0,0,0,0,0, 0,0,0,0,0,0, 0,0,0,0,0,1, 0,0,0,0,0,0	Not Applicable	Times of day when puff can be split after being split previously (Not used)
	ZISPLIT	100	100	Puff split only occurs if previous hours mixing height exceeds this value (Not used)
	ROLDMAX	0.25	0.25	Maximum allowable ratio previous hour mixing height to maximum mixing height experience by puff (Not used)
	NSPLITH	5	5	Number of puffs that result from each split (Not used)
	SYSPLITH	1	1	Minimum sigma-y off puff before it may be split (Not used)
	SHSPLITH	2	2	Minimum puff elongation rate due to wind shear, before it may be split (Not used)
	CNSPLITH	1e-7	1e-7	Minimum concentration (g m^{-3}) of each species in puff before it may be split (Not used)
	EPSSLUG	1e-4	1e-4	Fraction convergence criterion for numerical slug sampling integration
	EPSAREA	1e-6	1e-6	Fraction convergence criterion for numerical area sources integration
	DSRISE	1	1	Trajectory step-length (m) used for numerical rise integration
	HTMINBC	500	500	Minimum height to mix boundary condition puffs (m)
	RSAMPBC	10	10	Search radius (BC length segments) about a receptor for sampling nearest BC puff.
	NDEPBC	1	1	Near surface depletion adjustment when sampling BC puffs
Group 13: Point Source Parameters	NPT1	-	Varies	Number of point sources modelled
	IPTU	1	1	Units used for emissions (g s^{-1})
	NSPT1	0	0	Number of source-species combinations with variable emissions scaling factors
	NPT2	-	0	Number of point sources with variable emissions
Group 14: Area Source Parameters	NAR1	-	0	Number of polygon area sources modelled
	IARU	1	1	Units used for emissions (g m^{-2} s^{-1})
	NSAR1	0	0	Number of source-species combinations with variable emissions scaling factors
	NAR2	-	0	Number of area sources with variable emissions

Input Group	Parameter	U.S. EPA Default	LNG Canada	Description
Group 15: Line Source Parameters	NLN2	-	0	Number of buoyant line sources with variable location and emission parameters
	NLINES	-	8	Number of buoyant line sources (base case)
	ILNU	1	1	Units for line source emission rates is g s^{-1}
	NSLN1	0	0	Number of source-species combinations with variable emission scaling factors
	MXNSEG	7	7	Maximum number of segments used to model each line
	NLRISE	6	6	Number of distances at which transitional rise computed
	XL	-	319.55	Average building length (base case)
	HBL	-	23.5	Average building height (base case)
	WBL	-	26.3	Average building width (base case)
	WML	-	6.0	Average line sources width (base case)
	DXL	-	36.88	Average separation between buildings (base case)
	FPRIMEL	-	607.64	Average buoyancy parameter (base case)
Group 16: Volume Source Parameters	NVL1	-	0	Number of volume sources applied
	IVLU	1	1	Units used for volume sources (g s^{-1})
	NSVL1	0	0	Number of source-species combinations with variable emission scaling factors
	NSVL2	-	0	Number of volume sources with variable location and emission parameters
Group 17: Non-Girded Receptor Information	NREC	-	11944 (near-field gridded) 7684 (near field human health discrete) 11841 (far-field gridded)	Number of non-girded discrete receptors that compose the series of nested grids, and property boundary.

F.3.5 Building Downwash

Buildings or other solid structures might affect airflow near a source and cause building downwash effects (e.g., eddies on the downwind side), which have potential to reduce plume rise and affect dispersion. For dispersion modelling purposes, building downwash effects were considered for the Project sources with the PRIME downwash routine and the U.S. EPA Building Profile Input Program. A simplified plot plan for the buildings and structures that were included in dispersion modelling is shown in Figure F.3-4.

ID	Building Description
1	Acid Gas incinerator 1
2	Acid Gas Recovery Unit 1
3	Field Auxiliary Room 1
4	Substation 1
5	Dehydration & Mercury Recovery Unit 1
6	Heat Transfer Fluid System 1
7	Liquefaction Module 1a
8	Liquefaction Module 1b
9	Liquefaction Module 1c
10	Compressor Turbine 1a
11	Compressor Turbine 1b
12	U-2000-1
13	Acid Gas incinerator 2
14	Acid Gas Recovery Unit 2
15	Field Auxiliary Room 2
16	Substation 2
17	Dehydration & Mercury Recovery Unit 2
18	Heat Transfer Fluid System 2
19	Liquefaction Module 2a
20	Liquefaction Module 2b
21	Liquefaction Module 2c
22	Compressor Turbine 2a
23	Compressor Turbine 2b
24	U-2000-2
25	Acid Gas incinerator 3
26	Acid Gas Recovery Unit 3
27	Field Auxiliary Room 3
28	Substation 3
29	Dehydration & Mercury Recovery Unit 3
30	Heat Transfer Fluid System 3
31	Liquefaction Module 3a
32	Liquefaction Module 3b
33	Liquefaction Module 3c
34	Compressor Turbine 3a
35	Compressor Turbine 3b
36	U-2000-3
37	Acid Gas incinerator 4
38	Acid Gas Recovery Unit 4
39	Field Auxiliary Room 4
40	Substation 4
41	Dehydration & Mercury Recovery Unit 4
42	Heat Transfer Fluid System 4
43	Liquefaction Module 4a
44	Liquefaction Module 4b
45	Liquefaction Module 4c
46	Compressor Turbine 4a
47	Compressor Turbine 4b
48	U-2000-4



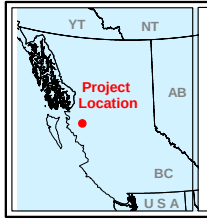
N

ID	Building Description
49	Cooling Water Tower 1a
50	Cooling Water Tower 1b
51	Cooling Water Tower 2a
52	Cooling Water Tower 2b
53	Cooling Water Tower 3a
54	Cooling Water Tower 3b
55	Cooling Water Tower 4a
56	Cooling Water Tower 4b
57	SS-1
58	SS-2
59	LNG Storage Tank 1
60	LNG Storage Tank 2
61	Boil Off Gas Compressor 1
62	Boil Off Gas Compressor 2
63	T2601
64	T2602
65	T2603
66	Waste Water Treatment
67	Feed Gas Intake System
68	Utilities 1
69	Utilities 2
70	Condensate Tank 1
71	Condensate Tank 2
72	Electric al HV Inlet
73	Existing Office 1
74	Existing Office 2
75	Existing Office 3
76	Main Admin
77	Central Workshop
78	Central Control Room
79	Laboratory
80	Warehouse 1
81	Warehouse 2
82	SS
83	Waste Storage
84	Chemical Storage

Fence Line
Stack
Building

METERS

UTM Zone 9 NAD 83



LNG CANADA

LNG Facility Simplified Plot Plan

PREPARED BY Stantec

PREPARED FOR LNG CANADA

FIGURE NO. F.3-4

V:\1231\active\EM123110458110_air\CALPUFF\Surfer\Simplified Plot Plan_Mar 14 2014.srf

F.3.6 Terrain Coefficients

Terrain in the model domain is described in Appendix E. As a plume passes over complex terrain, where the ground level of some receptors is higher than the plume/puff release point, it has the potential to move closer to the ground. The plume path coefficient (PPC) method can be used to account for this potential by adjusting the height of the plume above the ground. A PPC of 1.0 assumes that the plume trajectory is parallel to the terrain features. The default CALPUFF values of 0.5, 0.5, 0.5, 0.5, 0.35, and 0.35 for PG stability categories A, B, C, D, E, and F, respectively, were used in this assessment.

F.3.7 Chemical Transformation

The CALPUFF model uses two alternate chemical reaction schemes: the MESOPUFF II and the RIVAD/ARM3 schemes. The RIVAD/ARM3 chemical scheme was selected because the MESOPUFF II scheme is viewed as being outdated (Morris et al. 2003). This chemistry scheme treats the NO and NO_2 conversion process in addition to the NO_2 to NO_3^- and SO_2 to SO_4^{2-} conversions, with equilibrium between gaseous HNO_3 and particulate NH_4NO_3 (Scire et al. 2000). The selected chemical transformation scheme was applied relative to the prediction of sulphate and nitrate compounds and the associated deposition.

The chemical transformation scheme requires NO and NO_2 emissions rates. Typically, only the NO_X emission rate is known and is expressed in terms of NO_2 mass equivalent. Based on the NO_X emission rate, the individual NO and NO_2 emission rates were calculated as follows:

- 90% NO and 10% NO_2 on a volume basis
- NO mass emission = 0.9*(30/46)*(NO_X mass emission), and
- NO_2 mass emission = 0.1 *(46/46)*(NO_X mass emission).

These assumptions result in 85% NO and 15% NO_2 emission on a mass basis.

F.3.8 NO to NO_2 Chemistry

The atmospheric chemical reaction for converting NO to NO_2 is:

$$NO + O_3 \xrightarrow{yields} NO_2 + O_2$$

The ozone (O_3) limiting method (OLM) was applied to account for the NO to NO_2 conversion. The OLM assumes that conversion of NO to NO_2 in the atmosphere is limited by the ambient O_3 concentrations according to the above chemical reaction. The approach assumes that 10% (on a volume basis) of the NO is converted to NO_2 before discharge into the atmosphere. For the remaining NO, the following is adopted:

- If 0.9 (NO_X) is greater than the ambient O_3 concentration, then NO_2 = 0.1 (NO_X) + (O_3). For this case, the conversion is not complete (ozone limited).
- If 0.9 (NO_X) is less than the ambient O_3 concentration, then NO_2 = 0.1 (NO_X) + 0.9 (NO_X) = NO_X. This is equivalent to the total conversion approach because there is sufficient O_3 to effect the complete conversion.

In the application of the OLM, the above relationships assume that concentrations are expressed in parts per billion (ppb).

To apply the OLM to this assessment, hourly O_3 data from the Smithers St. Josephs monitoring station were used for the 2008 to 2010 simulation period.

F.3.9 Ammonia Concentrations

The *Interagency Workshop of Air Quality Modeling Phase 2* report (IWAQM 1998) recommends using a background NH_3 concentration of 0.5 ppb for forested land. Because most of the area surrounding Kitimat is forested, a constant value of 0.5 ppb was selected as a monthly background NH_3 concentration for this assessment.

F.3.10 Particulate Formation

The CALPUFF model is used to predict secondary $PM_{2.5}$ formation attributable to precursor SO_2 and NO_X emissions. The model predicts particulate NO_3^-, which can exist as an aerosol (i.e., dissolved in a water droplet) or as a particle (e.g., NH_4NO_3). Similarly, sulphate SO_4^{2-} can also exist as an aerosol or as a particle (e.g., $(NH_4)_2SO_4$). As the predicted NO_3^- and SO_4^{2-} concentrations are assumed to react with ambient NH_3 to produce ammonium nitrate and ammonium sulphate, respectively, the predicted sulphate and nitrate are multiplied by the factors indicated in Table F.3-4.

The $PM_{2.5}$ predictions derived from the CALPUFF model include the primary $PM_{2.5}$ contribution plus the secondary sulphate contribution and the secondary nitrate contribution.

Table F.3-4: $PM_{2.5}$ Multipliers for SO_4^{2-} and NO_3^-

Predicted Parameter	SO_4^{2-}	NO_3^-
Molecular Mass	96	62
End Product	$(NH_4)_2SO_4$	NH_4NO_3
Molecular Mass	132	80
Multiplier	1.375	1.290

NOTE:
Multiplier = (Molecular Mass of End Product) / (Molecular Mass of Predicted Parameter)

F.3.11 Deposition Calculation Approach

Deposition is comprised of dry and wet removal mechanisms. The dry and wet deposition rates depend on the phase of the compound being deposited (e.g., vapour or particle) and other physical and chemical properties of the compound. For this assessment, deposition is required to predict the following:

- deposition of nitrogen and sulphur compounds, because these compounds can have potential acidification or eutrophication effects on terrestrial and aquatic systems.

The potential compound groups associated with the Project are listed in Table F.3-5; the associated deposition assumptions are also included. For some of the compounds (e.g., greenhouse gases), deposition values were not calculated. Some compounds can exist in both the vapour and particle phases.

For dry deposition, the compound groups are discussed in terms of the deposition options that are available in the CALPUFF model:

- For SO_2, NO, NO_2, and HNO_3, dry deposition is calculated using the CALPUFF internal vapour-phase resistance sub-model.
- For other vapour-phase dominated compounds, the dry deposition is based on a user-specified dry deposition velocity. For these compounds, a constant deposition velocity of 0.5 cm/s (or 0.005 m/s) was selected as per U.S.EPA guidance (U.S.EPA 2005).
- For SO_4^{-2} and NO_3^-, dry deposition is calculated using the CALPUFF internal particle-phase resistance sub-model. Geometric mass mean diameters and standard deviations of 0.48 µm and 2 µm (respectively) based on the CALPUFF manual (Scire et al. 2000) were adopted.
- For other particle-phase dominated compounds, dry deposition is calculated using the CALPUFF internal particle phase resistance sub-model. The particle size parameters associated with SO_4^{-2} and NO_3^- were used. This approach assumes that the particle size range and physical properties for SO_4^{-2} and NO_3^- particles are similar to the particles that PAH and metals reside on.

The calculation of wet deposition requires wet scavenging coefficients that vary with phase and form of the precipitation (i.e., liquid or solid). The CALPUFF model assumes the scavenging coefficient approach for both gases and particles. The following assumptions have been made relative to these parameters:

- For the nitrogen and sulphur compounds, the wet scavenging coefficients are based on the CALPUFF manual (Scire et al. 2000) and on work undertaken for the Trace Metals and Air Contaminants Committee (RWDI 2005).
- For other vapour-phase dominated compounds, the liquid scavenging coefficient was assumed to be equivalent to a 0.1 µm diameter particle as per U.S. EPA guidance (U.S. EPA 1999). The liquid scavenging coefficient for a particle of this diameter is 1.7×10^{-4} s^{-1} (U.S. EPA 1999).
- For other particle-phase dominated compounds, a diameter of 0.48 µm was adopted and is consistent with the sulphate and nitrate deposition assumptions. The associated scavenging coefficient of 1×10^{-4} s^{-1} was adopted.
- For particles other than SO_4^{-2} and NO_3^-, the solid scavenging coefficient was assumed to be about one-third (i.e., 3×10^{-5} s^{-1}) the corresponding liquid scavenging coefficient as per U.S. EPA guidance (U.S. EPA 1999). For gas-phase compounds, the solid scavenging coefficient was assumed to be zero.

For compounds that are both vapour and particle bound, the two associated depositions were combined to provide the total deposition.

Sulphur Deposition

The total sulphur deposition (S) was calculated as follows:

$$S = \frac{32}{64}[SO_2] + \frac{32}{96}[SO_4^{-2}]$$

where S is expressed in kg S/ha/y and the values in the square brackets represent the sum of the predicted wet and dry deposition values in kg/ha/y. The multiplication coefficients account for molecular mass differences for the individual species.

Nitrogen Deposition

The total nitrogen deposition (N) was calculated as follows:

$$N = \frac{14}{30}[NO] + \frac{14}{46}[NO_2] + \frac{14}{63}[HNO_3] + \frac{14}{62}[NO_3^-]$$

where the N is expressed in kg N/ha/y and the values in the square brackets represent the sum of the predicted wet and dry deposition values in kg/ha/y. The multiplication coefficients account for molecular mass differences for the individual species.

Table F.3-5: Potential Compound Groups Associated with the LNG Canada Project

Compound	Percent Vapour	Dry Deposition Method	Wet Deposition Diameter Assumption (µm)
Common Air Contaminants			
SO_2	100	Gas Phase Resistance Model	-
SO_4^{-2}	0	Particle Phase Resistance Model	0.48
NO	100	Gas Phase Resistance Model	-
NO_2	100	Gas Phase Resistance Model	-
HNO_3	100	Gas Phase Resistance Model	-
NO_3^-	0	Particle Phase Resistance Model	0.48
$PM_{2.5}$	0	Particle Phase Resistance Model	0.48
CO	100	Deposition Velocity = 0.5 cm/s	0.1
O_3	100	Not Calculated	Not Calculated
Greenhouse Gases			
CO_2	100	Not Calculated	Not Calculated
CH_4	100	Not Calculated	Not Calculated
N_2O	100	Not Calculated	Not Calculated

NOTES:

The percent vapour is primarily based on the 2005 U.S.EPA Chemdata database (rounded to the nearest 10%). For compounds not in this database, physical and chemical screening based on Henry's law coefficient, molecular mass and vapour pressure were used.

All metals are assumed to be in the particle phase.

F.3.12 Interpretation of Predictions

Comparison to Applicable Objectives for Air Quality

Ambient criteria for criteria air contaminants include the BC Ambient Air Quality Objectives (AAQO), the National AAQO, and the Canadian Ambient Air Quality Standards. In mid-2013, the BC government announced the proposed development of new AAQO for SO_2 and NO_2 to be released in mid-2014. In the intervening time, BC MOE has been requesting that proponents consider selected AAQO from other jurisdictions, namely, USEPA and the World Health Organization.

The above objectives and standards are applied in this air quality assessment by comparing worst-case scenario model-predicted concentrations with the most stringent of the applicable objectives and standards for each substance of interest.

Contour Maps

Ambient concentration predictions are displayed as contour plots superimposed over a base map of the study areas. The concentration contour plots are based on the worst-case year 2009. In preparing these maps, a grid spacing of 500 m was adopted for the contour plots. This might result in some "smoothing" of the contours. The tabular results, however, are based on the model output and not smoothed data.

F.4 CALPUFF Output Quality Assurance and Quality Control

A numerical air quality simulation model is one of the more powerful tools available to estimate the effect of air emissions on ambient air quality. The air quality assessment required the preparation of a large amount of numerical data required for model input and the processing of a large amount of numerical data taken from the model output. A number of quality assurance and quality control checks were undertaken for all components of the assessment. These included the following:

- **Emissions inventory:** The Project emission inventory was constructed using standard methodologies based on the available engineering information. The air emission inventories for other facilities were based on information taken from recent publications. The information contained in these publications has already been reviewed and approved by stakeholders, including regulatory agencies. The locations of the emission sources were confirmed using mapping tools, such as latitudes and longitudes of facilities that report to the National Pollutant Release Inventory (available from Environment Canada); satellite imagery to confirm project locations; and maps presented in other applications. The emission inventory (Appendix D) was reviewed for logical consistency to confirm that values such as emission rates, stack heights, diameters, exhaust temperatures, and velocities were within the range of typical values for each source type.
- **Meteorology:** The output of the CALMET model was compared with observations to confirm consistency. Wind direction, wind speed, temperature, mixing height, stability, and precipitation plots were prepared (see Appendix E) for multiple locations for comparison with measured data and to confirm reasonable model performance.
- **Model application:** CALPUFF concentration predictions were rationalized against the emission inventory information to confirm that model concentration predictions are logically consistent with the source emission inventory (e.g., high concentrations occur where expected). During post-processing, unexpected model results were investigated and rationalized in detail for consistency with model input.

The air quality assessment was undertaken by the air assessment team working together under the direction of the air discipline lead. Critical components of the quality assurance/quality control process were numerous progressive reviews and ongoing communication among team members.

F.5 Summary and Conclusions

The CALPUFF dispersion model (Version 6.42, Level 110325) was selected as the primary air quality assessment tool to predict ambient concentrations and deposition for this assessment. The following were adopted for the application of the model:

- In total, 11,944 gridded receptor grid points were selected for the 78 km by 78 km near-field model domain, and 11,841 gridded receptors grid points for the 320 km by 320 km far-field model domain. An additional 112 lake, ambient monitoring, and human health receptors from the study area were also selected. Five additional sets of receptor grids (7,684 receptor locations) were selected for further human health assessment.
- Three years of meteorological data for the period January 2008 to December 2010 were selected. The CALMET model (see Appendix E) was used to provide the meteorological data for the CALPUFF model.
- The CALPUFF model was applied to the existing base case scenario and the three assessment cases (Project alone, application, and future cases) using the source and emission inventory information described in Appendix D.
- The OLM was selected to estimate ambient NO_2 concentrations from the predicted NO_X values. Hourly O_3 concentrations from the Smithers St. Josephs monitoring station were used for this method.

The approach and input parameters were chosen to best represent changes in air quality attributable to the Project in conjunction with other emission sources.

F.6 References

British Columbia Ministry of the Environment (BC MOE). 2008. *Guidelines for Air Quality Dispersion Modelling in British Columbia*. Environmental Protection Division, Environmental Quality Branch, Air Protection Section. Victoria, BC.

Interagency Workgroup for Air Quality Modeling Phase 2 (IWAQM). 1998. *Summary Report and Recommendations for Modeling Long Range Transport Impacts*. United States National Park Service – Air Resources Division, U.S.D.A. Forest Service – Air Program, and U.S. Fish and Wildlife Service – Air Quality Branch. December 1998.

Morris, R.E., C. Tana, and G. Yarwood. 2003. *Evaluation of the Sulphate and Nitrate Formation Mechanism in the CALPUFF Modelling System.* Presented at A&WMA Conference Guideline on Air Quality Models: The Path Forward. October 22-24, 2003. Mystic, CT.

RWDI Consulting Engineers and Scientists (RWDI). 2005. NOx Dispersion and Chemistry Assumptions in the CALPUFF Model. CEMA Contract 2003-0034. Prepared for the Cumulative Environmental Management Association.

Scire, J.S., D.G. Strimaitis and R.J. Yamartino. 2000. *A User's Guide for the CALPUFF Model (Version 5)*. Earth Technologies Inc., Concord, MA.

United States Environmental Protection Agency (USEPA). 1995. *SCREEN3 Model User's Guide*. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Emissions, Monitoring, and Analysis Division. September 1995. EPA-454/B-95-004.

United States Environmental Protection Agency (USEPA). 1999. *Air Quality Criteria for Particulate Matter* (Vol. II). Technical Report EPA document 600/P-99/002b.

United States Environmental Protection Agency (USEPA). 2004. *AERMOD: Description of Model Formulation*. EPA- 454/R-03-004.

United States Environmental Protection Agency (USEPA). 2005. *Appendix W to Part 51, Revision to the Guideline on Air Quality Models: Adoption of a Preferred General Purpose (Flat and Complex Terrain) Dispersion Model and Other Revisions; Final Rule*. (November 9, 2005 Edition).