REPORT

METRO VANCOUVER WASTE TO ENERGY FACILITY

VANCOUVER, BC

AIR DISPERSION MODELLING STUDY

RWDI #1702445
May 26, 2020

SUBMITTED TO
Bruce Howie
HDR Corporation
100 York Blvd
Suite 300,
Richmond Hill, ON L4B 1J8
bruce.howie@hrinc.com

SUBMITTED BY
Greg Conley, M.Eng., P. Eng.,
Senior Project Manager / Principal
greg.conley@rwdi.com

Jeff Lundgren, M.Sc.
Technical Director / Principal
jeff.lundgren@rwdi.com

RWDI
Suite 280-1385 West 8th Avenue,
Vancouver, BC, V6H 3V9
T: 604.730.5688
F: 519.823.1316

EXECUTIVE SUMMARY

Study Objectives

The Metro Vancouver Waste-to-Energy Facility ("the Facility") is a waste to energy facility located at 5150 Riverbend Drive, Burnaby. The waste received and incinerated on site is used to generate electricity. The Facility is owned by Greater Vancouver Sewerage and Drainage District and operates under an existing British Columbia Ministry of Environment & Climate Change Strategy air quality permit dated December 15, 2016 (Operational Certificate 107051). The Operational Certificate, among other items, authorizes and limits the discharge of contaminants from three separate mass burn incinerators/boilers (the "Boilers") from a common support stack containing three individual flues (the "Boiler Stack"). The site reference number for this discharge is E300670.

Section 2.17 of the Operational Certificate requires a Contaminant Dispersion Evaluation and Health Risk Assessment. The purpose of this report is to fulfill the site-specific contaminant dispersion evaluation component of this section. A companion report completed by Ollson Environmental Health Management fulfills the health risk assessment component.

Predicted ambient concentrations of criteria air contaminants, metals and volatile organic compounds were assessed in this air quality study. The criteria air contaminants of interest are: particulate matter with particle diameter of less than 2.5 µm ($PM_{2.5}$, often referred to as respirable PM), carbon monoxide, sulphur dioxide, and nitrogen oxides. The metals and volatile organic compounds of interest in this study are: hydrogen chloride, hydrogen fluoride, total dioxins and furans, cadmium, mercury, the sum of lead, arsenic and chromium, polycyclic aromatic hydrocarbons, and polychlorinated biphenyls.

Ambient concentrations and deposition rates were provided to Ollson Environmental Health Management in support of their health risk assessment. These results are not included in this report.

Emission Scenarios

Four scenarios were considered for this study:

- **Permit Scenario:** representing maximum permitted operations, 24 hours a day, each day of the year
  - Continuous emissions prescribed in the Operational Certificate were considered in this scenario.
  - As the facility does not emit at full capacity for any parameter, this scenario represents a conservative emissions scenario.
- **Operational Scenario:** representing typical operations
  - Typical emissions from 2017 continuous emissions monitoring systems data were considered in this scenario.
  - Emissions rates for pollutants of interest that were not included in the continuous emissions monitoring systems monitoring were obtained from 2017 and 2016 stack test data.

- **Start Up Scenario:** representing typical operations with a boiler starting up
    - A series of stack tests were conducted to obtain emission rates for this scenario.
    - Emission rates for pollutants of interest that were not included in the stack test were obtained from continuous emissions monitoring systems data during known start up times.
- **Shut Down Scenario:** representing typical operations with a boiler shutting down
    - A series of stack tests were conducted to obtain emission rates for this scenario.
    - Emission rates for pollutants of interest that were not included in the stack test were obtained from continuous emissions monitoring systems data during known shut down times.

Methodology

The dispersion modelling methodology was based on the British Columbia Ministry of Environment & Climate Change Strategy Air Quality Dispersion Modelling Guideline (BC MOE, 2015). A detailed modelling plan was submitted to Fraser Health Authority, Vancouver Coastal Health, and the British Columbia Ministry of the Environment & Climate Change Strategy for review before commencing the study. The air dispersion modelling study involved running a computer simulation that predicted worst-case concentrations of air contaminants in the neighbourhood surrounding the Facility.

The CALPUFF dispersion model was run to simulate the impacts of the Boilers over a 50 km by 50 km study area around the Facility for three full years using meteorological data and ambient background measurements for the calendar year 2013, 2014 and 2015.

Ambient concentrations of criteria air contaminants, metals and volatile organic compounds were predicted for the study area, including at sensitive receptors selected near the Facility.

Predicted concentrations were compared to Metro Vancouver ambient air quality objectives. Since there are no Metro Vancouver or British Columbia Ministry of Environment & Climate Change Strategy (BC MoECCS) air quality objectives for metals or volatile organic compounds, objectives from other jurisdictions (Ontario, Alberta, Texas and California) were considered.

Results

Maximum predicted concentrations of criteria air contaminants for each of the four scenarios are summarized in Table E-1. Maximum predicted concentrations of metals and volatile organic compounds are summarized in Table E-2. The results are provided along with the applicable Ambient Air Quality Objectives and respective ambient background.

Predicted SO_2 concentrations under all operating scenarios are within the Metro Vancouver 1-hour ambient objective for SO_2 for greater than 99.9% of all hours in any year modelled. Predicted concentrations are also within Metro Vancouver ambient objectives for all other pollutants and averaging times under all operating scenarios. Model predictions for SO_2 are within the 2020 and 2025 CAAQS for SO_2 for all operational scenarios. Comparing measured SO_2 concentrations to modelled concentrations at an existing nearby air quality monitoring station (T18) show that the short-term model predictions of ambient SO_2 are very likely conservative and that actual SO_2 due to facility emissions will be lower than predicted.

Predicted concentrations of 1-hour NO_2 from the facility emissions alone are within the 2020 and 2025 CAAQS for all operating scenarios. When background is included using the Metro Vancouver guidance for NO_2, predicted cumulative concentrations of daily peak 1-hour NO_2 are above the CAAQS. The predicted concentrations for all scenarios show that any potential exceedances would not occur from facility emissions alone and that the existing background concentration of NO_2 from all other sources is a large contributor to the potential for exceedance under all scenarios. When using BC MoECCS's guidance for including background NO_2, cumulative model predictions are within the 2020 CAAQS for all scenarios.

Among pollutants with objectives borrowed from Alberta and Ontario, the predicted concentration of HCl is above the 1-hour objective from Alberta for the permit scenario only, and predicted concentration of PAH is above the 24-hour objective from Ontario for the permit and shut down scenario, and the annual objective from Ontario for the permit scenario. The model results indicate that there will be no exceedances of HCl and PAHs under normal operations. The is a potential for PAH concentration to be slightly above the 24-hr Ontario PAH objective during shut down conditions.

Model predictions are within all other of Alberta or Ontario objectives assessed for all scenarios and averaging times.

Table E-1: Maximum predicted concentrations for Criteria Air Contaminants for all scenarios, over the study area

Air Contaminant	Averaging Period	Background (98th Percentile)	Permitted Model Concentrations	Permitted Model Concentrations	Operational Model Concentrations	Operational Model Concentrations	Start Up Boiler Model Concentrations + other 2 boilers	Start Up Boiler Model Concentrations + other 2 boilers + BG	Shut Down Boiler Model Concentrations + other 2 boilers	Shut Down Boiler Model Concentrations + other 2 boilers + BG	Ambient Objective	Jurisdiction of Objectives
		(µg/m^3)	MPOI (no background; µg/m^3)	MPOI (with background; µg/m^3)	MPOI (no background; µg/m^3)	MPOI (with background; µg/m^3)	MPOI (no background; µg/m^3)	MPOI (with background; µg/m^3)	MPOI (no background; µg/m^3)	MPOI (with background; µg/m^3)		
PM$_{2.5}$	24-hour	16.5	2.0	18.5	0.5	17.0	0.5	17.0	0.5	17.0	25	Metro Vancouver
	Annual	5.9	0.2	6.1	0.03	6.0	0.03	6.0	0.03	6.0	8 [1]	Metro Vancouver
Carbon Monoxide (CO)	1-hour	607.0	104.7	711.7	52.9	659.9	59.7	666.7	125.1	732.1	30,000	B.C. Ambient Air Quality Objectives
	8-hour	559.7	19.3	579.0	9.9	569.6	11.3	571.0	23.9	583.6	10,000	B.C. Ambient Air Quality Objectives
Sulphur Dioxide (SO$_2$)	1-hour	5.2	**418.8**	**424.1**	**190.4**	**195.7**	**190.4**	**195.7**	**190.4**	**195.7**	183	Metro Vancouver
	99th percentile, 1h daily max; averaged over 3 years	5.2	154.9	160.1	53.4	58.7	53.4	58.7	53.4	58.7	183 (2020) 170 (2025)	Canadian Ambient Air Quality Standards (CAAQS)
	Annual	1.1	3.9	5.0	1.3	2.4	1.3	2.4	1.3	2.4	13	Metro Vancouver
Oxides of Nitrogen (NO$_X$) (Assumes 100% Conversion to NO$_2$; Background and Objectives for NO$_2$)	1-hour	62.4	397.8	460.2	257.2	319.7	257.2	319.7	257.2	319.7	200, for NO$_2$	Metro Vancouver
	98th percentile, 1h daily max; averaged over 3 years	62.4	102.3	164.7	70.2	132.6	70.2	132.6	70.2	132.6	113, for NO$_2$	Canadian Ambient Air Quality Standards (CAAQS)
	Annual	25.2	3.7	28.9	2.6	27.8	2.6	27.8	2.6	27.8	40, for NO$_2$	Metro Vancouver
Nitrogen Dioxide (NO$_2$) (Converted from NO$_X$) [2]	1-hour[3]	62.4	102.4	164.8	91.8	154.2	125.2	187.6	123.7	186.2	200	Metro Vancouver
	98th percentile, 1h daily max; averaged over 3 years, MV method [2]	62.4	72.8	**135.3**	66.2	**128.7**	66.2	**128.7**	66.2	**128.7**	113 (2020) 79 (2025)	Canadian Ambient Air Quality Standards (CAAQS)
	98th percentile, 1h daily max; averaged over 3 years, MOECC method [2]	62.4	72.8	**91.2**	66.2	**88.1**	66.2	**88.1**	66.2	**88.1**		
	Annual [3]	25.2	3.7	28.9	2.6	27.8	2.6	27.8	2.6	27.8	40	Metro Vancouver

Notes:

[1] There is also a planning annual objective goal of 6 µg/m^3

[2] Under Metro Vancouver guidance, ambient NO$_2$ background is added to the model results *after* they are converted to NO$_2$. This is different than the method recommended by the BC Ministry of Environment & Climate Change Strategy, in which ambient NO$_X$ background is added to the NO$_X$ model results *before* they are converted to NO$_2$

[3] Using Metro Vancouver guidance for conversion

- Values that exceed the applicable objectives are shown in bold text

Table E-2: **Maximum predicted concentrations for Metals and Volatile Organic Compounds for all scenarios, over the study area**

Air Contaminant	Averaging Period	Background (98th Percentile)	Permitted Model Concentrations	Permitted Model Concentrations	Operational Model Concentrations	Operational Model Concentrations	Start Up Boiler Model Concentrations + other 2 boilers	Start Up Boiler Model Concentrations + other 2 boilers + BG	Shut Down Boiler Model Concentrations + other 2 boilers	Shut Down Boiler Model Concentrations + other 2 boilers + BG	Ambient Objective	Jurisdiction of Objectives
		(µg/m^3)	MPOI (no background; µg/m^3)	MPOI (with background; µg/m^3)	MPOI (no background; µg/m^3)	MPOI (with background; µg/m^3)	MPOI (no background; µg/m^3)	MPOI (with background; µg/m^3)	MPOI (no background; µg/m^3)	MPOI (with background; µg/m^3)		
Hydrogen Chloride (HCl)	1-hour	0	**115.2**	**115.2**	40.8	40.8	40.8	40.8	44.8	44.8	75	Alberta Environment and Parks Ambient Air Quality Objectives (adopted from Texas)
Hydrogen Fluoride (HF)	1-hour	0	2.1	2.1	0.03	0.03	0.1	0.1	0.3	0.3	4.9	Alberta Environment and Parks Ambient Air Quality Objectives (adopted from Texas)
Total Dioxins and Furans (as PCDD/F TEQ)	24-hour	0	1.4E-08	1.4E-08	1.4E-12	1.4E-12	5.4E-10	5.4E-10	9.3E-11	9.3E-11	0.1 pg TEQ/m^3	Ontario Ambient Air Quality Criteria (Health Limiting Effect)
Cadmium (Cd)	24-hour	3.7E-04	1.2E-03	1.6E-03	4.1E-05	4.1E-04	4.1E-05	4.1E-04	5.5E-05	4.2E-04	0.025	Ontario Ambient Air Quality Criteria (Health Limiting Effect)
	Annual	7.3E-05	1.4E-04	2.1E-04	4.5E-06	7.7E-05	4.5E-06	7.7E-05	4.8E-06	7.8E-05	0.005	Ontario Ambient Air Quality Criteria (Health Limiting Effect)
Mercury (Hg)	24-hour	0	3.5E-03	3.5E-03	2.7E-04	2.7E-04	2.7E-04	2.7E-04	2.7E-04	2.7E-04	2	Ontario Ambient Air Quality Criteria (Health Limiting Effect)
Sum of Lead (Pb), Arsenic (As), Chromium (Cr)	1-hour	3.0E-02	1.3E-01	1.6E-01	7.4E-03	3.7E-02	7.4E-03	3.7E-02	7.4E-03	3.7E-02	1.5	Alberta Environment and Parks Ambient Air Quality Objectives (adopted from Texas)
Polycyclic Aromatic Hydrocarbons (PAHs)	24-hour	0	**8.7E-04**	**8.7E-04**	2.5E-07	2.5E-07	8.5E-06	8.5E-06	**5.1E-05**	**5.1E-05**	5.0E-05	Ontario Ambient Air Quality Criteria (Health Limiting Effect)
	Annual	0	**9.8E-05**	**9.8E-05**	2.8E-08	2.8E-08	1.1E-07	1.1E-07	5.3E-07	5.3E-07	1.0E-05	Ontario Ambient Air Quality Criteria (Health Limiting Effect)
Polychlorinated Biphenyls (PCBs)	24-hour	0	1.7E-04	1.7E-04	4.0E-10	4.0E-10	1.4E-09	1.4E-09	2.5E-09	2.5E-09	0.15	Ontario Ambient Air Quality Criteria (Health Limiting Effect)
	Annual	0	2.0E-05	2.0E-05	4.4E-11	4.4E-11	5.5E-11	5.5E-11	6.7E-11	6.7E-11	0.035	Ontario Ambient Air Quality Criteria (Health Limiting Effect)

Notes: Values that exceed the applicable objectives are shown in bold text
A background value of zero (0) indicates no monitoring data available for that contaminant. In this case, a background value of zero (0) has been assumed for modelling purposes

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

APPENDICES

VERSION HISTORY

Index	Date	Pages	Author(s)
DRAFT	November 14, 2018	All	Greg Conley M.Eng., P. Eng. Jeff Lundgren M.Sc. Julia Veerman, B. Eng., EIT
Revision	November 28, 2018	All	Greg Conley M.Eng., P. Eng. Jeff Lundgren M.Sc. Julia Veerman, B. Eng., EIT
Revision	July 31, 2019	v, 19, 22, 24, 25, Appendix C	Greg Conley M.Eng., P. Eng. Jeff Lundgren M.Sc. Julia Veerman, B. Eng., EIT
Revision	May 26, 2020	iii, iv, v, 4, 24, 25, 26, 27, 31,32	Greg Conley M.Eng., P. Eng. Jeff Lundgren M.Sc. Julia Veerman, B. Eng., EIT

1 INTRODUCTION

The Metro Vancouver Waste-to-Energy Facility ("the Facility") is a waste to energy facility located at 5150 Riverbend Drive, Burnaby. The waste received and incinerated on site is used to generate electricity. The facility is owned by Greater Vancouver Sewerage and Drainage District under an existing British Columbia Ministry of Environment & Climate Change Strategy (BC MoECCS) air quality permit dated December 15, 2016 (Operational Certificate 107051; "the OC"). The OC authorizes and limits the discharge of contaminants from three separate mass burn incinerators/boilers (the "Boilers") from a common support stack containing three individual flues (the "Boiler Stack"). The site reference number for this discharge is E300670. The project location, surrounding neighbourhoods, computational grid, and receptors used to perform the air dispersion modelling and health studies are shown in Figure 1-1.

Section 2.17 of the OC requires a Contaminant Dispersion Evaluation and Health Risk Assessment. The purpose of this report is to fulfill the site-specific contaminant dispersion evaluation component of this section. A companion report completed by Ollson Environmental Health Management fulfills the health risk assessment component.

Predicted ambient concentrations of criteria air contaminants (CACs), metals and volatile organic compounds (VOCs) were assessed in this air quality study. The CACs of interest are: particulate matter with particle diameter of less than 2.5 µm ($PM_{2.5}$, often referred to as respirable PM), carbon monoxide (CO), sulphur dioxide (SO_2), and nitrogen oxides (NO_X). The metals and VOCs of interest in this study are: hydrogen chloride (HCl), hydrogen fluoride (HF), total dioxins and furans, cadmium (Cd), mercury (Hg), the sum of lead (Pb), arsenic (As) and chromium (Cr), polycyclic aromatic hydrocarbons (PAHs), and polychlorinated biphenyls (PCBs).

Ambient concentrations and deposition rates were provided to Ollson Environmental Health Management in support of their health risk assessment. These results are not included in this report.

1.1 Project Operations, Emission Sources and Scenarios

The Facility is permitted to incinerate a maximum of 310,000 tonnes waste (wet weight) per year. The authorized discharge period is continuous. Emissions from the waste incineration are discharged through the Boiler Stack. The Boiler Stack location is shown in Figure 1-1.

Four operating scenarios were considered for this study: one representing maximum permitted operations; one representing typical operations; one representing typical operations with a boiler starting up; and one representing typical operations with a boiler shutting down. The full details outlining the methodology for each scenario are provided in the Methodology section. Below are brief summaries of each scenario:

- **Permit Scenario:** Continuous emissions at the permit limits prescribed in the OC were considered in this scenario. No adjustments were made to the emissions for any of the averaging periods (e.g., the same emission rate was used for the 1-hour results as the annual results). As the facility does not emit at permitted limits, this scenario represents a conservative emissions scenario.

- **Operational Scenario:** Typical emissions from 2017 continuous emissions monitoring systems (CEMS) data were considered in this scenario. Emissions rates for pollutants of interest that were not included in the CEMS monitoring were obtained from 2017 and 2016 stack test data. Even though this scenario is more realistic than the Permit Scenario, the Operations Scenario is still conservative because it included the Boilers as continuous sources.

- **Start Up Scenario:** This scenario considered emissions from one boiler starting up added to normal operation of the other two boilers as defined in the Operational Scenario. A series of stack tests of a boiler starting up were completed from November 28-30, 2017 (A. Lanfranco, 2017) to obtain emission rates for this scenario. Emission rates for pollutants of interest that were not included in the stack test were obtained from CEMS data during known start up times.

  The boiler starting up was modelled as a constant point source representing the maximum emissions measured during testing. Because a start up is a transient condition that in reality will always blend back into normal operations, model predictions from this scenario will always be greater than or equal to concentrations from the Operational Scenario.

- **Shut Down Scenario**: This scenario considered emissions from one boiler shutting down added to normal operation of the other two boilers as defined in the Operational Scenario. A series of stack tests of a boiler shutting down were completed from November 28-30, 2017 (A. Lanfranco, 2017) to obtain emission rates for this scenario. Emission rates for pollutants of interest that were not included in the stack test were obtained from CEMS data during known shut down times.

  The boiler shutting down was also modelled as a constant point source representing the maximum emissions measured during testing. Then, model results for this scenario were added to the Operational Scenario results.

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Map Document: C:\GIS\1702445 WTE\WTE Buildings_forReport.mxd

Modelled Source and Buildings

True North

Map Projection: NAD 1983 UTM Zone 10N

Waste-To-Energy Facility - Burnaby, British Columbia

Project #: 1702445

Drawn by: JFV

Figure: 1-1

Approx. Scale: 1:3,500

Date Revised: Nov 6, 2018

1.2 Contaminants and Ambient Air Quality Objectives

This study focuses on contaminants for which there are ambient air quality criteria. Ambient air quality objectives are developed by environment and health authorities. These objectives are based on scientific studies that consider the influence of the contaminant on such receptors as humans, wildlife, vegetation, as well as aesthetic qualities such as visibility. Since there are no MV or BC MoECCS air quality objectives for metals or VOCs, objectives from other jurisdictions (Ontario, Alberta, Texas and California) were considered. All the ambient air quality objectives and the source jurisdiction that were considered in this study are listed in Table 1-1.

Table 1-1: Ambient Air Quality Objectives

Air Contaminant	Averaging Period	Metro Vancouver Objective (µg/m^3)	Other Criteria[1]	Jurisdiction of Other Criteria
Total Particulate Matter (TPM)	24-hour		120 (µg/m^3)	National Ambient Air Quality Objectives
	Annual		60 (µg/m^3)	National Ambient Air Quality Objectives
Particulate Matter Less than or Equal to 10 Microns (PM_{10})	24-hour	50		
	Annual	20		
Particulate Matter Less than or Equal to 2.5 Microns ($PM_{2.5}$)	24-hour	25		
	Annual	8		
Carbon Monoxide (CO)	1-hour	30,000	14,300 (µg/m^3)	B.C. Ambient Air Quality Objectives
	8-hour	10,000	5,500 (µg/m^3)	B.C. Ambient Air Quality Objectives
Hydrogen Chloride (HCl)	1-hour		75 (µg/m^3)	Alberta Environment and Parks Ambient Air Quality Objectives (adopted from Texas)
Hydrogen Fluoride (HF)	1-hour		4.9 (µg/m^3)	Alberta Environment and Parks Ambient Air Quality Objectives (adopted from Texas)
Sulphur Dioxide (SO_2)	1-hour	183	183 (2020) * 170 (2025)	Canadian Ambient Air Quality Standards (CAAQS)
	Annual	13	10.5 (2020)	Canadian Ambient Air Quality Standards (CAAQS)
Nitrogen Oxides (NO_x) (Objective for NO_2)	1-hour	200	113 (2020) * 79 (2025)	Canadian Ambient Air Quality Standards (CAAQS)
	Annual	40	32 (2020) 23 (2025)	Canadian Ambient Air Quality Standards (CAAQS)

Air Contaminant	Averaging Period	Metro Vancouver Objective ($\mu g/m^3$)	Other Criteria[1]	Jurisdiction of Other Criteria
Total Dioxins and Furans (as PCDD/F TEQ)	24-hour		0.1 pg TEQ/m^3	Ontario Ambient Air Quality Criteria (Health Limiting Effect)
Cadmium (Cd)	24-hour		0.025 ($\mu g/m^3$)	Ontario Ambient Air Quality Criteria (Health Limiting Effect)
	Annual		0.005 ($\mu g/m^3$)	Ontario Ambient Air Quality Criteria (Health Limiting Effect)
Mercury (Hg)	24-hour		2 ($\mu g/m^3$)	Ontario Ambient Air Quality Criteria (Health Limiting Effect)
Sum of Lead (Pb), Arsenic (As), Chromium (Cr)	1-hour		1.5 ($\mu g/m^3$)	Alberta Environment and Parks Ambient Air Quality Objectives (adopted from Texas)
Chlorophenols				(Assessed in PHRA)
Chlorobenzenes				(Assessed in PHRA)
Polycyclic Aromatic Hydrocarbons (PAHs)	24-hour		0.00005 ($\mu g/m^3$)	Ontario Ambient Air Quality Criteria (Health Limiting Effect)
	Annual		0.00001($\mu g/m^3$)	Ontario Ambient Air Quality Criteria (Health Limiting Effect)
Polychlorinated Biphenyls (PCBs)	24-hour		0.15($\mu g/m^3$)	Ontario Ambient Air Quality Criteria (Health Limiting Effect)
	Annual		0.035($\mu g/m^3$)	Ontario Ambient Air Quality Criteria (Health Limiting Effect)

Notes: [1] If there are no Metro Vancouver objectives for the air contaminant to be modelled, then criteria from other jurisdictions (e.g., Alberta, Ontario, California or Texas) have been used to put predicted ambient contaminant concentrations in perspective. CAAQS objectives are based on annual 99th (for SO_2) and 98th (for NO_2) percentile of daily 1-hour maximum, averaged over three consecutive years.

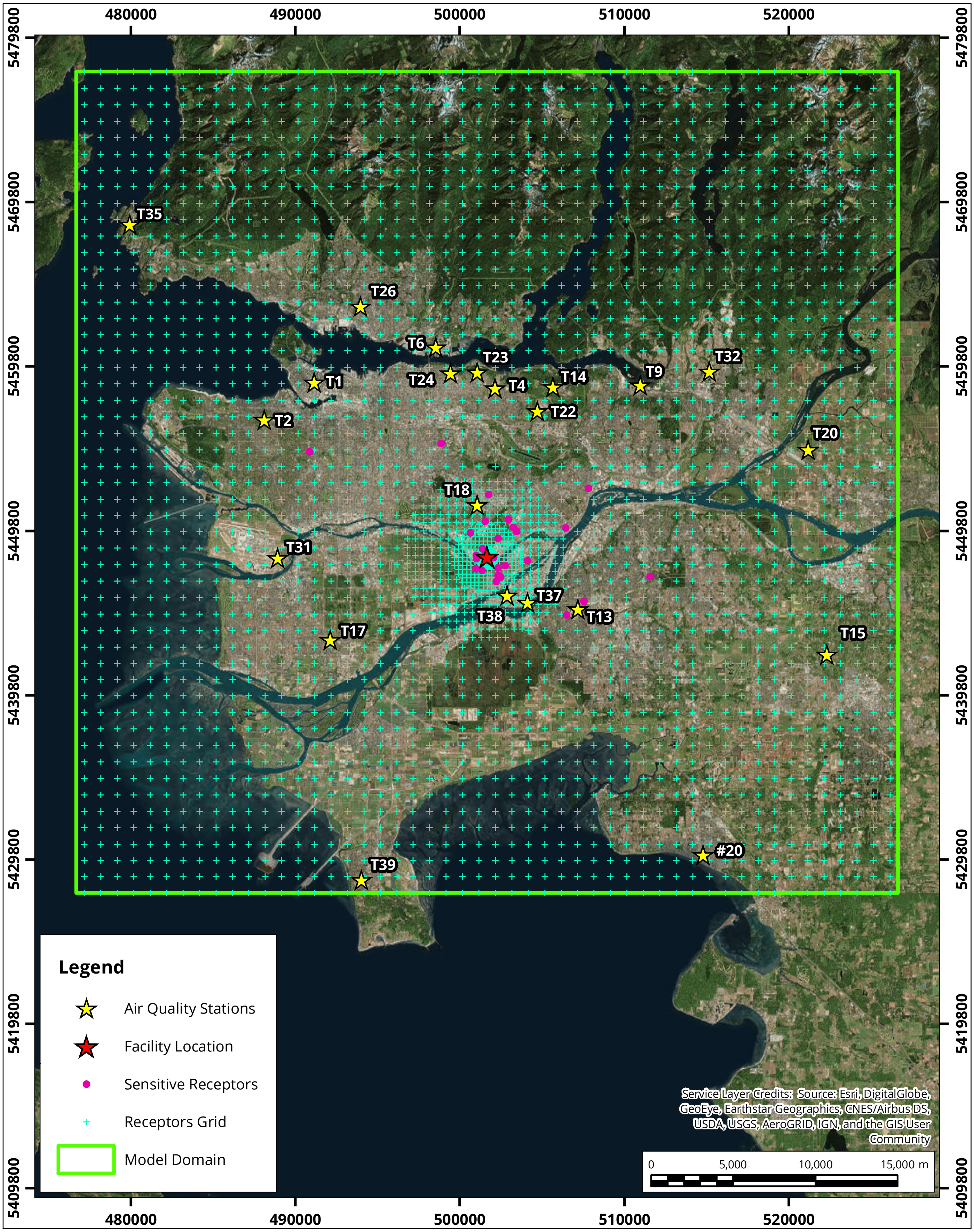
2 METHODOLOGY

The air dispersion modelling study was conducted using the CALMET-CALPUFF dispersion modelling suite (Version 7) which is the recommended model under the BC MoECCS Air Quality Dispersion Modelling Guideline (BC modelling guideline) (BC MOE, 2015) for studies of this type. A detailed modelling plan was submitted to the appropriate health authorities and BC MoECCS for review. The model plan is provided in Appendix A. Details about the modelling are presented in this section.

2.1 Spatial and Temporal Boundaries

The Facility is located on complex terrain and is within 0.5 km of the Fraser River. Due to the surrounding land use cover and terrain, complex flow needed to be considered for this air quality assessment. Modelling was performed on a 50 km by 50 km study area around the Facility, as illustrated in Figure 2-1. A zoomed in image of the surrounding area is illustrated in Figure 2-2. The study area is slight offset to the North and West (the facility is not in the exact middle). This was done to avoid including the United States in the study area, and to have more of the domain over the eastern Fraser Valley where populations reside and less over the open water to the west. The study area is sufficiently large to capture the isopleth of model predicted concentrations that represents 10% of the relevant ambient air quality objectives for the pollutants in question, as per the BC modelling guideline. Any potential air quality effects from the Boilers are expected to occur within this study area.

Three years of hourly meteorological data was used, from January 1, 2013 to December 31, 2015. The meteorological data inputs to the model consists of observations made at several MV weather stations within or near the study area, and three-dimensional outputs from the BC MoECCS province wide Weather Research and Forecasting (WRF) mesoscale meteorological simulations that are recommended by the BC model guidelines for use in CALMET. The years 2013, 2014 and 2015 represent the three most recent full calendar years for which meteorological observations within the study area were complete and prognostic meteorological model output was available, at the time of the submission of the model plan to MV.



Map Document: C:\Users\djh\Desktop\GIS Temp\1702445\WTE Domain Receptor Figure.mxd

Study area, receptors, and meteorological stations used for dispersion modelling

True North

Map Projection: NAD 1983 UTM Zone 10N

Waste-To-Energy Facility - Burnaby, British Columbia

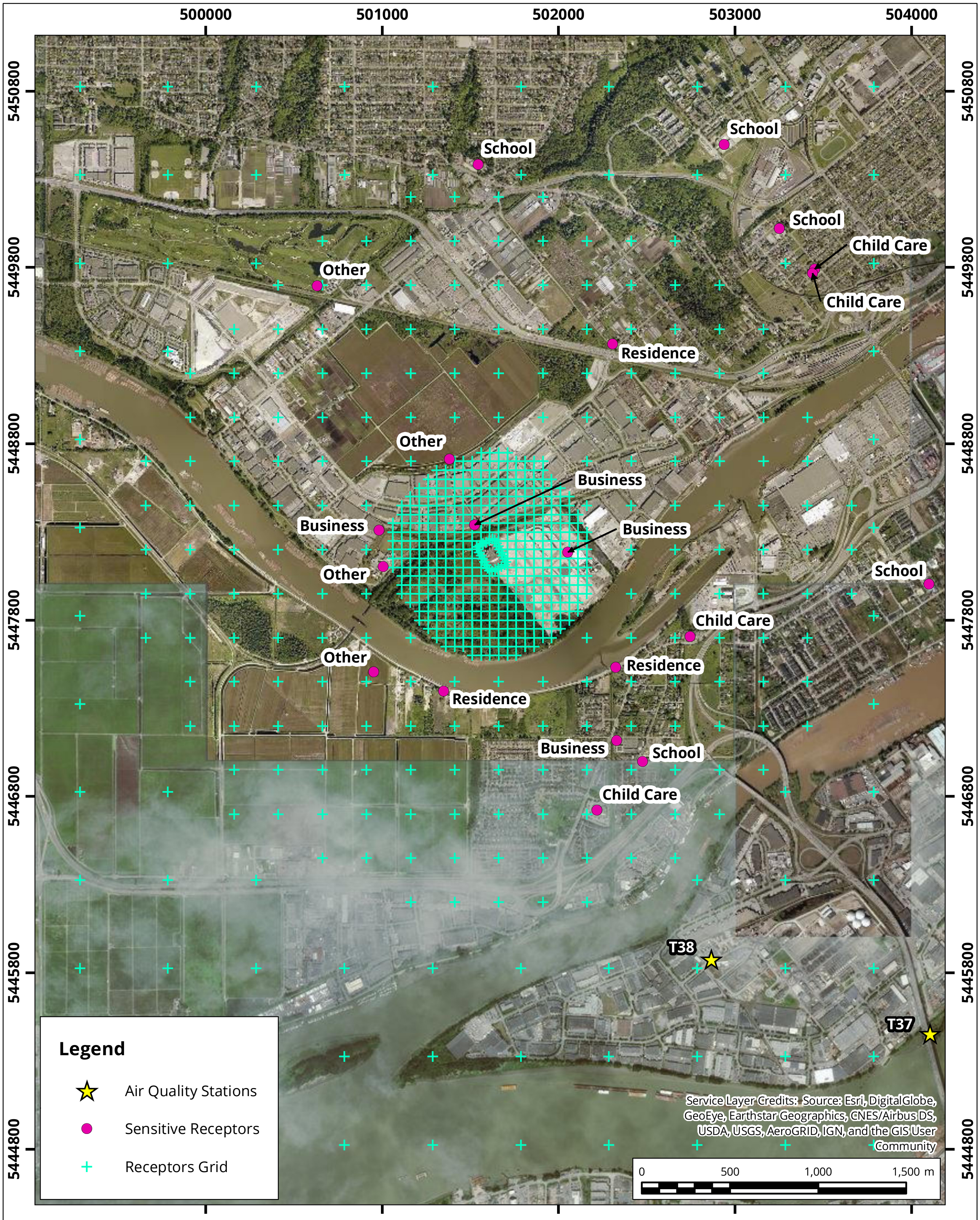
Project #: 1702445

Drawn by: DJH

Figure: 2-1

Approx. Scale: 1:320,000

Date Revised: Mar 21, 2018



Receptors, and meteorological stations within 5 km of Facility used for dispersion modelling

True North

Drawn by: DJH

Figure: 2-2

Approx. Scale: 1:30,000

Date Revised: Mar 21, 2018

Map Projection: NAD 1983 UTM Zone 10N

Waste-To-Energy Facility - Burnaby, British Columbia

Project #: 1702445

Map Document: C:\Users\djh\Desktop\GIS Temp\1702445\WTE Site Receptor Figure.mxd

2.2 Emission Estimation

The three boilers are the emissions sources that must be assessed under the OC. Representative values from the operating certificate, stack tests, and CEMS data were used to model the Boiler Stack for the various scenarios. The methodology for each scenario is described in this section.

Four scenarios were considered for this study, one representing maximum permitted operations, one representing typical operations, one representing typical operations with a boiler starting up, and one representing typical operations with a boiler shutting down.

As no size fraction data were available, all particulate matter was assumed to be $PM_{2.5}$.

The emission rates are summarized in Table 2-1.

Table 2-1: Emission Rates for Each Scenario

	Emission Rate (g/s; per boiler)				Total Emission Rate (g/s; combined operations)			
Pollutant	**Permitted**	**Operational**	**Start Up**	**Shut Down**	**Permitted**	**Operational**	**Start Up**	**Shut Down**
$PM_{2.5}$	0.22	0.02	8.6E-03	1.4E-02	0.65	0.05	0.05	0.05
Carbon Monoxide (CO)	1.20	0.59	0.81	2.98	3.60	1.76	1.76	1.98
Hydrogen Chloride (HCl)	1.32	0.45	0.43	0.58	3.96	1.36	1.36	1.36
Hydrogen Fluoride (HF)	0.02	2.88E-04	1.1E-03	1.9E-04	0.07	8.65E-04	8.65E-04	1.68E-03
Sulphur Dioxide (SO_2)	4.80	1.45	1.23	0.39	14.40	4.36	4.36	4.36
Oxides of Nitrogen (NO_X); (Background as Nitrogen Dioxide (NO_2)	4.56	2.86	2.12	2.08	13.68	8.57	8.57	8.57
Total Dioxins and Furans (as PCDD/F TEQ)	1.9E-09	1.7E-13	1.8E-10	3.1E-11	5.8E-09	5.13E-13	1.80E-10	3.09E-11
Cadmium (Cd)	1.7E-04	4.9E-06	1.8E-06	9.4E-06	5.0E-04	1.47E-05	1.47E-05	1.92E-05
Mercury (Hg)	4.8E-04	3.3E-05	9.2E-06	1.1E-05	1.4E-03	9.77E-05	9.77E-05	9.77E-05
Sum of Lead (Pb), Arsenic (As), Chromium (Cr)	1.5E-03	8.2E-05	5.3E-05	5.1E-05	4.6E-03	2.45E-04	2.45E-04	2.45E-04
Chlorophenols	2.4E-05	1.9E-09	3.8E-06	1.9E-06	7.2E-05	5.82E-09	3.80E-06	1.95E-06
Chlorobenzenes	2.4E-05	1.7E-07	2.9E-05	3.9E-05	7.2E-05	4.97E-07	2.95E-05	3.98E-05
Polycyclic Aromatic Hydrocarbons (PAHs)	1.2E-04	3.1E-08	2.8E-06	1.7E-05	3.6E-04	9.20E-08	2.83E-06	1.67E-05
Polychlorinated Biphenyls (PCBs)	2.4E-05	4.8E-11	3.7E-10	7.5E-10	7.2E-05	1.45E-10	4.63E-10	8.45E-10

Notes: The emission rates for the Start Up and Shut Down scenarios only show the emissions for the boiler that is starting up or shutting down. To represent typical operations, concentrations from the Operations Scenario modelling were added to the Start Up and Shut Down scenarios.

2.2.1 Permit Scenario

The current limits enforced in the OC were considered in this scenario. A Discharge Limit that was in effect as of December 31, 2017 was used, otherwise the Interim Discharge Limit was used. These limits and the maximum combined flow rate in the OC (72 m^3/s) were evenly distributed among the three Boilers. The Boilers were modelled as point sources with constant emission rates.

No adjustments were made to the emissions for any of the averaging periods (e.g., the same emission rate was used for the 1-hour results as the annual results). As the facility does not emit at full capacity, this scenario represents a conservative emissions scenario.

2.2.2 Operations Scenario

Typical emissions from 2017 CEMS data were considered in this scenario. The hourly emission rate for CO, SO_2, and NO_X was calculated for each Boiler using hourly CEMS data for the pollutant. The hourly rate for each contaminant was summed together to obtain the total emissions from the Boiler Stack. The median emission rate value was selected to model typical conditions.

Emissions rates for pollutants of interest that were not included in the CEMS monitoring were obtained from the last five stack tests (May 9-12, 2016; February 6-9, 2017; August 14-18, 2017; August 23-25, 2017; and November 14-16, 2017; all conducted by A. Lanfranco & Associates Inc.). Most detailed VOCs required for the health risk assessment were only available in the August 23-25, 2017 stack test report. The average of the total emission rates from these stack tests was used. If a pollutant of interest was not detected in a stack test, the detection limit was used in lieu of other data. Even though this scenario is more realistic than the Permit Scenario, the Operations Scenario is still conservative because it included the Boilers as continuous sources.

2.2.3 Start Up Scenario and Shut Down Scenario

These scenarios considered typical emissions during periods when one of the boilers was either starting up or shutting down. A series of stack tests were conducted on November 28-30, 2017 (A. Lanfranco, 2017) to obtain emission rates for start up and shut down scenarios. Emission rates for pollutants of interest that were not included in the stack test were obtained from CEMS data during known start up times. The data were obtained from the Start Up / Shut Down Test Report written by HDR (HDR, 2018).

A boiler starting up/shutting down was modelled as a constant point source representing the maximum emission rate measured during start up or shut down. Model results for both start up and shut down were added to the Operational Scenario results for the other two boilers.

For averaging periods less than annual, the modelled concentration for a boiler starting up/shutting down was added to the results for two Boilers in the Operational Scenario. This is to represent the situation where two boilers are operating under typical conditions while one boiler is starting up/shutting down. As the start up or shut down situation will always merge back into normal operations, predicted concentrations for short term averages over the course of a year (i.e., the annual maximum one-hour predicted concentration) for these scenarios will be always be greater than or equal to predicted concentrations from the Operational Scenario. That is, the effect of considering start up or shut down can only increase potential short-term concentrations compared to the Operations Scenario alone.

For the annual averaging period, the annual duration of start ups and shut downs was added to the Operational Scenario results: 164 shut downs and start ups were counted in 2017 (Gregory H. Gesell, personal communication, March 12, 2018). Based on typical durations, a conservative value of five hours was assumed for each period, resulting in a maximum of 5 * 164 = 820 hours of annual start up and shut down. The annual average obtained from the constant start up or shut down emissions was prorated according to this number of hours versus the number of hours in a year (i.e., a factor of 820/8760) and added to the annual average previously determined for the Operational Scenario.

Normal operation of the other two boilers is defined in the Operational Scenario.

2.3 Dispersion Modelling

Dispersion modelling was conducted for each or the four emission scenarios described above. Predicted concentrations were compared to ambient air quality objectives, which are listed in Table 1-1. The dispersion modelling methodology is based on the BC modelling guideline. A detailed modelling plan was submitted to the Fraser Health Authority, Vancouver Coastal Health, and BC MoECCS for review before commencing the study. The model plan is provided in Appendix A.

Topography around the Facility is spatially varied, resulting in complex wind flow patterns. Therefore, a refined dispersion model, capable of simulating complex wind flow patterns was selected. Specifically, the CALPUFF model in full three-dimensional CALMET mode (Earth Tech 2000a, 2000b). This model is accepted for regulatory use by MV, the BC MoECCS and US EPA, among other jurisdictions. CALMET is a meteorological pre-processor that develops hourly three-dimensional meteorological fields of wind and temperature used to drive pollutant transport and dispersion within CALPUFF. CALPUFF is a multi-layer, multi-species, non-steady-state puff dispersion model. It simulates the influences of time- and space-varying meteorological conditions on pollutant transport, transformation and deposition. CALPUFF was used to predict ambient concentrations for the pollutants of interest in this study. CALPUFF was also used to predict deposition rates for the heath risk assessment.

Two separate runs of CALPUFF were carried out. For ambient concentration results, dry deposition and wet deposition were disabled for all pollutants to be more conservative. For deposition rate results (provided for the health risk assessment), dry deposition and wet deposition were enabled for all pollutants.

2.3.1 CALMET

A 50 km x 50 km model domain approximately centred on the Facility will was used for CALMET and CALPUFF. Grid cells were spaced at 250 m.

CALMET (version 6.5.0) is the meteorological pre-processor for the CALPUFF model. Dispersion modelling was conducted using the full 3-D CALMET mode because it has the ability to assimilate observations at multiple meteorological stations, as well as prognostic meteorological model output (WRF), and to simulate the changes in mixing height and boundary layer mechanics that result from the variable land cover characterization and terrain in the air quality dispersion modelling study area. The following is a summary of CALMET model inputs. More detailed information is provided in Appendix B.

2.3.1.1 Model Period

CALMET was run for a three-year period from January 1, 2013 to December 31, 2015. This represents the most recent three years for which the BC MoECCS province WRF data which are required for use in the model study were available, at the time of the submission of the model plan to MV.

2.3.1.2 Model Domain

The CALMET model domain, shown in Figure 2-1, was chosen to be a 50 km by 50 km area and allowing for several kilometres of buffer on all sides to avoid edge effects influencing dispersion at the boundaries. Horizontal domain resolution was set at 250 m. In the vertical direction, 10 layers were chosen, with the top of the layers set as 20, 40, 80, 160, 300, 600, 1000, 1500, 2200 and 3000 m above ground level.

The Universal Transverse Mercator (UTM) coordinates of the domain vertices are given in Table 2-2.

Table 2-2: UTM Coordinates of CALPUFF Model Domain

Domain Vertex	UTM Easting (km)	UTM Northing (km)
Southwest	476.654	5427.754
Northwest	476.654	5477.754
Southeast	526.654	5427.754
Northeast	526.654	5477.754

Note: All coordinates are for North American datum 83 grid zone 10.

2.3.1.3 Prognostic Meteorology

CALMET was initialized for the three-year model period using the WRF model. The WRF model is a mesoscale, numerical, weather prediction system designed to serve both atmospheric research and operational forecasting needs. It represents the latest numerical weather forecasting model to be adopted by the United States National Weather Service and by the United States military and private meteorological services. The BC MoECCS WRF dataset for 2013, 2014 and 2015, with a 4-km configuration covering a 100 km by 100 km area over Vancouver and southwestern B.C., was obtained from Exponent Inc.

2.3.1.4 Surface Meteorology

Surface meteorological data collected from the MV network were used in the CALMET model, as well as data from the Environment Canada station at the Vancouver Airport (YVR) and Abbotsford Airport (YXX). A total of 20 surface stations were used in the CALMET model as presented in Table 2-3. The locations of the surface meteorological stations are shown in 2-1and Figure 2-2.

Table 2-3: Surface Meteorological Data Stations

Station ID	Location (lat/long or indicate on map)	Data Source MOE, MV, MSC, Site Specific, other (specify) [1]	Parameter(s)[2]	Years	% of Wind Speeds = calm [3]	Anemometer Height (m) [4]
Vancouver Airport	49.19° N 123.18° W	MSC	Temperature, Relative humidity, Pressure, Precipitation, Cloud cover	2013, 2014, 2015	-	-
Abbotsford Airport	49.03° N 122.36° W	MSC	Relative humidity, Pressure, Precipitation, Cloud cover	2013, 2014, 2015	-	-
Vancouver Airport (MV Station Richmond-Airport; T31)	49.1863° N 123.1524° W	MV	Wind speed, Wind direction, Temperature, Relative humidity, Precipitation	2013, 2014, 2015	0%	10.3
Abbotsford Airport (T45)	49.0215° N 122.3265° W	MV	Wind speed, Wind direction, Temperature, Relative humidity, Precipitation	2013, 2014, 2015	0.43%	12.1
Burnaby South (T18)	49.2152° N 122.9857° W	MV	Wind speed, Wind direction, Temperature, Relative humidity, Precipitation	2013, 2014, 2015	0.01%	19.9
North Delta (T13)	49.1583° N 122.9017° W	MV	Wind speed, Wind direction, Temperature, Relative humidity, Precipitation	2013, 2014, 2015	0.08%	18.3

Station ID	Location (lat/long or indicate on map)	Data Source MOE, MV, MSC, Site Specific, other (specify) [1]	Parameter(s)[2]	Years	% of Wind Speeds = calm [3]	Anemometer Height (m) [4]
Annacis Island (T38)	49.1675° N 122.9607° W	MV	Wind speed, Wind direction, Temperature, Relative humidity, Precipitation	2013, 2014, 2015	0.22%	10.0
Vancouver – Kitsilano (T2)	49.2617° N 123.1635° W	MV	Wind speed, Wind direction, Temperature, Relative humidity, Precipitation	2013, 2014, 2015	1.16%	12.5
Burnaby Kensington (T4)	49.2792° N 122.9707° W	MV	Wind speed, Wind direction, Temperature, Relative humidity	2013, 2014, 2015	0.04%	13.5
North Vancouver Second Narrow (T6)	49.3015° N 123.0204° W	MV	Wind speed, Wind direction	2013, 2014, 2015	0.01%	11.9
Port Moody (T9)	49.2809° N 122.8493° W	MV	Wind speed, Wind direction, Temperature, Relative humidity, Precipitation	2013, 2014, 2015	2.47%	12.8
Burnaby Mountain (T14)	49.2798° N 122.9223° W	MV	Wind speed, Wind direction, Temperature, Relative humidity, Precipitation	2013, 2014, 2015	0.01%	29.8
Surrey East (T15)	49.1329° N 122.6942° W	MV	Wind speed, Wind direction, Temperature, Precipitation	2013, 2014, 2015	0.10%	16.9
Richmond South (T17)	49.1414° N 122.1082° W	MV	Wind speed, Wind direction, Temperature, Precipitation	2013, 2014, 2015	0.13%	12.5
Pitt Meadows (T20)	49.2452° N 122.7089° W	MV	Wind speed, Wind direction, Temperature, Relative humidity, Precipitation	2013, 2014, 2015	0.90%	10.1

Station ID	Location (lat/long or indicate on map)	Data Source MOE, MV, MSC, Site Specific, other (specify) [1]	Parameter(s)[2]	Years	% of Wind Speeds = calm [3]	Anemometer Height (m) [4]
Burnaby Burmount (T22)	49.2667° N 122.9355° W	MV	Wind speed, Wind direction, Temperature	2013, 2014, 2015	0.38%	10.0
Burnaby Capitol Hill (T23)	49.2879° N 122.9856° W	MV	Wind speed, Wind direction, Temperature	2013, 2014, 2015	0.17%	10.0
Burnaby North (T24)	49.2875° N 123.0080° W	MV	Wind speed, Wind direction, Temperature, Precipitation	2013, 2014, 2015	0.10%	10.0
N. Vancouver Mahon Park South (T26)	49.3240° N 123.0835° W	MV	Wind speed, Wind direction, Temperature, Precipitation	2013, 2014, 2015	0.21%	14.2
Coquitlam (T32)	49.2883° N 122.7916° W	MV	Wind speed, Wind direction, Temperature, Relative humidity, Precipitation	2013, 2014, 2015	0.06%	24.0

Note: Measured wind speeds less than 1.1 km/h at the Metro Vancouver stations were set as calms in the CALMET model to account for the anemometer stall speed, as recommended by Metro Vancouver for previous projects

2.3.1.5 Terrain Elevation and Land Cover Characterization

The terrain elevation characterization information used as input into the CALMET model was obtained from GeoBase, 1:50,000 Scale Canadian Digital Elevation Data (Natural Resources Canada, 2007). The land cover characterization information used as input into CALMET was obtained from baseline thematic mapping for BC (BC Ministry of Forests, Lands and Natural Resource Operations, 2015). This land use was further updated based on comments from MV, and visually assessing satellite imagery. The terrain elevation and land use information for the study area used as input into the CALMET model are illustrated in Figure B.1, Appendix B.

2.3.1.6 Geophysical Parameters

The CALMET model requires gridded geophysical parameters including surface roughness length, albedo, Bowen ratio, soil heat flux, vegetation leaf area index, and anthropogenic heat flux. To more accurately represent the seasonally dependent geophysical parameters in the CALMET model, five seasons were specified:

- Season 1: Mid-summer with lush vegetation (June to August)
- Season 2: Autumn with cropland that has not yet been harvested (September and October)
- Season 3: Winter with freezing temperatures, no snow on ground (November to March)

- Season 4: Winter with sub-freezing temperatures, snow cover on ground (Not Used)
- Season 5: Transitional spring with partially green short annuals (April and May)

All geophysical parameters were defined by land cover characterization type and seasonal category based on the BC modelling guideline.

2.3.1.7 Model Options and User Switches

The CALMET diagnostic model options were chosen in accordance with the BC modelling guideline and other CALMET studies performed with similar meteorological data. Features of note include:

- The model was initialized using WRF prognostic meteorological model output at 4 km resolution.
- Surface observations were extrapolated upward. This was done using the option to invoke Monin-Obukhov similarity theory to more accurately represent winds at lower levels above surface in areas of complex terrain.
- Upper air temperature and winds, cloud cover, relative humidity and precipitation and overwater conditions were based on WRF modelling output.

A list of the CALMET model options used is provided in Appendix B.

2.3.2 CALPUFF

The CALMET output (three years of hourly three-dimensional meteorological fields) was used as input to the CALPUFF dispersion model (version 7.2.1). CALPUFF was run over the full CALMET domain (50 km by 50 km study area).

2.3.2.1 Receptor Locations

In the CALPUFF model, a discrete set of receptor points are specified at which pollutant concentrations are predicted. A Cartesian nested grid of receptors was defined within the study area, as per the BC modelling guideline. All receptors were modelled at a flagpole height of 1.5 metres above ground for ambient concentrations and at ground level (0 metres above ground) for deposition rates (used in the health risk assessment). Receptor spacing for the Cartesian grid is as follows:

- 20-m spacing along the Facility property line;
- 50-m spacing within 500 m of the Facility;
- 250-m spacing within 2 km of the Facility and over all residential areas within the model domain;
- 500-m spacing within 5 km of the Facility; and
- 1,000-m spacing for the remainder of the study area.

In addition to the nested grid, 29 nearby locations were defined as sensitive receptors. These sensitive receptors include schools, child care facilities, senior care facilities and health care facilities. The sensitive receptor locations are shown in 2-1and Figure 2-2.

Terrain elevations for all receptors included as input to the CALPUFF model were extracted from 1:50,000 scale Canadian Digital Elevation Data obtained from GeoGratis, as was also used for the geophysical data in CALMET.

2.3.2.2 Technical Dispersion Options

All technical options relating to the CALPUFF dispersion model were set according to the BC modelling guideline or to model defaults. These include parameters and options such as the calculation of plume dispersion coefficients, the plume path coefficients used for terrain adjustments, and building downwash methodology. A list of the technical options is included in Appendix B.

2.3.2.3 Particle Size and Deposition Parameters

For PM related species (i.e., PM and components thereof) the particle size distributions recommended by the BC modelling guidelines were used.

A unit emission rate was modelled for VOC deposition. VOC deposition parameters followed the same approach outlined in the Air Quality Assessment conducted for the waste thermal treatment facility in Clarington, Ontario (Jacques Whitford, 2009). A deposition velocity of 0.5 cm/s was used, and the liquid scavenging rate was obtained from the ISC User's Guide (EPA, 1995)

For deposition results, deposition rates for metals were pro-rated from PM results and deposition rates for VOCs were pro-rated from the generic VOC pollutant.

2.3.2.4 Chemical Transformation

The chemical transformation option was used to obtain secondary PM results only. The RIVAD scheme with ISORROPIA equilibrium was selected for the chemical transformation option.

Emissions of NO_X from the Boilers are comprised of NO and NO_2. The primary emission is in the form of NO with reactions in the atmosphere resulting in the conversion of NO to NO_2. In order to use the RIVAD scheme with the ISORROPIA equilibrium chemical reaction scheme, individual emissions of NO and NO_2 are required. For this assessment, it was assumed that 90% of the NO_X emissions would be in the form of NO, and 10% would be in the form of NO_2. However, the final results from the chemical transformation option was not used to obtain NO_X and SO_2 results. Although NO_X and SO_2 are required for the chemical transformation, the final results from the chemical transformation option was not used to obtain the final NO_X and SO_2 results. NO_X and SO_2 were also modelled as inert gases to obtain conservative results.

2.3.2.5 Point Source Parameters

Since all scenarios assumed emissions were evenly distributed among the Boilers, the Boiler Stack was modelled as a single point source in CALPUFF. There are three openings in the Boiler Stack – one associated with each boiler. Constant, unit emission rates were modelled then concentrations pro-rated for each respective emission rate (i.e., a third of the emission rates were modelled from the stack, then the predicted concentration was multiplied by three to obtain the resultant concentration). The only exception is for pollutants involved in secondary particulate matter chemistry (NO_X, SO_2 and $PM_{2.5}$) – the actual emissions rate was modelled for these pollutants to properly account for PM formation.

Stack parameters for each boiler including stack height, stack diameter, and exit velocity are summarized for each scenario in Table 2-4. Exit temperatures were determined from the start up and shut down stack tests, then the most conservative value was used for the remaining scenarios. Stack height and diameter were provided by Metro Vancouver. Stack exit velocities were calculated based on the flow rates, which were taken from the OC for the Permit Scenario, CEMS data for the Operational Scenario, and the start up and shut down stack tests for the remaining scenarios. The source location was determined from satellite imagery and is shown in Figure 1-1.

Table 2-4: Point source stack parameters applied to each of the three emission sources in the Boiler Stack, for each scenario

Model Scenario	Permitted	Operational	Start Up	Shut Down
Stack Height (m)	60.0			
Stack Diameter (m)	1.25			
Exit Flow (m^3/s; per boiler)	24.0	20.5	18.3	18.7
Exit Velocity (m/s; per boiler)	19.6	16.7	14.9	15.3
Exit Temperature (°C)	147.0	147.0	151.0	147.0
Number of Point Sources Coming from Boiler Stack	3 operating at full, permitted capacity	3 operating at typical capacity	3: 2 operating at typical capacity, and 1 starting up	3: 2 operating at typical capacity, and 1 shutting down

2.3.2.6 Building Effects

Buildings located close to stacks may influence the dispersion of emissions. The effect of large buildings and structures that are part of the Facility on the modelled point sources was incorporated using the Building Profile Input Program Plume Rise Model Enhancement (BPIP-PRIME) algorithm. The algorithm explicitly treats the trajectory of the plume near the building and uses the position of the plume relative to the building to calculate interactions with the building wake. On-site building heights were estimated from site plan drawings and Google Earth. Off-site building heights were obtained from Google Earth. The buildings included in the model are shown in Figure 1-1.

Post-Processing of Model Results

Hourly flagpole-level concentrations were predicted for each emissions scenario run at each receptor. Post-processing of hourly model results was conducted to determine required results for comparison with ambient air quality objectives over various averaging periods.

2.3.2.7 Derived Total Modelled Concentrations and Deposition

To account for total PM (primary PM + secondary PM formed in chemistry), the POSTUTIL post-processor was used to combine the PM sub- species. The POSTUTIL post-processor was also used to add wet and dry deposition rates together. The CALPOST post-processors was then used to extract required metrics from the resulting binary files.

The maximum results from each of the scenarios were selected for each contaminant, averaging period and receptor.

2.3.2.8 Representative Background Concentrations

The BC modelling guideline requires that representative background concentrations be added to concentrations predicted by dispersion modelling to account for other emission sources in the study area.

As per the BC modelling guideline, the 98th percentile of historical hourly monitoring data is to be added to maximum predicted concentrations for short term averaging periods in a Level 3 assessment, such as this one. This methodology is very conservative as it assumes that the maximum predicted concentration and the background concentration would occur at the same time even though, by definition, concentrations equal to or greater than the 98th percentile occur only 2% of the time and the maximum predicted concentration, by definition, would occur once during the modelled period. The annual mean calculated from all hourly data is to be used for annual average cumulative predictions.

For this study, background concentrations for the criteria air contaminants (CACs; PM, CO, SO_2 and NO_2) were based on four years (2014 to 2017) of hourly ambient air quality observations from the MV Burnaby South station (also referred to as "T18"; Reid, personal communication 2018). The 98th percentile of the entire monitoring period was calculated for each short-term background concentration. The average value of the entire monitoring period was calculated for each annual background concentration. Rolling averages were used to calculate background for the 8-hour and 24-hour averaging periods, and they were only used if the data were more than 75% complete (e.g., 24-hour periods with less than 18 hours of data were not included).

Where available measurements of VOCs and metals were also obtained from the MV Burnaby South station. Data were obtained from the National Air Pollution Surveillance (NAPS) website for two years (2015 and 2016) (EC, 2018). NAPS data are obtained at a sampling period of 24-hours, every six days. The 24-hour background values were converted for the 1-hour averaging period using scaling factors from the US EPA AERSCREEN model (AERSCREEN User's Guide, 2015). For each contaminant, the average of all 24-hour values were used as background values for the annual period. Background concentrations used for all contaminants and relevant averaging periods are presented in Table 2-5. No background was considered for any VOCs due to the lack of available measurement data.

Table 2-5: Representative background concentrations

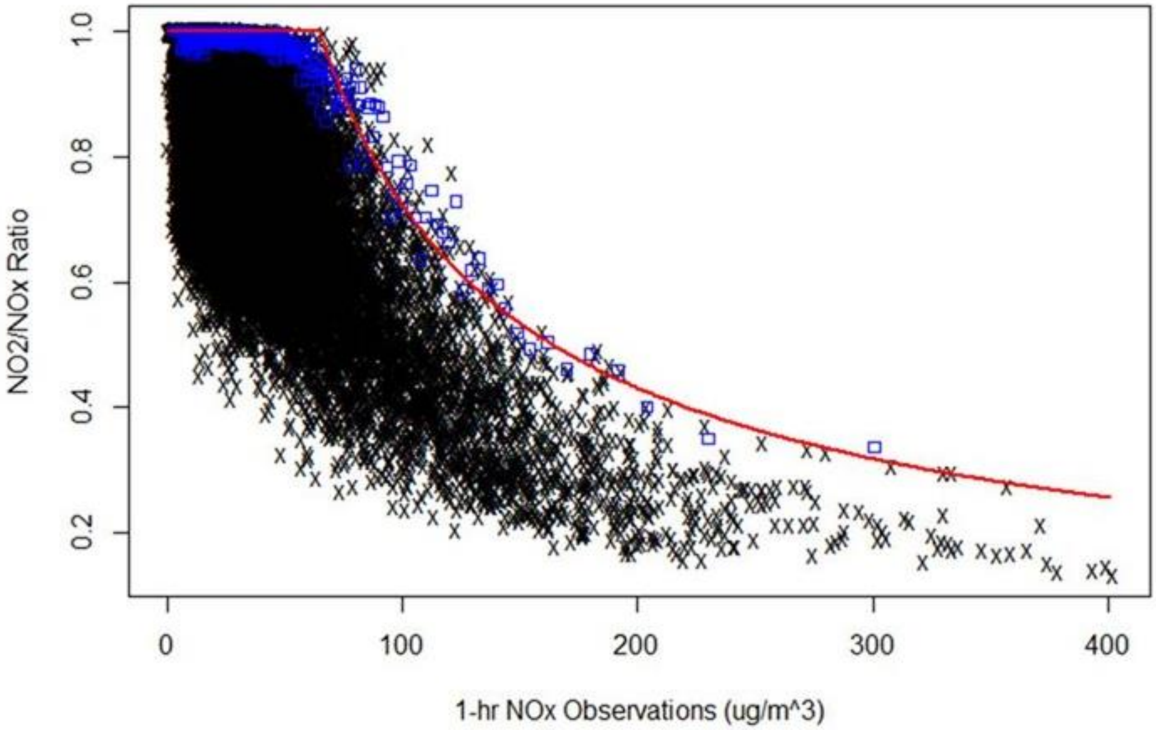
Air Contaminant	Averaging Period	Background (98th Percentile)
$PM_{2.5}$	24-hour	16.5
	Annual	5.9
Carbon Monoxide (CO)	1-hour	607
	8-hour	560
Sulphur Dioxide (SO_2)	1-hour	5.2
	Annual	1.1
Nitrogen Dioxide (NO_2)	1-hour	62.4
	Annual	25.2
Cadmium (Cd)	1-hour	9.2E-04
	24-hour	3.7E-04
	Annual	7.3E-05
Sum of Lead (Pb), Arsenic (As), Chromium (Cr)	1-hour	3.0E-02

2.3.2.1 NO_X to NO_2 Conversion

According to the BC modelling guideline (BC MOE 2008), the first and most conservative method of estimating NO_2 is to assume 100% conversion of NO_X into NO_2. If a more accurate estimate is desired, the ambient ratio method or the ozone limiting method may be used. The ambient ratio method (ARM) is recommended in areas where representative NO_X and NO_2 ambient monitoring data are available. For this assessment, NO_2 concentrations were estimated using the ARM, based on the representative background concentrations. Chemical transformations in CALPUFF (e.g., RIVAD scheme with ISORROPIA) were not used to obtain NO_2 from NO_X. The steps to obtain NO_2 are summarized below:

1. The NO_X emission rates were modelled in CALPUFF as inert NO and NO_2 gases;
2. The NO and NO_2 were summed back together using the POSTUTIL post-processing software. This produced NO_X model concentrations;
3. NO_X model concentrations were converted to NO_2 using the ambient ratio method. This produced NO_2 model concentrations;
4. As required by Metro Vancouver, ambient background concentrations of NO_2 were added to model concentrations *after* they were converted to NO_2.

The ratio of hourly NO_2/NO_X versus total NO_X, based on ambient monitoring data from T18 is plotted in Figure 2-3. An exponential curve was fitted to the upper-envelope of the scatter plots, as shown in the figure. The maximum NO_2/NO_X ratio was set to 1 and a minimum NO_2/NO_X ratio was set to 0.1, as per the BC modelling guideline (BC MOE 2015).



```
[1] "A = 22.775715"
[1] "B = 0.748882"
[1] "Min.NOx.Limit = 64.962900"
[1] "Max.NOx.Limit = 1406.014238"
```

Where $\frac{NO_2}{NO_x} = A \times NO_X{}^{-B}$

Figure 2-3: ratio of hourly NO_2/NO_X versus total NO_X, based on ambient monitoring data from T18

3 DISPERSION MODELLING RESULTS

This section describes predictions of model concentrations in the study area, and comparisons to applicable ambient air quality objectives. Maximum predicted concentrations of the CACs for all scenarios, including ambient background, are presented in Table 3-1. Maximum predicted concentrations of the metals and VOCs for all scenarios, including ambient background, are presented in Table 3-2. As the Permit Scenario is the highest emissions case scenario for all pollutants, except for CO, predicted concentration contours are only shown for the Permit Scenario. These concentration contours are provided in Appendix C. Predicted CO concentrations were higher in the Operations Scenario, although the predicted concentrations are well below the respective objectives. Predicted values that are above the applicable ambient air quality objectives are highlighted in in bold in both tables. As demonstrated in the contour plots the highest concentrations are localized effects very close to the Facility.

Predicted concentrations are within Metro Vancouver and BC MoECCS ambient objectives for all species except for 1-hour SO_2 and NO_2. Modelling result for SO_2 and NO_x are discussed in greater detail in the flowing sections,

Among pollutants with objectives borrowed from Alberta and Ontario, the predicted concentration of HCl exceeds the 1-hour objective from Alberta for the permit scenario only, and predicted concentration of PAH exceeds the 24-hour objective from Ontario for the permit and shut down scenario, and the annual objective from Ontario for the permit scenario. The model results indicate that there will be no exceedances of HCl and PAHs under normal operations. There is a potential for a slight exceedance of the 24-hr Ontario PAH objective during shut down conditions.

There are no other predicted exceedance of Alberta or Ontario objective for any scenarios or averaging times across all scenarios.

3.1 SO_2 Modelling Results

Model predictions for SO_2 are within 2020 and 2025 CAAQS for SO_2 under all operating scenarios. Predicted SO_2 concentrations under all operating scenarios are within the Metro Vancouver 1-hour ambient objective of 183 µg/m3 for SO_2 for greater than 99.9% of all hours in any year modelled.

A breakdown of the frequency of 1-hour SO_2 predictions above the Metro Vancouver one-hour objective for each year of the model period is provided in Table 3-1. The table provides the maximum number of hours at any single receptor that predicted SO_2 concentration is above the Metro Vancouver objective for each individual year and for the full three-years model period. (Note that the values for each year do not equal the maximum for all three years. This is because the maximums for the individual years do not occur at the same model receptor.)

At the most impacted receptor, there are fewer than 10 hours over the three-year model period for which hourly SO_2 including background is predicted to be above the Metro Vancouver threshold. In terms of total hours modelled, this amounts to 10 out 26,280 assessed, or less than 0.04% of the time. Similarly, for any one year the maximum number of hours for which SO_2 is predicted to be above the objective is 6 or fewer, which is less than 0.1% of the hours of in the year. It is also worth noting that the low number of hours above the Metro Vancouver objective does not also result in exceedances of the CAAQS for SO_2 because its is too small to influence the CAAQS calculation which is based on the 99th percentile of daily one-hour maximum SO_2. A plot of the spatial extent of the maximum number of exceedances at each receptor for any year of the modelling is shown in Figure 10 of Appendix C. The figure shows that the exceedances are limited to within a few hundred meters of the facility, and anything is excess of 2 hours per year is predicted to occur at or very close to the Facility fenceline

Table 3-1: Number of Hours per Year with Predicted Concentrations above the Metro Vancouver 1-hour SO_2 Objective of 183 ug/m^3 for Permitted Scenario including Background

	Model Year or Period			
	2013	2014	2015	2013-2015
Number of hours*	6	2	3	9

* Maximum Number of hours for a single receptor in model domain

A comparison of the model predictions to measurements of hourly SO_2 from Station T18 Burnaby South of the Metro Vancouver ambient monitoring network is shown in Table 3-2. The table shows the maximum 1-hour SO_2 concentration and annual average from 2013 through to 2019, coinciding with the 2013-2015 model period and continuing through to the most recent complete calendar year. Also shown are the model prediction at T18 and the domain maximum for each year of the model period.

For each year in Table 3-2, 1-hour model predictions at T18 and at the MPOI (maximum point of impingement) are several multiples higher that actual observations at T18. This demonstrates that the short-term model predictions of ambient SO_2 are very likely conservative and that actual SO_2 due to facility emissions will be lower than predicted. This is due both to the conservatism of the CALPUFF dispersion model itself and to the fact that SO_2 emissions during normal operations will be less than the permitted emission limit.

The modelled annual average at the MPOI is also several multiples higher than the annual average at T18. However, the modelled annual average at T18 is actually lower than what it is observed at T18. This is because the model prediction at T18 is only influenced by hours for which the modelled plume from the Facility passes over that receptor location, while in reality the monitor at T18 will be influenced at every hour by SO_2 coming from other emission sources in the region

Further, though 1-hour SO_2 at T18 appears to show an increase over the last five years, in fact for the longer period over which the WTE facility has been in operation, ambient SO_2 in the region has consistently trended downwards as shown by Metro Vancouver historical records of SO_2 monitoring T18 and elsewhere in the Lower Fraser Valley (Metro Vancouver, 2016), which suggest that the WTE is not a major source of regional ambient SO_2 concentrations. This is perhaps reflected in the annual average at T18 which does seem to show a general decrease over the years shown in Table 3-2.

Monitoring of ambient SO_2 concentrations during normal operations of the WTE facility could help to confirm that model predictions are conservative and that actual concentration of SO_2 in the area around the Facility will remain within the Metro Vancouver objective.

Table 3-2 Comparison of SO_2 Measurements from T18 versus Model Results for Permit Scenario. not including background. SO_2 in μg/m³.

Year	Measured T18		Modelled T18		Modelled MPOI	
	1-hour	Annual Average	1-hour	Annual Average	1-hour	Annual Average
2013	23.0	1.5	87.1	0.9	418.8	3.4
2014	20.4	1.5	74.7	0.8	403.1	3.4
2015	19.3	0.9	104.2	0.8	332.0	3.9
2016	13.6	0.8				
2017	24.1	0.9				
2018	23.8	0.8				
2019	50.7	0.9				

3.2 NO_2 Modelling Results

Predicted concentrations of 1-hour NO_2 from the facility emissions alone are within the 2020 and 2025 CAAQS for all operating scenarios. When background is included using the Metro Vancouver guidance for NO_2, predicted cumulative concentrations of daily peak 1-hour NO_2 above the CAAQS threshold for up to 54 days in any year modelled. When using BC MoECCS guidance for including background NO_2, cumulative model predictions are within the 2020 CAAQS for all scenarios. The predicted concentrations for all scenarios show that any potential exceedances would not occur from facility emissions alone and that the existing background concentration of NO_2 from all other sources is a large contributor to the potential for exceedance under all scenarios.

A breakdown of the frequency of daily 1-hour peak NO_2 predictions versus the CAAQS threshold for each year of the model period is provided in Table 3-3. The table gives the maximum number of days for any single receptor that predicted maximum NO_2 concentration is above the CAAQS threshold over each individual year and for the full three-year model period. (Again, that the values for each year do not equal the maximum for all three years. This is because the maximums for the individual years do not occur at the same model receptor.)

At the most impacted receptor, there are between 45 and 54 days in a year for which the daily 1-hour peak NO_2 concentration including background is predicted to be above the Metro Vancouver threshold.

Table 3-3 Number of Days per Year with Predicted Daily Maximum 1-hour NO_2 above the 2020 CAAQS threshold of 113 µg/m³ for Permitted Scenario including Background

	Year/Period			
	2013	2014	2015	2013-2015
Number of Days*	45	46	54	136

*Maximum Number of Days for a single receptor in model domain

A plot of the spatial extent of the number of days with predictions above the 2020 NO_2 CAAQS threshold is shown in Figure 6 of Appendix C. The areas with the highest number of days are located within the first few hundred meters of the Facility fence line. Single annual occurrences of daily peak NO_2 above the threshold may occur up to seven kilometers distance from the Facility. A comparison of the model predictions to measurements of hourly NO_2 from T18 shown in Table 3-4. Again, as per Table 3-2 for SO_2 above, shows the maximum 1-hour and annual NO_2 concentration from the most recent five-year period from 2015 through to 2019 along with the model predictions at T18 and for domain maximum for each year of the model period. Note that the maximum 1-hour NO_2 values measured from T18 are themselves in the range of 70-85% of the 2020 CAAQS threshold of 113 µg/m3 and are above the threshold of 79 µg/m3 for the 2025 CAAQS.

Unlike for SO_2, model predicted 1-hour concentrations at T18 are lower than the measured values. Model predicted 1-hour NO_2 at the MPOI is approximately 10% higher than what is observed at T18. The model predictions of annual average at T18 and at the MPOI are both well below the annual average at T18, This is because of the preponderance of other source of NO_x emissions, most notably mobile vehicles, within the region.

Despite the similarity between the observed and predicted 1-hour NO_2 values, the conservatism in model prediction that is demonstrated by the SO_2 value shown in Table 3-2 is likely also present in the model predictions for NO_2 given in Table 3-4, and the actual contributions to NO_2 concentrations resulting from Facility emissions are likely much smaller than the modelled values shown in the table. Thus what Table 3-4 really demonstrates is that the existing background ambient concentration of NO_2 in the region is the dominant contributor to occurrence of model predictions of cumulative NO_2 concentration above the CAAQS threshold.

Table 3-4: Comparison of NO_2 Measurements from T18 versus Model Results for Permit Scenario, not including background. NO_2 in µg/m^3

Year	Measured T18		Modelled T18		Modelled MPOI	
	1-hour	Annual Average	1-hour	Annual Average	1-hour	Annual Average
2013	86.4	27.0	68.6	0.8	102.4	3.2
2014	99.6	26.3	66.1	0.7	101.4	3.2
2015	95.1	26.0	71.1	0.8	96.6	3.7
2016	84.8	23.0				
2017	99.6	25.5				
2018	90.0	23.6				
2019	92.1	23.8				

All NO_2 values with ambient background were calculated following the method recommended by Metro Vancouver; ambient NO_2 background was added to the model results *after* they were converted to NO_2. This is different than the method recommended by the BC Ministry of Environment & Climate Change Strategy, where ambient NO_X background is added to the NO_X model results *before* they are converted to NO_2.

An additional sensitivity analysis was conducted to assess the difference between the two methods and how they affect the final NO_2 results.

The sensitivity analysis demonstrated that using the BC Ministry of Environment & Climate Change Strategy method reduces 1-hour model predictions and brings results to less than the CAAQS. This is because when using the Metro Vancouver method wherein the components are converted separately, both background and model concentration will fall further to the left (i.e., lower NO_x) side of the ARM curve where the conversion ratio for each will be higher, thus providing a higher combined NO_2 concentration. When, as in the BCMOECC method, the NO_x components are combined before conversion, the NO_x total will lie further to the right side of the curve where the conversion ratio is lower, resulting in a lower combined NO_2 total.

However, the BC Ministry of Environment & Climate Change Strategy method actually increases the annual NO_2 results. This is because the combination of the model and background annual NO_X as per MOE method, is still less than the cut-off for 100% conversion of NO_X to NO_2 in the ARM curve. That is, for the annual average specifically, the modelled plus background is such that the ARM curve is functionally the same as assuming 100% conversion of modelled and background NO_X.

Table 3-5: Maximum predicted concentrations for CACs for all scenarios, over the study area

Air Contaminant	Averaging Period	Background (98th Percentile)	Permitted Model Concentrations	Permitted Model Concentrations	Operational Model Concentrations	Operational Model Concentrations	Start Up Boiler Model Concentrations + other 2 boilers	Start Up Boiler Model Concentrations + other 2 boilers + BG	Shut Down Boiler Model Concentrations + other 2 boilers	Shut Down Boiler Model Concentrations + other 2 boilers + BG	Ambient Objective	Jurisdiction of Objectives
		(µg/m³)	MPOI (no background; µg/m³)	MPOI (with background; µg/m³)	MPOI (no background; µg/m³)	MPOI (with background; µg/m³)	MPOI (no background; µg/m³)	MPOI (with background; µg/m³)	MPOI (no background; µg/m³)	MPOI (with background; µg/m³)		
$PM_{2.5}$	24-hour	16.5	2.0	18.5	0.5	17.0	0.5	17.0	0.5	17.0	25	Metro Vancouver
	Annual	5.9	0.2	6.1	0.03	6.0	0.03	6.0	0.03	6.0	8[1]	Metro Vancouver
Carbon Monoxide (CO)	1-hour	607.0	104.7	711.7	52.9	659.9	59.7	666.7	125.1	732.1	30,000	B.C. Ambient Air Quality Objectives
	8-hour	559.7	19.3	579.0	9.9	569.6	11.3	571.0	23.9	583.6	10,000	B.C. Ambient Air Quality Objectives
Sulphur Dioxide (SO_2)	1-hour	5.2	**418.8**	**424.1**	**190.4**	**195.7**	**190.4**	**195.7**	**190.4**	**195.7**	183	Metro Vancouver
	99th percentile, 1h daily max; averaged over 3 years	5.2	154.9	160.1	53.4	58.7	53.4	58.7	53.4	58.7	183 (2020) 170 (2025)	Canadian Ambient Air Quality Standards (CAAQS)
	Annual	1.1	3.9	5.0	1.3	2.4	1.3	2.4	1.3	2.4	13	Metro Vancouver
Oxides of Nitrogen (NO_x) (Assumes 100% Conversion to NO_2; Background and Objectives for NO_2)	1-hour	62.4	397.8	460.2	257.2	319.7	257.2	319.7	257.2	319.7	200, for NO_2	Metro Vancouver
	98th percentile, 1h daily max; averaged over 3 years	62.4	102.3	164.7	70.2	132.6	70.2	132.6	70.2	132.6	113, for NO_2	Canadian Ambient Air Quality Standards (CAAQS)
	Annual	25.2	3.7	28.9	2.6	27.8	2.6	27.8	2.6	27.8	40, for NO_2	Metro Vancouver
Nitrogen Dioxide (NO_2) (Converted from NO_x)[2]	1-hour	62.4	102.4	164.8	91.8	154.2	125.2	187.6	123.7	186.2	200	Metro Vancouver
	98th percentile, 1h daily max; averaged over 3 years, MV method [2]	62.4	72.8	**135.3**	66.2	**128.7**	66.2	**128.7**	66.2	**128.7**	113 (2020) 79 (2025)	Canadian Ambient Air Quality Standards (CAAQS)
	98th percentile, 1h daily max; averaged over 3 years, MOECC method [2]	62.4	72.8	**91.2**	66.2	**88.1**	66.2	**88.1**	66.2	**88.1**		
	Annual [3]	25.2	3.7	28.9	2.6	27.8	2.6	27.8	2.6	27.8	40	Metro Vancouver

Notes: Values that exceed the applicable objectives are shown in bold text

[1] there is also a planning annual objective goal of 6 µg/m³

[2] Under Metro Vancouver guidance, ambient NO_2 background is added to the model results *after* they are converted to NO_2. This is different than the method recommended by the BC Ministry of Environment & Climate Change Strategy, in which ambient NO_X background is added to the NO_X model results *before* they are converted to NO_2

[3] Using Metro Vancouver guidance for conversion

Table 3-6: Maximum predicted concentrations for Metals and VOCs for all scenarios, over the study area

Air Contaminant	Averaging Period	Background (98th Percentile)	Permitted Model Concentrations	Permitted Model Concentrations	Operational Model Concentrations	Operational Model Concentrations	Start Up Boiler Model Concentrations + other 2 boilers	Start Up Boiler Model Concentrations + other 2 boilers + BG	Shut Down Boiler Model Concentrations + other 2 boilers	Shut Down Boiler Model Concentrations + other 2 boilers + BG	Ambient Objective	Jurisdiction of Objectives
		(µg/m^3)	MPOI (no background; µg/m^3)	MPOI (with background; µg/m^3)	MPOI (no background; µg/m^3)	MPOI (with background; µg/m^3)	MPOI (no background; µg/m^3)	MPOI (with background; µg/m^3)	MPOI (no background; µg/m^3)	MPOI (with background; µg/m^3)		
Hydrogen Chloride (HCl)	1-hour	0	**115.2**	**115.2**	40.8	40.8	40.8	40.8	44.8	44.8	75	Alberta Environment and Parks Ambient Air Quality Objectives (adopted from Texas)
Hydrogen Fluoride (HF)	1-hour	0	2.1	2.1	0.03	0.03	0.05	0.05	0.03	0.03	4.9	Alberta Environment and Parks Ambient Air Quality Objectives (adopted from Texas)
Total Dioxins and Furans (as PCDD/F TEQ)	24-hour	0	1.4E-08	1.4E-08	1.4E-12	1.4E-12	5.4E-10	5.4E-10	9.3E-11	9.3E-11	0.1 pg TEQ/m^3	Ontario Ambient Air Quality Criteria (Health Limiting Effect)
Cadmium (Cd)	24-hour	3.7E-04	1.2E-03	1.6E-03	4.1E-05	4.1E-04	4.1E-05	4.1E-04	5.5E-05	4.2E-04	0.025	Ontario Ambient Air Quality Criteria (Health Limiting Effect)
	Annual	7.3E-05	1.4E-04	2.1E-04	4.5E-06	7.7E-05	4.5E-06	7.7E-05	4.8E-06	7.8E-05	0.005	Ontario Ambient Air Quality Criteria (Health Limiting Effect)
Mercury (Hg)	24-hour	0	3.5E-03	3.5E-03	2.7E-04	2.7E-04	2.7E-04	2.7E-04	2.7E-04	2.7E-04	2	Ontario Ambient Air Quality Criteria (Health Limiting Effect)
Sum of Lead (Pb), Arsenic (As), Chromium (Cr)	1-hour	3.0E-02	1.3E-01	1.6E-01	7.4E-03	3.7E-02	7.4E-03	3.7E-02	7.4E-03	3.7E-02	1.5	Alberta Environment and Parks Ambient Air Quality Objectives (adopted from Texas)
Polycyclic Aromatic Hydrocarbons (PAHs)	24-hour	0	**8.7E-04**	**8.7E-04**	2.5E-07	2.5E-07	8.5E-06	8.5E-06	**5.1E-05**	**5.1E-05**	5.0E-05	Ontario Ambient Air Quality Criteria (Health Limiting Effect)
	Annual	0	**9.8E-05**	**9.8E-05**	2.8E-08	2.8E-08	1.1E-07	1.1E-07	5.3E-07	5.3E-07	1.0E-05	Ontario Ambient Air Quality Criteria (Health Limiting Effect)
Polychlorinated Biphenyls (PCBs)	24-hour	0	1.7E-04	1.7E-04	4.0E-10	4.0E-10	1.4E-09	1.4E-09	2.5E-09	2.5E-09	0.15	Ontario Ambient Air Quality Criteria (Health Limiting Effect)
	Annual	0	2.0E-05	2.0E-05	4.4E-11	4.4E-11	5.5E-11	5.5E-11	6.7E-11	6.7E-11	0.035	Ontario Ambient Air Quality Criteria (Health Limiting Effect)

Notes: Values that exceed the applicable objectives are shown in bold text

A background value of zero (0) indicates no monitoring data available for that contaminant. In this case, a background value of zero (0) has been assumed for modelling purposes

4 CONCLUSIONS

Four scenarios were considered for this study:

- **Permit Scenario:** representing maximum permitted operations, 24 hours a day, each day of the year
    - Continuous emissions prescribed in the Operational Certificate were considered in this scenario.
    - As the facility does not emit at full capacity for any parameter, this scenario represents a conservative emissions scenario.
- **Operational Scenario:** representing typical operations
    - Typical emissions from 2017 continuous emissions monitoring systems data were considered in this scenario.
    - Emissions rates for pollutants of interest that were not included in the continuous emissions monitoring systems monitoring were obtained from 2017 and 2016 stack test data.
- **Start Up Scenario:** representing typical operations with a boiler starting up
    - A series of stack tests were conducted to obtain emission rates for this scenario.
    - Emission rates for pollutants of interest that were not included in the stack test were obtained from continuous emissions monitoring systems data during known start up times.
- **Shut Down Scenario:** representing typical operations with a boiler shutting down
    - A series of stack tests were conducted to obtain emission rates for this scenario.
    - Emission rates for pollutants of interest that were not included in the stack test were obtained from continuous emissions monitoring systems data during known shut down times.

Predicted SO_2 concentrations under all operating scenarios are within the Metro Vancouver 1-hour ambient objective for SO_2 for greater than 99.9% of all hours in any year modelled. Predicted concentrations are also within Metro Vancouver ambient objectives for all other pollutants and averaging times under all operating scenarios. Model predictions for SO_2 are within the 2020 and 2025 CAAQS for SO_2 for all operational scenarios. Comparing measured SO_2 concentrations to modelled concentrations at an existing nearby air quality monitoring station (T18) show that the short-term model predictions of ambient SO_2 are very likely conservative and that actual SO_2 due to facility emissions will be lower than predicted.

Predicted concentrations of 1-hour NO_2 from the facility emissions alone are within the 2020 and 2025 CAAQS for all operating scenarios. When background is included using the Metro Vancouver guidance for NO_2, predicted cumulative concentrations of daily peak 1-hour NO_2 above the CAAQS. The predicted concentrations for all scenarios show that any potential exceedances would not occur from facility emissions alone and that the existing background concentration of NO_2 from all other sources is a large contributor to the potential for cumulative concentration above the CAAQS under all scenarios When using BC MoECCS guidance for including background NO_2, cumulative model predictions are within the 2020 CAAQS for all scenarios.

Among pollutants with objectives borrowed from Alberta and Ontario, the predicted concentration of HCl is above the 1-hour objective from Alberta for the permit scenario only, and predicted concentration of PAH is above the 24-hour objective from Ontario for the permit and shut down scenario, and the annual objective from Ontario for the permit scenario. The model results indicate that there will be no exceedances of HCl and PAH objectives under normal operations. The is a potential for concentrations to be slightly above the 24-hr Ontario PAH objective during shut down conditions.

Model predictions are within all other of Alberta or Ontario objectives assessed for all scenarios and averaging times.

5 REFERENCES

1. HDR. April 9, 2018. Metro Vancouver Waste-to-Energy Facility Operational Certificate Assessment Reports: Start Up / Shut Down Test Report. 161 pp.
2. Gesell, Greg. Mechanical Engineer, HDR. Personal Communication, March 12, 2018.
3. A. Lanfranco & Associates Inc. (A. Lanfranco). 2017. Waste to Energy Facility: Start Up and Shut Down Emissions Report: November 2017 Survey $PM_{2.5}$ 36 pp.
4. Alberta Environment and Parks. 2017. Alberta Ambient Air Quality Objectives and Guidelines Summary. 6 pp. Accessed online: https://open.alberta.ca/dataset/0d2ad470-117e-410f-ba4f-aa352cb02d4d/resource/97d1afdf-b66b-4805-be41-a5a3f589c988/download/aaqo-summary-jun29-2017.pdf
5. British Columbia Ministry of Environment (BC MOE). 2015. British Columbia Air Quality Dispersion Modelling Guideline. 111 pp. Accessed online: https://www.bcogc.ca/node/13339/download
6. BC Ministry of Forests, Lands and Natural Resource Operations. 2015. Baseline Thematic Mapping Present Land Use Version 1 Spatial Layer.
7. Earth Tech. 2000a. A User's Guide for the CALMET Meteorological Model (Version 5). 332 pp. Accessed online: http://www.src.com/calpuff/download/CALMET_UsersGuide.pdf
8. Earth Tech. 2000b. A User's Guide for the CALPUFF Dispersion Model (Version 5). 521 pp. Accessed online: http://www.src.com/calpuff/download/CALPUFF_UsersGuide.pdf
9. Metro Vancouver, 2016. 2016 Lower Fraser Valley Air Quality Monitoring Report, 103 pp Accessed online: http://www.metrovancouver.org/services/air-quality/AirQualityPublications/2016-LFVAQMonitoringReport.pdf
10. Metro Vancouver. 2018. Metro Vancouver Ambient Air Quality Objectives. 1 pp. Accessed online: http://www.metrovancouver.org/services/air-quality/AirQualityPublications/CurrentAmbientAirQualityObjectives.pdf
11. Natural Resources Canada, Canada Centre for Mapping and Earth Observation. 2007. GeoBase, 1:50,000 Scale Canadian Digital Elevation Data (CDED1) Level 1.
12. Ontario Ministry of the Environment and Climate Change. 2012. Ontario's Ambient Air Quality Criteria – Sorted by Contaminant Name. Accessed online: https://www.ontario.ca/page/ontarios-ambient-air-quality-criteria-sorted-contaminant-name
13. Reid, Ken. 2018. Superintendent, Environmental Sampling and Monitoring, Metro Vancouver. Personal Communications: May 2018.
14. Texas Commission on Environmental Quality. 2016. Effects Screening Levels (ELSs). Accessed online: https://www.tceq.texas.gov/toxicology/esl
15. US EPA. 2016. AERSCREEN User's Guide. 115pp. Accessed online: https://www3.epa.gov/scram001/models/screen/aerscreen_userguide.pdf
16. Environment Canada (EC). 2018. National Air Pollutant Surveillance Network. Accessed online.

APPENDIX A

Metro Vancouver Waste-to-Energy Facility Dispersion Modelling Plan

Version 2.1

metrovancouver

SERVICES AND SOLUTIONS FOR **A LIVABLE REGION**

Table of Contents

Part 1: Information for All Levels of Assessment

1.1 General Information

Date	January 23, 2018
Facility Name	Metro Vancouver Waste to Energy Facility
Company Name	Metro Vancouver
GVRD Air Quality Permit Number	Operational Certificate 107051
Facility Address	5150 Riverbend Drive, Burnaby, British Columbia

1.2 Primary Contact Information

Information	Company	Air Quality Consultant
Name	Sarah Wellman	Greg Conley
Title	Senior Engineer – Solid Waste Services	Senior Project Manager
Telephone	604.436.6764	(519) 823-1311 ext 2280
E-mail	Sarah.Wellman@metrovancouver.org	Greg.conley@rwdi.com

1.3 Purpose of Dispersion Modelling

Describe the purpose of the dispersion modelling study (e.g., in support of an application for a new permit or a permit amendment; in support of registration under Bylaw 1087; to fulfill a permit reporting requirement):

The purpose of the dispersion modelling study is to fulfill a permit reporting requirement.

The operational certificate issued to the facility on December 15, 2016 requires:

- A Start Up / Shut Down Evaluation report within 18 months from the issuance of this Operational Certificate (The stack tests were completed in November 2017. Evaluation report is in development).
- A Contaminant Dispersion Evaluation and Health Risk Assessment within 24 months from the issuance of this Operational Certificate.

If the dispersion modelling study is in support of an application for a new permit or permit amendment, a draft application should be submitted with the draft model plan. Has a draft application been submitted? (Y/N): N

What level of assessment is proposed – 1, 2 or 3? (*Section 1.5*[1]):

A Level 3 Assessment (Comprehensive) is proposed.

Provide the rationale for the proposed level of assessment (e.g., exceedances predicted for a Level 1 assessment):

Although the WTE facility is a single source, the modelling effort must include multiple operating scenarios and provide detailed results that will be sufficient to inform a comprehensive human health risk assessment and to compare with regional monitoring.

1.4 Geographic Setting

Will complex flow (i.e., meteorology) need to be considered? Justify your response based on the terrain and land use characteristics within at least 5 km of facility location (e.g., flat, rolling, river valley, mountainous).

Complex flow will need to be considered to provide sufficient resolution of the nearby heterogeneity of the land use cover and terrain elevation. The facility is located on complex terrain and is within 0.5 km of the Fraser River.

What is the dominant land cover within 5 km of the facility location (e.g., urban, rural, forest, agricultural, industrial, water)?

The facility is surrounded by mixed land use including:

- Urban,
- Agricultural,
- Industrial, and
- Water (Fraser River).

To provide context, provide the minimum distance to the nearest (note that for Level 2 and 3 assessments, several receptors for each category that span a range of potential wind directions should be modelled to ensure the maximum for each category is captured):

➢ Business	Tippet-Richardson is 90 m away. There is an industrial park (including Tippet Richardson) with multiple businesses at a distance from 100-1000m to the north. BC Roofing Products is 500m to east There is a strip mall with several businesses on Westminster Hwy 1.2 km to SSE Industrial park with several businesses (eg Vanguard Steel) 800m to west.
➢ Residence	Houses at Queen and River Rd are 800 m away toward south

---

[1] *Numbers in italics refer to applicable sections or tables of the British Columbia Air Quality Dispersion Modelling Guideline, 2015.*

	Residential neighbourhood in Queensborough starting approximately 1km to east Closest Residences in New Westminster are 1.4 km to NNE
➢ School	Hamilton Elementary is 1.4 km to South Glenwood Elementary is 2.1 km North Taylor Park Elementary is 2.5 km away to NNE Queen Elizabeth Elementary is 2.1 km to East Connaught Heights Elementary is 2.5 km to NE
➢ Child care facility	Cranberry Children's Center is 1.2km to ESE Betheny Child Care Centre is 1.5 km to south Happy Learning Child Centre is 2.1 km to east Burnaby Children's Centres Society is 2.6 km away to North
➢ Seniors facility	Seniors Services Society is 3.7 km away to north and 5.1 km to east Kennedy Senior Recreation Center is 6.4 km to ESE
➢ Hospital	RYT Hospital medical centre is 5.9 km to SW Royal Columbia is 6km to ENE Children's and Women's Hospital is 12 km away to WNW Surrey Memorial Hospital is 10km to WSW

Are there any other nearby receptors of concern?

Burnaby Youth Custody Center (~300 m to west)

Richberry Cranberry Farm – Richmond (900m SW of facility)

The farm to the NW of the Facility

Riverway Golf Course (1.8 km NE)

Burnaby South Secondary School (3.2 km N) (also a MV meteorology and AQ station)

Walking trails There are numerous other park and open spaces in the nearby area. However, due to their spatial extent they are better represented by the coverage of the base receptor grid than a single special receptor.

Additional receptors of interest may be identified in consultation with the human health study and with Metro Vancouver staff.

Also note that a typical recommended receptor grid should have sufficient resolution to resolve most areas of interest.

1.5 Air Contaminants and Averaging Periods to be Modelled

Table 1.5 (add/delete rows as needed)

Air Contaminant	Averaging Period	Metro Vancouver Objective (ug/m3)	Other Criteria[1]	Jurisdiction of Other Criteria
Total Particulate Matter (TPM)	24-hour		120 (ug/m3)	National Ambient Air Quality Objectives
	Annual		60 (ug/m3)	National Ambient Air Quality Objectives
Particulate Matter Less than or Equal to 10 Microns (PM_{10})	24-hour	50		
	Annual	20		
Particulate Matter Less than or Equal to 2.5 Microns ($PM_{2.5}$)	24-hour	25		
	Annual	8		
Carbon Monoxide (CO)	1-hour	30,000	14,300 (ug/m3)	B.C. Ambient Air Quality Objectives
	8-hour	10,000	5,500 (ug/m3)	B.C. Ambient Air Quality Objectives
Hydrogen Chloride (HCl)	1-hour		75 (ug/m3)	Alberta Environment and Parks Ambient Air Quality Objectives (adopted from Texas)
Hydrogen Fluoride (HF)	1-hour		4.9 (ug/m3)	Alberta Environment and Parks Ambient Air Quality Objectives (adopted from Texas)
Sulphur Dioxide (SO_2)	1-hour	183 196* (2020) 170 (2025)		
	24-hour	125		
	Annual	13 10.5 (2020)		
Nitrogen Oxides (NO_x) (Objective for NO_2)	1-hour	200 113 (2020) 79 (2025)		
	Annual	40		

		32 (2020) 23 (2025)		
Total Dioxins and Furans (as PCDD/F TEQ)	24-hour		0.1 pg TEQ/m^3	Ontario Ambient Air Quality Criteria (Health Limiting Effect)
Cadmium (Cd)	24-hour		0.025 (ug/m3)	Ontario Ambient Air Quality Criteria (Health Limiting Effect)
	Annual		0.005 (ug/m3)	Ontario Ambient Air Quality Criteria (Health Limiting Effect)
Mercury (Hg)	24-hour		2 (ug/m3)	Ontario Ambient Air Quality Criteria (Health Limiting Effect)
Sum of Lead (Pb), Arsenic (As), Chromium (Cr)	1-hour		1.5 (ug/m3)	Alberta Environment and Parks Ambient Air Quality Objectives (adopted from Texas)
Chlorophenols				(Assessed in HHRA)
Chlorobenzenes				(Assessed in HHRA)
Polycyclic Aromatic Hydrocarbons (PAHs)	24-hour		0.00005 (ug/m3)	Ontario Ambient Air Quality Criteria (Health Limiting Effect)
	Annual		0.00001(ug/m3)	Ontario Ambient Air Quality Criteria (Health Limiting Effect)
Polychlorinated Biphenyls (PCBs)	24-hour		0.15(ug/m3)	Ontario Ambient Air Quality Criteria (Health Limiting Effect)
	Annual		0.035(ug/m3)	Ontario Ambient Air Quality Criteria (Health Limiting Effect)

[1] If there are no Metro Vancouver objectives for the air contaminant to be modelled, then criteria from other jurisdictions (e.g., Alberta, Ontario, California or Texas) should be used to put predicted ambient contaminant concentrations in perspective. For odorous air contaminants, the Yoshio Nagata "Measurement of Odor Threshold by Triangle Odor Bag Method" reference should be used.

1.6 Baseline Air Quality

What metric will be used to determine baseline air quality for short-term averaging periods (98th, 99th or 100th percentile[2])?

The 98th percentile will be used to determine baseline air quality for 1-hour, 8-hour and 24-hour averaging periods. This will be based on available observation data from existing stations in the Metro Vancouver network.

[2] Metro Vancouver's ambient air quality objectives for SO_2 and NO_2 are "not to be exceeded" values and therefore the percentiles used to calculate the baseline values should be based on the hourly data set and not the daily maximum one-hour values indicated in *Section 8.1.4*. Baseline values for 24-hour averages should be calculated as rolling averages and not daily averages indicated in *Section 8.1.4*.

Table 1.6 Monitoring Data that will be used to Develop Baseline Concentrations
(add/delete rows as needed)

Air Quality Stations	Source of Data[1]	Air Contaminants	Years	Will any wind directions be excluded? (If yes, provide wind directions and justification) [2]
Burnaby South (T18)	Metro Vancouver	SO_2, NO_2, CO, O3, PM_{10}, $PM_{2.5}$ Particulate speciation	2015,2016,2017	No
North Delta	Metro Vancouver	NO2, O3	2015,2016,2017	No

1. It is recommended that data are obtained directly from Metro Vancouver to ensure that data are verified.
2. For excluding air quality data during certain wind directions, see *Section 8.1.4*.

1.7 NO to NO_2 Conversion *(Section 8.2)*

Results assuming 100% conversion of NO_x to NO_2 must be provided.
If exceedances are predicted using 100% conversion, what alternative method and ambient data will be used?

If exceedances are predicted using 100% conversion, ARM method will be used.

If the Ambient Ratio Method is proposed, what NO_x and NO_2 monitoring data will be used?

NO_2 and NO_X monitoring data from the MV Burnaby South (T18) station will be used.

Note: If the Ambient Ratio Method is proposed, predicted NO_x should be converted to NO_2 first and then a baseline NO_2 value should be added. This differs from the guidance provided in *Section 8.2.2*.

~~If OLM or PVMRM is proposed:~~

- ~~Specify O3 concentration and how it was selected:~~
- ~~Specify and provide rationale for any non-default in-stack ratio or equilibrium ratio:~~

1.8 Building Downwash

Table 1.8 (add/delete rows as needed)

Emission Source ID	Source Height (m)	Is Emission Source on a Building? If no, provide distance to nearest building (m)	Height of Building (m)	Width of Building (m)
E300670	60 m	Emission source is directly beside building (approximately 3 m)	20 m	Approximately 40 m x 70 m (MV to provide dimensions)

Will building downwash be modelled?
If no, provide rationale.

Building downwash will be modelled.

1.9 Emission Sources and Characteristics

Are there any liquid storage tanks?
If yes, indicate whether they are fixed or floating roof tanks. Follow the guidance provided in *Section 10.5*.

No

Table 1.9 Emission Sources and Characteristics (add/delete rows as needed)

Emission Number[2]	Description	Type: Point (P), Area (A), Line (L), Volume (V)	Contaminants (SO_2, NO_x, $PM_{2.5}$[3]. . .)	Basis of Emissions[4] *(Section 3.3)*	Stack Orientation (Vertical, Horizontal, Angled)	Raincap *(Section 10.4)* (Y/N)
E300670	**Mass Burn Incinerator/Boilers** (Discharge of air contaminants from three separate Mass Burn Incinerators/Boilers from a common support stack containing three individual flues)	P	• TPM • PM_{10} • $PM_{2.5}$ • Carbon Monoxide (CO) • Hydrogen Chloride (HCl) • Hydrogen Fluoride (HF) • Sulphur Dioxide (SO_2) • Nitrogen Oxides (NO_x) • Total Hydrocarbons (THC) • Total Dioxins and Furans (as PCDD/F TEQ) • Cadmium (Cd) • Mercury (Hg) • Sum of Lead (Pb), Arsenic (As), Chromium (Cr) • Chlorophenols • Chlorobenzenes • Polycyclic Aromatic Hydrocarbons (PAHs) • Polychlorinated Biphenyls (PCBs)	**X current emission limits** (Emissions from the operational certificate will be used for the permitted emissions limits) **X other (specify & justify)** (emissions from continuous CEMS monitoring during normal operation) **X other (specify & justify)** (Emissions from stack testing will be used for modelling the start-up and shut-down operations)	Vertical	N

---

[2] Emission numbers should be the same as in existing permit or permit application.

[3] For PM emissions indicate whether it is filterable, or filterable + condensables, or if unknown (see *Section 3.6*)

[4] If dispersion modelling is being conducted in support of an application for an air quality permit or permit amendment then current or proposed emission limits should be modelled. If it is being conducted for a registration under Bylaw 1087, the emission concentrations listed in Appendix 1 or 2 of the Bylaw should be modelled.

Source Emission Rate Variability (*Section 3.4*)

Are there any batch processes?
If yes, provide plots of emission rate vs. time for each batch process.

No

Are emissions expected to vary with load?
If yes, describe how this will be modelled.

Yes. Four scenario will be assessed:

1) Permitted
2) Operational
3) Start-up
4) Shutdown

Permitted emissions will be the allowable limits in the OC

For the Operational scenario, emissions will be the average (or typical) emissions during normal operations as determined from continuous CEMS data.

The variation in start-up and shut-down emissions will be modelled as described in the “abnormal emission scenario” section below.

Will actual emissions or flow rates be less than 75% of permitted levels?
If yes, describe how this will be modelled (e.g., additional scenarios)

See above for 2).

Describe anticipated abnormal emission scenarios (e.g., start-up, shut-down, maintenance of control works) and their anticipated frequency:

Start-up and shut-down scenarios will be modelled. These are transient processes that may occur at any time for less than 5 hours each. Stack testing emissions will be used to determine the modelled emissions during the start-up and shut-down.

The modelling will be conducted to include the potential for a given start-up or shut-down cycle to occur on any hour of the year. The model will be configured such any one possible 5-hour emission for any of the process lines will be allowed to fully disperse in the model without interacting with any previous or subsequent 5-hour emission (i.e. a start-up could occur at any time, but if one start-up or shut down is already underway, another cannot start with the same 5-hour window). This is done by using a combination of multiple pollutants within the model to represent the single WTE stack. The multiple source/species are then recombined in post processing to give the final modelling result.

Does the proposed permit emission limit scenario represent the worst case scenario, in terms of ambient air quality concentrations, that can be anticipated (*Section 3.4.2 and 10.1.2*)?

Yes

1.10 Dispersion Model

List model(s) and version(s) to be used (*Section 2*):

CALPUFF - Version 7.2.1
CALMET - Version 6.5.0
CALPOST - Version 7.1.0

If modifications to any of the models are planned, provide a description and the rationale (*Section 2.3.2*):

N/A

If AERSCREEN is proposed, will it be run using:

1) The stand-alone MAKEMET program to generate the matrix of meteorological conditions and running AERMOD directly with the SCREEN option (preferred) or
2) The AERSCREEN command prompt interface?

Please justify your response.

N/A

If a Level 1 assessment is proposed, indicate whether a standard screening dataset will be used or whether a project-specific dataset will be developed:

N/A

If a project-specific dataset will be developed for a Level 1 assessment, describe the proposed inputs (source and period of meteorological data, range of wind speeds and stability classes, range of wind directions, seasonal values of surface characteristics etc.):

N/A

If any of the emission sources have ambient exit temperatures, please explain how this will be modelled (e.g., buoyancy will be turned off, variable emission file with actual ambient temperature, exit temperature set to annual average ambient temperature).

N/A

1.11 Planned Model Output

Model results for all levels of assessment should include a table comparing overall maximum predicted concentrations as well as maximum concentrations predicted for each sensitive receptor type (e.g., school, hospital, daycare) to Metro Vancouver ambient air quality objectives or other relevant criteria. Please confirm the planned model output (*Section 8.3.1*).

Tables will show maximum predicted concentrations in the study area and at sensitive receptors. This includes elevated receptors representing nearby sensitive receptors.

Plots will show the maximum predicted concentrations and frequencies of exceeding MV objectives or other relevant objectives.

As recommended by the BC Model Guidelines, the maximum concentrations over the 3-year model period will be provided.

Model outputs will also include additional metrics as required to inform the HHRA. For example, 10min averages, 100,99,98 percentile of COPCs identified by the HHRA. Specific requirements to be supplied by the HHRA work plan.

Part 2: Information for Level 2 and 3 Assessments Only

2.1 Planned Model Domain and Receptor Grid

Dimensions of proposed model domain (*Section 7.1*):

A 50 km x 50 km model domain approximately centred on the facility will be used for CALMET and CALPUFF. Grid cells will be spaced at 250 m.

The domain will be offset to the north to prevent overlap with the US. This will also provide more coverage of North Shore mountains for potential recirculation from upslope/downslope flows.

A map of the proposed domain is provided in Figure 1.

Proposed receptor spacing (*Section 7.2*):

Receptor locations in CALPUFF will be set according to the BC Guidelines as follows:

- 20 m receptor spacing along the plant boundary
- 50 m spacing within 500 m of source
- 250 m spacing within 2 km of source
- 500 m spacing within 5 km of source
- 1000 m spacing beyond 5 km of source

Receptors of interest such as other schools, hospitals, senior homes, daycare facilities will be included in the assessment. A preliminary list was identified in Section 1.4 Additional locations (if any) will be determined through consultation with the human health assessment study and/or MetroVancouver.

Provide a map of the proposed model domain and receptor grid that also shows the locations of all schools, hospitals, daycares and senior facilities within the study domain (Figure 1).

Provided in Figure 2.

Please use a flagpole receptor height of 1.5 m. If a different height is proposed, please provide the height and rationale.

A flagpole receptor height of 1.5 m will be used for airborne concentration

Deposition is only defined at the earth surface. To assess deposition, any pertinent model simulations will need to be re-run with the receptor heights set to 0 m.

2.2 Default Switch Settings

For AERMOD identify any switch settings that could be different than the recommended defaults (see *Section 7.7*). Provide rationale.

N/A

For CALPUFF/CALMET identify any switch settings in CALMET Input Groups 4 & 5 and CALPUFF Input Groups 2 & 12 that could be subject to deviation from the "black (do not touch)" defaults as per *Tables 6.2 and 7.1*. Provide rationale.

No deviation from the "black (do not touch)" defaults is planned.

2.3 CALMET Parameters

If CALMET is planned to be used, provide (*Section 6.4.2*):

- a domain map (Figure 1b) **(provided in Figure 1)**
- anticipated grid resolution: **250 m**
- number of grids in X and Y direction (**NX = 200 cells, NY = 200 cells**)
- vertical levels (m): **0, 20, 40, 80, 160, 300, 600, 1000, 1500, 2200, 3000**

2.4 Planned Geophysical Data Input *(Section 4)*

Source of terrain data:

GeoBC

Source of land use data:

BTM

Is modification of the land use data necessary? If so, please describe the proposed modification and provide the rationale[5].

Prior to modelling land use will be modified according to known issues in the data. This will be done by adjusting the derived CALMET land use category to match actual conditions.

Provide a land use map (Figure 2) plotted from the dispersion model input data (e.g., GEO.DAT).

A draft based on the un-adjusted BTM land use data is provided in Figure 1. Prior to modeling, the land use database will be corrected for any known issues, as noted above. A corrected map can be prepared once the domain extents are approved by all interested stakeholders.

If AERMOD is proposed, will land use surrounding the meteorological station or the location of emissions be used? Provide rationale.

---

[5] Modification of land use may be necessary to appropriately represent features such as a continuous Fraser River or large forested parks that may be absent from the land use data.

N/A

If surface characteristics are required, use *Tables 4.8, 4.9, 4.10 and 4.12* for summer, autumn, winter and spring, respectively. If these Tables are not used, indicate source of data.

These tables will be used.

If CALMET is proposed, it is recommended that four GEO.DAT files be used to represent different seasons (*Section 4.4*) as outlined below[6]**:**

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
3	3	3	5	5	1	1	1	2	2	3	3

If this is not followed, please indicate an alternative approach and rationale.

This will be followed.

If building downwash is applicable, use BPIP-PRIME. If not BPIP-PRIME, indicate method used to specify downwash parameters.

BPIP-PRIME will be used.

2.5 Planned Meteorological Data Input and Processing

Table 2.5a Surface Meteorological Data (add/delete rows as needed)

Station ID	**Location (lat/long or indicate on map)**	**Data Source MOE, MV, MSC, Site Specific, other (specify)** [1]	**Parameter(s)**[2]	**Years**	**% of Wind Speeds = calm** [3]	**Anemometer Height (m)** [4]
Vancouver Airport	49.19° N 123.18° W	MSC	Temperature, Relative humidity, Pressure, Precipitation, Cloud cover	2013, 2014, 2015		-
Abbotsford Airport	49.03° N 122.36° W	MSC	Relative humidity, Pressure, Precipitation, Cloud cover	2013, 2014, 2015		-

---

[6] This differs from guidance in the British Columbia Air Quality Dispersion Modelling Guideline (2015) since the climate in Metro Vancouver is different than the rest of BC.

Vancouver Airport (MV Station Richmond-Airport; T31)	49.1863° N 123.1524° W	MV	Wind speed, Wind direction, Temperature, Relative humidity, Precipitation	2013, 2014, 2015	4.8%	
Abbotsford Airport (T45)	49.0215° N 122.3265° W	MV	Wind speed, Wind direction, Temperature, Relative humidity, Precipitation	2013, 2014, 2015	9.7%	
Burnaby South (T18)	49.2152° N 122.9857° W	MV	Wind speed, Wind direction, Temperature, Relative humidity, Precipitation	2013, 2014, 2015		19.9
North Delta (T13)	49.1583° N 122.9017° W	MV	Wind speed, Wind direction, Temperature, Relative humidity, Precipitation	2013, 2014, 2015		18.3
Alex Fraser Bridge (T37)	49.1583° N 122.9017° W	MV	Wind speed, Wind direction, Temperature, Relative humidity	2013, 2014, 2015		160
Annacis Island (T38)	49.1675° N 122.9607° W	MV	Wind speed, Wind direction, Temperature, Relative humidity, Precipitation	2013, 2014, 2015		10.0

Vancouver – Kitsilano (T2)	49.2617° N 123.1635° W	MV	Wind speed, Wind direction, Temperature, Relative humidity, Precipitation	2013, 2014, 2015		12.5
Burnaby Kensington (T4)	49.2792° N 122.9707° W	MV	Wind speed, Wind direction, Temperature, Relative humidity	2013, 2014, 2015		13.5
North Vancouver Second Narrow (T6)	49.3015° N 123.0204° W	MV	Wind speed, Wind direction	2013, 2014, 2015		11.9
Port Moody (T9)	49.2809° N 122.8493° W	MV	Wind speed, Wind direction, Temperature, Relative humidity, Precipitation	2013, 2014, 2015		12.8
Burnaby Mountain (T14)	49.2798° N 122.9223° W	MV	Wind speed, Wind direction, Temperature, Relative humidity, Precipitation	2013, 2014, 2015		29.8
Surrey East (T15)	49.1329° N 122.6942° W	MV	Wind speed, Wind direction, Temperature, Precipitation	2013, 2014, 2015		16.9
Richmond South (T17)	49.1414° N 122.1082° W	MV	Wind speed, Wind direction, Temperature, Precipitation	2013, 2014, 2015		12.5

Pitt Meadows (T20)	49.2452° N 122.7089° W	MV	Wind speed, Wind direction, Temperature, Relative humidity, Precipitation	2013, 2014, 2015		10.1
Burnaby Burmount (T22)	49.2667° N 122.9355° W	MV	Wind speed, Wind direction, Temperature	2013, 2014, 2015		10.0
Burnaby Capitol Hill (T23)	49.2879° N 122.9856° W	MV	Wind speed, Wind direction, Temperature	2013, 2014, 2015		10.0
Burnaby North (T24)	49.2875° N 123.0080° W	MV	Wind speed, Wind direction, Temperature, Precipitation	2013, 2014, 2015		10.0
N. Vancouver Mahon Park South (T26)	49.3240° N 123.0835° W	MV	Wind speed, Wind direction, Temperature, Precipitation	2013, 2014, 2015		14.2
Coquitlam (T32)	49.2883° N 122.7916° W	MV	Wind speed, Wind direction, Temperature, Relative humidity, Precipitation	2013, 2014, 2015		24.0

[1] If data from a non - ministry, MV or MSC station is proposed, follow guidance in *Section 5.8 or 5.9*

[2] List all meteorological parameters that will be used from each station (e.g., wind speed, wind direction, air temperature, relative humidity, cloud cover)

[3] For light wind/calm treatment of Metro Vancouver data consult with Metro Vancouver. For other data sources, follow guidance in *Section 5.8.2.*

[4] Not all meteorological stations measure winds at the standard 10 m height (e.g., some MV observations are different heights). http://www.metrovancouver.org/services/air-quality/AirQualityPublications/LowerFraserValleyAirQualityMonitoringNetwork2012StationInformation.pdf

Table 2.5b Upper-Air Meteorological Data (add/delete rows as needed)

Station Name	Years	Distance between the Upper Air Station and Project (km)
N/A, will not use upper air stations		

Table 2.5c Mesoscale Meteorological Model Output (attach map of domain)

Model (name, version, configuration)	Model Output Provider	Horizontal Grid Resolution (km)	Height of Vertical Levels (m)	Years	Planned Model Output Use [1]
WRF	Exponent	4 km	Reference heights below 1,000 m: 0.0, 10.9, 34.1, 60.3, 89.6, 122.5, 160.0, 202.1, 249.6, 303.7, 364.8, 433.5, 511.5, 600.1, 700.4, 814.4, and 944.1 m Reference heights between 1,000 – 3,500: 1092.1, 1261.5, 1455.3, 1677.7, 1934.1, 2230.9, 2576.1, 2980.0, and 3455.7 m	2013, 2014, 2015	___CALMET No-Obs mode **X__CALMET Hybrid mode** ___AERMET/AERMOD pseudo surface station and pseudo upper air sounding ___AERMOD .SFC and .PFL files

[1] *Sections 6.1 & 6.4.1*.

If CALMET Hybrid mode is proposed, describe in detail the choice of R1, RMAX1 and TERRAD.

R1 = 1 km (complex, mixed terrain; keep observation effects contained to near the stations only)
RMAX1 = 10 km (limit observation effects)
TERRAD = 3 km (account for complex terrain that is very close; Edmonds to Burnaby Mountain Area is 6 km, divided by 2)

2.6 Special Topics

Indicate the conditions that are planned to be considered as part of the assessment.

Stagnation Conditions

Provide an estimate of the frequency of stagnation based on local meteorological data. If AERMOD is proposed, provide methodology on how stagnation periods will be treated (see *Section 10.2)*

Frequency of calms (0.5 m/s) for each station is given in Table 2.5.

For CALMET, ICALM will be set to 0 as per MOE guidance when using NWP model output. The threshold wind speed for calms processing (WSCALM) will be set to the CALPUFF default of 0.5 m/s.

Shore/Coastal Effects

[✓ Y] or **N** If Yes, indicate whether sub-grid-scale Thermal Internal Boundary Layer option is selected along with the required input coastline coordinate data (see *Section 10.3)*

Yes, shore/coastal effects will be included because CALMET/CALPUFF is being used for the assessment, and the CALMET micrometeorological module uses the underlying land use in the calculation boundary layer depth and stability.
The TIBL option will not be used. A COASTLN.DAT file is not required.

CALPUFF always computes the effect of nearby water on boundary layer heights. The sub-grid-scale TIBL is only required when the resolution of CALMET is not sufficient to accurately derive the distance to the land-water interface. At the 250m resolution of CALMET the upwind distance to water can be sufficiently derived from the geo.dat land use data.

Plume Condensation (Fogging) and Icing

Y or **[✓ N]** If Yes follow guidance in *Section 10.6*

No.

Chemical Transformation

[✓ Y] or **N** If Yes, specify transformation method and provide details on inputs if Secondary $PM_{2.5}$, Acid Deposition or Visibility effects are to be estimated. Depending on the transformation method, this could include ammonia, ozone, hydrogen peroxide concentrations, nighttime loss and formation rates for nitrates and sulphates.

Yes. As recommended by the BC Model Guidelines, the RIVADARM3 method will be used. Note that although the RIVAD/ARM3 scheme does explicitly calculate the amounts of NO and NO2 as part of its calculation of secondary PM species, this will NOT be used to assess NOX from the facility. NOx from the facility will be modelled as an inert species with the Ambient Ratio Method (i.e. ARM which is not to be confused with the 'ARM' in RIVAD/ARM3) used to determine the NO/NO2 balance

Particle Deposition

[✓ Y] or **N** If Yes follow guidance in *Section 3.7.* If non-recommended particle size distributions are used, provide table of particle (including heavy metals) emission size/density distribution and indicate the basis for the table.

Important: a separate model run should be conducted with deposition turned on. Maximum predicted concentration results should be presented with deposition turned off.

Yes.

For PM related species (i.e. PM and components thereof) the particle size distributions recommended by the BC Model Guidelines will be used.

For other species that the HHRA identifies for deposition analysis, as per the BC Guidelines, an estimate of size class will constructed by adjusting the size fractions by the relative density as referenced in http://www.mae.gov.nl.ca/env_protection/science/gd_ppd_019_2.pdf

2.7 Quality Management Program

Geophysical and Meteorological Input Data

~~Strikeout~~ the tests that will not be undertaken to assure the quality of the inputs and provide rationale.

Geophysical input data:

- contour plot of topography
- plots of land use and land cover

Meteorological data:

- wind rose (annual and/or seasonal)
- frequency distribution of surface wind speeds
- average hourly temperature plot (annual and/or seasonal)

NWP output (*Section 6.1*)

- wind rose at selected locations and heights (annual and/or seasonal)
- average hourly temperature plot at selected locations and heights (annual and/or seasonal)
- wind field plots for selected periods that indicate topographic influences such as channeling and thermally generated flows

~~AERMOD QA/QC~~

~~List the tests that will be conducted to confirm the quality of the model input and output~~

- ~~___~~
- ~~___~~
- ~~___~~

CALMET/CALPUFF QA/QC

~~Strikeout~~ the tests that will not be conducted and provide justification (*Section 9.1*). All plots or other proof that the tests have been conducted should be provided in an appendix to the dispersion modelling report. We recommend that you provide a draft of this appendix to Metro Vancouver for review prior to commencing CALPUFF modelling to limit the need to remodel; however, this review should not be considered final approval of the CALMET. Metro Vancouver may have additional comments on the CALMET methodology once it reviews CALPUFF model results.

CALMET/CALPUFF QA Files:

- Plot the locations of the grid, NWP grid points, and source locations and compare to Google Earth or aerial photographs
- Check for blanks, comma instead of period, wrong UTM zone etc.

CALMET Input data:

- Plot of terrain and land use from the GEO.DAT input files to ensure they match with other maps of the area.
- Plot the locations of the meteorological observation stations to check whether they are located properly in the horizontal and vertical.
- Compare all the CALMET-ready input files with the raw data to ensure no errors in data conversion to CALMET-ready files (reformatting, unit conversions, etc.).
- Compare each month of CALMET input meteorological files with each other to ensure all parameters are consistent from month to month.
- Review all source information (values, formats, units) associated with Input Group 13-16 of the CALPUFF.INP file to ensure emission information is correct.
- Plot the source locations to ensure that they are located properly and ensure that their vertical location (stack base relative to terrain height for that location) is correct.
- Review locations (horizontally and vertically) of all specified receptors.

CALMET Output data:

- For a few representative periods where thermally driven flows would be expected, plot the wind vector fields at various levels to confirm that the wind fields are reasonable given the terrain and the meteorological conditions.
- For a few representative periods, when thermally driven flows would be expected, plot wind speed isopleths, derived from all grid cells in CALMET.
- Plot the frequency distribution of surface wind speeds for different locations in the domain and at the surface station locations and check for reasonableness.
- Plot annual and seasonal surface wind roses for different locations as well as the surface station locations and check for realism (compare with observations, consider the location, and what might be expected based on topography).
- For different 24-h periods within a summer and winter season, plot a surface, mid-level and upper-level wind field every hour for a 24-h period with light winds and stable conditions. Check for reasonableness of the wind fields in the domain (extent of terrain effects and the appropriateness of the settings that require expert judgment).
- Plot time series of average surface temperature by month for the source location as well as surface station locations. Compare with observations/climate normals. Check for reasonable monthly variation for the given locations.
- Plot time series of average surface temperature by hour-of-day for the source location as well as surface station locations. Compare with observations/climate normals. Check for reasonable diurnal variation for the given locations.
- Plot time series of average precipitation by month (if precipitation is an input) for one location as well as surface station locations. Compare with observations. Check for reasonable monthly variation for the given locations.
- Plot the frequency distribution of mixing heights for different locations. Check for reasonableness.

- Plot a time series of mixing heights for a 24-h summer and winter period during a light wind, and a clear sky period. Examine the diurnal behaviour for reasonableness.
- Plot the frequency distribution of P-G stability class for the source location as well as surface station location. ~~Compare to the airport observation P-G class frequency distribution (if available).~~ Check for reasonableness for the given locations.
- If NWP model output is used, examine CALMET-generated wind fields for a 24-h period of light winds, and clear skies at surface, mid and upper levels with and without NWP output and check for reasonableness.

Note: Metro Vancouver may request submission of all computer files associated with the modelling.

2.8 Additional Model Output for Level 2 and 3 Assessments

~~Strikeout~~ model output that will not be included in the report and provide justification:

- documentation (text and plots) of tests conducted as part of the QA/QC program,
- spatial distribution maps of air quality parameters including baseline values (maximums, exceedance frequencies, annual averages),
- tables of maximum short- and long-term average air quality parameters with and without baseline values (locations and associated meteorological conditions),
- tables of maximum predicted concentrations at any (not just the closest) residence, business, hospital, school, daycare, senior facility or other type of sensitive receptor within the study domain with and without baseline values,
- if exceedances are predicted, tables and spatial distributions of the frequency of exceedance both with and without baseline values,
- tables of air quality parameters under certain emission situations (upsets, start-up),
- special output required for vegetation or health risk assessments,
- ~~other (specify):~~

Metro Vancouver Acceptance of Original Plan: ___________________________
(Name, title):

Date:_____________________

APPENDIX B

B.1 INTRODUCTION

This Appendix provides details on CALMET (Section A.2) and CALPUFF (Section A.4) inputs that are not provided in the main text of the Burnaby WTEF Air Dispersion Modelling Study Report. Some CALMET output is shown and briefly discussed in Section A.3 to demonstrate that CALMET produces meteorological input to CALPUFF that qualitatively agrees with expected meteorological conditions.

B.2 CALMET INPUTS

This section presents the input parameters needed to run CALMET. These are divided into two broad categories: geophysical parameters, which specify surface properties as a function of season and land-use type, and model switch settings, which specify how CALMET will process the input.

B.2.1 Geophysical Parameters

The following tables provide geophysical parameters that vary over five seasons identified using climate normal data from Vancouver International Airport as described in the main text of the report. Surface roughness, albedo, Bowen ratio, soil heat flux, anthropogenic heat flux and leaf area index are from the British Columbia Air Quality Dispersion Modelling Guideline (British Columbia Ministry of Environment [BC MOE] 2015). Surface roughness, albedo, and Bowen ratio in the give in the BC Guideline are derived from the AERSURFACE User's Guide from the United States Environmental Protection Agency for the conterminous United States. Leaf area index values are derived from generic values for land-use type, which have been used previously for Canada (Zhang et al. 2002, 2003).

Table B.1: Season 1 (Summer) Geophysical Parameters

CALMET Land Use Type	Description	Surface Roughness Length	Albedo	Bowen Ratio	Soil Heat Flux	Anthropogenic Heat Flux	Leaf Area Index
10	Urban	0.54	0.16	0.8	0.25	8.0	0.3
20	Agricultural	0.20	0.20	0.50	0.15	0.0	2.0
30	Rangeland	0.15	0.20	0.5	0.15	0.0	1.0
32	Shrub	0.3	0.18	1	0.15	0.0	0.0
40	Transition Forest	0.3	0.18	1.0	0.15	0.0	4.5
41	Deciduous	1.30	0.16	0.3	0.15	0.0	3.4
42	Coniferous	1.30	0.12	0.3	0.15	0.0	5.0
43	Mixed	1.3	0.14	0.3	0.15	0.0	4.5
51	Small Water Body	0.001	0.1	0.1	1.00	0.0	0.0
55	Large Water Body	0.001	0.1	0.1	1.00	0.0	0.0
60	Wetland	0.2	0.14	0.1	0.3	0.0	0.2
61	Forested Wetland	0.7	0.14	0.2	0.3	0.0	0.2
62	Non-forested Wetland	0.2	0.14	0.1	0.3	0.0	0.2
70	Barren Land	0.05	0.2	1.5	0.15	0.0	0.0
90	Perennial Snow or Ice	0.2	0.7	0.5	0.15	0.0	0.0

Table B.2: Season 2 (Autumn) Geophysical Parameters

CALMET Land Use Type	Description	Surface Roughness Length	Albedo	Bowen Ratio	Soil Heat Flux	Anthropogenic Heat Flux	Leaf Area Index
10	Urban	0.54	0.16	1.0	0.25	12.0	0.2
20	Agricultural	0.20	0.20	0.70	0.15	0.0	1.5
30	Rangeland	0.15	0.20	0.7	0.15	0.0	1.0
32	Shrub	0.3	0.18	1.5	0.15	0.0	0.0
40	Transition Forest	0.3	0.18	1.5	0.15	0.0	3.5
41	Deciduous	1.30	0.16	1.0	0.15	0.0	1.9
42	Coniferous	1.30	0.12	0.8	0.15	0.0	5.0
43	Mixed	1.3	0.14	0.9	0.15	0.0	3.5
51	Small Water Body	0.001	0.1	0.1	1.00	0.0	0.0
55	Large Water Body	0.001	0.1	0.1	1.00	0.0	0.0
60	Wetland	0.2	0.14	0.1	0.3	0.0	0.2
61	Forested Wetland	0.7	0.14	0.2	0.3	0.0	0.2
62	Non-forested Wetland	0.2	0.14	0.1	0.3	0.0	0.2
70	Barren Land	0.05	0.2	1.5	0.15	0.0	0.0
90	Perennial Snow or Ice	0.2	0.7	0.5	0.15	0.0	0.0

Table B.3: Season 3 (Winter 1) Geophysical Parameters

CALMET Land Use Type	Description	Surface Roughness Length	Albedo	Bowen Ratio	Soil Heat Flux	Anthropogenic Heat Flux	Leaf Area Index
10	Urban	0.50	0.18	1.0	0.25	21.0	0.1
20	Agricultural	0.02	0.18	0.7	0.15	0.0	1.0
30	Rangeland	0.02	0.18	0.70	0.15	0.0	1.0
32	Shrub	0.3	0.18	1.5	0.15	0.0	0.0
40	Transition Forest	0.3	0.18	1.5	0.15	0.0	2.3
41	Deciduous	0.60	0.17	1.0	0.15	0.0	0.1
42	Coniferous	1.30	0.12	0.8	0.15	0.0	5.0
43	Mixed	0.95	0.14	0.9	0.15	0.0	2.3
51	Small Water Body	0.001	0.10	0.10	1.00	0.0	0.0
55	Large Water Body	0.001	0.10	0.10	1.00	0.0	0.0
60	Wetland	0.2	0.14	0.1	0.3	0.0	0.1
61	Forested Wetland	0.6	0.14	0.3	0.3	0.0	0.1
62	Non-forested Wetland	0.2	0.14	0.1	0.3	0.0	0.1
70	Barren Land	0.05	0.2	1.5	0.15	0.0	0.05
90	Perennial Snow or Ice	0.2	0.7	0.5	0.15	0.0	0.0

Table B.4: Season 4 (Winter 2) Geophysical Parameters

CALMET Land Use Type	Description	Surface Roughness Length	Albedo	Bowen Ratio	Soil Heat Flux	Anthropogenic Heat Flux	Leaf Area Index
10	Urban	0.50	0.45	0.5	0.15	17.0	0.0
20	Agricultural	0.01	0.60	0.5	0.15	0.0	0.0
30	Rangeland	0.01	0.60	0.5	0.15	0.0	1.0
32	Shrub	0.15	0.5	0.5	0.15	0.0	0.0
40	Transition Forest	0.2	0.50	0.5	0.15	0.0	2.3
41	Deciduous	0.50	0.50	0.5	0.15	0.0	0.0
42	Coniferous	1.30	0.35	0.5	0.15	0.0	5.0
43	Mixed	0.9	0.42	0.5	0.15	0.0	2.3
51	Small Water Body	0.002	0.7	0.5	0.15	0.0	0.0
55	Large Water Body	0.002	0.7	0.5	0.15	0.0	0.0
60	Wetland	0.1	0.3	0.5	0.3	0.0	0.0
61	Forested Wetland	0.5	0.3	0.5	0.3	0.0	0.0
62	Non-forested Wetland	0.1	0.3	0.5	0.3	0.0	0.0
70	Barren Land	0.05	0.6	0.5	0.15	0.0	0.05
90	Perennial Snow or Ice	0.2	0.7	0.5	0.15	0.0	0.0

Table B.5: Season 5 (Transitional Spring) Geophysical Parameters

CALMET Land Use Type	Description	Surface Roughness Length	Albedo	Bowen Ratio	Soil Heat Flux	Anthropogenic Heat Flux	Leaf Area Index
10	Urban	0.52	0.16	0.8	0.25	15.0	0.2
20	Agricultural	0.03	0.14	0.30	0.15	0.0	1.0
30	Rangeland	0.03	0.14	0.3	0.15	0.0	1.0
32	Shrub	0.3	0.18	1	0.15	0.0	0.0
40	Transition Forest	0.3	0.18	1.0	0.15	0.0	3.3
41	Deciduous	1.00	0.16	0.7	0.15	0.0	0.8
42	Coniferous	1.30	0.12	0.7	0.15	0.0	5.0
43	Mixed	1.15	0.14	0.7	0.15	0.0	3.3
51	Small Water Body	0.001	0.1	0.1	1.00	0.0	0.0
55	Large Water Body	0.001	0.1	0.1	1.00	0.0	0.0
60	Wetland	0.2	0.14	0.1	0.3	0.0	0.1
61	Forested Wetland	0.7	0.14	0.2	0.3	0.0	0.1
62	Non-forested Wetland	0.2	0.14	0.1	0.3	0.0	0.1
70	Barren Land	0.05	0.2	1.5	0.15	0.0	0.0
90	Perennial Snow or Ice	0.2	0.7	0.5	0.15	0.0	0.0

B.2.2 Model Switch Settings

Table B.6: CALMET model switch settings group 5 - Wind Field Options and Parameters

Parameter	Default	Project	Comments
IWFCOD	1	1	Diagnostic wind module used
IFRADJ	1	1	Froude number adjustment effects computed
IKINE	0	0	Kinematic effects not computed
IOBR	0	0	No adjustment to vertical velocity profile at top of model domain
ISLOPE	1	1	Slope flow effects computed
IEXTRP	-4	-4	Similarity Theory used except layer 1 data at upper air stations ignored
ICALM	0	0	Surface winds not extrapolated if calm
BIAS	NZ*0	0, 0, 0, 0, 0, 0, 0, 0, 0, 0	Not used since no upper air station data
RMIN2	4	-1	Used to ensure extrapolation of all surface stations for IEXTRP = -4
IPROG	0	14	Used WRF prognostic model output for initial guess field
ISTEPPGS	3600	3600	Timestep (seconds) of the prognostic model input data
IGFMET	0	0	Use coarse CALMET fields as initial guess fields
LVARY	F	F	Varying radius of influence not used (recommended in Dispersion Modelling Guideline)
RMAX1	NA	10	Maximum radius of influence over land in the surface layer.
RMAX2	NA	10	Maximum radius of influence over land aloft
RMAX3	NA	NA	Over-water stations not used
RMIN	0.1	0.1	Small value used as recommended
TERRAD	NA	3	Identified from main terrain feature of influence Accounts for complex terrain that is very close; Edmonds to Burnaby Mountain Area is 6 km, divided by 2.
R1	NA	1	Complex, mixed terrain. Influence of observations limited to near the stations.

Parameter	Default	Project	Comments
R2	NA	1	No upper air data, but R2 is still used when surface stations extrapolated aloft
RPROG	NA	0	Not used since IPROG = 14
DIVLIM	5×10^{-6}	5×10^{-6}	Not used since IKINE = 0
NITER	50	50	Not used since IKINE = 0
NSMTH	2,(mxnz-1)*4	2, 4, 4, 4, 4, 4, 4, 4, 4, 4	Default number of passes in the smoothing procedure
NINTR2	99	99	All stations can be used
CRITFN	1	1	Default critical Froude number used
ALPHA	0.1	0.1	Not used since IKINE = 0
FEXTR2	NZ*0	0, 0, 0, 0, 0, 0, 0, 0, 0, 0	Not used since IEXTRP = -4
NBAR	0	0	Barriers not used
KBAR	NZ	10	Level (1 to NZ) up to which barriers apply
XBAR, YBAR, XEBAR, YEBAR	NA	0, 0, 0, 0	Not used since NBAR = 0
IDIOPT1	0	0	Surface temperatures computed internally
ISURFT	-1	-1	Diagnostic module surface temperatures based on 2-D spatially varying temperature field
IDIOPT2	0	0	Lapse rate computed internally
IUPT	-1	-1	Upper air stations not used for lapse rate.
ZUPT	200	200	Lapse rate computed for default depth
IDIOPT3	0	0	Domain-averaged wind components computed internally
IUPWND	-1	-1	Upper air stations not used
ZUPWND	1, 1000	1, 1000	Default used
IDIOPT4	0	0	Observed surface wind components for wind field module
IDIOPT5	0	0	Observed upper air wind components for wind field module

Table B.7: CALMET model switch settings group 6 - Mixing Height, Temperature and Precipitation Parameters

Parameter	Default	Project	Comments
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
FCORIOL	1.0E-4	1.0E-04	Absolute value of Coriolis (1/s)
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 (Deg.)
ILEVZI	1	1	Layer of winds used in upwind averaging
IMIXH	1	1	Method to compute the convective mixing height
THRESHL	0	0	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)
IZICRLX	1	1	Flag to allow relaxation of convective mixing height to equilibrium value
TZICRLX	800	800	Relaxation time of convective mixing height to equilibrium value (s)
ITWPROG	0	0	Option for overwater lapse rates used in convective mixing height growth
ILUOC3D	16	16	Land use category ocean in 3D.DAT datasets
DPTMIN	0.001	0.001	Minimum potential temperature lapse rate in the stable layer above the current convective missing height (K/m)
DZZI	200	200	Depth of layer above current convective mixing height through which lapse rate is computed (m)
ZIMIN	50	50	Default minimum overland mixing height (m)
ZIMAX	3000	3000	Default maximum overland mixing height (m)

Parameter	Default	Project	Comments
ZIMINW	50	50	Default minimum over-water mixing height (m)
ZIMAXW	3000	3000	Default maximum over-water mixing height (m)
ICOARE	10	10	COARE with no wave parameterization
DSHELF	0	0	Coastal/shallow water length scale
IWARM	0	0	COARE warm layer computation
ICOOL	0	0	COARE cool skin layer computation
IRHPROG	0	1	3D relative humidity from prognostic data
ITPROG	0	1	3D temperature from surface stations
IRAD	1	1	Default interpolation type
TRADKM	500	500	Default radius of influence for temperature interpolation (km)
NUMTS	5	21	Allow all surface stations to be included for temperature interpolation
IAVET	1	1	Conduct spatial averaging of temperatures
TGDEFB	-.0098	-.0098	Default temperature gradient below the mixing height over water (K/m)
TGDEFA	-.0045	-.0045	Default temperature gradient above the mixing height over water (K/m)
JWAT1	-	99	No over water temperature interpolation used
JWAT2	-	99	No over water temperature interpolation used
NFLAGP	2	2	Method of interpolation
SIGMAP	100	100	Radius of Influence (km)
CUTP	0.01	0.01	Default minimum precipitation rate cut-off (mm/hr)

B.3 RESULTS

The CALMET model results were assessed by reviewing various model outputs and, where possible, comparing to observations. These outputs include surface wind roses for various monitoring locations, CALMET-derived stabilities and mixing heights and domain wind vector plots under various stability and flow regimes.

B.3.1 Surface Winds

The combined frequency distributions of wind speed and direction as observed and as modelled by CALMET at North Delta, Burnaby North, Burnaby-Burmount, and Annacis Island stations are shown as wind roses in Figure B.1 to Figure B.3, respectively.

Observed and modelled surface wind roses are similar at all four stations. The predominant wind directions of the observed and modelled wind roses at North Delta are from the east and east-northeast. The predominant wind directions of the observed and modelled wind roses at Burnaby North are from the south and east. The predominant wind directions of the observed and modelled wind roses at Burnaby-Burmount are from the east and east-southeast. The predominant wind directions of the observed and modelled wind roses at Annacis Island are from the east-northeast and south.

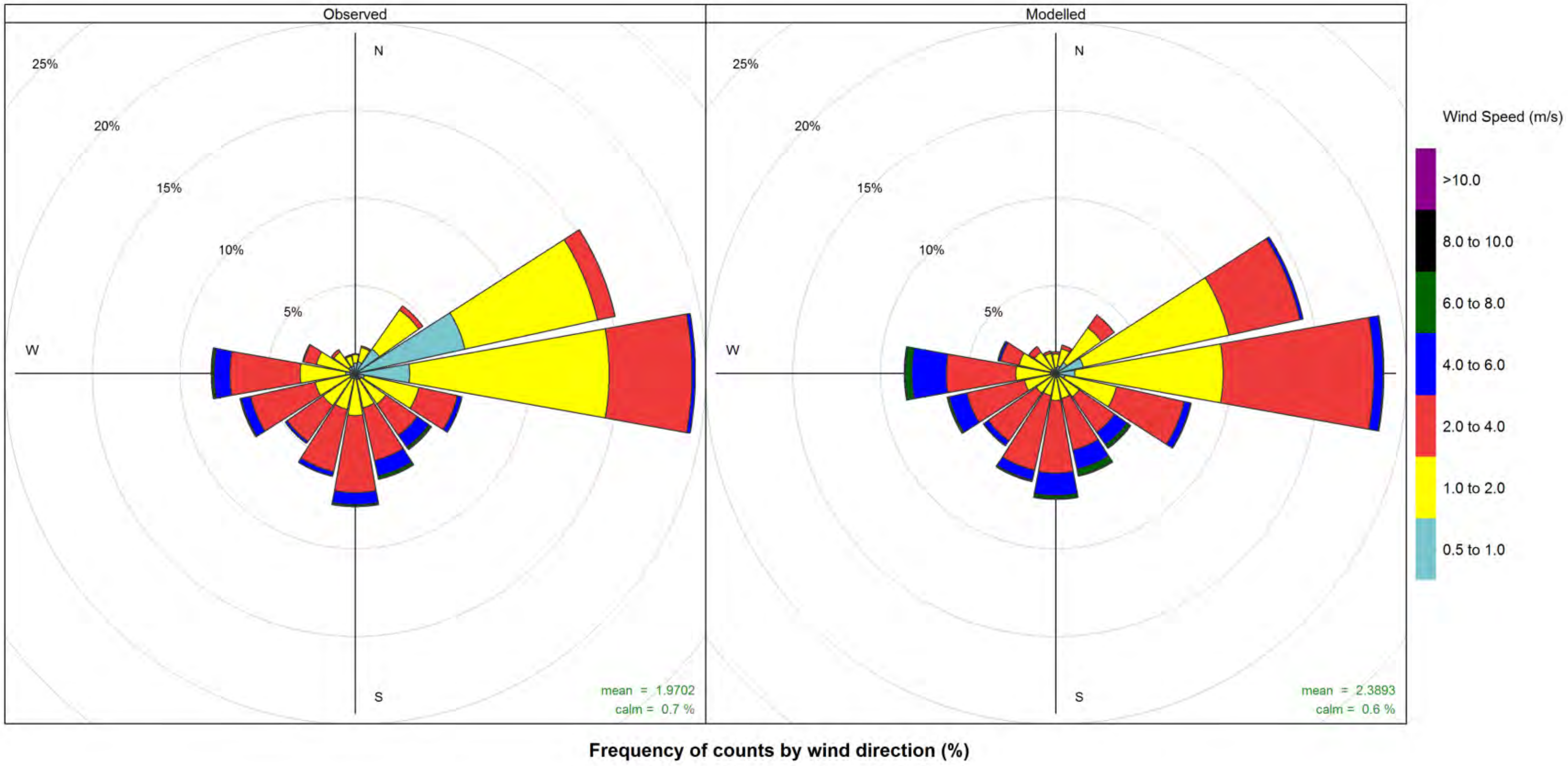


Figure B.1: Observed and modelled wind roses at T13 North Delta

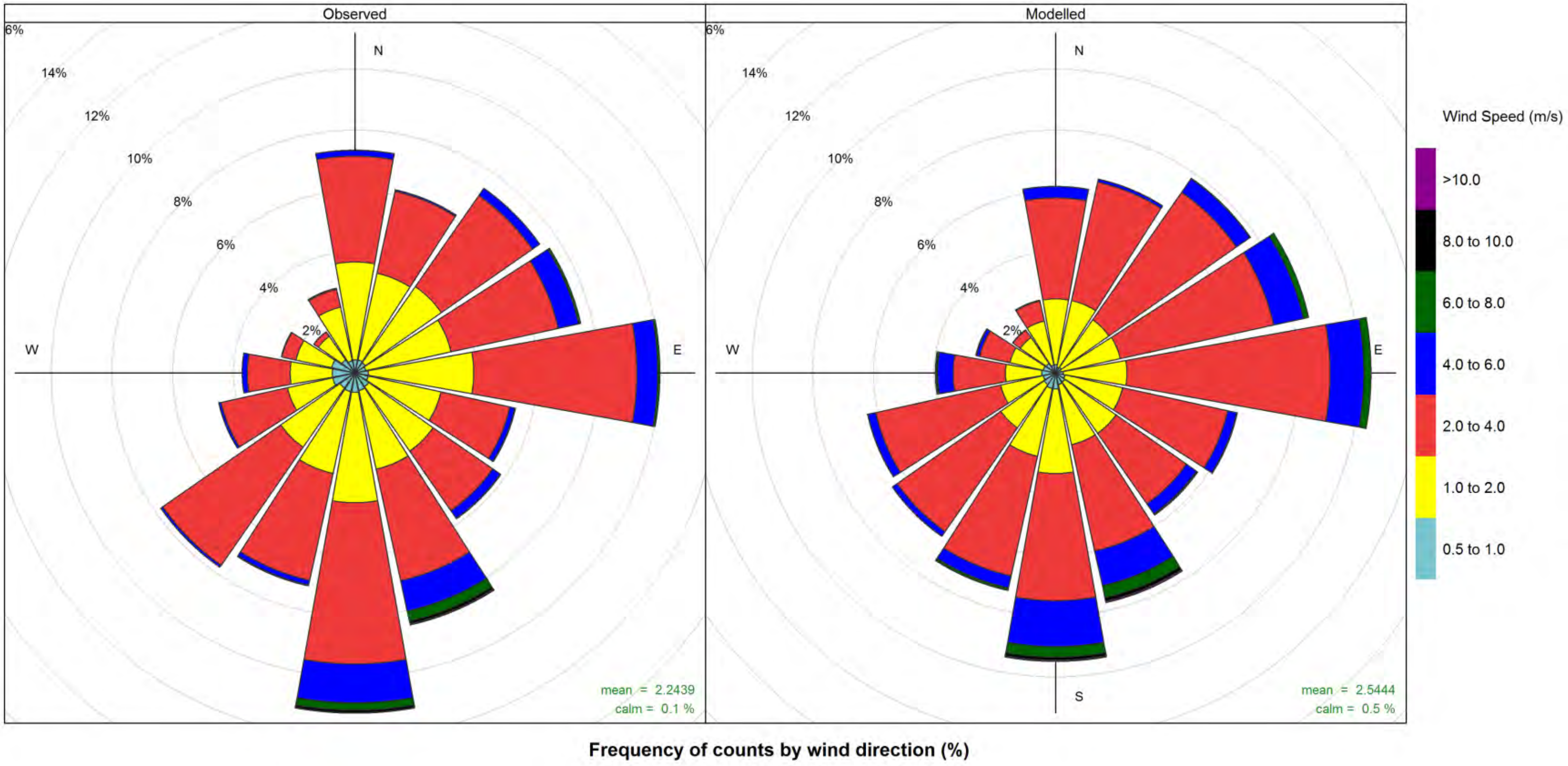


Figure B.2: Observed and modelled wind roses at T18 Burnaby North

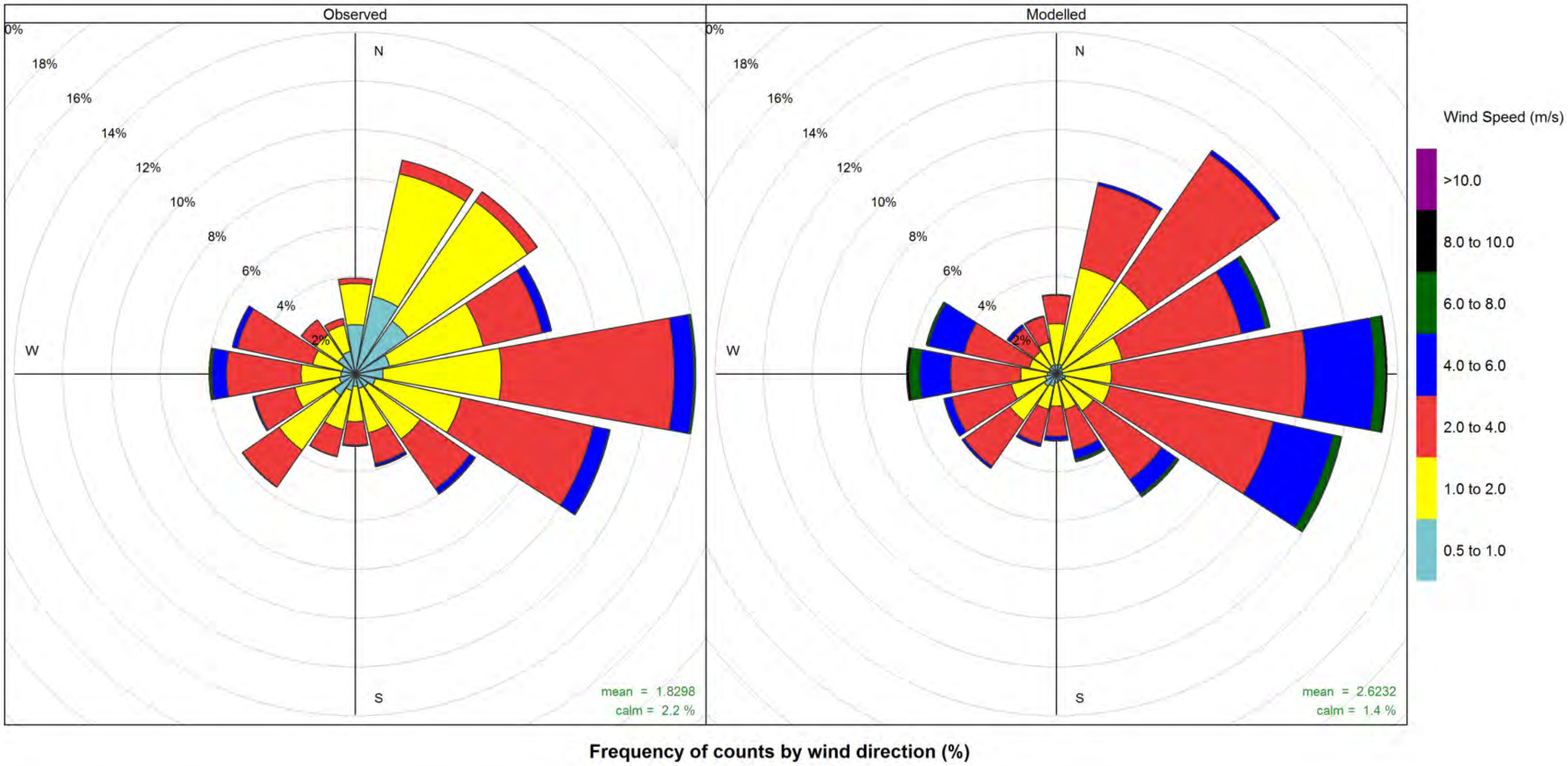


Figure B.3: Observed and modelled wind roses at T22 Burnaby-Burmount

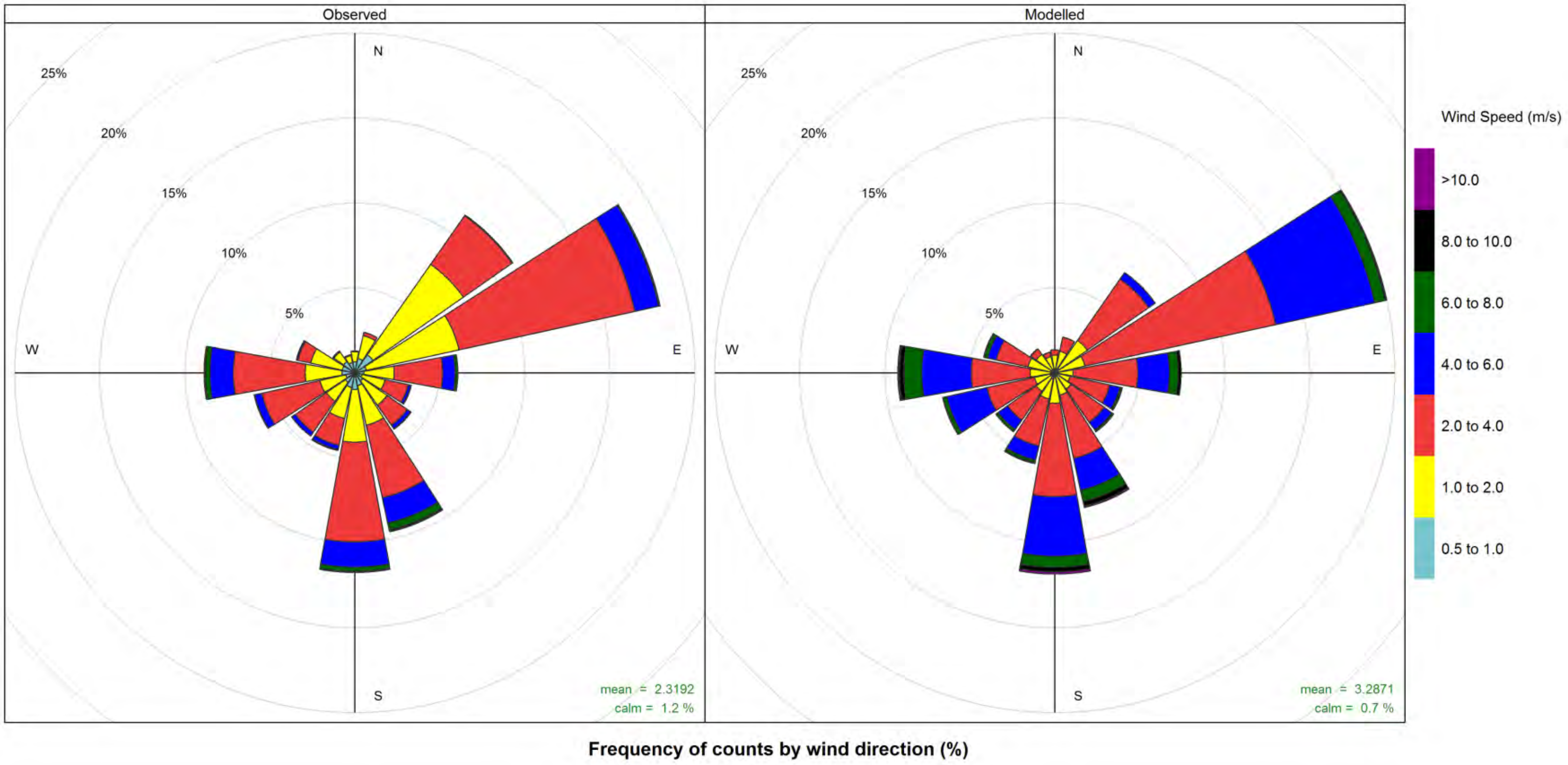
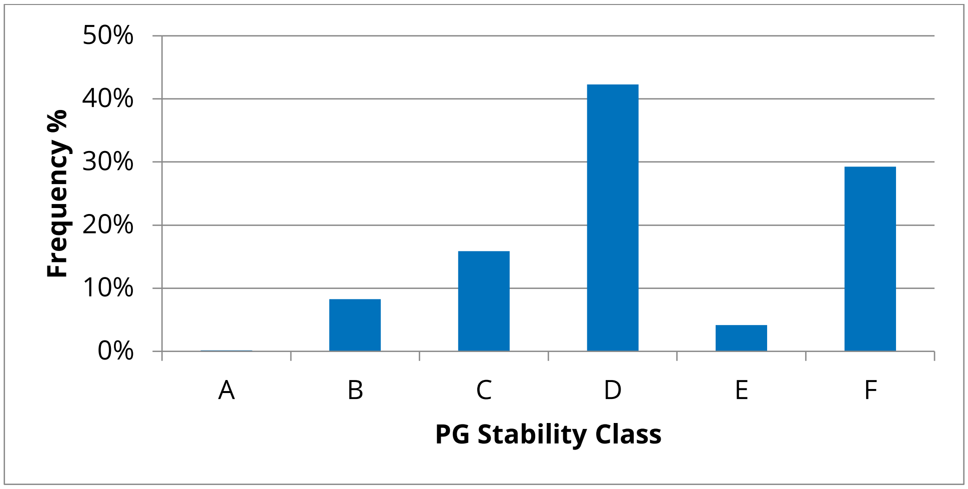


Figure B.4: Observed and modelled wind roses at T38 Annacis Island

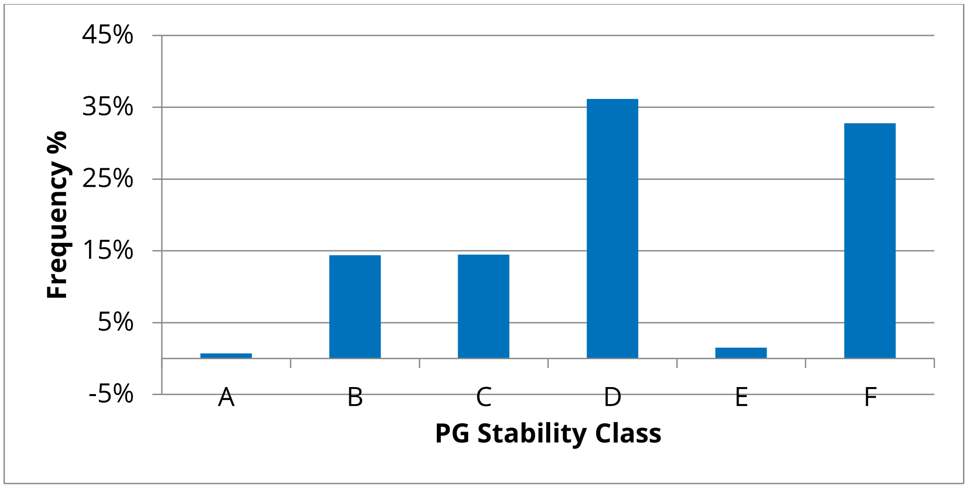
B.3.2 Pasquill-Gifford Stability Class

In CALMET, the Pasquill-Gifford stability scheme is used to classify atmospheric stratification in the boundary layer over land. These classes range from unstable (Classes A, B and C), through neutral (Class D), to stable (Classes E and F). Normally, unstable conditions are associated with daytime ground-level heating and lower wind speeds which means that boundary layer turbulence is generated mostly through thermal buoyancy and less so by mechanical wind shear. Stable conditions are primarily associated with night-time cooling that results in the suppression of buoyant turbulence and prevalence of near surface temperature inversions. Neutral conditions are mostly associated with high wind speeds or overcast sky conditions and boundary layer mixing driven mostly by mechanical wind shear.

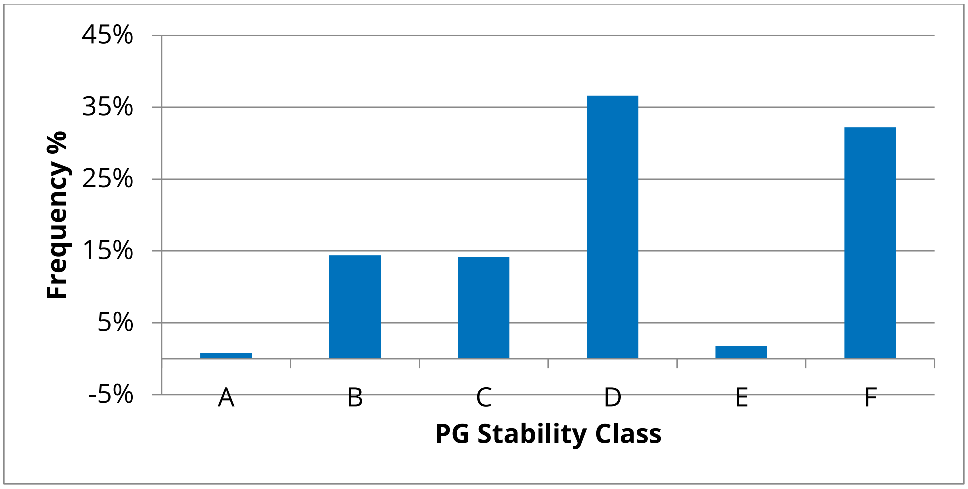
The frequency distributions of CALMET-derived Pasquill-Gifford stability classes for the WTE Facility, as well as the North Delta, Burnaby South, Burnaby-Burmount, and Annacis Island stations are shown in Figure B.5. For all listed locations, the most frequent stability class is Class D neutral, with the stable classes E and F second most frequent, and the unstable classes A, B and C least frequent. This is typical of most locations in BC. Unstable classes occur only during warm clear weather in daytime so their occurrence is limited to a lesser fraction of hours during the warmest months. The stable classes occur mostly at night during cooler weather. They dominate during winter and can occur during other periods as well. And neutral can occur day or night during at any time of year given higher wind speeds.



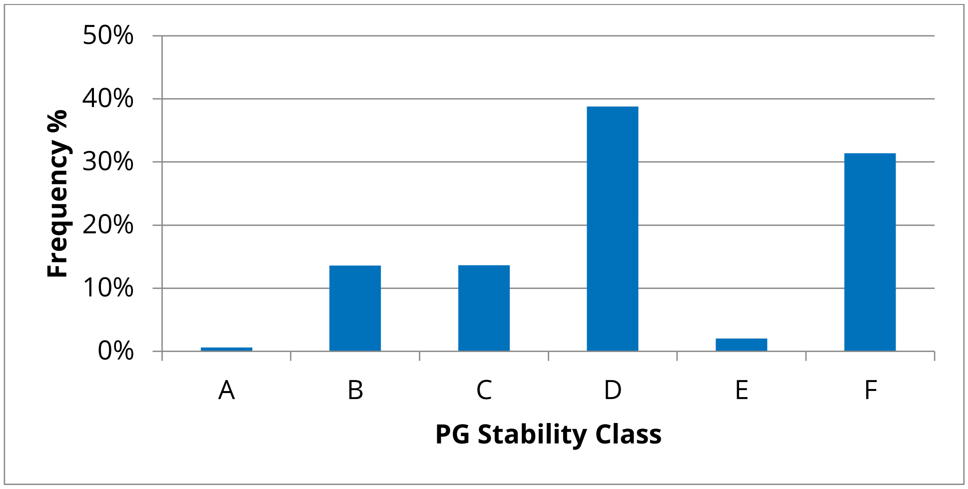
WTE Facility



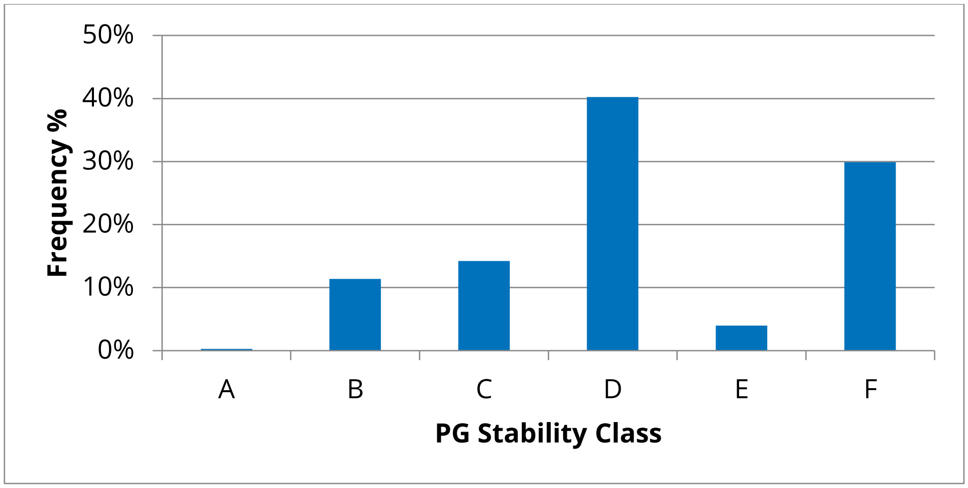
T13 North Delta



T18 Burnaby South



T22 Burnaby-Burmount

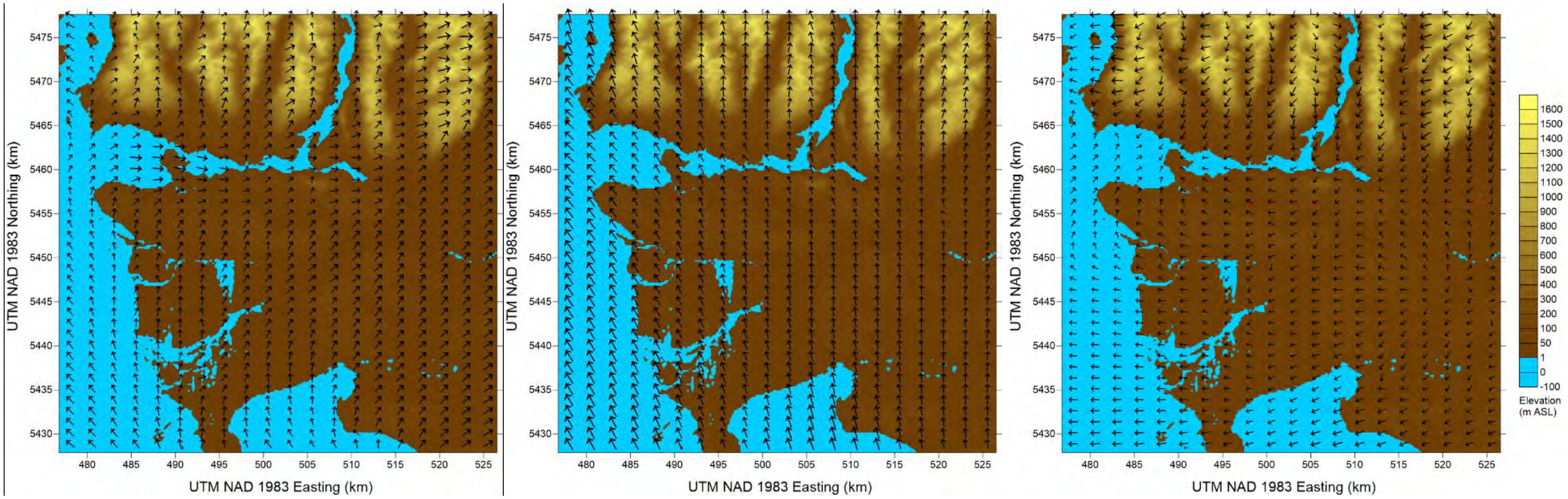


T22 Annacis Island

Figure B.5: Frequency of modelled Pasquill-Gifford stability classes

B.3.3 Modelled Wind Fields

Spatial wind plots are used to evaluate a meteorological model's ability to replicate wind flow patterns, particularly with respect to expected terrain influences. Vector wind fields plots representing examples of unstable, neutral, and stable conditions for the study area are illustrated in Figure B.6. In general, CALMET-derived wind fields follow the expected terrain features under various stability and flow regimes. In particular, upslope and onshore winds are seen during unstable periods when strong hearting over the valley slopes and differential heating between land and water results in mountain and sea breezes. Similarly, katabatic downslope winds are prevalent during stable, night-time conditions when cooling at the surface creates density driven winds over sloped terrain. Under neutral conditions, the characteristic high wind speeds result in less noticeable terrain effects and wind fields are relatively uniform across the model domain.



Unstable

June 23, 2014 13:00

Neutral

April 18, 2013 24:00

Stable

January 5, 2013 00:00

Arrow lengths show relative wind speed from 0 to 8.0 m/s.

Figure B.6: Modelled wind fields at 10 m above ground level during unstable, neutral, and stable conditions

B.3.4 Mixing Heights

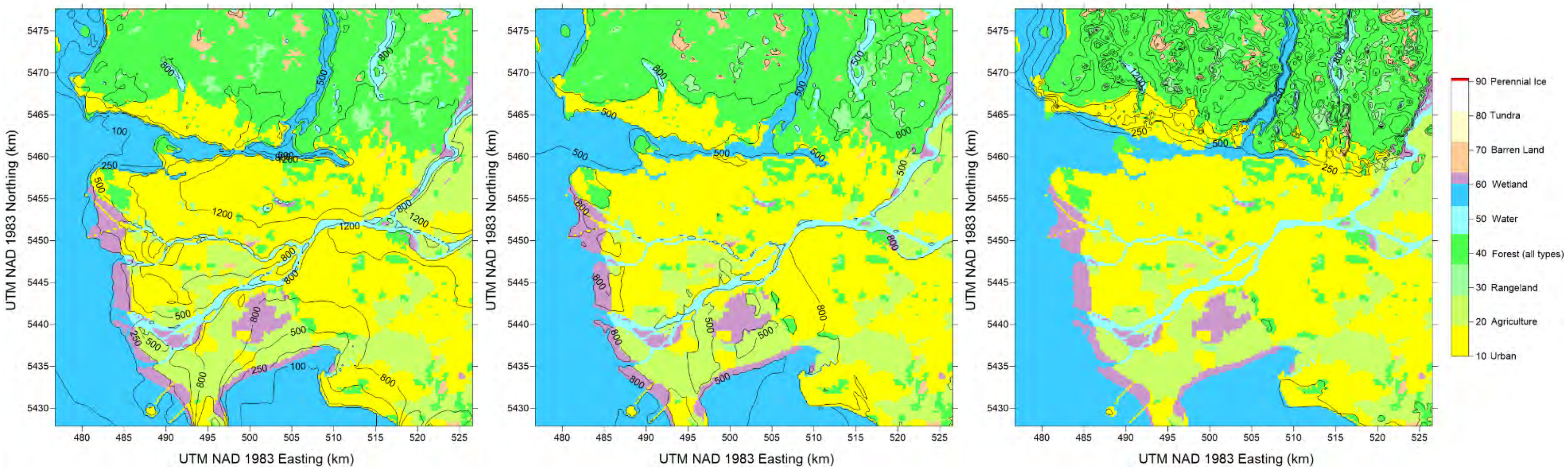
Mixing heights are estimated in CALMET through the influence of both thermally and mechanically generated turbulence as determined from modeled surface heat flux, vertical temperature profiles, and vertical wind shear. Table B.8 shows the average modelled mixing heights by Pasquill-Gifford stability class. Overall, the highest mixing heights are associated with unstable conditions (Classes A, B and C), while the lowest mixing heights are associated with stable conditions (Classes E and F).

The spatial distribution of mixing heights under unstable, neutral, and stable conditions is shown in Figure B.7. Spatial changes in mixing height align with changes in the land use, due to difference in energy balance and surface roughness resulting for differing land cover categories. Mixing height tends to be lowest over water due to lower surface temperature and heating and increases with higher surface temperature and heating and larger surface roughness over land.

Diurnal variations in mixing heights at are shown in Figure B.8, respectively for a typical summer day (August 10) and a typical winter day (January 1). Mixing heights tend to increase with solar heating during the day and decrease with surface radiative cooling during the night, although daytime mixing heights may be suppressed during stable winter conditions due to weak solar insolation, high reflectivity of snow-covered surfaces, low wind speeds and synoptic subsidence.

Table B.8: Average modelled mixing height by Pasquill-Gifford Stability Class (in m)

Station	A	B	C	D	E	F
WTE Facility	877	636	689	472	283	79
T13 North Delta	1,204	856	581	439	323	77
T18 Burnaby South	1,304	900	586	425	267	72
T22 Burnaby-Burmount	1,375	953	658	468	312	81
T38 Annacis Island	994	668	558	430	263	73



Unstable

June 23, 2013 12:00

Neutral

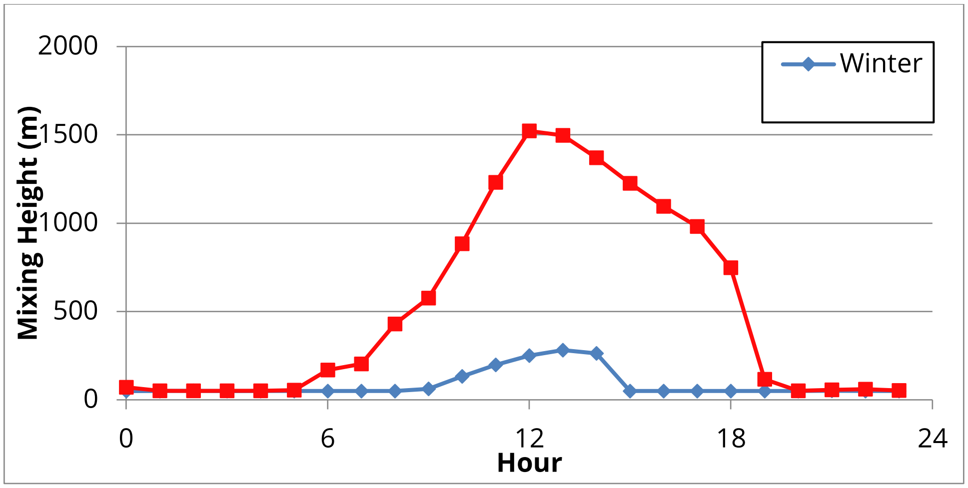
November 18, 2013 22:00

Stable

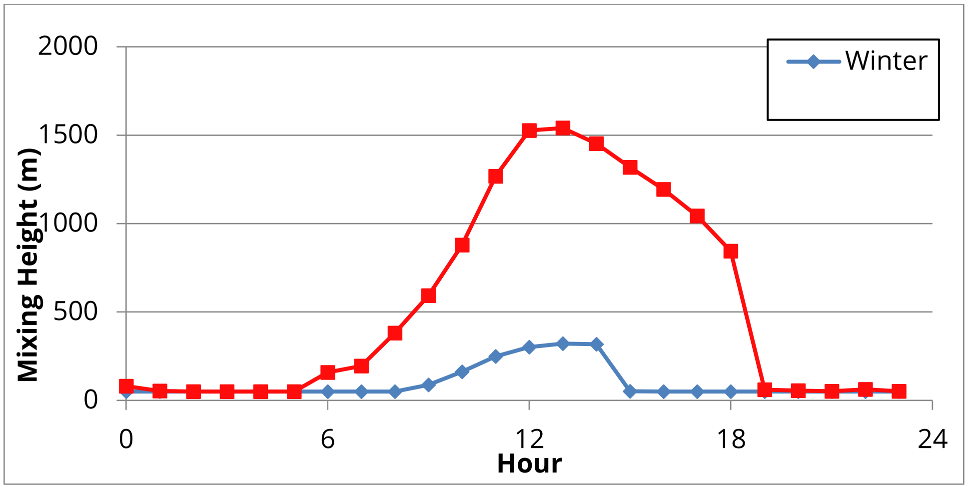
December 27, 2013 22:00

Contour intervals are 250 m.

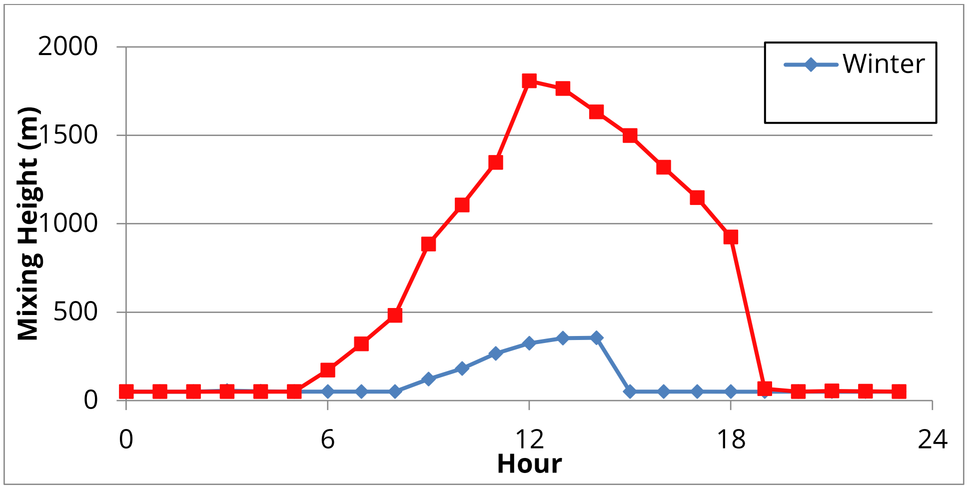
Figure B.7: Modelled mixing heights (contour lines, labels in metres) overlaid on top of land cover characterization during unstable, neutral, and stable atmospheric conditions.



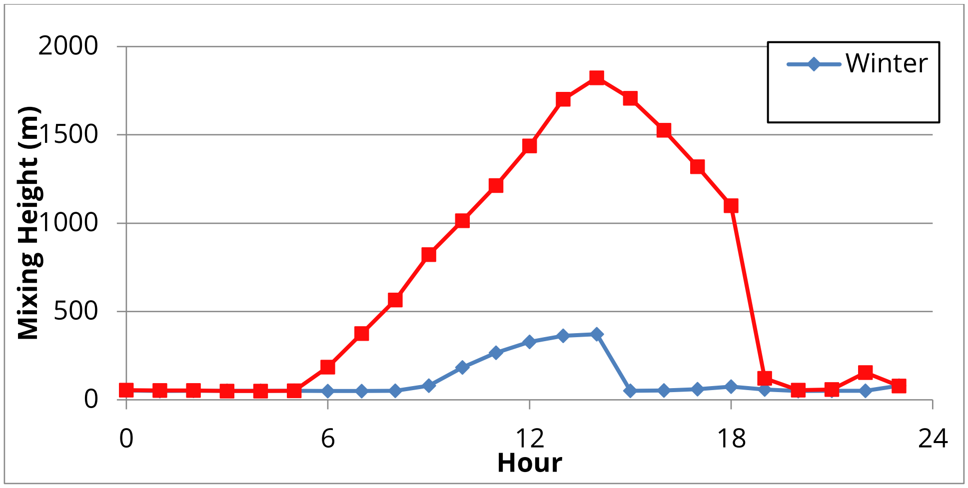
WTE Facility



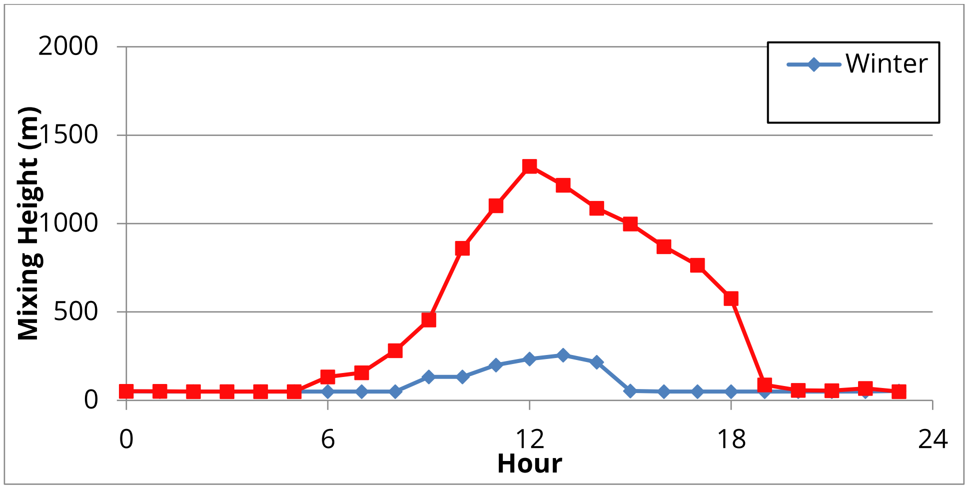
T13 North Delta



T18 Burnaby South



T22 Burnaby-Burmount

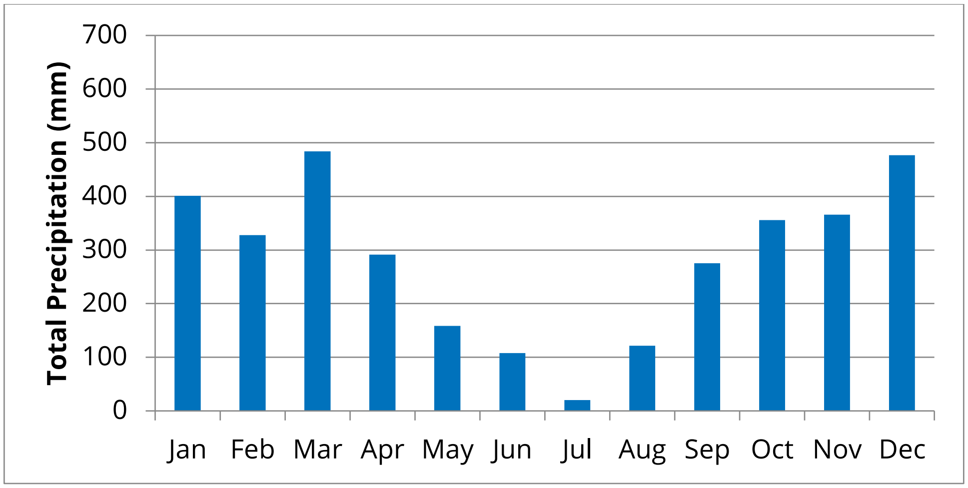


T38 Annacis Island

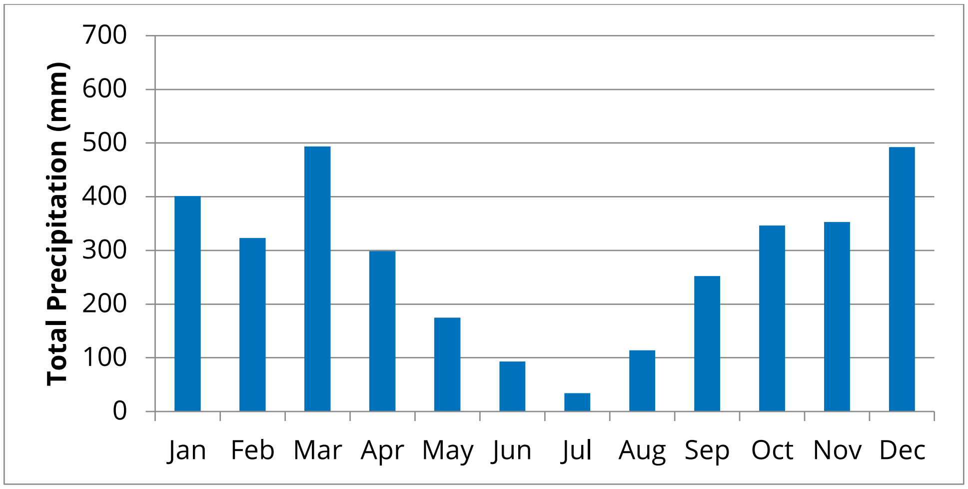
Figure B.8: Diurnal variation of modelled mixing heights

B.3.5 Precipitation

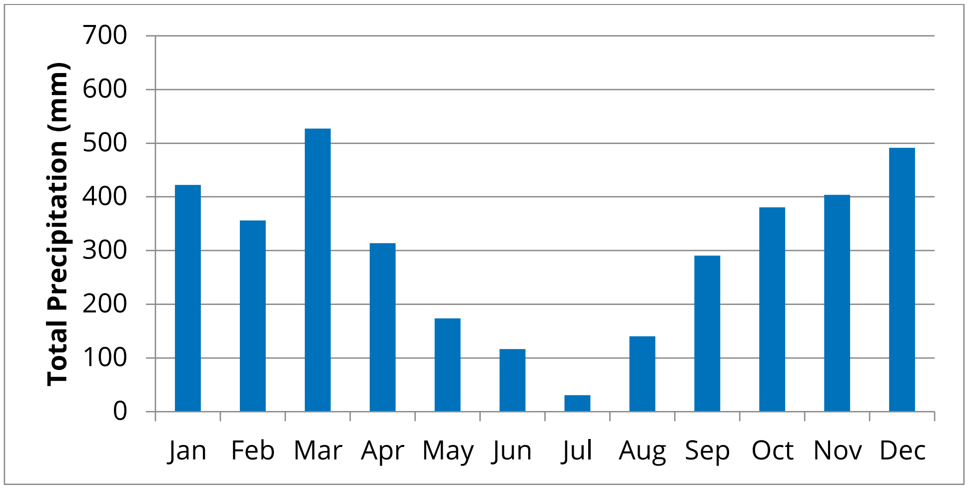
CALMET-derived monthly precipitation patterns at various stations are illustrated in Figure B.9 at all stations. The least amount of precipitation is expected to occur in the summer months from May to August, and the greatest amount of precipitation is expected to occur in December, January, and March.



WTE Facility



T13 North Delta



T18 Burnaby South

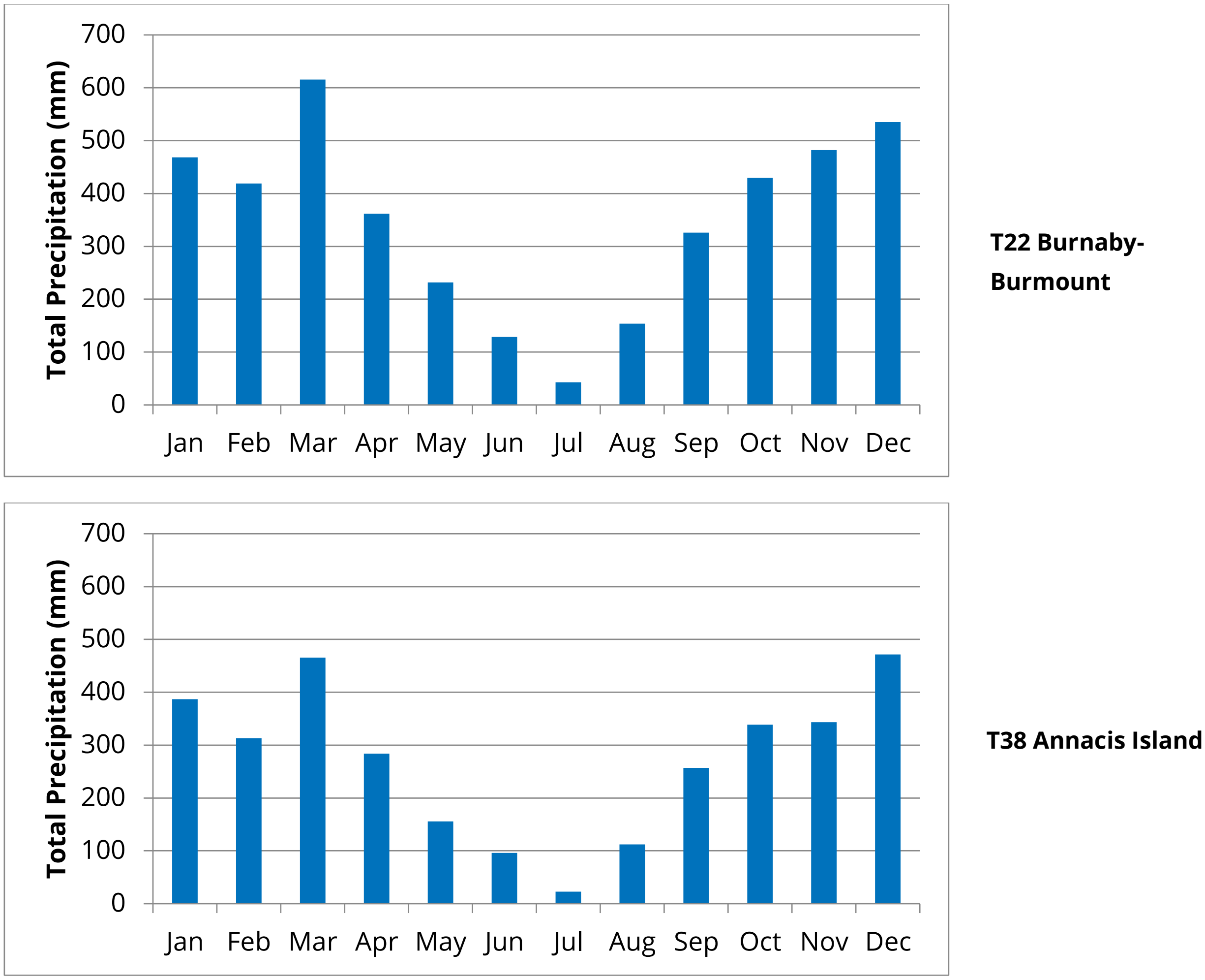


Figure B.9: Monthly distribution of modelled precipitation

B.4 CALPUFF INPUTS

All technical options relating to the CALPUFF dispersion model were set according to the Guidelines for Air Quality Dispersion Modelling in BC (BCMOE 2008) or to model defaults. These include parameters and options such as the calculation of plume dispersion coefficients, the plume path coefficients used for terrain adjustments, exponents for the wind speed profile, and wind speed categories. A list of the technical options is shown in Table B.9.

Table B.9: CALPUFF model switch settings

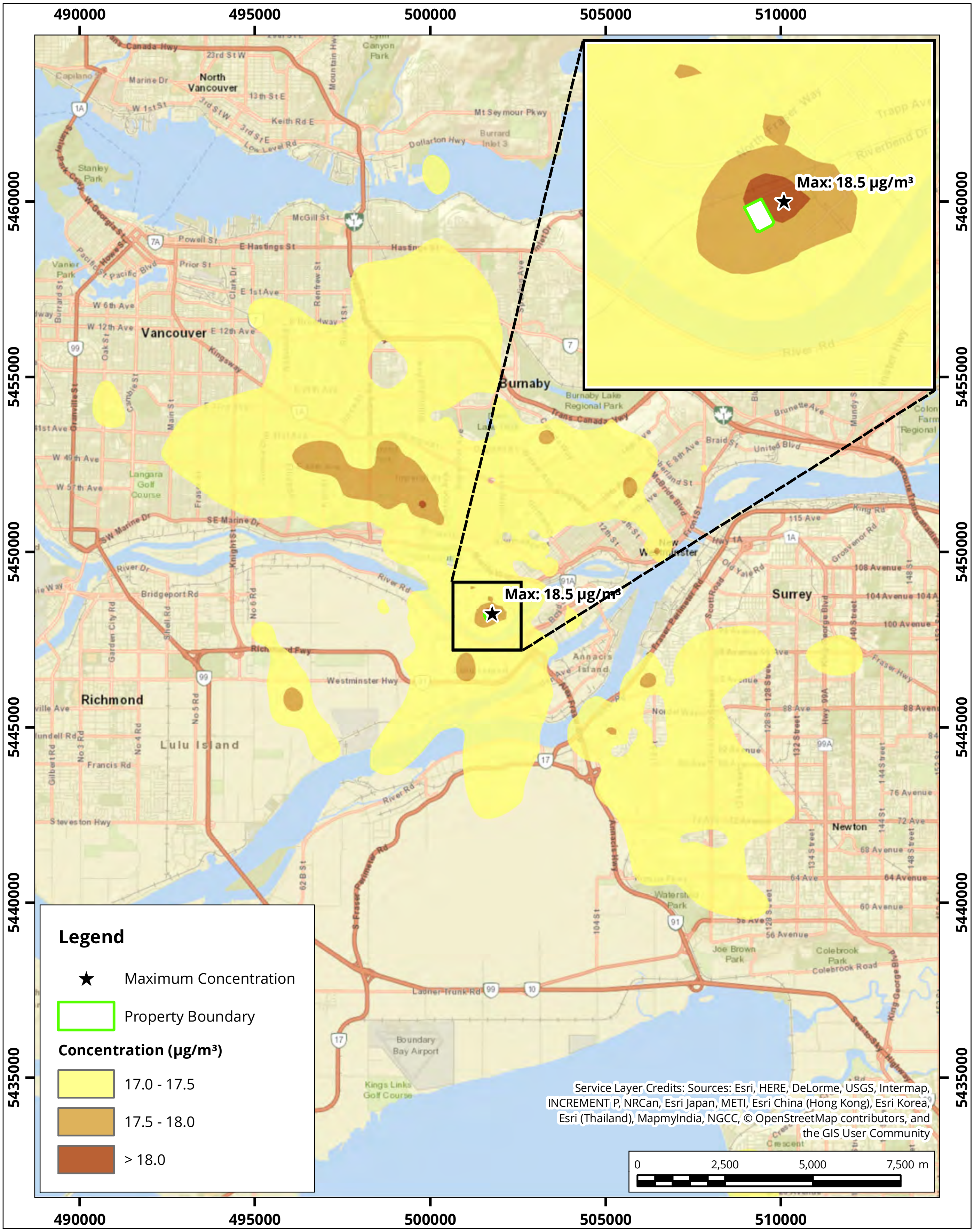
Parameter	Default	Project	Comments
MGAUSS	1	1	Gaussian distribution used in near field
MCTADJ	3	3	Partial plume path terrain adjustment
MCTSG	0	0	Sub-grid scale complex terrain not modelled
MSLUG	0	0	Near-field puffs not modelled as elongated
MTRANS	1	1	Transitional plume rise modelled
MTIP	1	1	Stack tip downwash used
MRISE	1	1	Briggs plume rise used to compute plume rise
MTIP_FL	0	0	No FLARE sources
MBDW	1	2	PRIME method used to stimulate building downwash
MSHEAR	0	0	Vertical wind shear not modelled
MSPLIT	0	0	Puffs are not split
MCHEM	1	6	Chemical transformation using RIVAD/ISORROPIA as per BC Guideline
MAQCHEM	0	0	Aqueous phase transformation not modelled
MLWC	1	1	Not modelled since MAQCHEM = 0
MWET	1	1	Wet removal modelled for all sources
MDRY	1	1	Dry deposition modelled for all sources
MTILT	0	0	Gravitational settling not modelled
MDISP	3	2	Near-field dispersion coefficients internally calculated from sigma-v, sigma-w using micrometeorological variables as recommended by guidelines
MTURBVW	3	23	Not used since MDISP = 3

Parameter	Default	Project	Comments
MDISP2	3	3	Not used since MDISP =
MTAULY	0	0	Default used
MTAUADV	0	0	Default used
MCTURB	1	1	Standard CALPUFF subroutines used to compute turbulence sigma-v & sigma-w
MROUGH	0	0	PG sigma-y, sigma-z not adjusted for roughness
MPARTL	1	1	Partial plume penetration of elevated inversion modelled for point sources
MPARTLBA	1	1	Partial plume penetration of elevated inversion modelled for buoyant area sources
MTINV	0	0	Strength of temperature inversion computed from default gradients
MPDF	0	0	PDF not used for dispersion under convective conditions
MSGTIBL	0	0	Sub-grid TIBL module not used for shoreline
MBCON	0	0	Boundary concentration conditions not modelled
MSOURCE	0	0	Individual source contributions not saved
MFOG	0	0	Do not configure for FOG model output
MREG	1	0	Do not test options specified to see if they conform to United States Environmental Protection Agency regulatory values

B.5 REFERENCES

1. BC MOE (BC Ministry of Environment). 2015. British Columbia Air Quality Dispersion Modelling Guideline. 111 pp.
2. Zhang, L., Moran, M.D., Makar, P.A., Brook, J.R., and Gong, S. 2002. Modelling gaseous dry deposition in AURAMS: a unified regional air-quality modelling system. Atmospheric Environment 36: 537-560.
3. Zhang, L., Brook, J.R., and Vet, R. 2003. A revised parameterization of gaseous dry deposition in air-quality models. Atmospheric Chemistry and Physics 3: 2067-2082.
4. United States Environmental Protection Agency, 2008: AERSURFACE User's Guide, EPA-454/B-08-001.

APPENDIX C



Maximum predicted 24-hour PM$_{2.5}$ concentrations, with background

Permit Scenario

Map Projection: NAD 1983 UTM Zone 10N

Waste-To-Energy Facility - Burnaby, British Columbia

True North

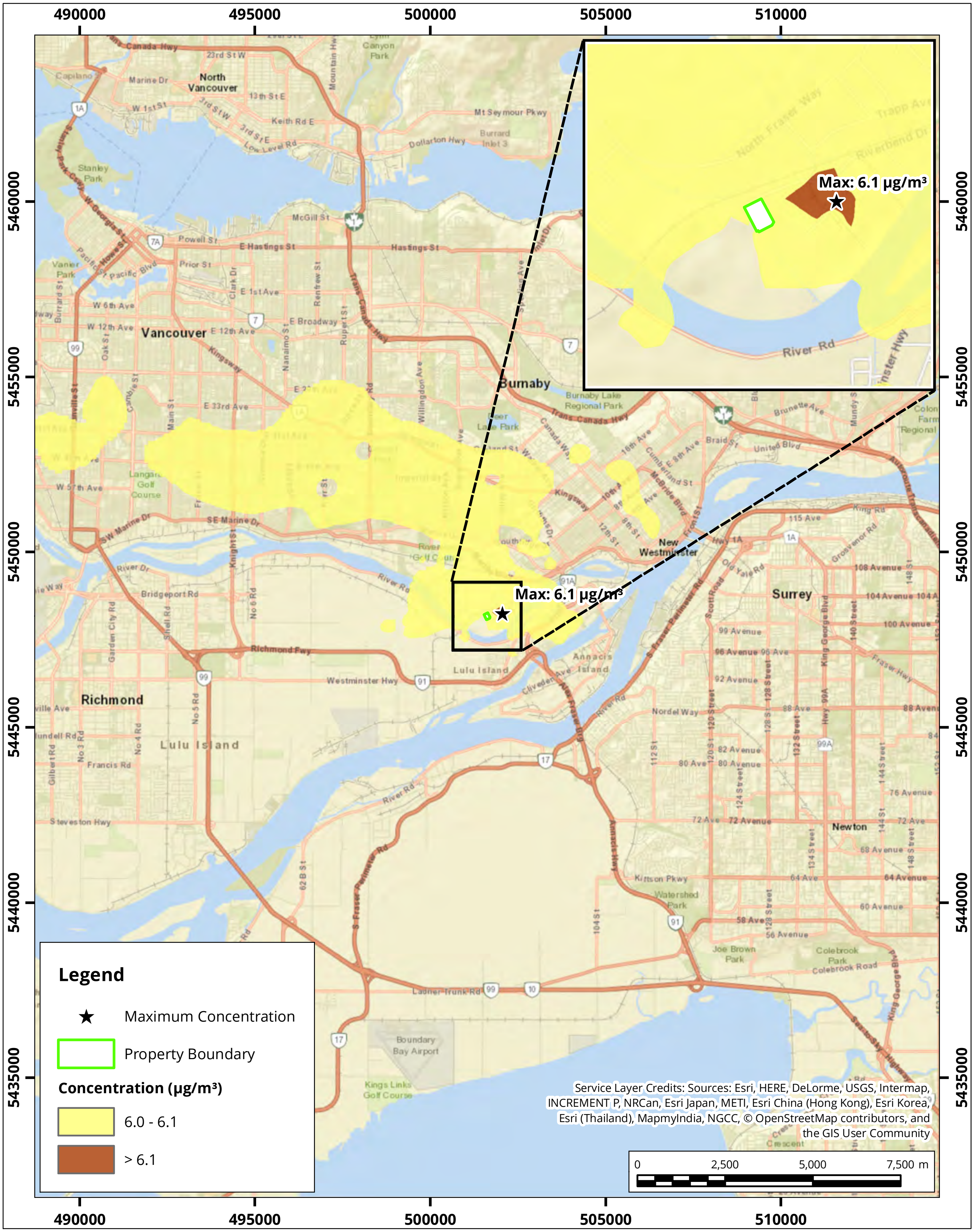
Background Concentration = 16.5 µg/m³

Metro Vancouver Objective = 25 µg/m³

Project #: 1702445

Drawn by: DJH	Figure: 1
Approx. Scale:	1:150,000
Date Revised:	Jul 30, 2019

Map Document: C:\Users\djh\OneDrive - ROWAN WILLIAMS DAVIES & IRWIN INC\GIS Temp\1702445\1702445_Burnaby_WTE_Contour_Figure_Template_181109.mxd



Service Layer Credits: Sources: Esri, HERE, DeLorme, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), MapmyIndia, NGCC, © OpenStreetMap contributors, and the GIS User Community

Map Document: C:\Users\djh\OneDrive - ROWAN WILLIAMS DAVIES & IRWIN INC\GIS Temp\1702445\1702445_Burnaby_WTE_Contour_Figure_Template_181109.mxd

Predicted annual average PM$_{2.5}$ concentrations, with background

Permit Scenario

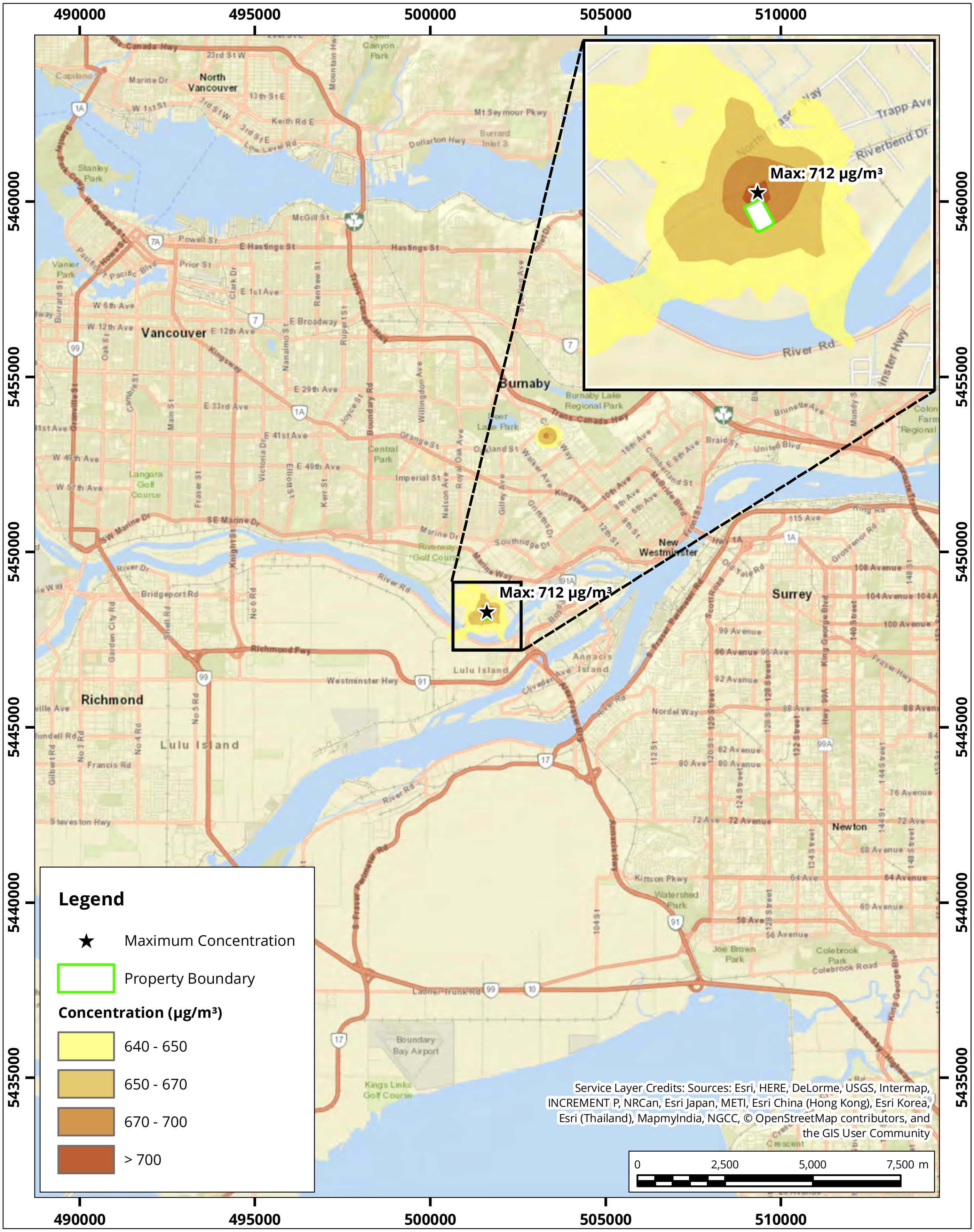
Map Projection: NAD 1983 UTM Zone 10N

Waste-To-Energy Facility - Burnaby, British Columbia

True North

Background Concentration = 5.9 µg/m³
Metro Vancouver Objective = 8 µg/m³
Project #: 1702445

Drawn by: DJH	Figure: 2
Approx. Scale:	1:150,000
Date Revised:	Jul 30, 2019



Maximum predicted 1-hour CO concentrations, with background

Permit Scenario

Map Projection: NAD 1983 UTM Zone 10N

Waste-To-Energy Facility - Burnaby, British Columbia

True North

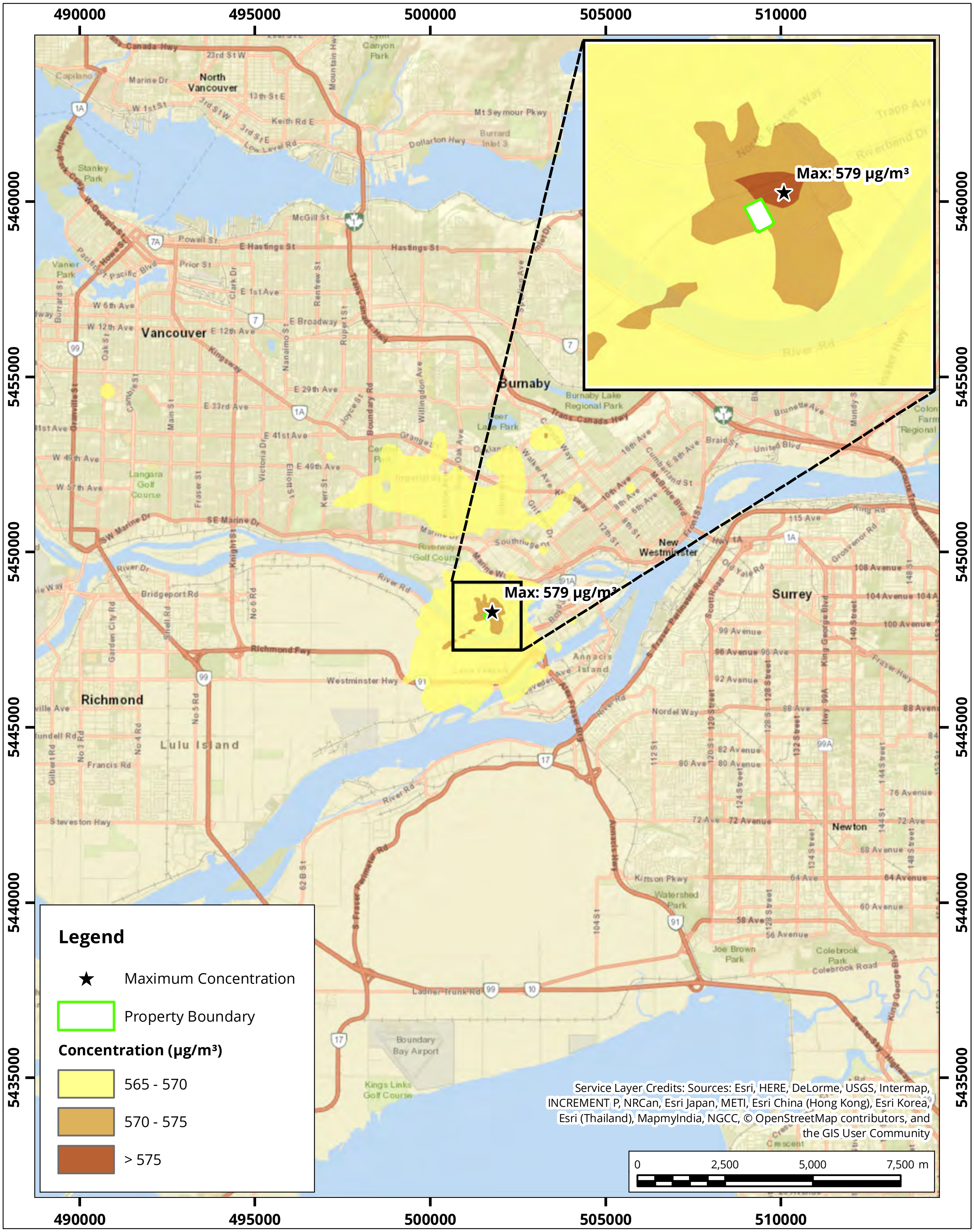
Background Concentration = 607 μg/m³

Metro Vancouver Objective = 30,000 μg/m³

Project #: 1702445

Drawn by: DJH	Figure: 3
Approx. Scale:	1:150,000
Date Revised:	Jul 30, 2019

Map Document: C:\Users\djh\OneDrive - ROWAN WILLIAMS DAVIES & IRWIN INC\GIS Temp\1702445\1702445_Burnaby_WTE_Contour_Figure_Template_181109.mxd



Service Layer Credits: Sources: Esri, HERE, DeLorme, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), MapmyIndia, NGCC, © OpenStreetMap contributors, and the GIS User Community

Maximum predicted 8-hour CO concentrations, with background

Permit Scenario

Map Projection: NAD 1983 UTM Zone 10N

Waste-To-Energy Facility - Burnaby, British Columbia

True North

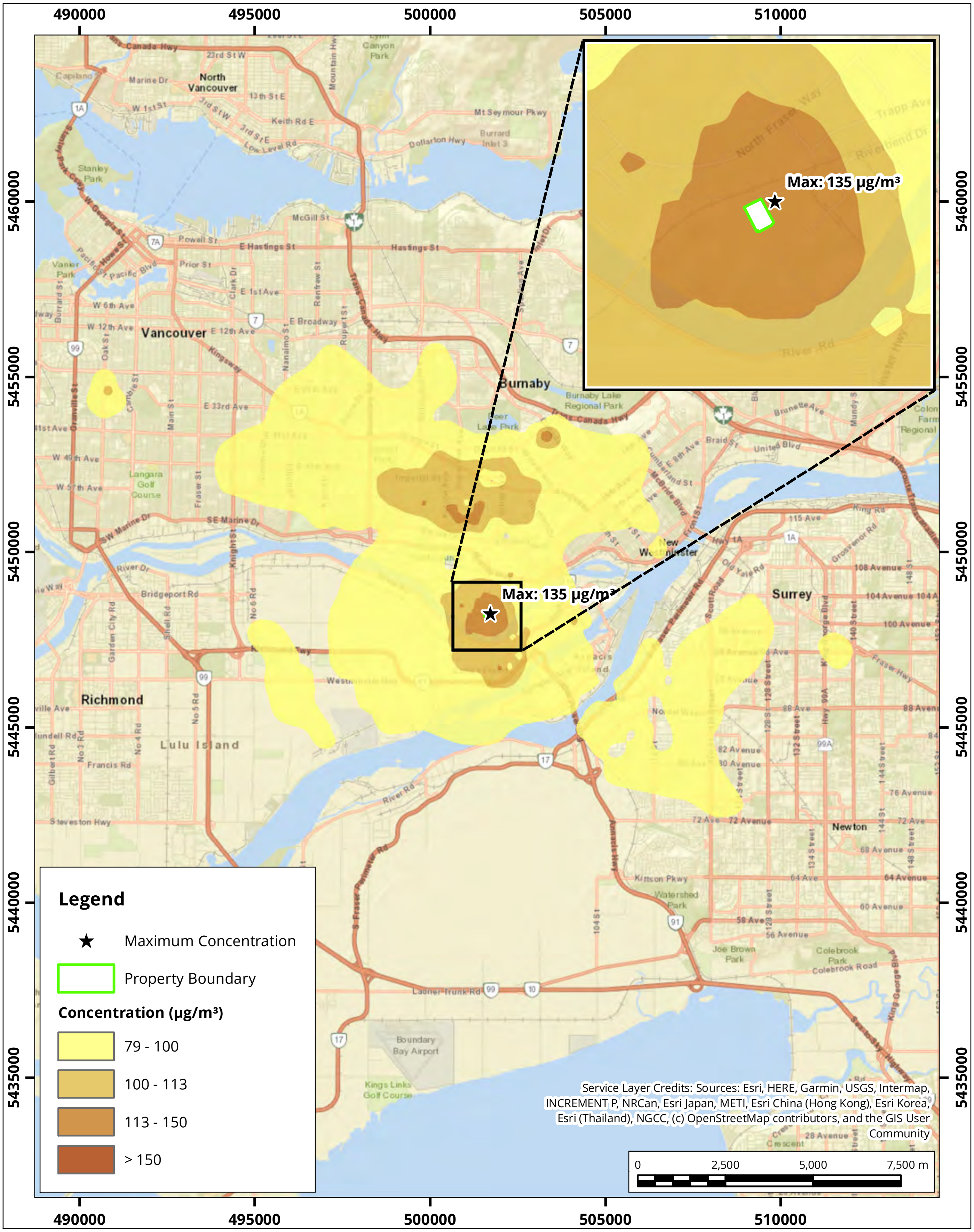
Background Concentration = 560 µg/m³

Metro Vancouver Objective = 10,000 µg/m³

Project #: 1702445

Drawn by:	DJH	Figure:	4
Approx. Scale:	1:150,000		
Date Revised:	Jul 30, 2019		

Map Document: C:\Users\djh\OneDrive - ROWAN WILLIAMS DAVIES & IRWIN INC\GIS Temp\1702445\1702445_Burnaby_WTE_Contour_Figure_Template_181109.mxd



98th percentile predicted daily maximum 1-hour NO_2 concentrations, with background

Permit Scenario

Map Projection: NAD 1983 UTM Zone 10N

Waste-To-Energy Facility - Burnaby, British Columbia

True North

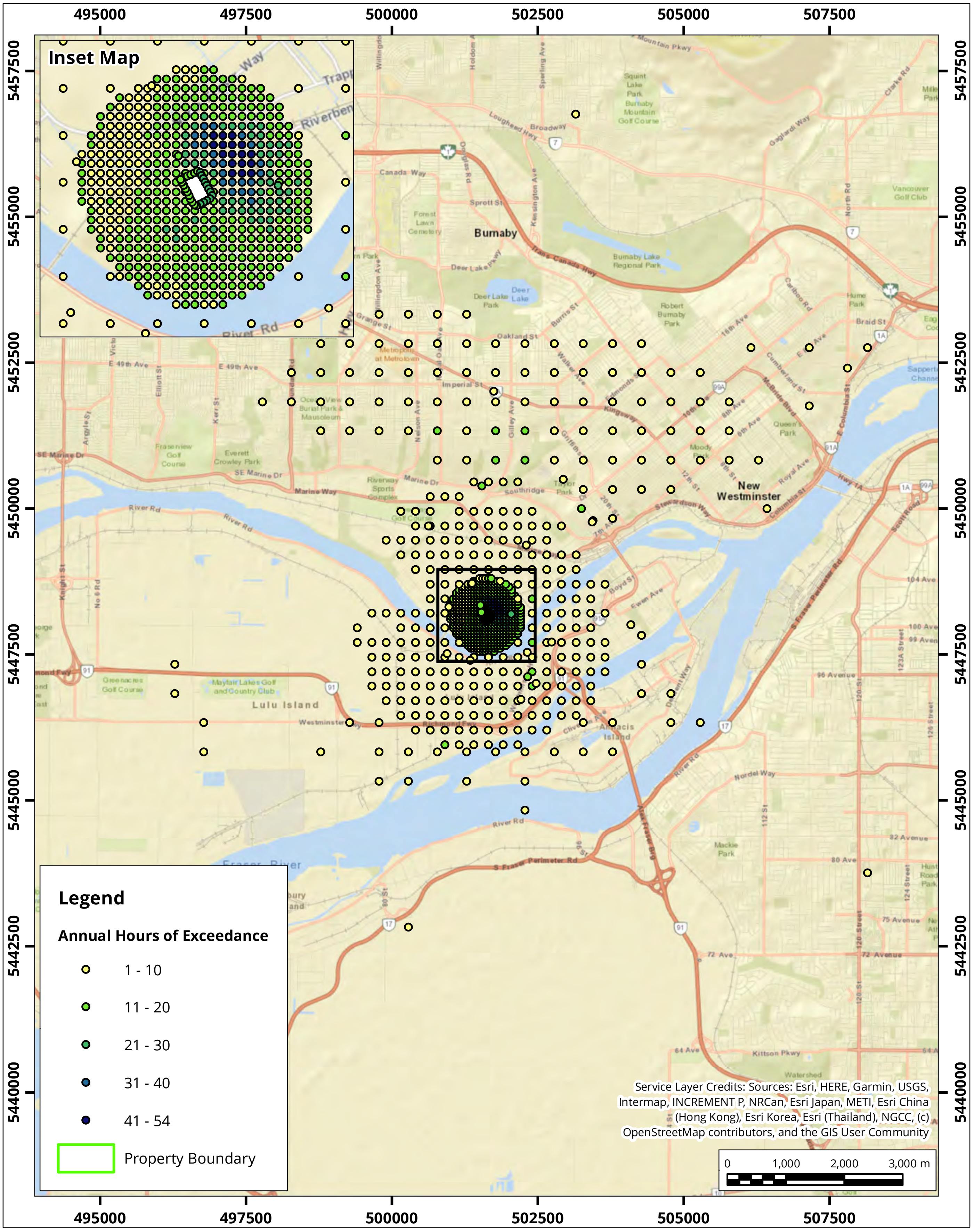
Background Concentration = 62.4 µg/m³

2020 CAAQS = 113 µg/m³; 2025 CAAQS = 79 µg/m³

Project #: 1702445

Drawn by: DJH	Figure: 5
Approx. Scale:	1:150,000
Date Revised:	May 5, 2020

Map Document: C:\GIS Temp - Copy\1702445\1702445_Burnaby_WTE_Contour_Figure_Template_181109-CAL-W10D-DJH.mxd



Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

Map Document: C:\GIS Temp - Copy\1702445\1702445_Burnaby_WTE_Contour_Figure_6_Exceedance_200506.mxd

Maximum annual counts where daily 1-hour peak NO_2 including background exceeds the threshold of the 2020 CAAQS

Map Projection: NAD 1983 UTM Zone 10N

Waste-To-Energy Facility - Burnaby, British Columbia

True North

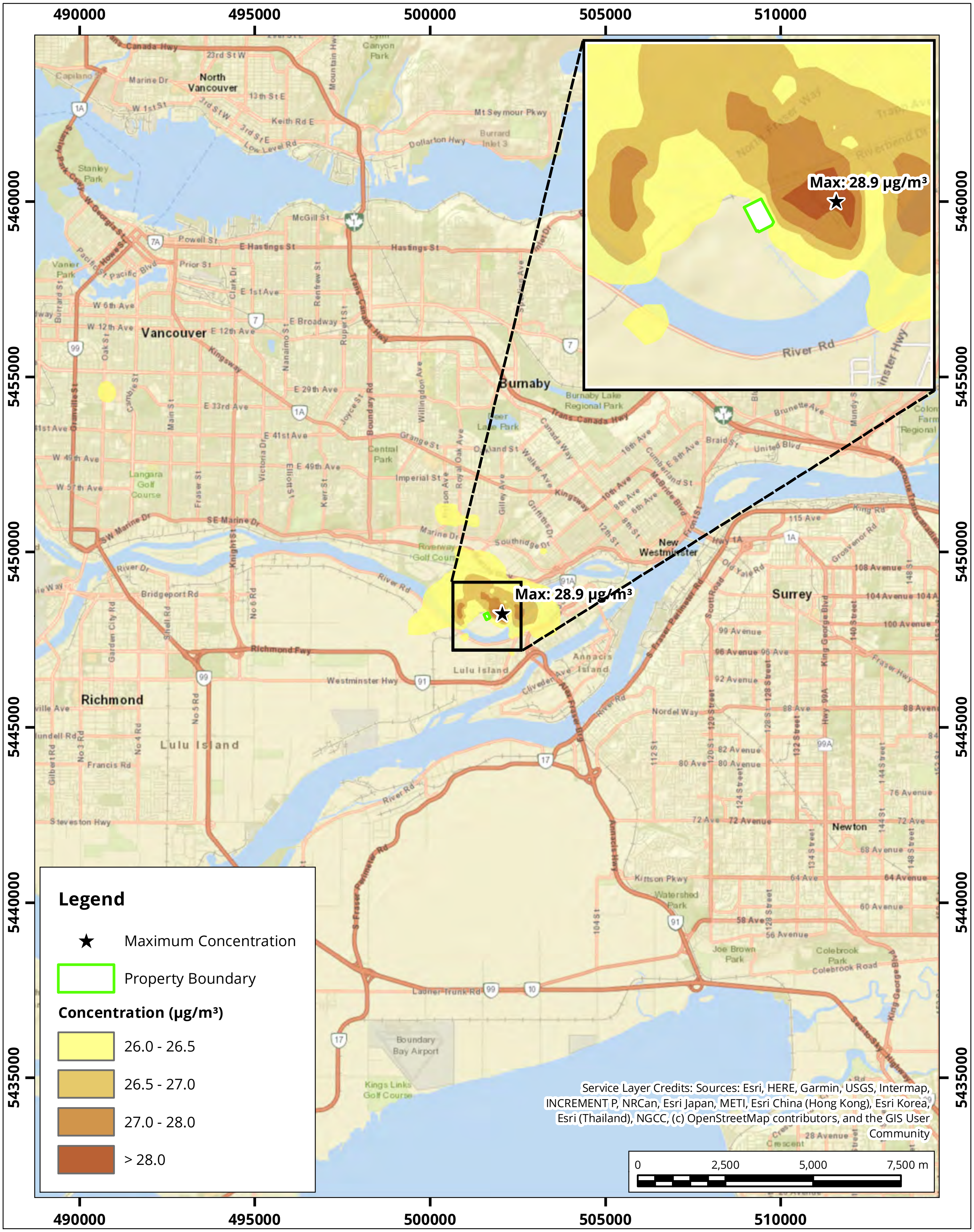
Project #: 1702445

Drawn by: DJH

Figure: 6

Approx. Scale: 1:90,000

Date Revised: May 6, 2020



Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

Map Document: C:\GIS Temp - Copy\1702445\1702445_Burnaby_WTE_Contour_Figure_Template_181109-CAL-W10D-DJH.mxd

Predicted annual average NO_2 concentrations, with background

Permit Scenario

Map Projection: NAD 1983 UTM Zone 10N

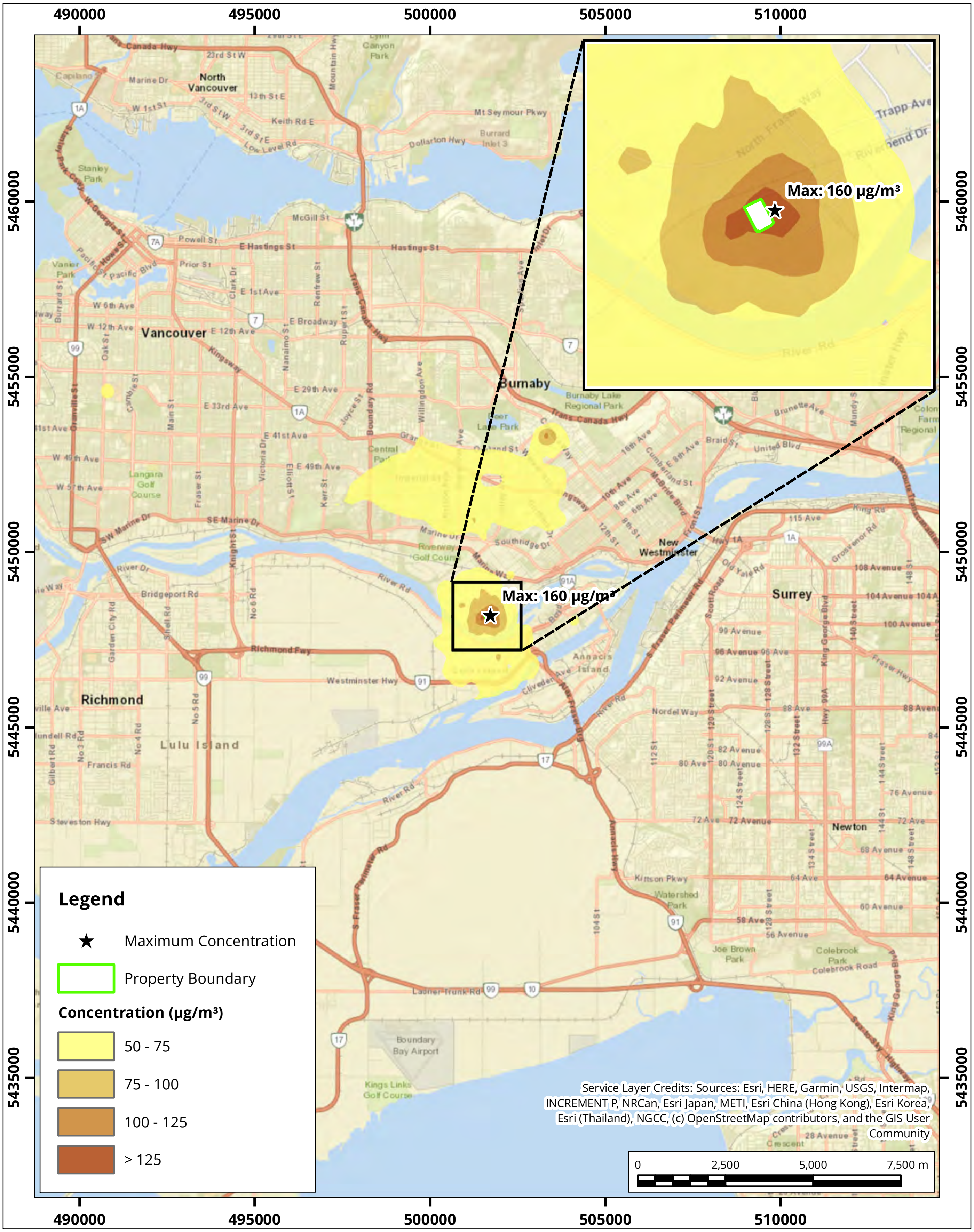
Waste-To-Energy Facility - Burnaby, British Columbia

True North

Background Concentration = 25.2 μg/m³
Metro Vancouver Objective = 40 μg/m³

Project #: 1702445

Drawn by: DJH	Figure: 7
Approx. Scale:	1:150,000
Date Revised:	May 5, 2020



Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

98th percentile predicted daily maximum 1-hour SO_2 concentrations, with background

Permit Scenario

Map Projection: NAD 1983 UTM Zone 10N

Waste-To-Energy Facility - Burnaby, British Columbia

True North

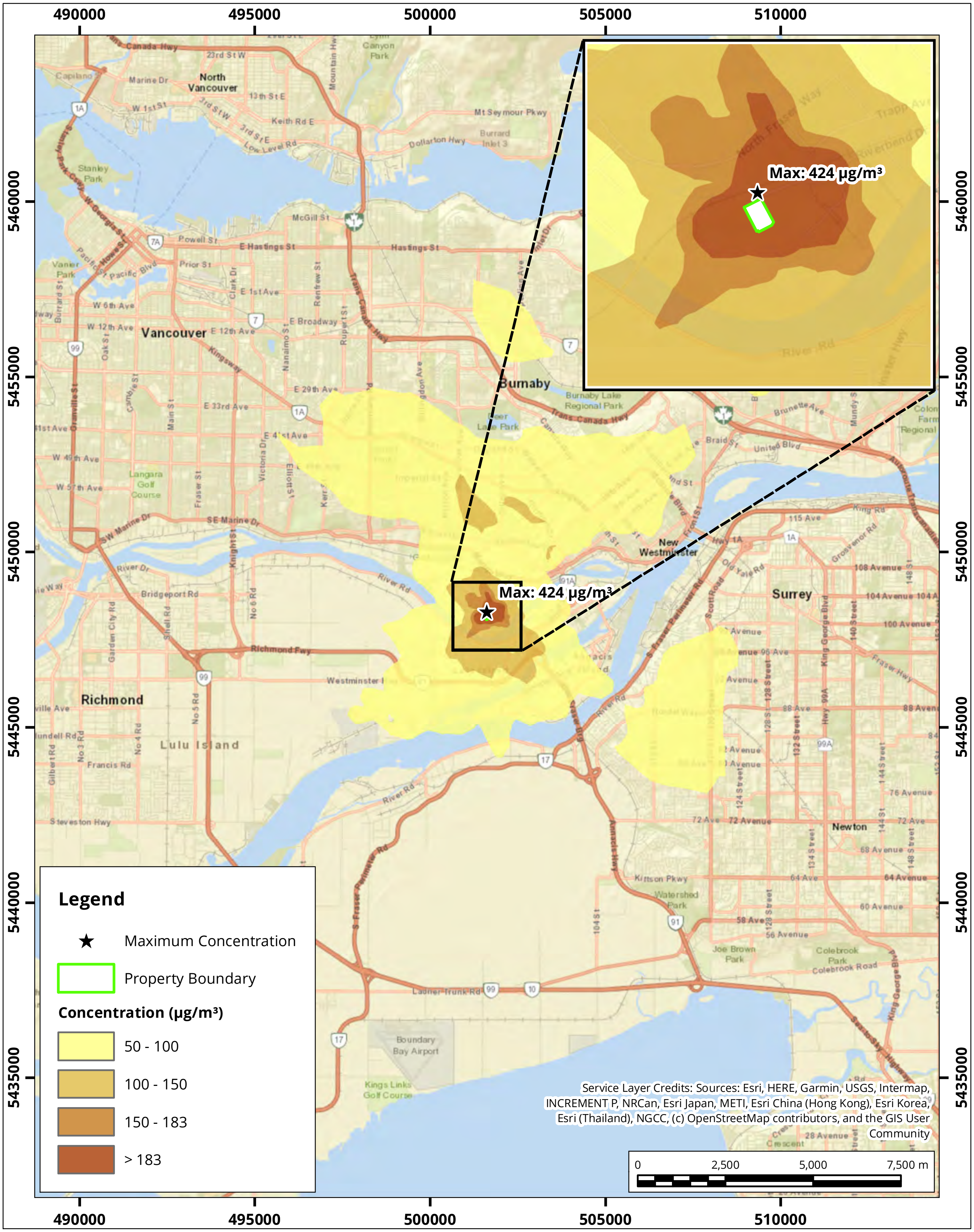
Background Concentration = 5.2 µg/m³

2020 CAAQS = 183 µg/m³; 2025 CAAQS = 170 µg/m³

Project #: 1702445

Drawn by: DJH	Figure: 8
Approx. Scale:	1:150,000
Date Revised:	May 5, 2020

Map Document: C:\GIS Temp - Copy\1702445\1702445_Burnaby_WTE_Contour_Figure_Template_181109-CAL-W10D-DJH.mxd



Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

Predicted maximum 1-hour SO_2 concentrations, with background

Permit Scenario

Map Projection: NAD 1983 UTM Zone 10N

Waste-To-Energy Facility - Burnaby, British Columbia

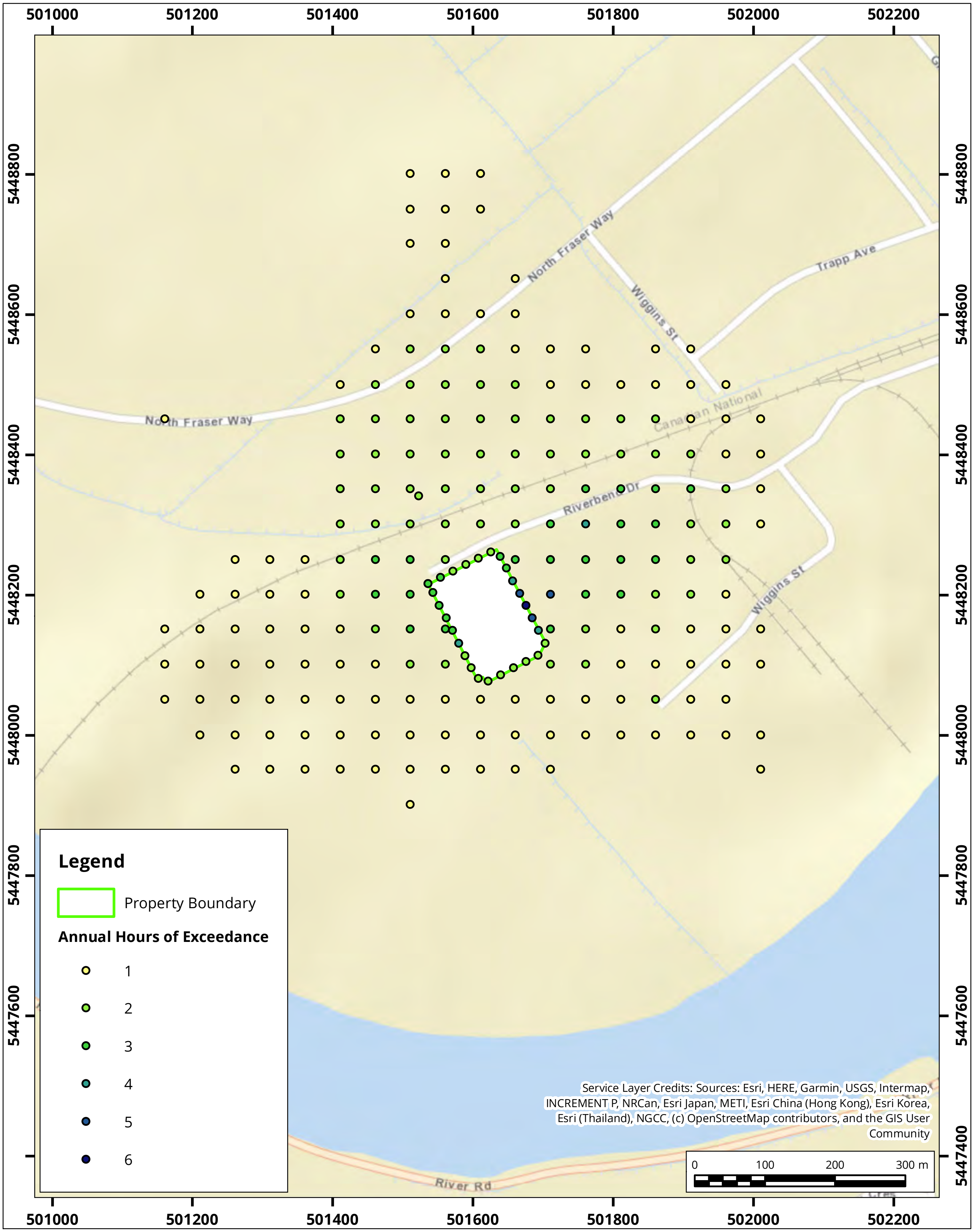
True North

Background Concentration = 5.2 µg/m³
Metro Vancouver Objective = 183 µg/m³

Project #: 1702445

Drawn by: DJH	Figure: 9
Approx. Scale:	1:150,000
Date Revised:	May 6, 2020

Map Document: C:\GIS Temp - Copy\1702445\1702445_Burnaby_WTE_Contour_Figure_Template_181109-CAL-W10D-DJH.mxd



Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

Maximum annual hours of exceedance of the 1-hour SO_2 2020 CAAQS (183 µg/m³)

True North

Drawn by: DJH

Figure: 10

Approx. Scale: 1:7,500

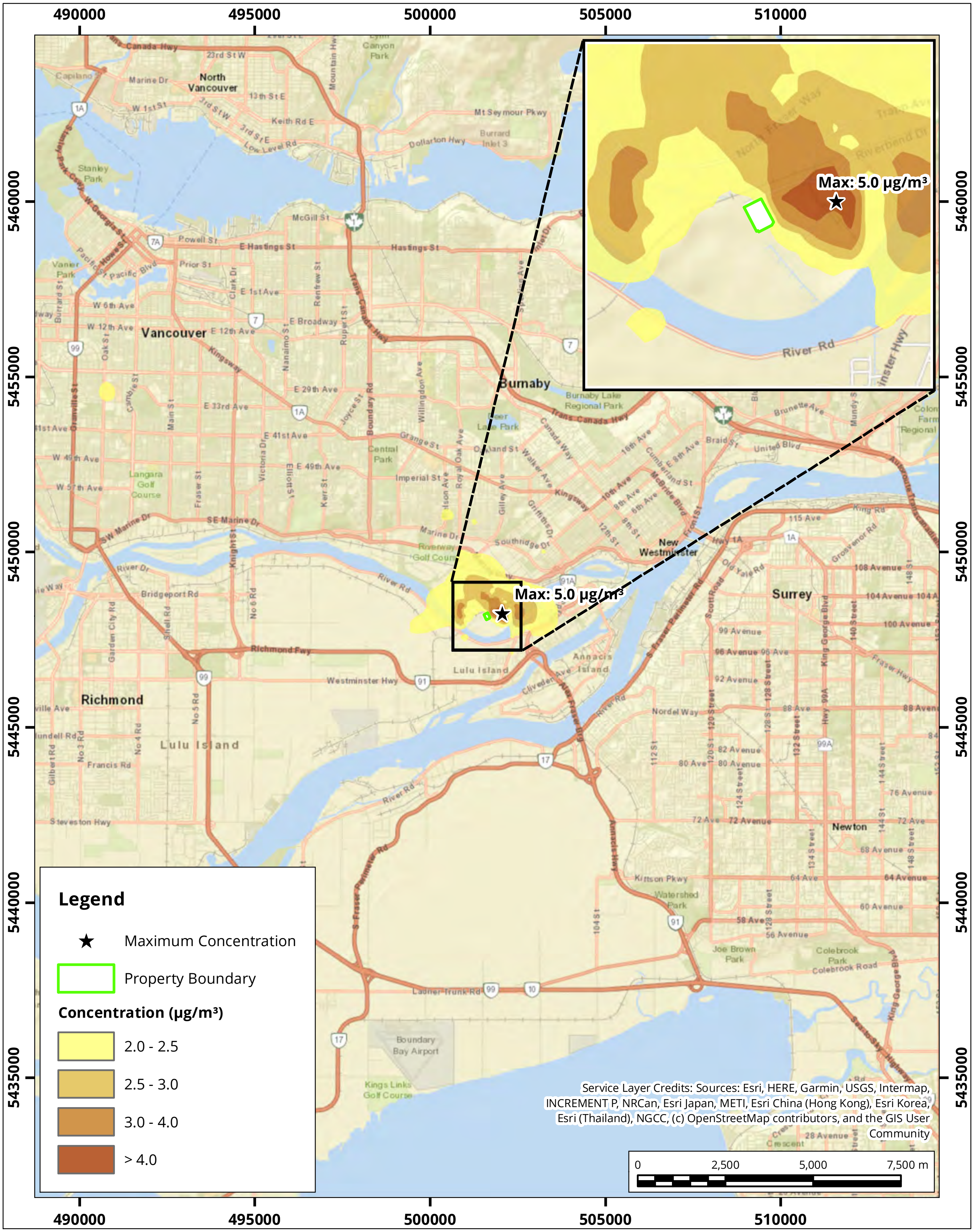
Date Revised: May 5, 2020

Map Projection: NAD 1983 UTM Zone 10N

Waste-To-Energy Facility - Burnaby, British Columbia

Project #: 1702445

Map Document: C:\GIS Temp - Copy\1702445\1702445_Burnaby_WTE_Contour_Figure_Exceedance_200313.mxd



Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

Predicted annual average SO_2 concentrations, with background

Permit Scenario

Map Projection: NAD 1983 UTM Zone 10N

Waste-To-Energy Facility - Burnaby, British Columbia

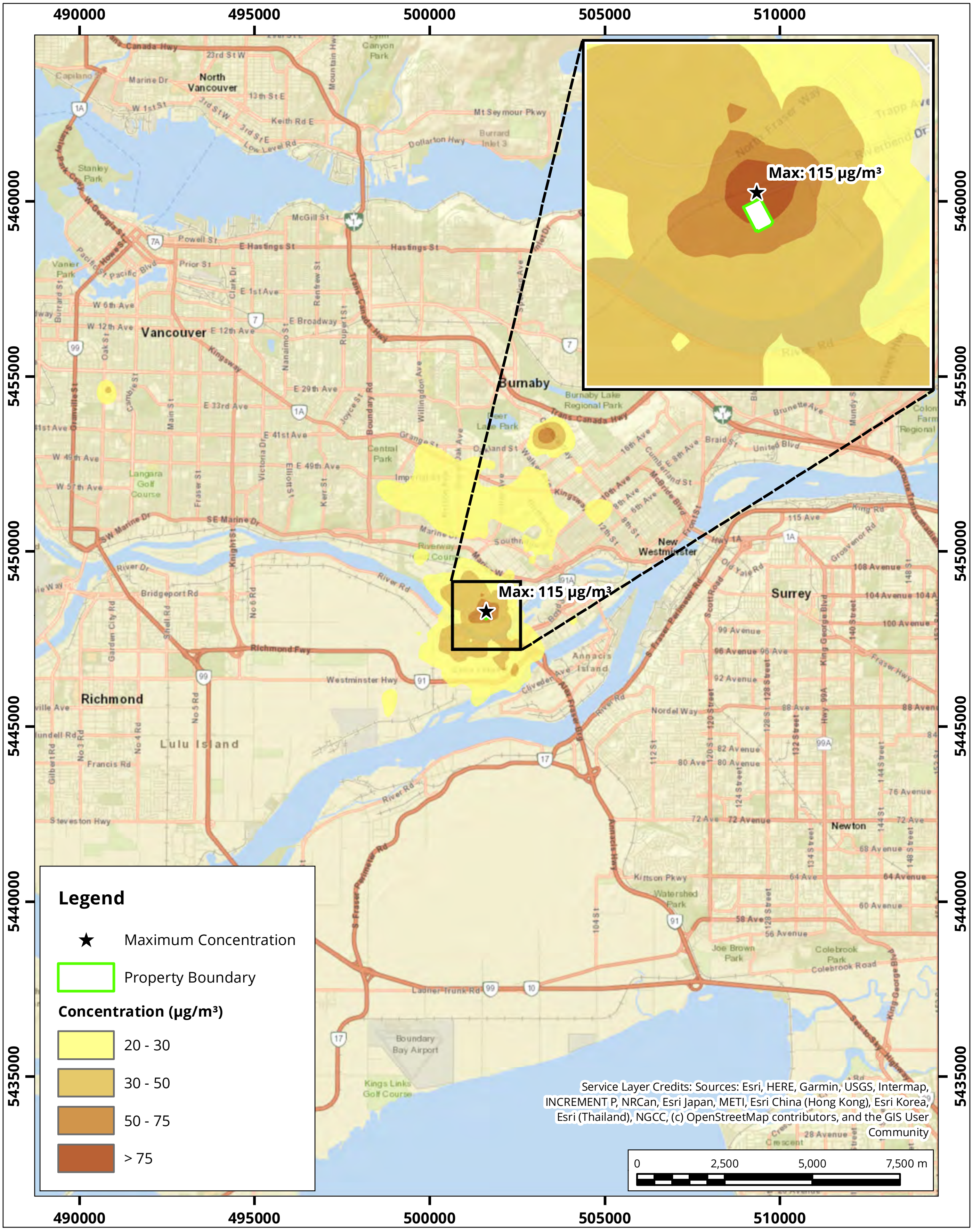
True North

Background Concentration = 1.1 µg/m³
Metro Vancouver Objective = 13 µg/m³

Project #: 1702445

Drawn by: DJH	Figure: 11
Approx. Scale:	1:150,000
Date Revised:	May 5, 2020

Map Document: C:\GIS Temp - Copy\1702445\1702445_Burnaby_WTE_Contour_Figure_Template_181109-CAL-W10D-DJH.mxd



Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

Maximum predicted 1-hour HCl concentrations

Permit Scenario

Map Projection: NAD 1983 UTM Zone 10N

Waste-To-Energy Facility - Burnaby, British Columbia

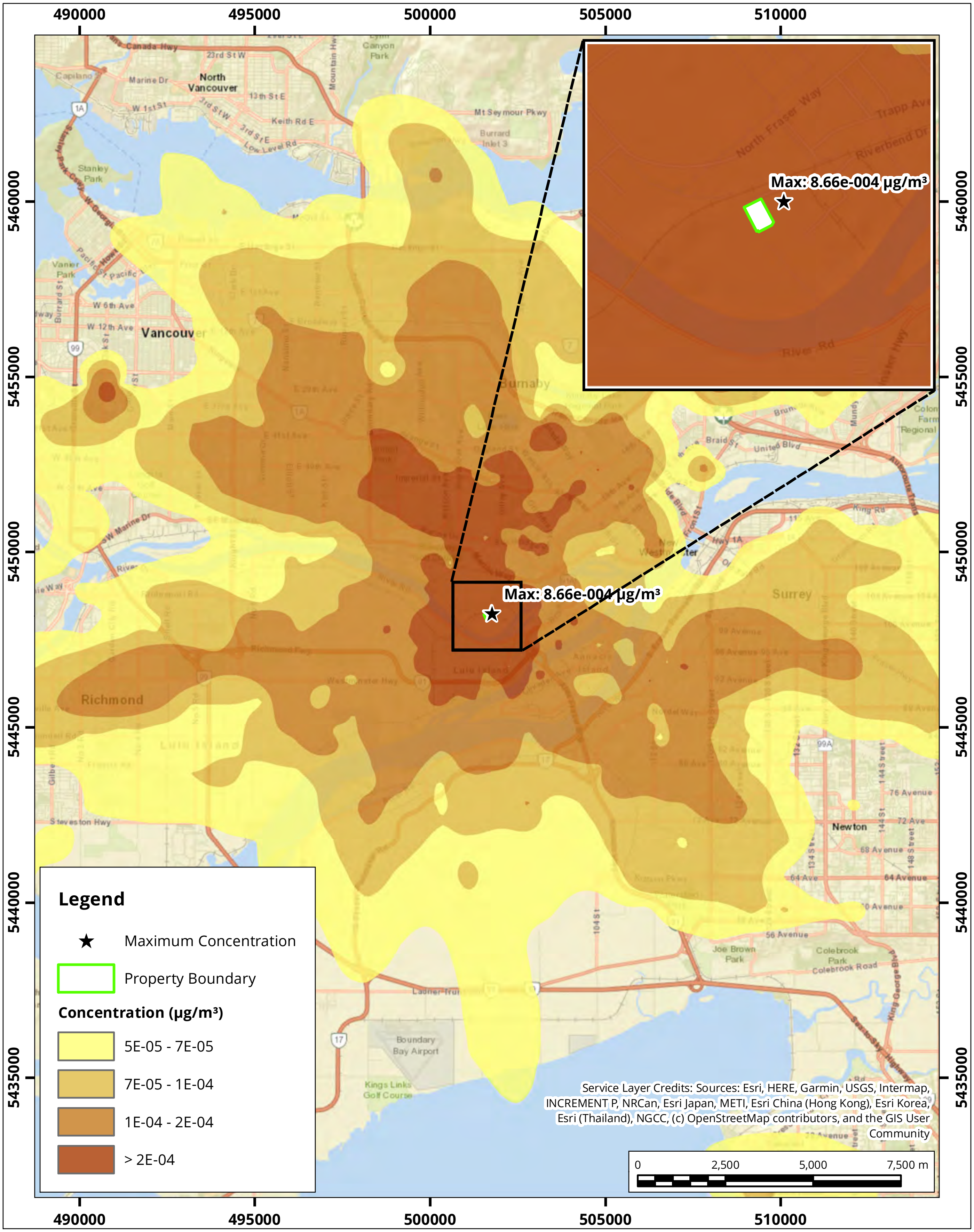
True North

Reference Objective from Alberta Parks Ambient Air Quality Objectives (adopted from Texas) = 75 µg/m³

Project #: 1702445

Drawn by: DJH	Figure: 12
Approx. Scale:	1:150,000
Date Revised:	May 5, 2020

Map Document: C:\GIS Temp - Copy\1702445\1702445_Burnaby_WTE_Contour_Figure_Template_181109-CAL-W10D-DJH.mxd



Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

Maximum predicted 24-hour PAH concentrations

Permit Scenario

Map Projection: NAD 1983 UTM Zone 10N

Waste-To-Energy Facility - Burnaby, British Columbia

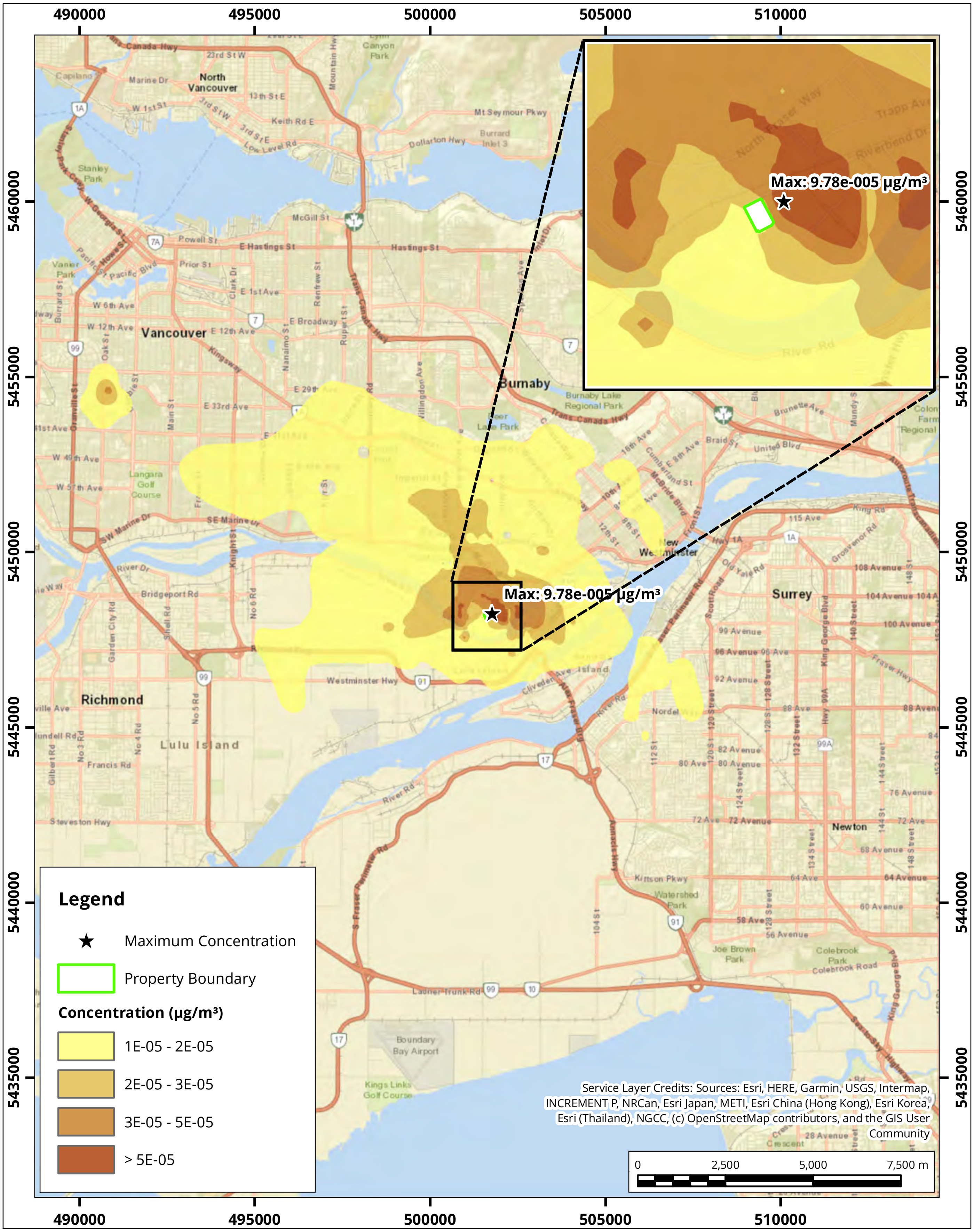
True North

Reference Objective from Ontario Ambient Air Quality Criteria (Health Limiting Effect) = 5E-05 µg/m³

Project #: 1702445

Drawn by: DJH	Figure: 13
Approx. Scale:	1:150,000
Date Revised:	May 5, 2020

Map Document: C:\GIS Temp - Copy\1702445\1702445_Burnaby_WTE_Contour_Figure_Template_181109-CAL-W10D-DJH.mxd



Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

Predicted annual average PAH concentrations

Permit Scenario

Map Projection: NAD 1983 UTM Zone 10N

Waste-To-Energy Facility - Burnaby, British Columbia

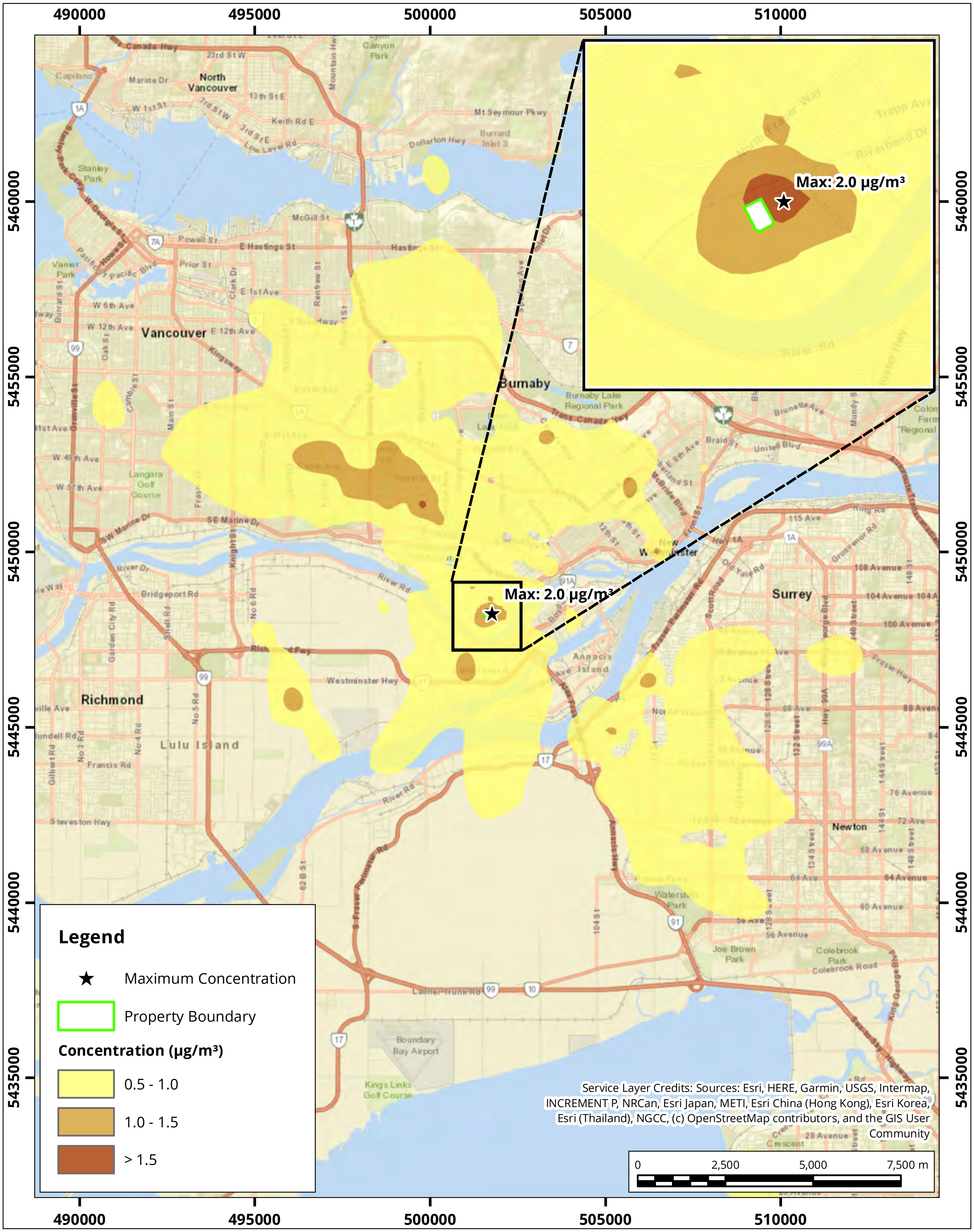
True North

Reference Objective from Ontario Ambient Air Quality Criteria (Health Limiting Effect) = 1E-05 µg/m³

Project #: 1702445

Drawn by: DJH	Figure: 14
Approx. Scale:	1:150,000
Date Revised:	May 5, 2020

Map Document: C:\GIS Temp - Copy\1702445\1702445_Burnaby_WTE_Contour_Figure_Template_181109-CAL-W10D-DJH.mxd



Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

Maximum predicted 24-hour $PM_{2.5}$ concentrations, without background

Permit Scenario

Map Projection: NAD 1983 UTM Zone 10N

Waste-To-Energy Facility - Burnaby, British Columbia

True North

Background Concentration = 16.5 µg/m³
Metro Vancouver Objective = 25 µg/m³

Project #: 1702445

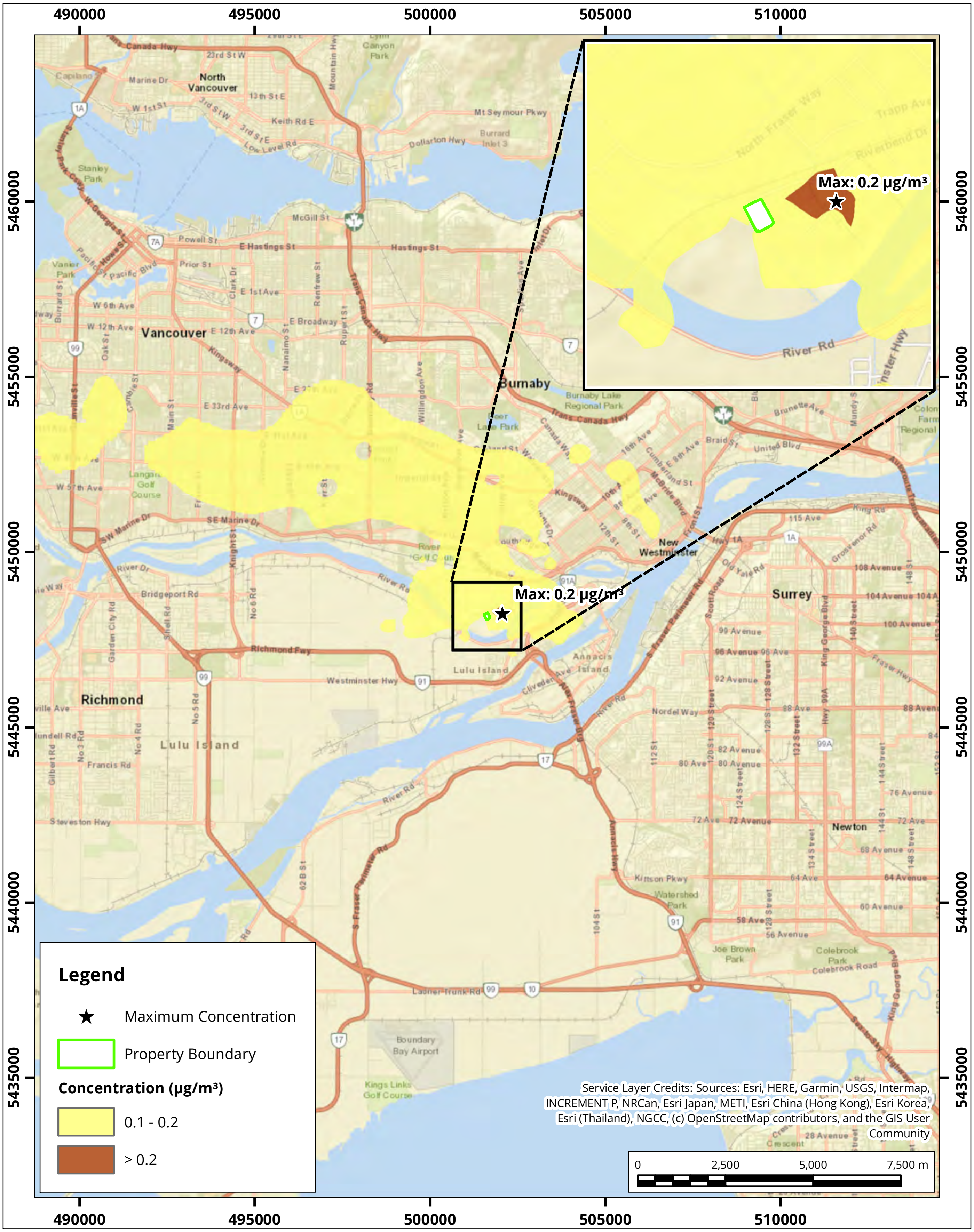
Drawn by: DJH

Figure: 15

Approx. Scale: 1:150,000

Date Revised: May 5, 2020

Map Document: C:\GIS Temp - Copy\1702445\1702445_Burnaby_WTE_Contour_Figure_Template_181109-CAL-W10D-DJH.mxd



Predicted annual average $PM_{2.5}$ concentrations, without background

Permit Scenario

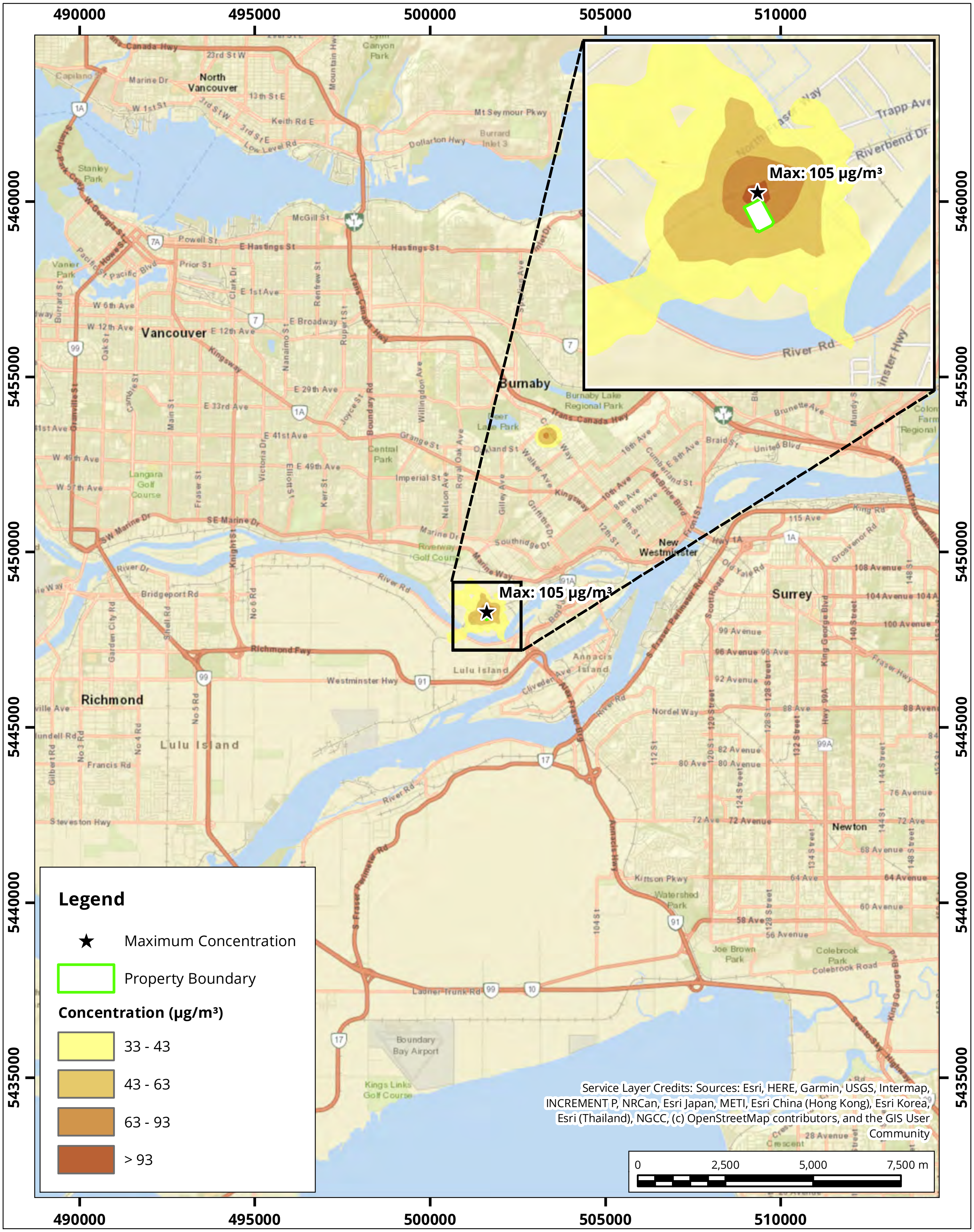
Map Projection: NAD 1983 UTM Zone 10N
Waste-To-Energy Facility - Burnaby, British Columbia

True North

Background Concentration = 5.9 µg/m³
Metro Vancouver Objective = 8 µg/m³
Project #: 1702445

Drawn by: DJH	Figure: 16
Approx. Scale:	1:150,000
Date Revised:	May 5, 2020

Map Document: C:\GIS Temp - Copy\1702445\1702445_Burnaby_WTE_Contour_Figure_Template_181109-CAL-W10D-DJH.mxd



Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

Maximum predicted 1-hour CO concentrations, without background

Permit Scenario

Map Projection: NAD 1983 UTM Zone 10N

Waste-To-Energy Facility - Burnaby, British Columbia

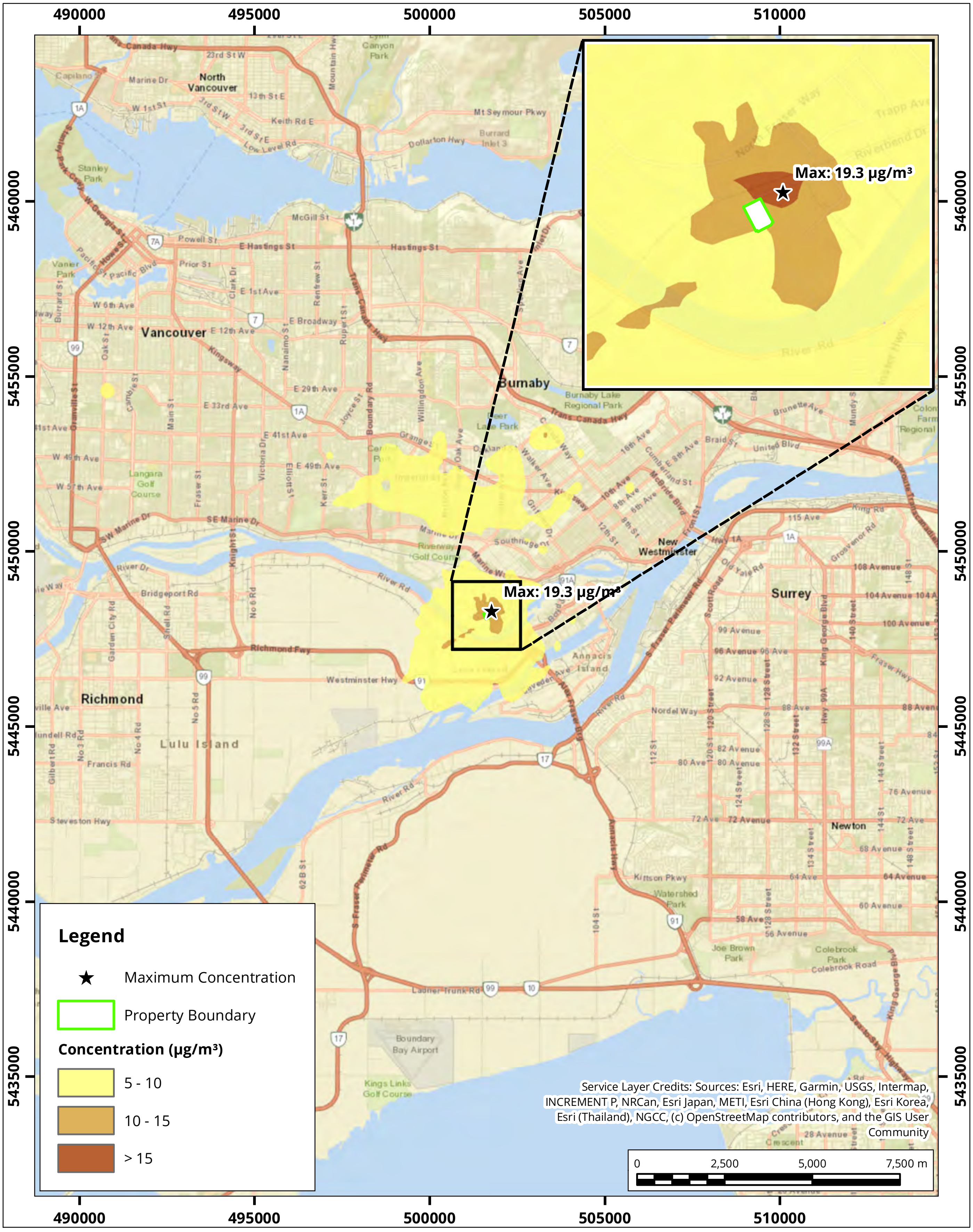
True North

Background Concentration = 607 µg/m³
Metro Vancouver Objective = 30,000 µg/m³

Project #: 1702445

Drawn by: DJH	Figure: 17
Approx. Scale:	1:150,000
Date Revised:	May 5, 2020

Map Document: C:\GIS Temp - Copy\1702445\1702445_Burnaby_WTE_Contour_Figure_Template_181109-CAL-W10D-DJH.mxd



Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

Maximum predicted 8-hour CO concentrations, without background

Permit Scenario

Map Projection: NAD 1983 UTM Zone 10N

Waste-To-Energy Facility - Burnaby, British Columbia

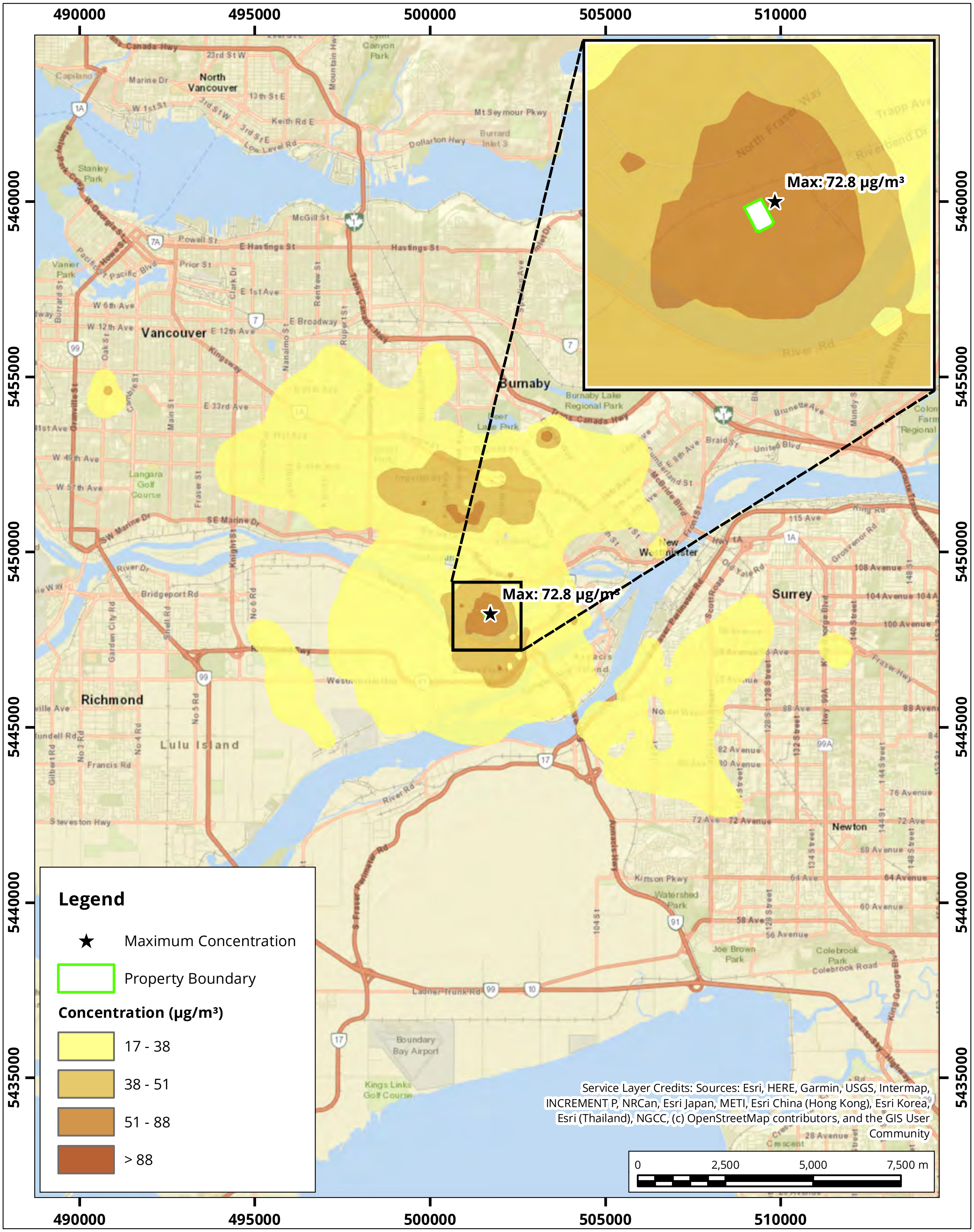
True North

Background Concentration = 560 µg/m³
Metro Vancouver Objective = 10,000 µg/m³

Project #: 1702445

Drawn by: DJH	Figure: 18
Approx. Scale:	1:150,000
Date Revised:	May 5, 2020

Map Document: C:\GIS Temp - Copy\1702445\1702445_Burnaby_WTE_Contour_Figure_Template_181109-CAL-W10D-DJH.mxd



Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

98th percentile predicted daily maximum 1-hour NO_2 concentrations, without background

Permit Scenario

Map Projection: NAD 1983 UTM Zone 10N

Waste-To-Energy Facility - Burnaby, British Columbia

True North

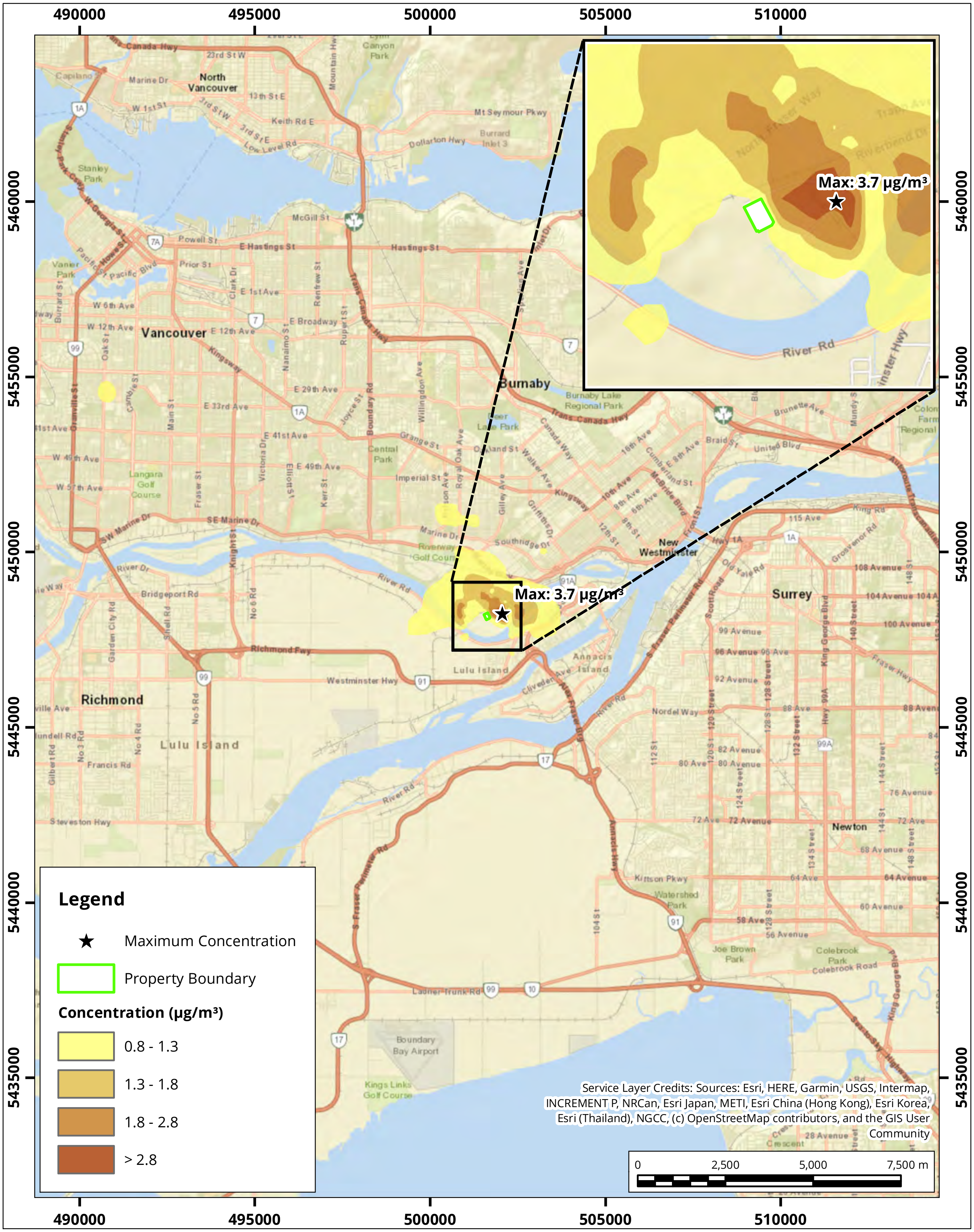
Background Concentration = 62.4 µg/m³

2020 CAAQS = 113 µg/m³; 2025 CAAQS = 79 µg/m³

Project #: 1702445

Drawn by: DJH	Figure: 19
Approx. Scale:	1:150,000
Date Revised:	May 5, 2020

Map Document: C:\GIS Temp - Copy\1702445\1702445_Burnaby_WTE_Contour_Figure_Template_181109-CAL-W10D-DJH.mxd



Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

Predicted annual average NO_2 concentrations, without background

Permit Scenario

Map Projection: NAD 1983 UTM Zone 10N

Waste-To-Energy Facility - Burnaby, British Columbia

True North

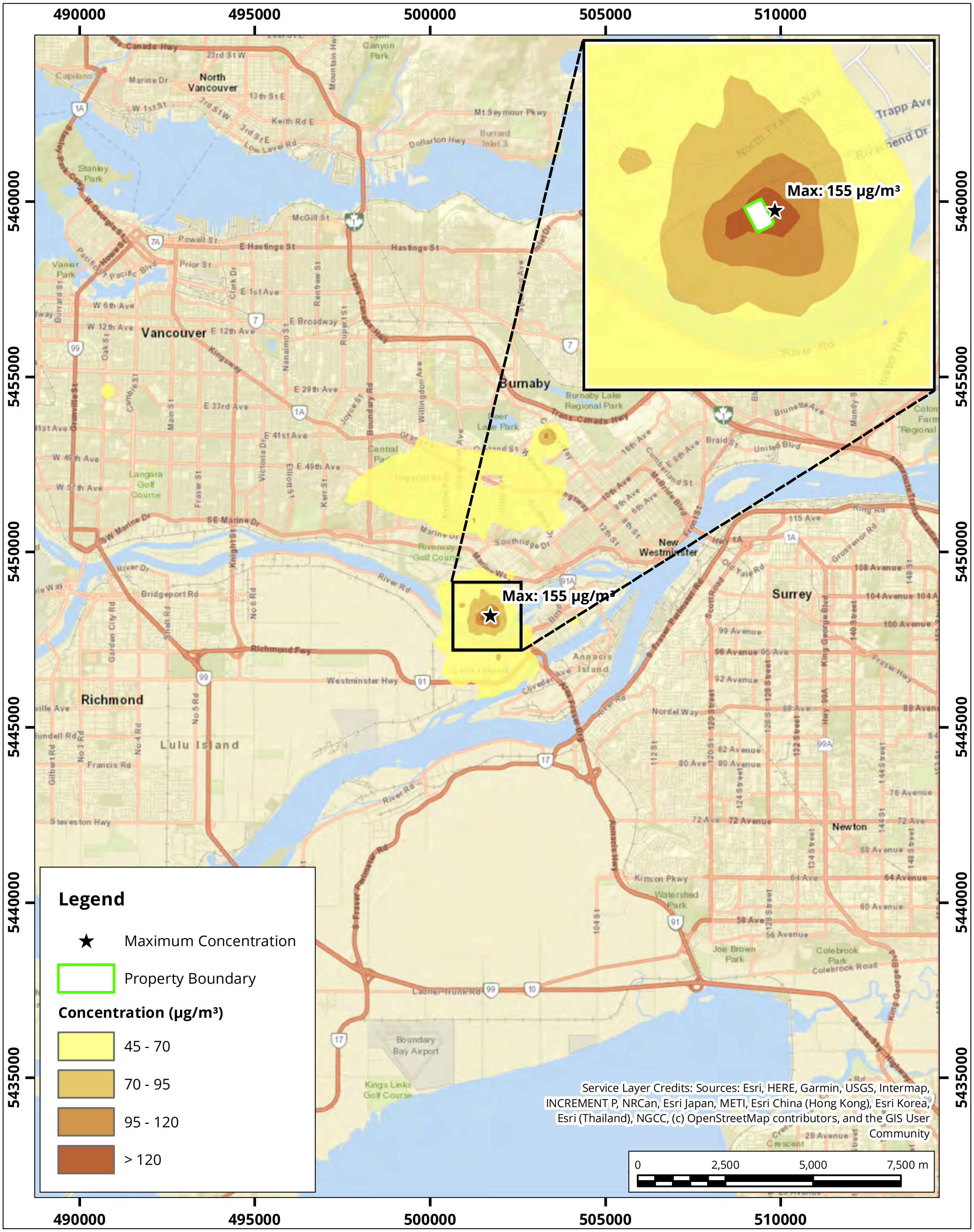
Background Concentration = 25.2 µg/m³

Metro Vancouver Objective = 40 µg/m³

Project #: 1702445

Drawn by: DJH	Figure: 20
Approx. Scale:	1:150,000
Date Revised:	May 6, 2020

Map Document: C:\GIS Temp - Copy\1702445\1702445_Burnaby_WTE_Contour_Figure_Template_181109-CAL-W10D-DJH.mxd



Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

98th percentile predicted daily maximum 1-hour SO_2 concentrations, with background

Permit Scenario

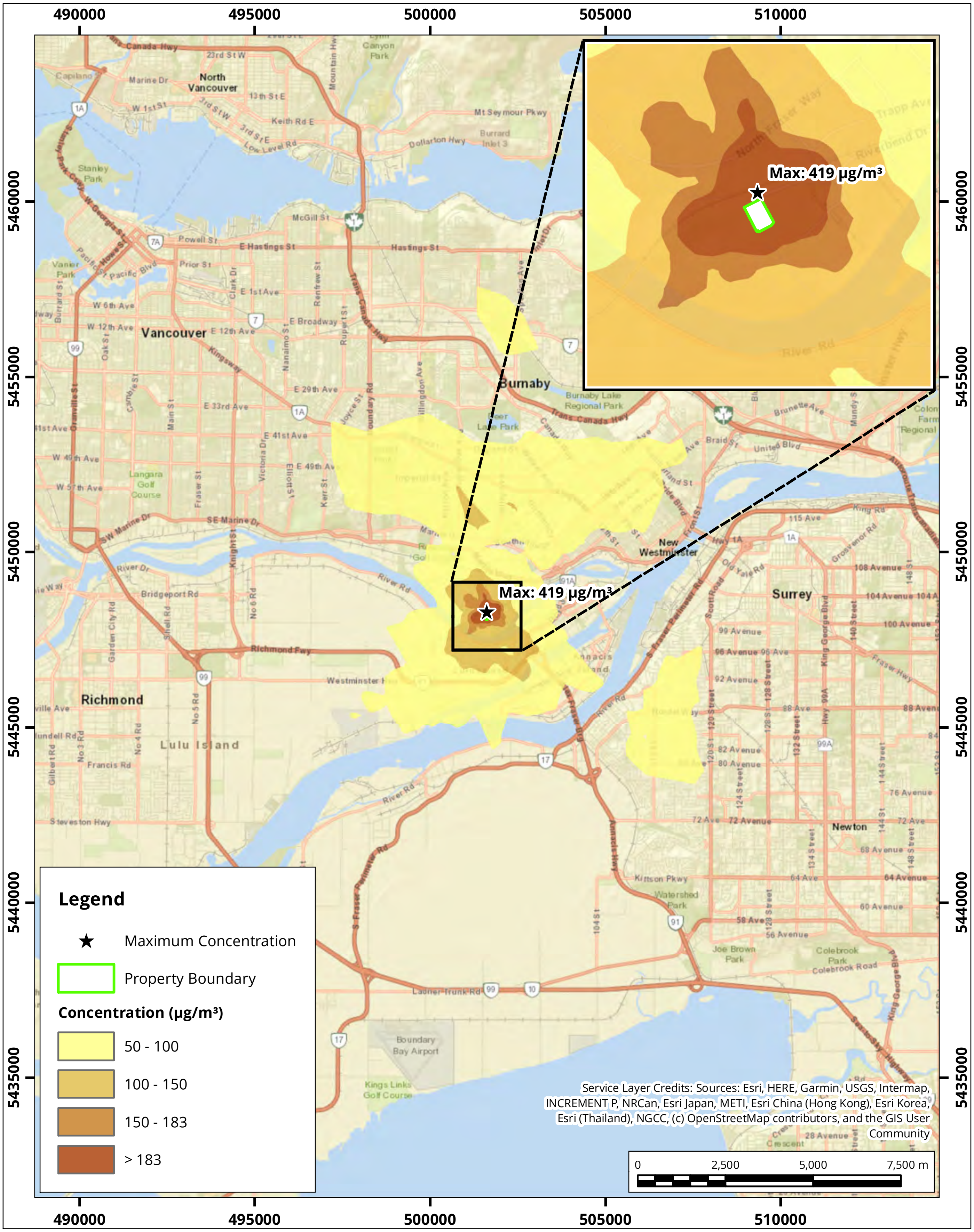
Map Projection: NAD 1983 UTM Zone 10N
Waste-To-Energy Facility - Burnaby, British Columbia

True North

Background Concentration = 5.2 µg/m³
Metro Vancouver Objective = 183 µg/m³
Project #: 1702445

Drawn by: DJH	Figure: 21
Approx. Scale:	1:150,000
Date Revised:	May 6, 2020

Map Document: C:\GIS Temp - Copy\1702445\1702445_Burnaby_WTE_Contour_Figure_Template_181109-CAL-W10D-DJH.mxd



Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

Predicted maximum 1-hour SO_2 concentrations, without background

Permit Scenario

Map Projection: NAD 1983 UTM Zone 10N

Waste-To-Energy Facility - Burnaby, British Columbia

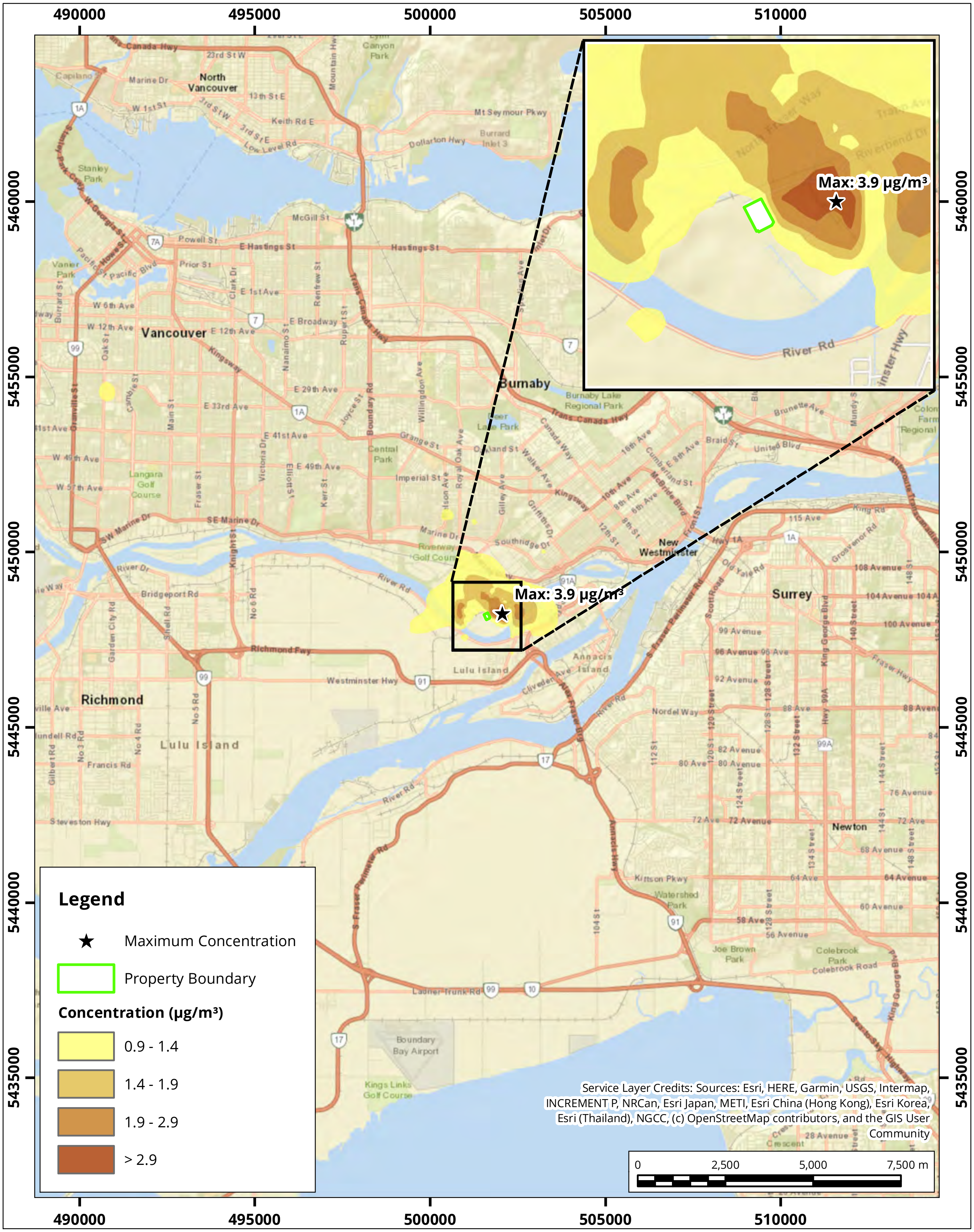
True North

Background Concentration = 5.2 µg/m³
Metro Vancouver Objective = 183 µg/m³

Project #: 1702445

Drawn by: DJH	Figure: 22
Approx. Scale:	1:150,000
Date Revised:	May 6, 2020

Map Document: C:\GIS Temp - Copy\1702445\1702445_Burnaby_WTE_Contour_Figure_Template_181109-CAL-W10-DJH.mxd



Service Layer Credits: Sources: Esri, HERE, Garmin, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), NGCC, (c) OpenStreetMap contributors, and the GIS User Community

Predicted annual average SO_2 concentrations, without background

Permit Scenario

Map Projection: NAD 1983 UTM Zone 10N

Waste-To-Energy Facility - Burnaby, British Columbia

True North

Background Concentration = 1.1 µg/m³

Metro Vancouver Objective = 13 µg/m³

Project #: 1702445

Drawn by: DJH	Figure: 23
Approx. Scale:	1:150,000
Date Revised:	May 6, 2020

Map Document: C:\GIS Temp - Copy\1702445\1702445_Burnaby_WTE_Contour_Figure_Template_181109-CAL-W10D-DJH.mxd