Air Quality Characterization of the Peace region of Northeast BC

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Executive Summary

This report provides a characterization of ambient air quality in the Peace region of BC. It is based on monitored ambient air quality for up to 15 years (1998-2013) and dispersion modelling based primarily on 2010 assessments of pollutant emissions and meteorology. It compares ambient air quality to 2013 BC air quality objectives. The two prime messages from this study are the following:

1. BC Ministry of Environment health-based air quality objectives were compared to ambient concentrations of three pollutants (sulfur dioxide (SO_2), fine particulate matter ($PM_{2.5}$) and nitrogen dioxide (NO_2)) in the Peace region of northeast British Columbia. The SO_2 hourly objective of 450 µg/m3 was rarely exceeded at the four air quality stations where continuous monitoring of SO_2 occurred in the Peace region. The highest number of exceedances was observed at the remote Pine River Gas Plant where the SO_2 objective was exceeded for about 1 hour per year, on average. No SO_2 exceedances were recorded at the air quality monitoring station in the nearest community (Pine River Hasler). The SO_2 objective was also only rarely exceeded at Taylor townsite (about 1 hour every eight years) and at Taylor South Hill, where only one year of monitoring data was available. No hourly NO_2 monitoring data was available for comparison to objectives.

   The communities targeted in this report are Taylor, Taylor South Hill, Fort St John, Dawson Creek, Chetwynd, Hudson's Hope, Buick and Blueberry #205. Based on predictions provided by a Human Health Risk Assessment air quality dispersion modelling study, no one-hour or 24-hour SO_2, NO_2 or $PM_{2.5}$ health based objectives would have been exceeded in any of these communities.

2. Hydrogen sulfide (H_2S) is responsible for considerable annoyance and concern in communities near sources such as pulp mills, sour gas wells or tanks containing petroleum liquids. MoE provides odour-based objectives for hydrogen sulfide (H_2S) based largely on thresholds at which humans can detect its odour. These thresholds are at very low concentrations. There is no evidence of health effects at these odour thresholds, though eye irritation, respiratory effects and headaches may occur above these thresholds (U.S. Department of Health and Human Services, 2014). It should be noted that the odour-based 1 hour threshold for TRS/H_2S is an order of magnitude less than the health based exposure limits that were referred to in the recently released HHRA report. An annual exposure limit is also referred to the HHRA report – indications are that the monitored results are well below this.

In this report, the BC Ministry of Environment odour-based air quality objectives were compared to ambient concentrations of hydrogen sulfide (H_2S) in the Peace region. Based on monitored data, the one-hour H_2S odour-based objectives were exceeded each year between 1998 and 2013. These exceedances ranged from 0.1% and 10% of the time at both Taylor Townsite and the Pine River Gas Plant, and to a lesser extent at the Pine River Hasler and Taylor South Hill. Model predictions of H_2S were not used.

Emissions of air pollutants from oil and gas activity in northeast BC are a health concern to the public. To address this concern, the Northeast Air Monitoring project was formed to monitor, report and assess air quality in Northeast BC, to engage the local community in this process and to establish a long-term air monitoring network. The project is a collaborative effort of the BC Ministry of Environment (MoE), the BC Oil and Gas Commission (OGC), the BC Ministry of Natural Gas Development (MNGD), the Canadian Association of Petroleum Producers (CAPP), and Spectra Energy. Phase I of this project led to the installation of three new portable air quality monitoring stations in the Peace region of NE BC that will provide additional pollutant information in the Peace for many years. An unrelated study, the Human Health Risk Assessment (HHRA), recently focussed on the community impacts of air pollutants in the Peace region. The aim of the HHRA study was to estimate the risk to human health of oil and gas activity.

This report is the result of a study that compares ambient concentrations of air contaminants to BC air quality objectives. It has been developed to support Phase II of the Northeast Air Quality Monitoring Project by providing an estimate of the current air pollutant concentrations that could impact health or that have offensive odours, particularly in communities. It is mainly based upon information from two sources:

- Dispersion modelling of air pollutants conducted as part of the Human Health Risk Assessment (HHRA) project
- Air pollutant data from monitoring networks operated by government, industry and universities in both rural and urban areas of the Peace.

A key question from the public is "Is the air that I am breathing safe?" To help answer this question, this report focusses on four important air pollutants:

- Sulfur dioxide (SO2). Main sources are gas plants.
- Total Reduced Sulfur (TRS), measured as hydrogen sulfide (H2S). Main sources are oil and gas facilities as well as anaerobic digestion.
- Particulate matter (PM2.5), largely from sources such as domestic wood heating in communities and the forest industry
- Nitrogen dioxide, produced from combustion.

Acrolein and formaldehyde will also be discussed.

There are several limitations of this air quality study.

- Multi-year hourly ambient monitoring data (SO2 and H2S) was only available from four air quality monitoring stations: Pine River Gas Plant, Pine River Hasler, Taylor Townsite and Taylor South Hill.
- Comparisons with monitored data suggested that the HHRA dispersion modelling tended to over-predict SO2 concentrations.
- Modelled pollutant concentrations are based on 2010 emission data, supplemented by 2011 data. Emission rates may be different in later years.

Introduction

For this report, *air quality characterization* is defined as a description of the average and extreme ambient concentrations of certain air pollutants of concern in a specific area during a specific time period. The report was prepared in support of the North East Air Monitoring project, and presents an overall estimate of the ambient air quality situation in the Peace region. It is based on:

- observational evidence of pollutant concentrations for the period 1998 to 2013 obtained from monitoring
- air quality dispersion modelling from the Human Health Risk Assessment that used meteorology and emission inventory information from 2010, supplemented by inventory data from 2011.

The project is a collaborative effort of the BC Ministry of Environment (MoE), the BC Oil and Gas Commission (OGC), the BC Ministry of Natural Gas Development (MNGD), the Canadian Association of Petroleum Producers (CAPP), and Spectra Energy. It was initiated to respond to increased demand for air quality information in northeastern British Columbia due to public concern about possible impacts from oil and gas activity on human health and the environment. This project focusses on the Peace region, where Fort St. John is the largest community.

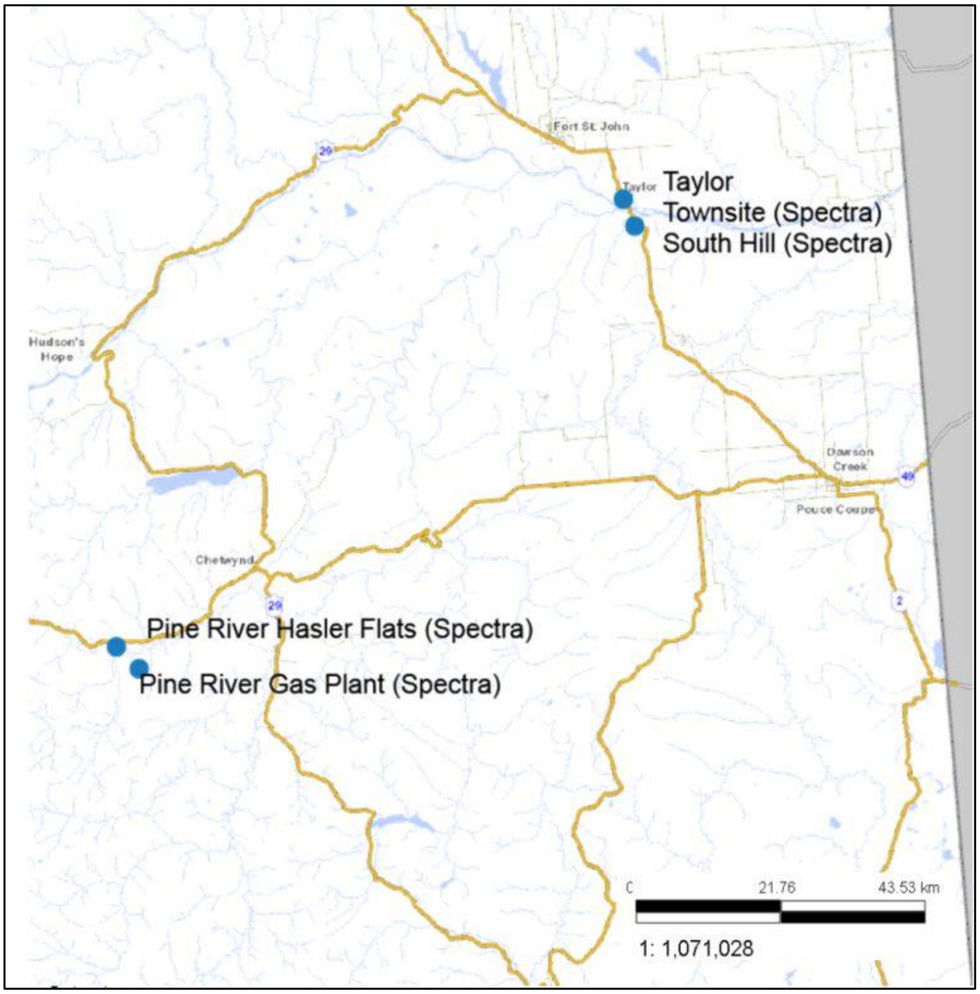

Figure 1 The focus of this report is the Peace Region of northeast BC. Blue dots are the four long term air quality monitoring sites operated by Spectra Energy that measured hourly concentrations of SO2 and H2S in 2013.

Geography

Wide plains and rolling hills typify much of the Peace region, much of which is within the BC Agricultural Land Reserve (Provincial Agricultural Land Commission 2014) and is sparsely populated. Atmospheric dispersion of pollutants is expected to be higher in Peace communities than in similar-sized communities west of the Rockies where deeper, narrower valleys tend to restrict atmospheric dispersion, therefore increasing pollution concentrations (Brook et al 2014). The region has a dry, continental climate, with warm summers and very cold winters. The largest population centres are Fort St. John, Dawson Creek and Chetwynd. Fort St. John temperatures range from minus 47°C to plus 34°C and average 2°C. Annual precipitation averages 445 millimetres at Fort St. John (Environment Canada 2014-1).

Data sources

Emission Data Sources

The National Pollutant Release Inventory (NPRI) is Canada's legislated, publicly-accessible inventory of pollutant releases to air. The Human Health Risk Assessment (HHRA) project developed emission inventories for their dispersion modelling, based on emission data from the NPRI from 2010, supplemented by 2011 data. Other emission data was provided directly by industry (David Chadder, personal communication). HHRA dispersion modelling, based on this emission inventory, was an essential scientific tool in the air quality characterization, particularly in those vast areas of the Peace region where no continuous air quality monitoring exists. Modelling was completed by Intrinsik Consultants of Calgary in 2014 through a contract with the BC Ministry of Health.

Ambient Monitoring Data Sources

In the Peace region, ambient sulfur dioxide (SO2) and total reduced sulfur/ hydrogen sulfide (TRS/H2S) concentrations were measured for up to sixteen years during the period 1998-2013 at four continuous hourly monitoring stations: Pine River Gas Plant, Pine River Hasler, Taylor townsite and Taylor south hill (Fig. 1). These data were collected by industry either as a requirement of their environmental permit or voluntarily. A fifth continuous monitoring station at the Fort St. John North Peace Cultural Centre measuring PM10 was operated by the Ministry of Environment (MoE). Temporary hourly monitoring from a number of other locations including the MoE mobile air monitoring laboratory (MAML) was also collected. Both industrial and MoE hourly data were stored in the MoE database in real time and subsequently validated.

Passive monitoring stations operated by industry or universities measured average concentrations of a range of pollutants at sites throughout the Peace region. These data were provided by the University of Northern BC and industry[1]. Passive monitoring only provided monthly (or longer) average concentrations.

Ambient air quality analysis in this report compares measured concentrations to air quality objectives. Table 1 lists the ambient air quality objectives in effect in 2013.

[1] Spectra Resources, Shell and CNRL

Table 1 Summary of relevant 2013 ambient air quality objectives in BC and some other jurisdictions[2].

Pollutant	Averaging Period	2013 Air Quality Objectives ($\mu g/m^3$)	Standard-setting jurisdiction
SO2	1 hour	450	BC
	1 hour	450	Alberta
	24 hour	160	BC
	24 hour	125	Alberta
NO2	1 hour	400	BC
	24 hour	200	
	Annual	100	
PM2.5	24 hour	25[3]	BC
	Annual	8	BC
Total reduced sulfur (TRS) measured as H2S	1 hour	7	BC[4]
	24 hour	3	
	1 hour	14	Alberta
	24 hour	4	
Acrolein	1 hour	4.4*	Ontario & Alberta
	24 hour	0.4*	
Formaldehyde	1 hour	60	BC
	1 hour	65	Alberta

Emission sources and types

This section identifies emissions sources and types in the Peace region outlined in green in Figure 2.

Emission sources in the oil and gas sector include condensate tanks, gas processing facilities, venting and flaring, compressor stations, construction activity, dehydrators, vehicles and engines. Significant pollutant types emitted from these and other oil and gas industry sources include sulfur dioxide, total reduced sulfur (TRS), volatile organic compounds (VOC) and nitrogen oxides. Total reduced sulphur (TRS) includes hydrogen sulphide, mercaptans, dimethyl sulphide, dimethyl disulphide and other sulphur compounds. Appendix 4 lists other significant emissions from the oil and gas sector and explains H2S and TRS measurement[5].

[2] Current BC and Alberta air quality objectives: www.bcairquality.ca/reports/pdfs/aqotable.pdf and environment.gov.ab.ca/info/library/5726.pdf

[3] Achievement based on annual 98th percentile of daily average, over one year.

[4] The H2S odour-based objective will be reviewed to take into account changes needed for TRS from the oil and gas industry. Also, other jurisdictions such as CalEPA and US EPA have other forms of H2S objectives.

[5] Emissions from the oil and gas sector do not necessarily result in the public being exposed to unhealthy concentrations of pollutants. For example, facilities such as the Pine River Gas Plant in the Grizzly Valley operate in natural gas producing areas with a high sour gas composition and emit significant amounts of SO2. However, low population density results in low public exposure to pollutants.

Emission sources from the wood products industry in British Columbia include sawmills and composite wood product facilities such as shingle mills, plywood mills, panel board mills, the wood door and window industry, prefab wooden buildings and outdoor burning of woody debris. Key pollutants emitted from the wood products industry (Environment Canada 2014-2) include volatile organic compounds, particulate matter (PM10 and PM2.5), nitrogen oxides and carbon monoxide. Other important emissions are listed in Appendix 4.

Of all of these pollutants, the Human Health Risk Assessment (HHRA) of Oil and Gas Activities in the Peace region recently identified the five pollutants in Table 2 as chemicals of potential concern due to acute inhalation. Health risks from these pollutants were interpreted by the HHRA based on sources of the emissions, the spatial extent of the pollutant exceedances of objectives, the likelihood of these exceedances and a degree of conservatism incorporated into the assessment (HHRA 2004-1).

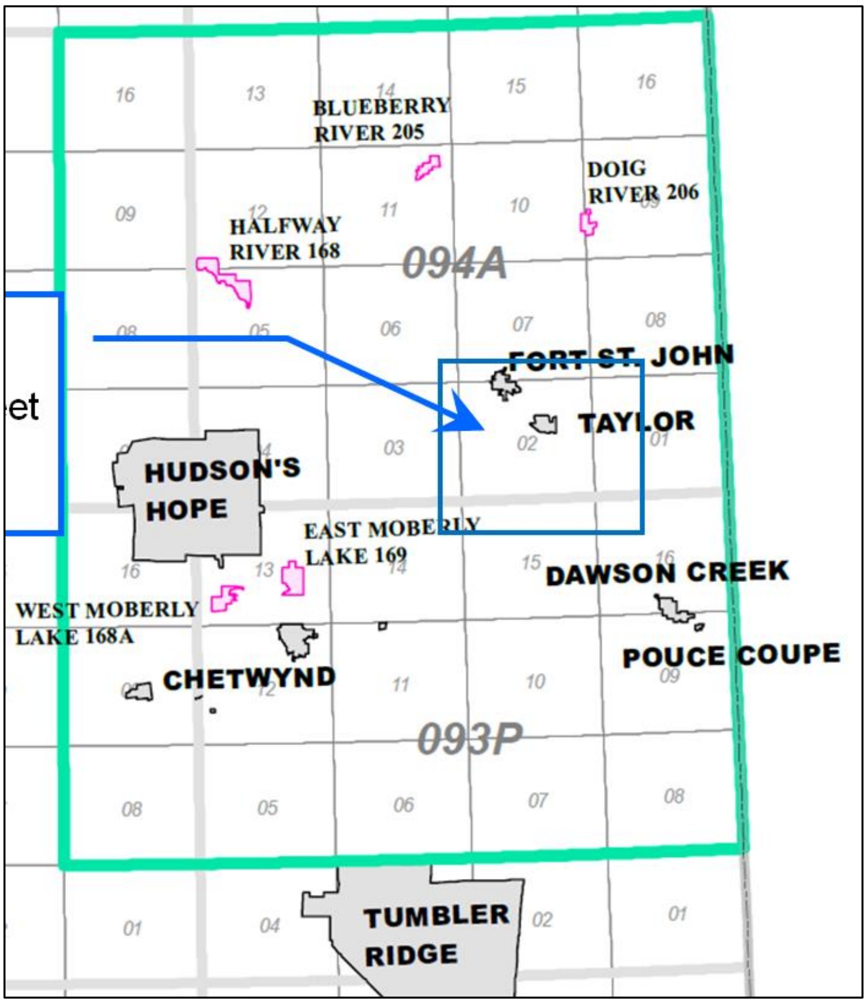

Figure 2 The domain of the HHRA dispersion modelling project.

Table 2 Chemicals of potential concern for acute inhalation risk identified by the report from the HHRA[6]

Pollutant	Main sources in Peace region
Nitrogen dioxide (NO2)	Gas plants, compressor stations, forest industry
Particulate Matter (PM2.5)	Forest industry, domestic heating
Sulfur dioxide (SO2)	Gas plants
Acrolein[7]	Combustion of petroleum fuels.
Formaldehyde[8].	Manufacture of building products and combustion of wood products and other organic compounds.

This report will provide information on ambient concentrations on these five pollutants. Due to public concern about odorous pollutants from oil and gas activity, this report will also provide information on ambient concentrations of H2S.

Characterizing Air Quality based on Monitoring and Modelling Results

This section outlines key results of the comparison of monitored data with the results of atmospheric dispersion modelling that was completed in 2014 through the Human Health Risk Assessment (HHRA 2014-1). Monitoring data from both continuous and passive monitors are used in these comparisons. Pollutant concentrations are generally shown as micrograms per cubic metre (µg/m3) and occasionally as parts per billion (ppb).

Dispersion Modelling in the Peace

Atmospheric dispersion modeling is a mathematical simulation of how air pollutants disperse in the atmosphere. Computer programs are used to solve the mathematical equations and algorithms which simulate the pollutant dispersion in the atmosphere. Dispersion models are used to predict the ambient concentration of air pollutants originating from sources such as industrial activity, domestic wood heating, vehicular traffic or chemical releases. HHRA dispersion modelling provided estimates of the potential impact of all major emission sources, including emissions from oil and gas activity. The green line in Figure 2 outlines the domain of the HHRA modelling project.

HHRA modelling was based on one of two scenarios:

1. Emissions from the oil and gas industry alone
2. Emissions from the oil and gas industry plus other emission sources, such as domestic heating or pulp and paper plants, and called the *cumulative scenario*.

Table 9 in Appendix 7 summarizes the maximum concentrations of SO2 and other pollutants predicted at 29 communities in the Peace, based on HHRA dispersion modelling (cumulative scenario) using estimated emissions in 2010, supplemented by emissions in 2011. Table 9 also contains 98th and 99th percentiles based on hourly averages or 24 hour averages over an entire year (not maximum daily averages over a year). Units are micrograms per cubic metre (µg/m3). These results are displayed in map form for sulfur dioxide (SO2), nitrogen dioxide (NO2), fine particulate matter (PM2.5), formaldehyde, and acrolein in Appendix 3.

The following is a summary of the results of the analysis of the predicted values of the pollutants in Table 2 as well as TRS/H2S.

[6] Slide presentation to HHRA Steering Committee Meeting 25 June 2014 , slide # 15.
[7] Acrolein is toxic and is a strong irritant for the skin, eyes, and nasal passages.
[8] Formaldehyde is known to be a human carcinogen (National Toxicology Program 2011)

Sulfur dioxide

Health Impacts:

Current scientific evidence links short-term exposures to SO2, ranging from 5 minutes to 24 hours, with an array of adverse respiratory impacts including bronchoconstriction and increased asthma symptoms. These effects are particularly important for asthmatics at high breathing rates (e.g., while exercising). Studies also show a connection between short-term exposure and increased visits to emergency departments and hospital admissions for respiratory illnesses, particularly in at-risk populations including children, the elderly, and asthmatics (Environmental Protection Agency 2014-1).

Ambient Concentrations:

Based on a comparison of HHRA dispersion modelling results of the oil and gas scenario and the cumulative scenario in Appendix 3, virtually all ambient SO2 appears to originate from the oil and gas industry (HHRA 2014-1).

The location of the maximum point of impact (MPOI) of SO2 was near the Stoddard Gas Plant, 50 km northwest of Fort St John near highway 97 (see Figure 23 in Appendix 3). This MPOI is in an area that has a number of oil and gas sources of SO2 such as sour gas plants. They are not located near a community. Figures 3 through 6 show the measured extreme and annual concentrations of SO2 that were used in the SO2 analysis. Table 3 compares predicted and observed SO2 concentrations.

Table 3 Comparison of extreme hourly SO2 concentrations in micrograms per cubic metre (µg/m3) that were both predicted by modelling (HHRA 2014 -1) and measured at four monitoring stations (BC Ministry of Environment, 2015).

SO2 (1998-2013) Units: **µg/m3**	**Taylor Townsite**	**Taylor South Hill**	**Pine River Gas Plant**	**Pine River Hasler**
Predicted hourly (99th) (2010 & 2011 average)	134	190	91	63
Observed hourly (99th) (2010 & 2011 average)	67	20	121	5.3
Predicted daily (max) (2010 & 2011 average)	36.1	NA	NA	NA
Observed daily (max) (2010 & 2011 average)	37	14	98	11
Average hours per year exceeding hourly objective, with [% of time] (1998-2013)	0.125 hrs [0.0015%]	0.0625 hrs [0.00078%]	1.125 hrs [0.014%]	0 hrs

*Estimate based on the ratio of the predicted hourly and daily concentrations at the Taylor townsite monitoring station.

In Table 3, observed and modelled extremes (hourly and daily) refer to the average of two years (2010 and 2011). The exceptions are exceedances which are averages for 1998 through 2013. The hourly extreme is expressed as the 99th percentile of both predicted and observed values. The daily extreme is the maximum average daily concentration. Predicted values are based on HHRA modelling (cumulative scenario) and from interpolation of the mapped model results in Appendix 3. The 2013 MoE one hour and 24 hour objectives for SO2 were 450 and 160 µg/m3 respectively. There were no exceedances of the 24 hour SO_2 standard.

The following is an analysis of SO_2 concentrations in Tables 3 and 4.

Exceedance of objectives:

- Based on Table 3 monitoring data, the SO_2 hourly objective of 450 µg/m3 was rarely (0 to 0.0015% of the time) exceeded during the period of record from 1998 to 2013 at these four monitoring stations: Taylor Townsite, Taylor South Hill, Pine River Gas Plant and Pine River Hasler.
- Based on monitoring, the 24 hour SO_2 objective of 160 µg/m3 was not exceeded for all years (1998-2013) for all four monitoring stations, though it was almost exceeded at the Pine River Gas Plant in 2013.
- Based on modelling data in Table 5, no daily average concentrations of SO_2 were predicted by HHRA modelling to exceed the 24 hour objective of 160 µg/m3 in the communities of Taylor, Fort St John, Dawson Creek, Chetwynd, Hudson's Hope, Buick, Blueberry #205 and Taylor South Hill.

In the following ambient SO_2 modelling results, extreme SO_2 concentrations are the 99th hourly percentile values:

- Comparing measured concentrations at the four monitored sites to predicted concentrations, HHRA modelling had a bias to over-prediction.
- Hourly HHRA modelling of SO_2 predicted that the largest areal extent of extreme concentrations of SO_2 would occur around Taylor and Fort St John. Extreme concentrations of up to 49 µg/m3 were predicted within 50 kilometres of Taylor. Extreme concentrations up to 98 µg/m3 were predicted within about 30 km of Taylor and up to 196 µg/m3 within 10 to 15 km of Taylor. Table 4 provides more information on areal extent of extreme SO_2 concentrations.
- Near the Pine River Gas Plant, HHRA modelling predicted extreme SO_2 concentrations of up to 98 µg/m3 within 25 km of the plant and up to 196 µg/m3 within 10 km from the plant.
- Near the community of Buick and southeast of Rose Prairie, extreme SO_2 concentrations above 98 µg/m3 and 49 µg/m3 are predicted within 5 and 10 km respectively from nearby industrial sources.
- The maximum extreme concentration of SO_2 in the Peace region was near the Stoddard Gas Plant, 40 km northwest of Fort St. John near highway 97. Extreme SO_2 concentrations of up to 98 µg/m3 were predicted within 5 kilometres of the plant.
- Graphs of passive monitoring data in Appendix 2 show that average long term SO_2 concentrations are generally very low, ranging from 0 to 5 µg/m3 for the following communities: Taylor, Chetwynd, Dawson Creek, Hasler, Stone Creek Road, Houde Road and Groundbirch. The exception is the Groundbirch area, where monthly average concentrations ranged from 2 to 10 µg/m3 from 2010 to 2013.

An air quality advisory program based on elevated SO_2 concentrations could be developed to minimize public health risk in conjunction with industry and the BC Oil and Gas Commission.

Nitrogen dioxide

Health Impacts:

Current scientific evidence links short-term NO_2 exposures, ranging from 30 minutes to 24 hours, with adverse respiratory effects including airway inflammation in healthy people and increased respiratory symptoms in people with asthma. Also, studies show a connection between breathing elevated short-term NO2 concentrations and increased visits to emergency departments and hospital admissions for respiratory issues, especially asthma (Environmental Protection Agency 2014-2).

Ambient Concentrations:

The only NO2 monitored data available was measured by passive monitors from 2010-2013 in the vicinity of Groundbirch. Monthly NO2 concentrations averaged 9 µg/m3. There is no monthly BC objective for NO2, but this value is well below the annual ambient MOE objective of 100µg/m3.

Comparison of HHRA NO2 modelling of the oil and gas scenario with the cumulative scenario suggests that the oil and gas sector is responsible for a portion of the ambient NO2 concentrations in the Peace region, with the remainder related to forestry and other industrial emissions as well as domestic heating emissions. The predictions of the 98th percentiles for 1-hour ambient concentrations for NO2 for each scenario are shown in Figure 25 and 26.
The extreme NO2 concentration from modelling in this summary are expressed as the predicted 98th percentile of the hourly concentrations, whereas the maximum value is the highest hourly concentration predicted.

- The maximum point of impingement of NO2 in the HHRA modelling was reported at the Buick Creek Gas Plant, 70 km N of Fort St. John (Figures 25 in Appendix 3). The extreme 1 hour NO2 concentration (98th percentile, cumulative scenario) was predicted to be up to 188 µg/m3 within 10 to 20 km of the plant. The maximum 1 hour NO2 concentration was predicted to be 145 µg/m3 at the nearby community of Buick and 200 µg/m3 at Blueberry # 205. There concentrations are both well below the MoE one hour objective of 400 µg/m3.
- Modelling (Figures 25 and 26 in Appendix 3) suggests that emission sources in and around Taylor have the largest areal impact on NO2 concentrations in the Peace region. Extreme concentrations from the cumulative scenario were predicted to be over 94 µg/m3 within 10 to 25 km of Taylor and encompass Fort St. John. Maximum one hour predictions were 368 µg/m3 at Taylor and 190 µg/m3 for Fort St. John, both below the 1 hour objective of 400 µg/m3 .

Table 4 Distance in kilometres that the HHRA predicted one hour extreme concentrations of SO2 and NO2 extend from the centres of a community, based on HHRA model output. SO2 extreme concentrations are the 99th hourly percentile. NO2 extreme concentrations are the 98th hourly percentile.

Distances from centre of community in kilometres	SO2 predicted extreme concentrations (99th percentile) (kilometres)			NO2 predicted extreme concentrations (98th percentile) (kilometres)		
	Up to 196 µg/m3	*Up to 98 µg/m3*	*Up to 49 µg/m3*	*Up to 188 µg/m3*	*Up to 94 µg/m3*	*Up to 47 µg/m3*
Taylor	10-15	30	50+	10-20	20-30	100
Fort St John	0-10	15	30	5-15	15-30	100
Dawson Creek	0	0	0	5-10	10-20	100
Chetwynd	0	0	10	5	5-8	15
Hudson's Hope	0	0	5	0	0	10
Buick	0	0	0	0	5-45	100
Blueberry #205	0	0	10-25	2-30	20-40	100
Taylor South Hill	10	15-30	50	5-20	10-25	100

PM2.5 (particulate matter 2.5 microns and less)

Health Impacts:

The size of airborne particles is directly linked to their potential for causing health effects. Small particles less than 2.5 micrometers in diameter (such as those found in smoke and haze) pose the greatest problems, because they can get deep into the lungs, and even into the bloodstream. Exposure to such particles (PM2.5) can affect both the lungs and the heart (Environmental Protection Agency 2014-3)

Ambient Concentrations:

No long term PM2.5 monitoring data was available.

HHRA modelling predicted that the 24 hour PM2.5 objective would not be exceeded in the main communities in the Peace listed in Table 5. Relatively low ambient concentrations of PM2.5 were predicted in most areas, from all sources, the exception being a mining operation about 40 km south of Chetwynd and in Pine Valley, 35 km WSW of Chetwynd on Highway 97. Localized elevated PM2.5 concentrations were also predicted in Fort St. John and Dawson Creek associated with the pulp and paper/wood industry, domestic heating, outdoor burning and mobile sources. Oil and Gas sources are relatively minor relative to other PM2.5 sources in the region. More information is available in Figures 26 through 29.

Hydrogen sulfide

Health Impacts:

Hydrogen sulfide gas (H2S) has an obnoxious odour similar to rotten eggs at very low concentrations and is thus responsible for considerable annoyance and concern in communities near H2S sources such as sour gas wells or tanks containing petroleum liquids. Odours can trigger symptoms such as nausea, headaches, and respiratory symptoms, but whether these are health issues is a subject of continued debate. BC ambient H2S objectives are based on odour thresholds. Human health data from communities around the world suggest health effects from H2S may result from concentrations that are substantially higher than these odour thresholds. The severity of these H2S health effects are dependent on both the concentration of H2S and the length of time being exposed. At relatively low concentrations, above the odour threshold, mild eye irritation may be experienced, while at H2S concentrations a thousand times higher, this irritation may become severe if exposures continue for several hours. Similarly, some people may experience mild respiratory effects and headaches at low concentrations, but above the odour threshold. These effects may become significant after prolonged exposure or much higher concentrations. (Campagnaa et al 2004).

The HHRA report refers to health based minimum risk level for hydrogen sulphide of 98 µg/m3 for 1 hour. This limit is an order of magnitude higher than the MoE odour-based objective (7 µg/m3). An annual health-based exposure limit of 2 µg/m3 is also referred to in the HHRA report. Monitored results are well below both of these exposure limits.

Ambient Concentrations:

The following summarizes H2S ambient concentrations where monitoring data was available. No H2S data from HHRA modelling was used in this study due to underestimated H2S emission rates from industrial facilities.

- **Taylor townsite**: A significant air quality issue in the Peace region appears to be the relatively high H2S concentrations at Taylor. Monitoring showed that the one hour H2S objective (7 µg/m3) was exceeded in every year between 1998 and 2013 between 1% and 10% of the time. The 24 hour objective (3 µg/m3) was exceeded between 2% and 26% of the time (H2S monitored data is graphed in Fig. 10 through 15). The maximum one hour concentrations at

Taylor were 199 µg/m3 (2006 and 2010) and the maximum 24-hour concentration was 48 µg/m3 (2012). These concentrations are much higher the BC H2S 1-hour and 24-hour objectives: 7 and 3 µg/m3 respectively. H2S concentrations measured at Taylor South Hill much lower, with very few exceedances.

- **Pine River gas plant and Hasler**: H2S exceedances of the 1 hour objective (7 µg/m3) occured each year (1998-2013) at the Pine River gas plant, varying between 0.1% and 3.9% of the time. The 24 hour objective (3 µg/m3) was exceeded up to 10% of the time. The 1 hr and 24 hr objective was also exceeded at Pine River Hasler, though less often.
- **Passive monitoring**: H2S monthly and seasonal averages remained very low (less than 2 µg/m3) for almost all passive monitoring sites. These included Taylor, Groundbirch, Buick, Dawson Creek, Stone Creek and Houde Road (Appendix 2).

HHRA modelling severely underestimated predicted concentrations of H2S at Taylor and other sites in the Peace, some by orders of magnitude. This may have been a result of a failure to include all H2S emission sources at industrial facilities, particularly fugitive emissions (David Chadder, personal communication). For this reason, H2S modelling results are not included in this study.

Acrolein

Health Impacts

Acrolein is toxic and is a strong irritant for the skin, eyes, and nasal passages.

Ambient Concentrations

No monitoring data exists for acrolein in the Peace. Modelled concentrations at the maximum point of impact of acrolein at Fort St. John were associated with the combustion of fuel wood with minor contribution from the pulp and paper and wood industry (HHRA 2014).

There are no BC ambient standards for Acrolein. Based on HHRA modelling, cumulative scenario, acrolein concentrations were well below the one hour Ontario standard of 4.5 µg/m3 in almost all areas. The exceptions where one hour concentrations approached the Ontario standard were within about 3 km of Fort St. John (Fig. 39 and 40) and were associated with the combustion of fuel wood, with minor contribution from the pulp and paper and wood industry. No monitoring data of ambient acrolein concentrations in the Peace was available for comparison to model estimates.

Formaldehyde

Health Impacts

Formaldehyde has been associated with eye and nasal irritation and to the development of childhood asthma.

Ambient Concentrations

No monitoring data exists for formaldehyde in the Peace. HHRA modelling showed that elevated formaldehyde concentrations mainly impacted only the immediate vicinity of the industrial sources (Figure 33). The maximum point of impact occurred on Highway 97 approximately 70 km northwest of Fort St. John. Sources associated with the transport of oil and gas products along with multiple minor sources from the oil and gas industry are located in the area of the maximum point of impact.

Characterizing community air quality

This section characterizes the potential concentrations of different air pollutants on these key communities: Taylor, Fort St John, Dawson Creek, Chetwynd, Hudson Hope, Buick, and Blueberry #205. It is based on both monitoring and HHRA modelling (cumulative scenario). Tables 4 and 5 provide characterizations of maximum and extreme concentrations and the distance from the centre of these communities that ranges of concentrations are predicted. Extreme concentrations are expressed as 98th or 99th percentiles of hourly or daily concentrations while maximum concentrations are the highest concentration predicted at that location. Note that, based on comparisons of modelled and observed concentrations at Pine River and Taylor areas, modelled concentrations have an over-prediction bias.

Table 5 Maximum and extreme percentiles of one hour SO2, NO2 and PM2.5 concentrations predicted by HHRA modelling for selected communities, using the cumulative scenario. BC air quality objectives for maximum hourly concentrations of SO2 and NO2 are 450 and 400 µg/m3 respectively

Community	SO2 (hourly) prediction µg/m3		SO2 (24hr) prediction µg/m3	NO2 (hourly) prediction µg/m3		PM2.5 (24 hr) prediction µg/m3	
	Max	Extreme (99th percentile)	Max	Max	Extreme (98th percentile)	Max	Extreme (98th percentile)
BC Objective	*450*	*NA*	*160*	*400*	*NA*	*NA*	*25*
Taylor	328	135	36	368	231	3.6	2.4
Fort St John	368	182	27	190	173	35	20
Dawson Creek	27	24	10	179	165	27	18
Chetwynd	55	33	9.8	148	143	4.2	2.9
Hudson Hope	45	23	4.9	44	33	0.9	0.45
Buick	18	16	4.1	145	116	0.6	0.35
Blueberry #205	73	45	15	161	142	1.1	0.46
Taylor South Hill	NA	190	NA	NA	NA	NA	NA

In addition to the modelling information data in Tables 4 and 5, the following provides additional monitoring information for the years 1998 through 2013.

Taylor:

SO2: Monitoring showed that the SO2 hourly objective of 450 µg/m3 was exceeded only for one hour at Taylor townsite in each of 1998 and 2009 and at Taylor South Hill for one hour in 2007. Average concentrations of SO2 and H2S were 2.1 µg/m3 based on passive monitoring for 5 months.

H2S / TRS - Monitoring showed that both the one hour and 24 hour H2S objectives were exceeded in every year between 1998 and 2013 between 1% and 10% of the time. The maximum measured one hour concentrations at Taylor were 199 µg/m3 (2006 and 2010) and the maximum 24-hour concentration was 48 µg/m3 (2012). These concentrations are much higher the BC H2S 1-hour and 24-hour objectives: 7 and 3 µg/m3 respectively. HHRA modelling of H2S was not used in this analysis because of an incomplete H2S / TRS emission inventory .

Dawson Creek

Based on 4 years of passive monitoring, average concentrations of SO2 were 0.5 µg/m3 and concentrations of H2S were 0.15 µg/m3.

Chetwynd

SO2 average concentrations were 1.8 µg/m3 based on 14 years of passive monitoring.

Hasler

SO_2 concentrations averaged 0.5 µg/m3 based on 13 years of passive monitoring.

Groundbirch

Based on 2 to 4 years of passive monitoring, SO_2 concentrations averaged 5.2µg/m3, H_2S averaged 0.15 µg/m3 , and NO_2 averaged 9.4 µg/m3..

Conclusion

Air pollutants from oil and gas activity in the Peace region of northeast BC has raised public concerns about possible health impacts of ambient air quality. This air quality characterization was developed to describe what is known about ambient concentrations of key air pollutants with health or odour impacts that are associated with the oil and gas industry.

The characterization relied upon both air quality monitoring and the Human Health Risk Assessment air quality dispersion modelling. Monitoring was limited mainly to the vicinity of the Pine River Gas Plant and the community of Taylor. Modelling provided predictions of air pollutant concentrations throughout the Peace and could be verified against the monitored data. These data were then analyzed to see if communities in the Peace could potentially be exposed to concentrations above BC air quality objectives. The communities targeted in this report are Taylor, Taylor South Hill, Fort St John, Dawson Creek, Chetwynd, Hudson's Hope, Buick and Blueberry #205.

The main results of this study were:

1. Based on monitoring, the SO_2 hourly objective of 450 µg/m3 was rarely exceeded at the air quality stations where continuous monitoring of SO_2 occurred. The highest number of exceedances was observed at the remote Pine River Gas Plant where the hourly SO_2 objective was exceeded for about 1 hour per year, on average. Even less exceedances occurred at Taylor Townsite, Taylor South Hill and Pine River Hasler. No exceedances of the 24 hour SO_2 objective was observed at these monitoring stations. No hourly NO_2 or $PM_{2.5}$ monitoring data was available for comparison to objectives.
2. Based on predictions provided by a Human Health Risk Assessment air quality dispersion modelling study, the one-hour and/or 24-hour SO_2, NO_2 or $PM_{2.5}$ health based objectives would not have been exceeded in any of the communities of Taylor, Taylor South Hill, Fort St John, Dawson Creek, Chetwynd, Hudson's Hope, Buick and Blueberry #205.
3. The hydrogen sulfide (H_2S) air quality objective is based on an odour threshold at which humans can detect its presence but at which no physiological health impacts occur. It is responsible for considerable annoyance and concern in communities near sources such as pulp mills and oil and gas facilities. Monitoring indicated that this odour-based objective was exceeded in and around Taylor and the Pine River Gas plant in all years when monitoring occurred, up to 10% of the time in some years. However, monitored H_2S is well below the health based exposure limits referred to in the HHRA report. Modelling results were not available for H_2S.
4. Long term (months and seasons) averages of H_2S and SO_2 as measured by seven passive monitors scattered throughout the Peace were very low and well within long term objectives where these objectives exist.

This report will provide information to the public on air quality in the Peace region of northeast

BC and can be used in management of the northeast BC monitoring network. Updates of this report may be published in the future to provide improved information on air quality in the Peace.

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Appendix 1 Continuous Monitoring Graphs

Continuous air quality monitors measure concentrations of air pollutants without interruption, except when the monitor is not operating due to maintenance, monitor failure etc. Measurements are made frequently each hour and stored in a logger, generally as hourly averages as well as averages, which are used in the graphs in this appendix.

This appendix displays graphs of monitored data from stations in Table 6. Stations such as Taylor Townsite and Pine River Gas Plant have data for the entire period from 1998 through 2013. Other stations have limited data and appear on the graph only for one or two years.

Table 6 Continuous Air Quality Monitoring Stations in the Peace Region from 1998 to 2013.

Bessborough 237 Road
Farmington MAML
Fort St John NP Cultural Centre
Groundbirch MAML
Kelly Lake MAML
Pine River Airport
Pine River Bend River Ranch
Pine River Gas Plant_60
Pine River Hasler_60
Rolla MAML
Taylor South Hill_60
Taylor Townsite_60
Tomslake MAML

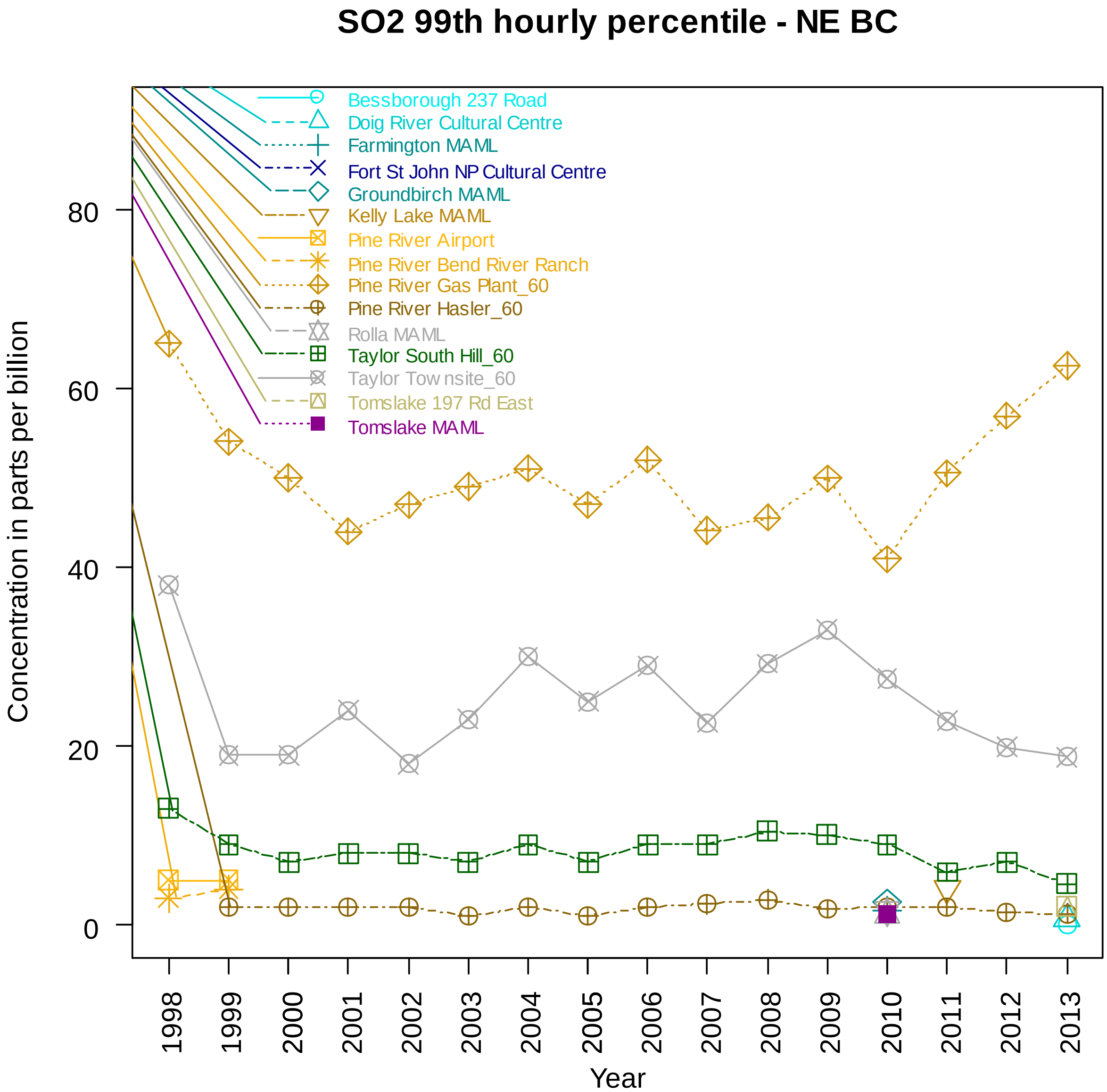

Figure 3 The extreme (99th percentile) hourly concentration of SO2 for each year at 15 monitoring sites for up to 15 years of continuous monitoring from 1998-2013. Both the 99th percentiles in this graph and the HHRA model results are based on one hour concentrations taken over the whole year, not the maximum daily one hour concentrations. These 99th percentile monitoring results were used to validate the model results in the airshed characterization analysis but not used in any comparison to air quality objectives.

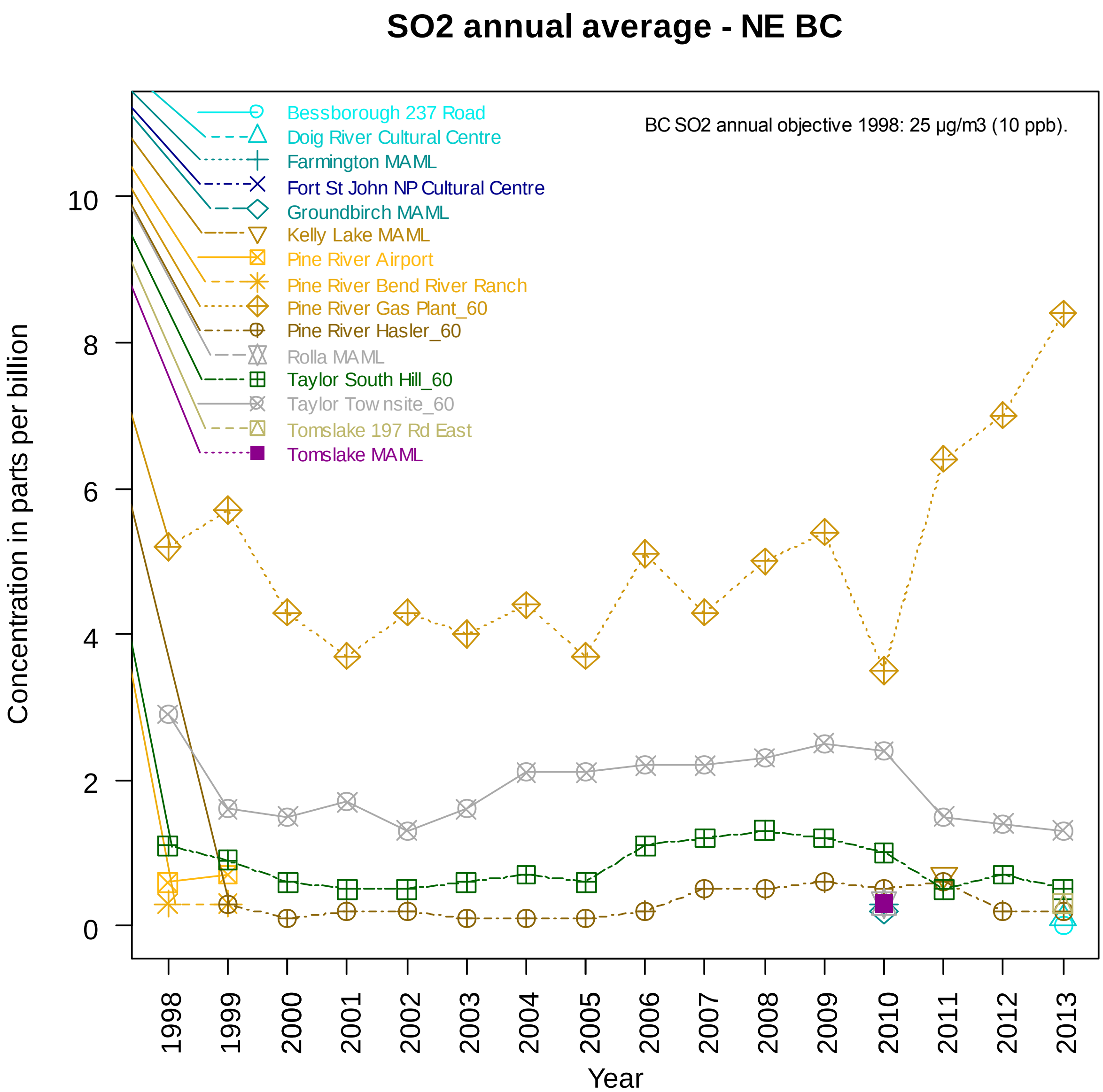

Figure 4 The annual average sulfur dioxide concentration at hourly air quality monitoring sites for up to 15 years of continuous monitoring from 1998 to 2013. No stations exceeded the BC annual objective of 25 µg/m3 (10 ppb) of SO2.

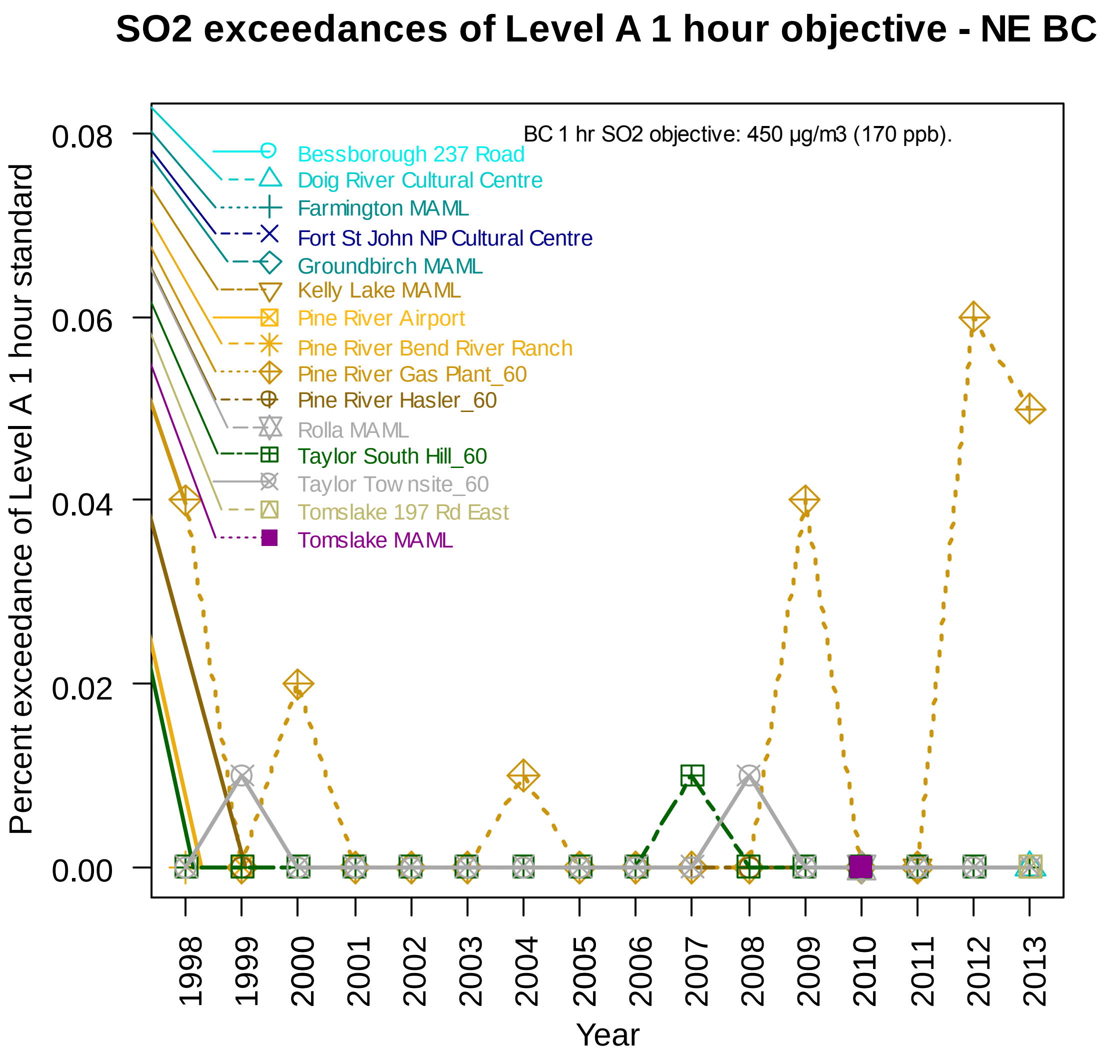

Figure 5 The percentage of annual exceedances of the SO2 one hour objective of 450 µg/m3 (170 ppb) at air quality stations in the Peace region for up to 15 years of continuous monitoring from 1998 to 2013. Aside from the isolated Pine River Gas Plant, this graph shows that there were very few exceedances of the one hourSO2 objective..

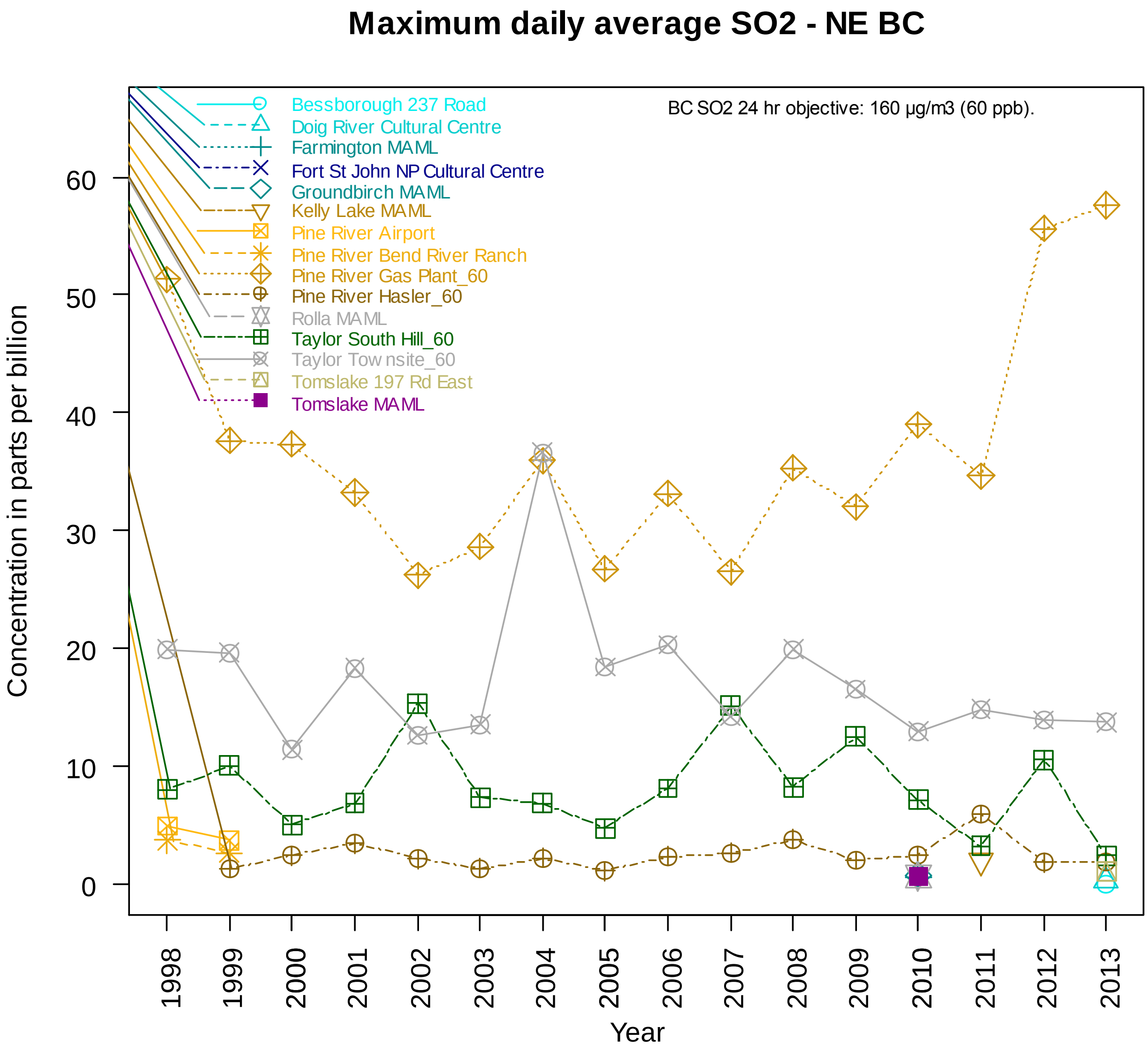

Figure 6 The maximum daily average SO2 concentration for stationary and mobile monitoring stations for up to 15 years of continuous monitoring from 1998 to 2013. There was no exceedance of the daily SO2 objective of 160 µg/m3 (60 ppb) at any station. The highest daily average was consistently from the isolated Pine River Gas Plant. This was followed by Taylor Townsite which reached its maximum daily concentration of 97 µg/m3 (37 ppb) in 2004.

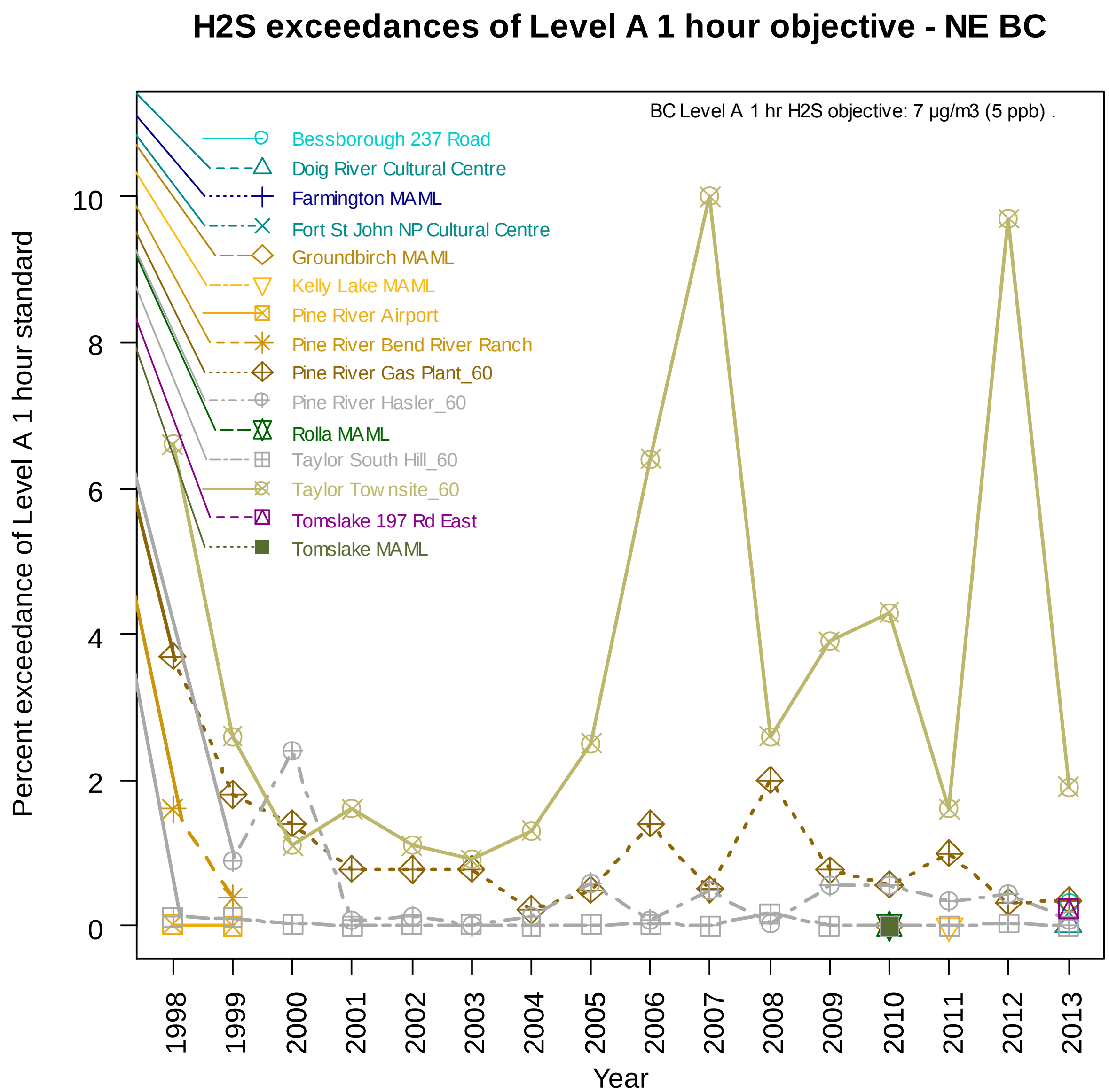

Figure 7 The percent exceedances of the 1 hour BC TRS (measured as H2S) objective (7 µg/m3 or 5 ppb) for up to 15 years of continuous monitoring in the Peace. Most exceedances of the BC one hour objective for H2S were at Taylor, with hourly exceedances occurring at least 1% of the time every year, throughout the period 1998-2013.

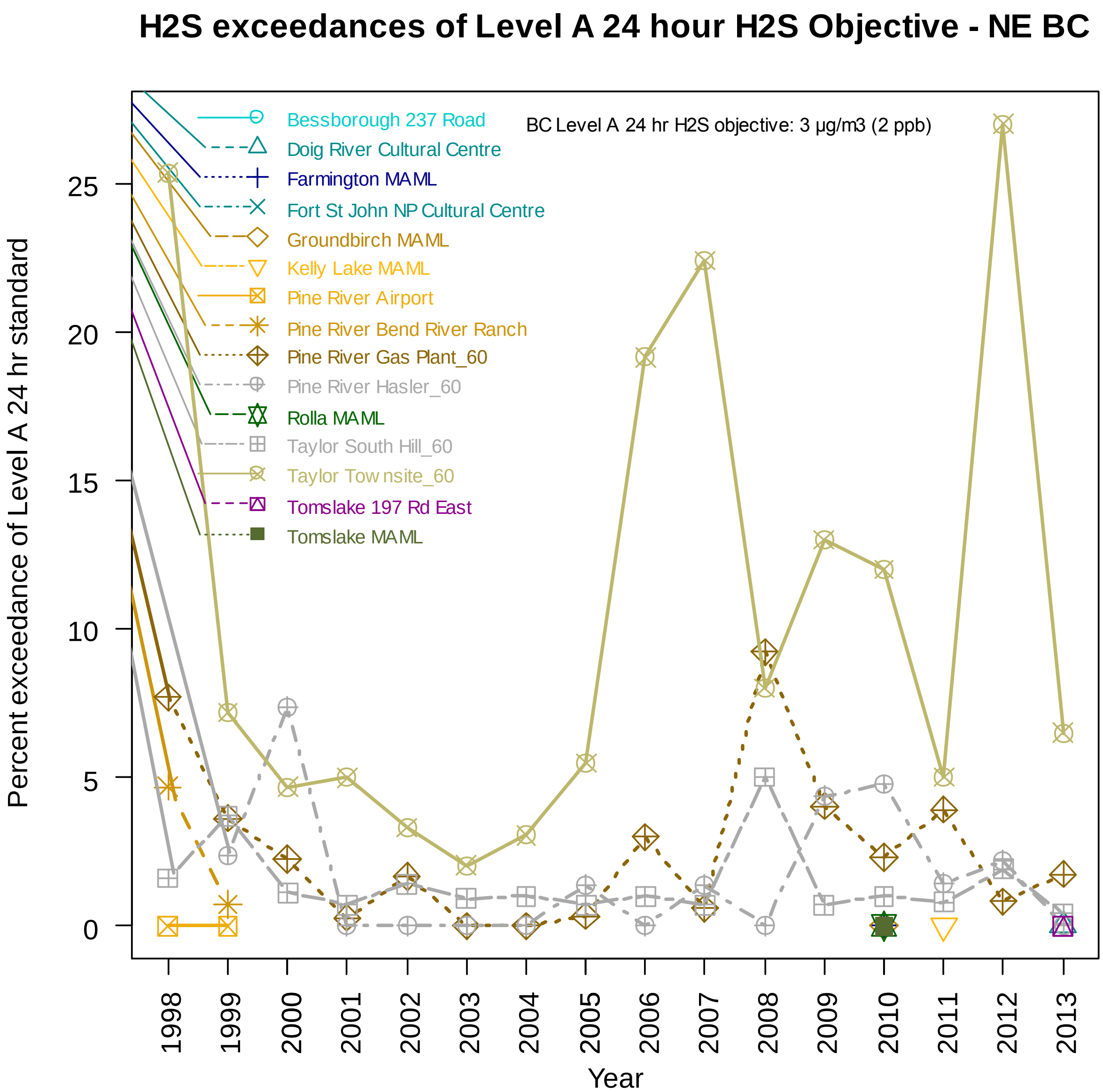

Figure 8 The percent exceedances of the daily BC TRS (measures as H2S) 24 hour objective (3 µg/m3 or 2 ppb) for up to 15 years of continuous monitoring in the Peace. Most exceedances of this objective were at Taylor, which never recorded less than 2% of days with no exceedances. This was followed by Pine River Gas Plant and Pine River Hassler, southwest of Chetwynd. The H2S objective is based on odour detection, not health impacts (Barry Jessiman, Health Canada, personal communication)

Appendix 2 Passive monitoring graphs

The Clean Air Strategic Alliance notes that passive monitoring methods provide a cost-effective solution for monitoring air quality at locations where continuous monitoring is not practical. Passive sampling devices can monitor air pollutants without the need for electricity, data loggers or pumps. Passive sampling devices are lightweight, portable and relatively simple to operate. No active movement of air through the sampler is necessary. Passive sampling involves the exposure of a reactive surface to the air, and transfer of the pollutant occurs by diffusion from the air to the surface. The surface consists of a solid chemical compound or a filter that is impregnated with a reactive solution. Samplers are typically exposed for periods of one month, and analysis is done in a laboratory. Sulphur dioxide, nitrogen dioxide, ozone, hydrogen sulphide and volatile organic compounds are common pollutants monitored using passive samplers.

A major advantage of using a passive sampling system is that a network of multiple samplers can be used over a large area to determine the spatial variation of pollutant levels. Passive samplers are also useful for looking at long-term trends of air pollutants at specific locations. However, since sampling is conducted over a period of about one month, events that last for a short time period, such as one or two hours, are rarely detected (Clean Air Strategic Alliance (2015-2)).

Table 7 summarizes the passive monitoring results in this appendix. Annual objectives for SO2 and NO2 were 25 and 60 µg/m3 respectively in 2013. There were no annual objectives for H2S.

Table 7 Average concentrations measured at passive monitoring sites in the Peace region. Concentrations are in µg/m3 with the period of record in brackets.

Community	SO2	H2S	NO2
Taylor Townsite	2.1 (5 months)	0.5 (5 months)	
Stone Creek	0.5 (1 year)	0.2 (1 year)	
Houde Rd	0.5 (1 year)	0.2 (1 year)	
Hasler	1 (13 years)		
Groundbirch	5.2 (3 years	0.2 (1 year)	9.4 (4 years)
Dawson Creek	1.3 4 years)	0.2 (1 year)	
Chetwynd	1.8 (4 years)		

The HHRA report contains an annual H2S standard set by the US EPA of 2 µg/m3. Table 7 suggests that the seven stations meet this standard.

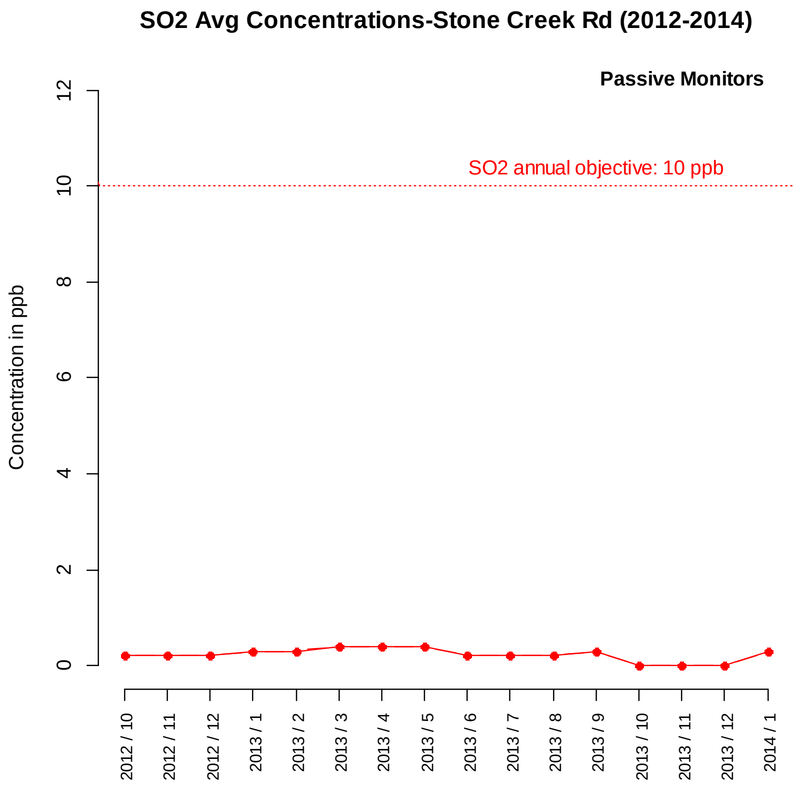

Figure 9 Average monthly SO2 concentrations at Stone Creek Road, southwest of Chetwynd near highway 97, based on passive monitors from 2012 to 2014. The annual SO2 objective was 25 µg/m3 (10 ppb). Average annual concentrations remained below 1.3 µg/m3 (0.5 ppb).

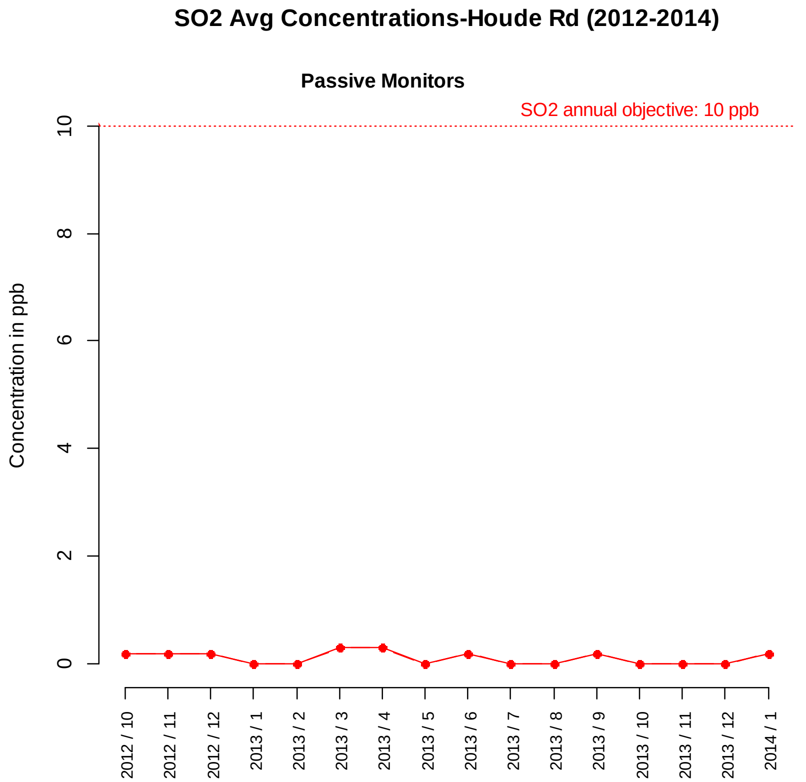

Figure 10 Average monthly SO2 concentrations at Houde Road, near Hasler Road on Highway 97, based on passive monitors from 2012 to 2014. Average concentrations remained below 1.3 µg/m3 (0.5 ppb). The annual SO2 objective was 25 µg/m3 (10 ppb).

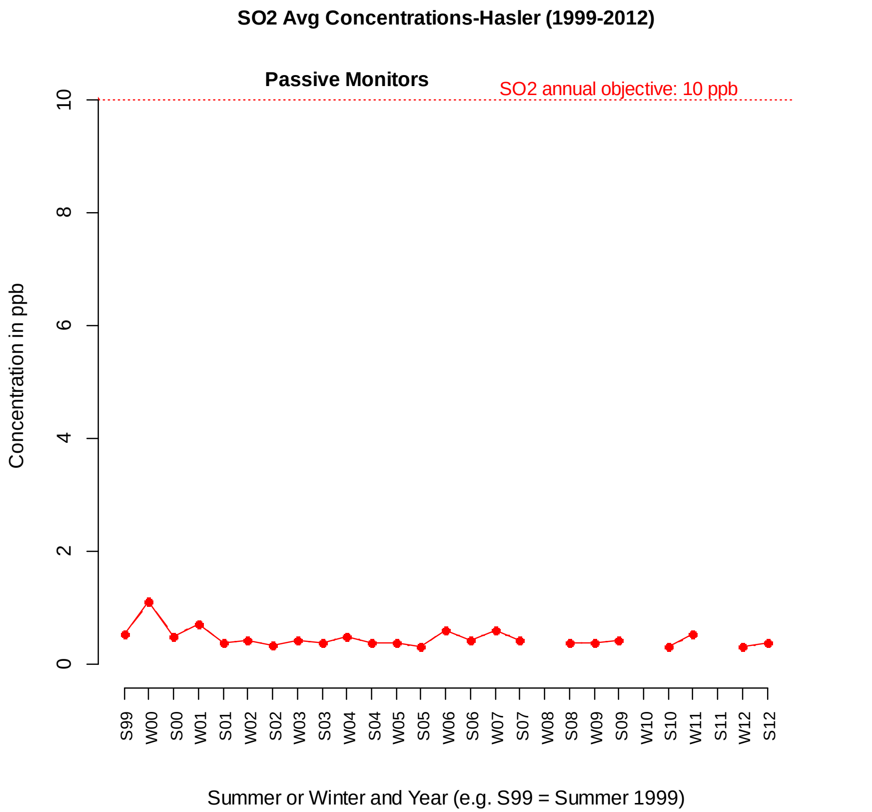

Figure 11 Average winter or summer (consecutive 6 month periods) of SO2 concentrations at Hasler, 30 km southwest of Chetwynd, based on passive monitoring from 1999 to 2012. Average concentrations remained below 2.6 µg/m3 (1 ppb) for the entire 14 years. The annual SO2 objective was 25 µg/m3 (10 ppb).

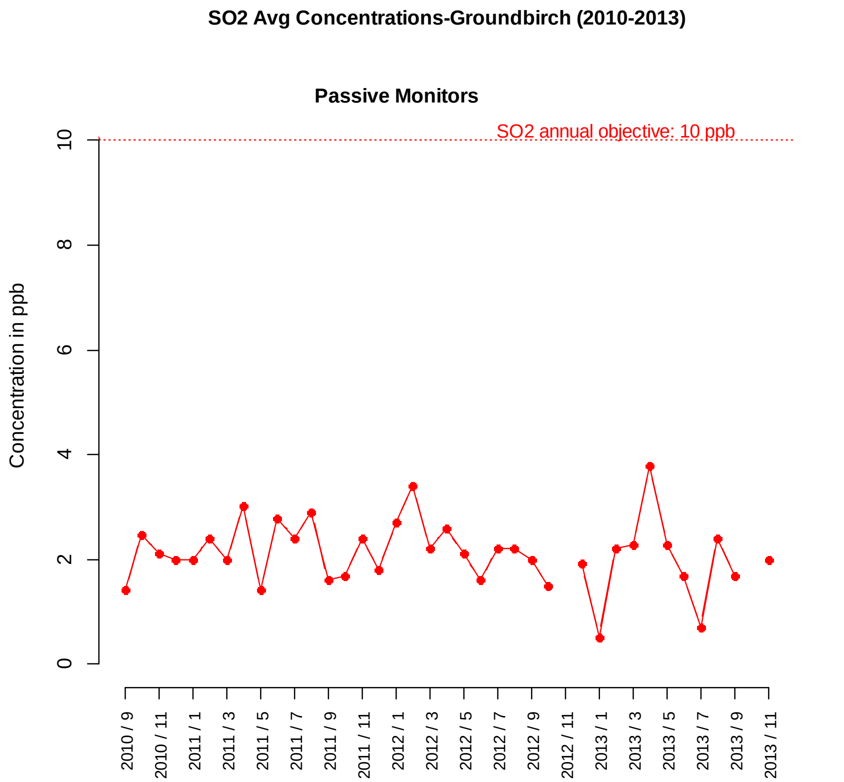

Figure 12 Average monthly SO2 concentrations north of Groundbirch based on passive monitoring from 2010 to 2013. Average monthly concentrations peaked at about 10 µg/m3 (4 ppb) in April 2013, averaging about 5 µg/m3 (2 ppb) for the entire period. The annual SO2 objective was 25 µg/m3 (10 ppb).

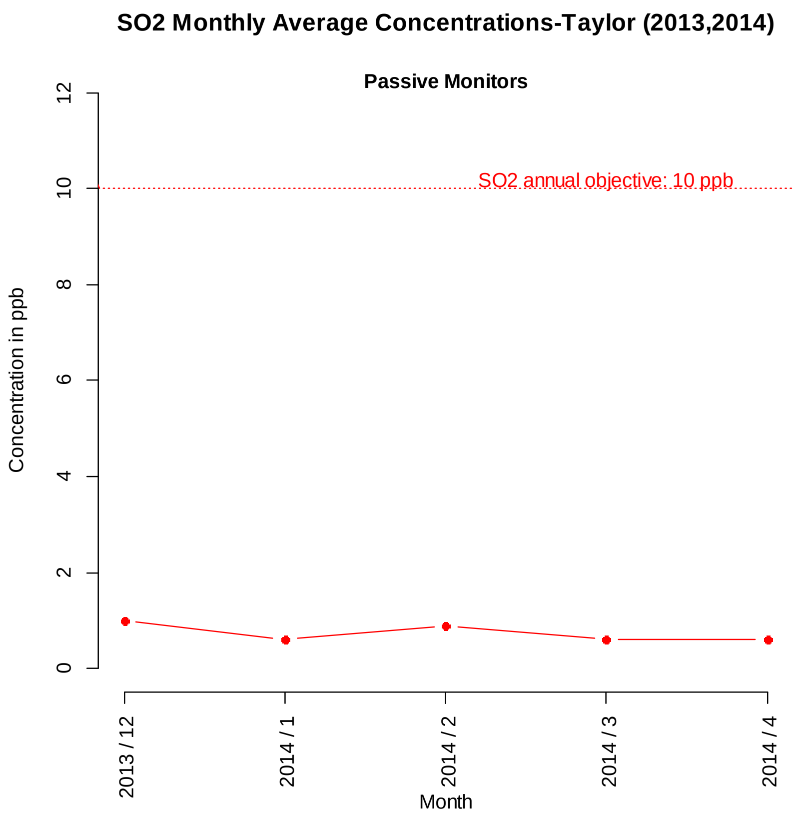

Figure 13 Average monthly SO2 concentration at Taylor Townsite based on passive monitors for 5 months beginning in Dec. 2013. Average concentrations remained below 2.6 µg/m3 (1 ppb). The annual SO2 objective was 25 µg/m3 (10 ppb).

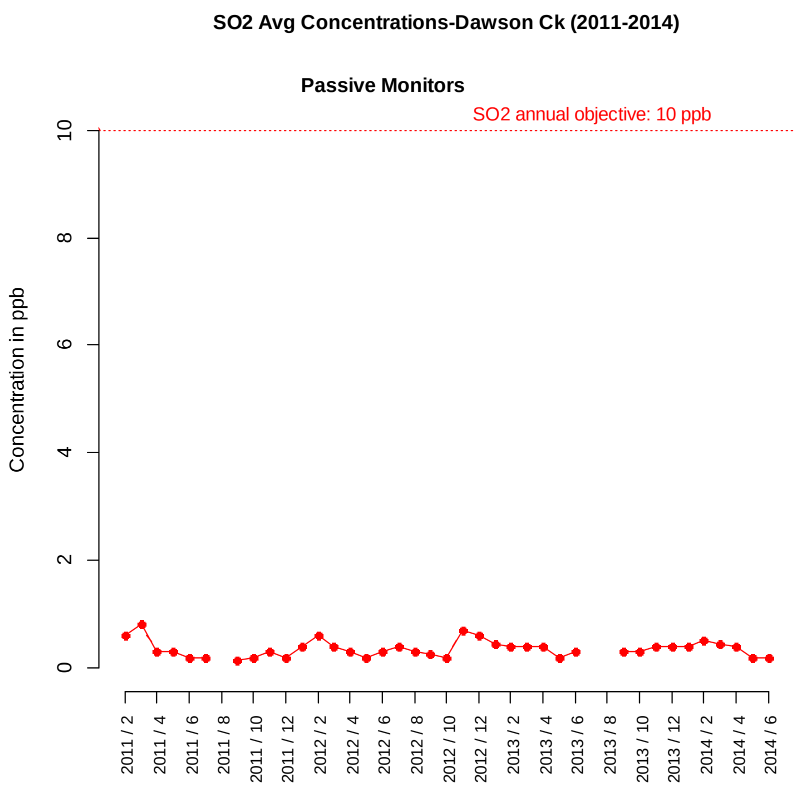

Figure 14 Average monthly SO2 concentrations at Dawson Creek based on passive monitoring from 2011 to 2014. Average monthly concentrations remained below 2.6 µg/m3 (1 ppb) for the entire three years. The annual SO2 objective was 25 µg/m3 (10 ppb).

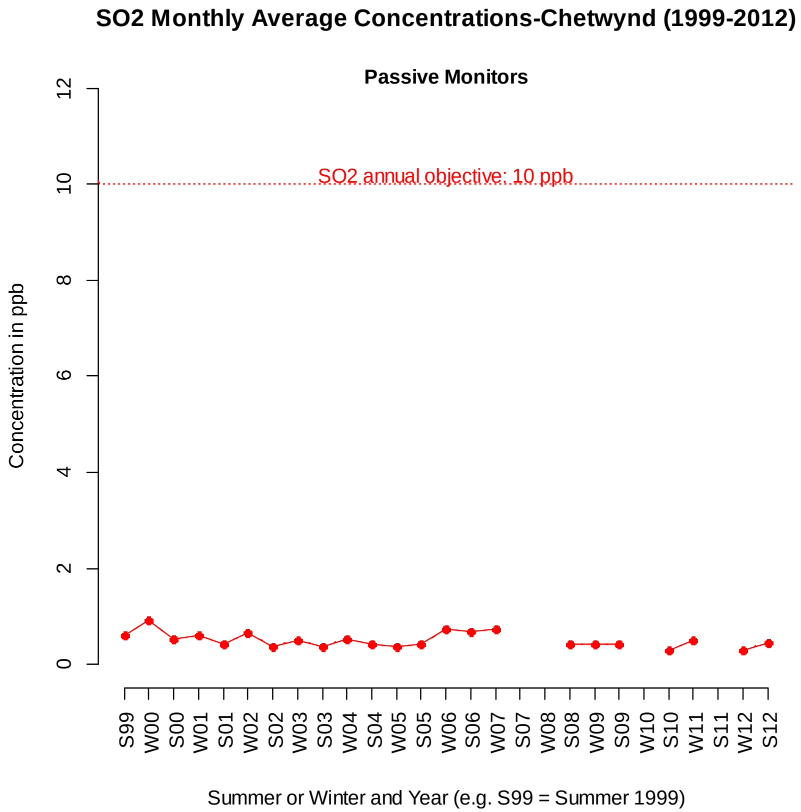

Figure 15 Average seasonal (winter or summer) SO2 concentrations in Chetwynd based on passive monitoring from 1999 to 2012. Average seasonal concentrations remained below 2.6 µg/m3 (1 ppb) for the entire 14 years. The annual SO2 objective was 25 µg/m3 (10 ppb).

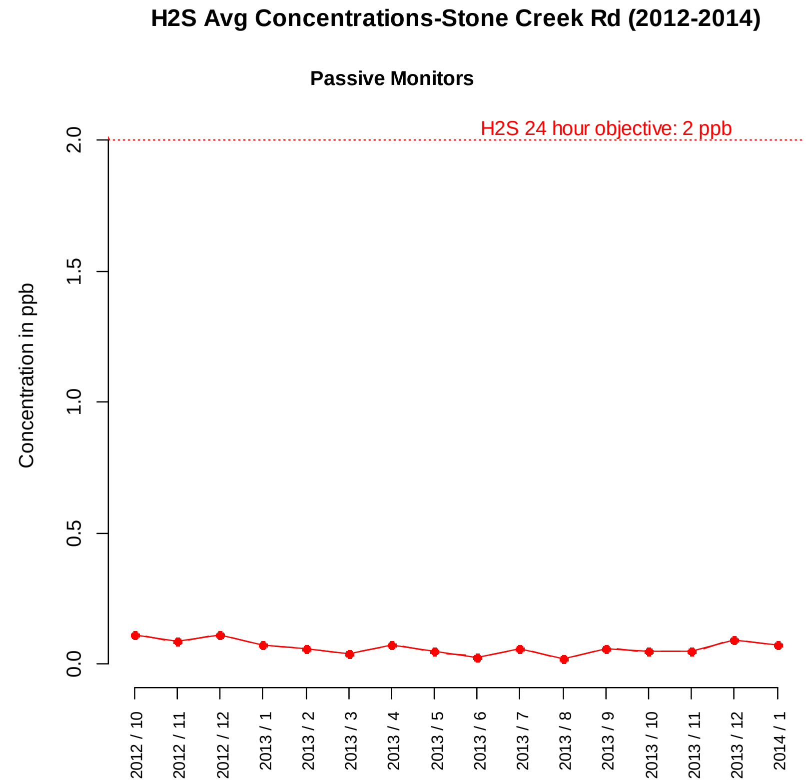

Figure 16 Average monthly H2S concentrations at Stone Creek Road, southwest of Chetwynd near Highway 97, based on passive monitoring from 2012 to 2014. Average monthly concentrations remained below 0.3 µg/m3 (0.2 ppb) for the period. There was no monthly or annual H2S objective.

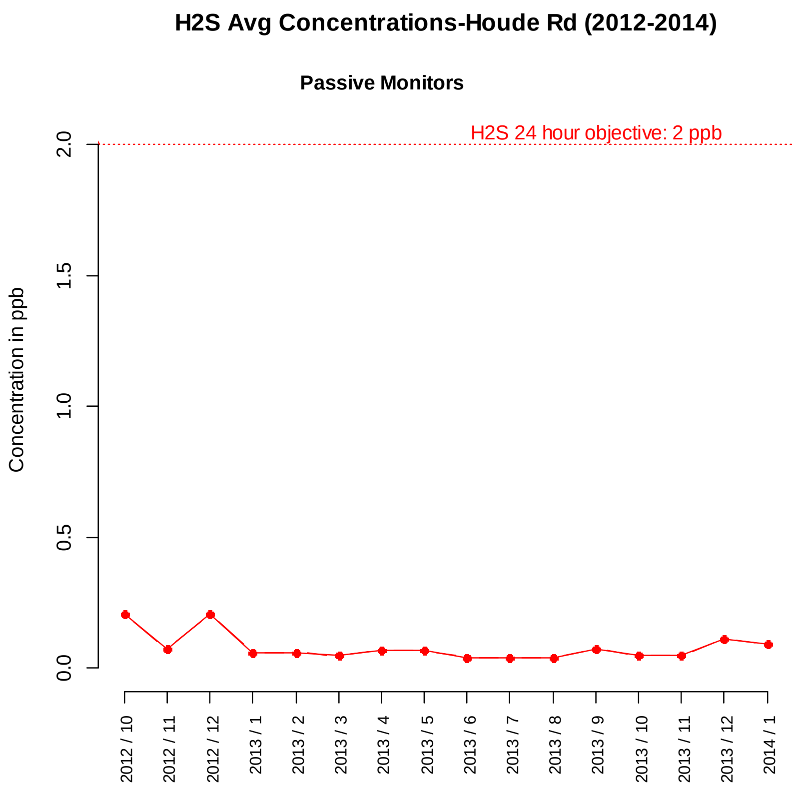

Figure 17 Average monthly H2S concentrations at Houde Road, near Hasler Road on Highway 97, based on passive monitors from 2012 to 2014. Average concentrations remained below 0.5 µg/m3 (0.3 ppb). There was no monthly or annual H2S objective.

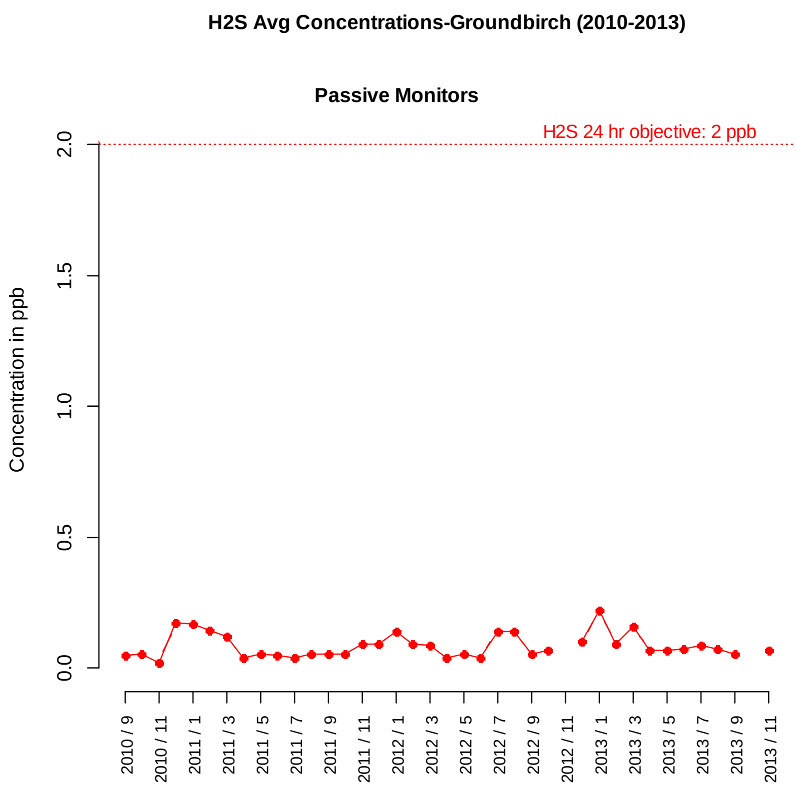

Figure 18 Average monthly H2S concentrations north of Groundbirch based on passive monitoring from 2010 to 2013. Average monthly concentrations remained below 0.5 µg/m3 (0.3 ppb) for the entire period. There was no monthly or annual H2S objective.

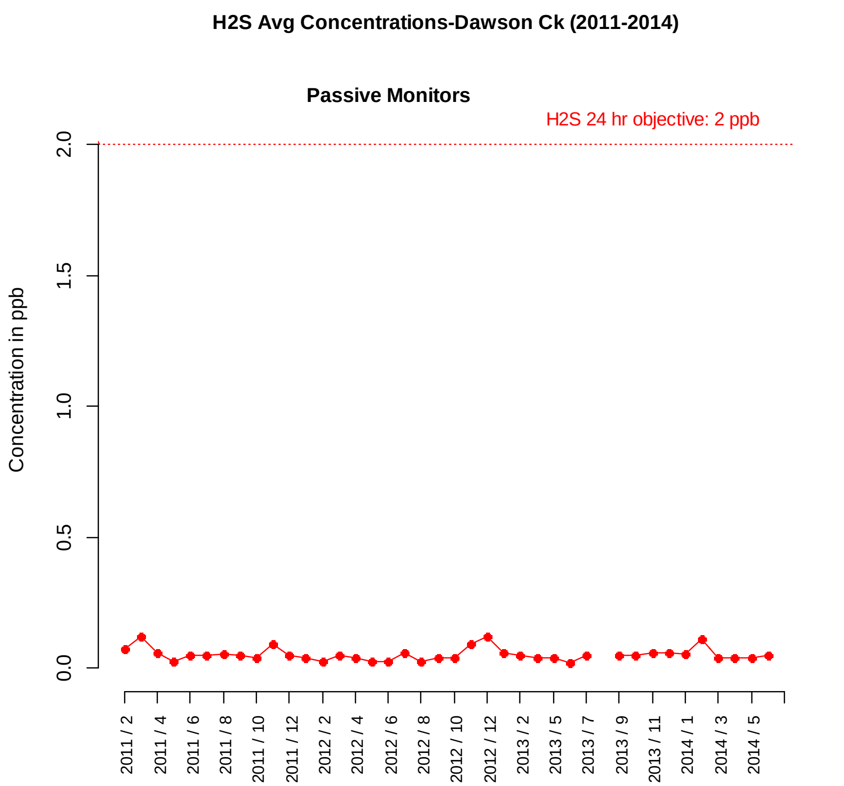

Figure 19 Average monthly H2S concentrations at Dawson Creek based on passive monitoring from 2011 to 2014. Average monthly concentrations remained below 0.3 µg/m3 (0.2 ppb) for the entire three years. There was no monthly or annual H2S objective.

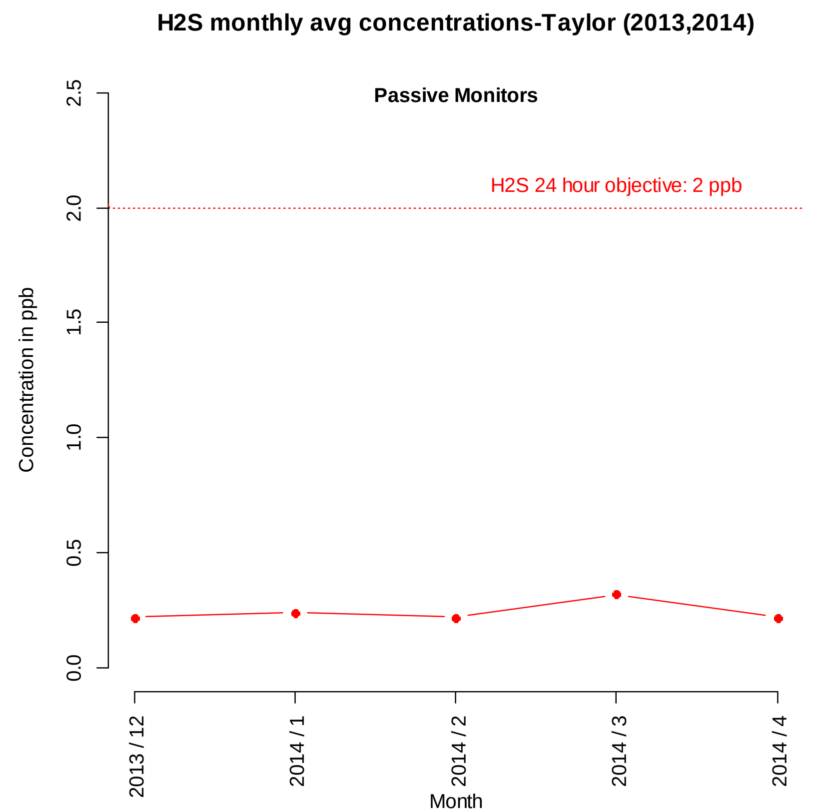

Figure 20 Average monthly H2S concentration at Taylor Townsite based on passive monitors for 5 months beginning in Dec. 2013. Average concentrations remained below 0.8 µg/m3 (0.5 ppb). There was no monthly or annual H2S objective.

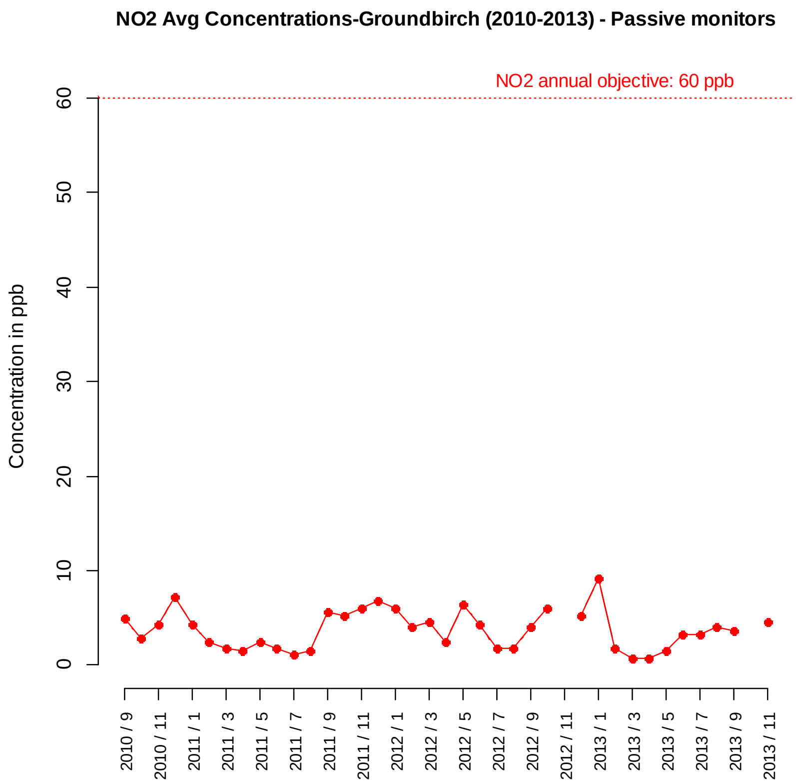

Figure 21 Average monthly NO2 concentrations north of Groundbirch based on passive monitoring from 2010 to 2013. Average monthly concentrations peaked at 19 µg/m3 (10 ppb) in January 2013, averaging about 9 µg/m3 (5 ppb) for the 4 year period. The BC annual NO2 objective was 60 µg/m3.

Appendix 3 Dispersion Model Results from the HHRA

The figures in this appendix show the air pollutant dispersion model results provided by RWDI Consulting as part of the Human Health Risk Assessment (HHRA (2014 -1). The dispersion modelling used CALPUFF to predict concentrations within the dispersion modelling study area. The figures depict annual average or maximum air quality modelling results for the upstream oil and gas sources and the background sources (µg/m3). In addition, for select species and time averaging periods, 99th or 98th percentiles over an entire year are also presented. These time averaging periods are one hour, 24 hour or annual.

No analysis has been presented based on an analysis of daily maximum values.

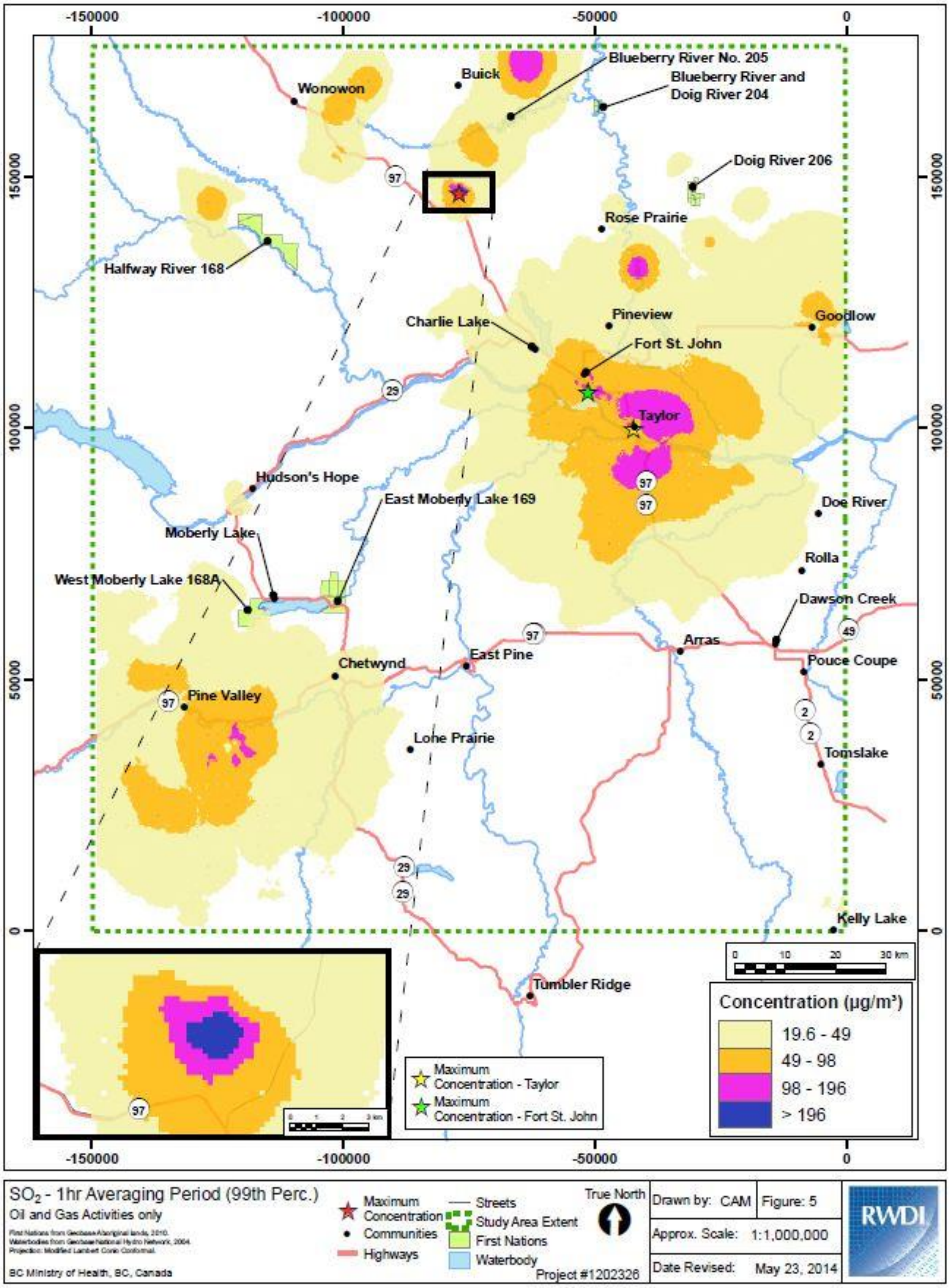

Figure 22 Dispersion model prediction of hourly extreme SO2 ambient concentrations from oil and gas activity alone. The coloured areas are associated with elevated one hour concentrations, displayed as the 99th percentile.

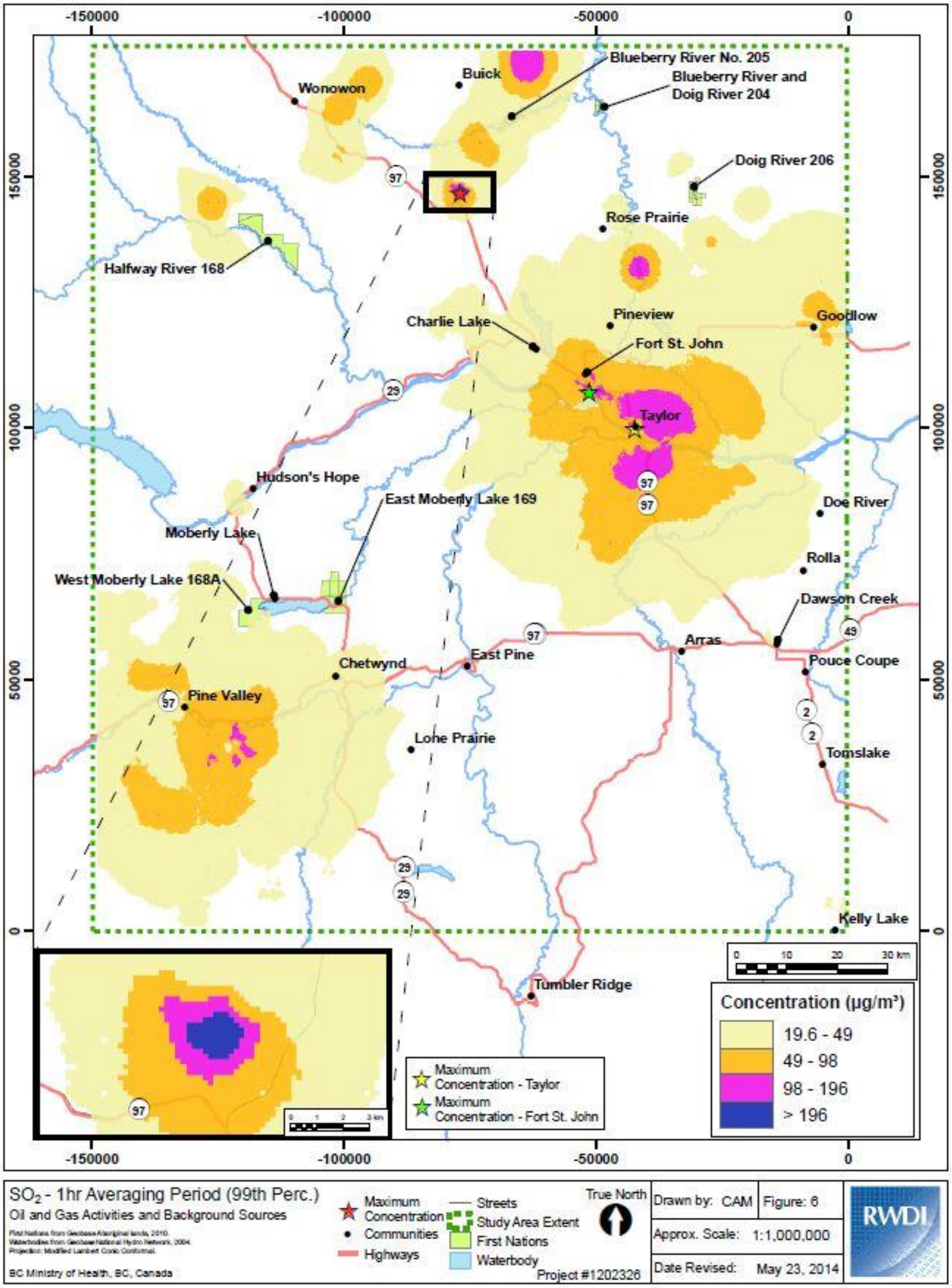

Figure 23 Dispersion model prediction of hourly extreme SO2 ambient concentrations from oil and gas activity plus background sources.

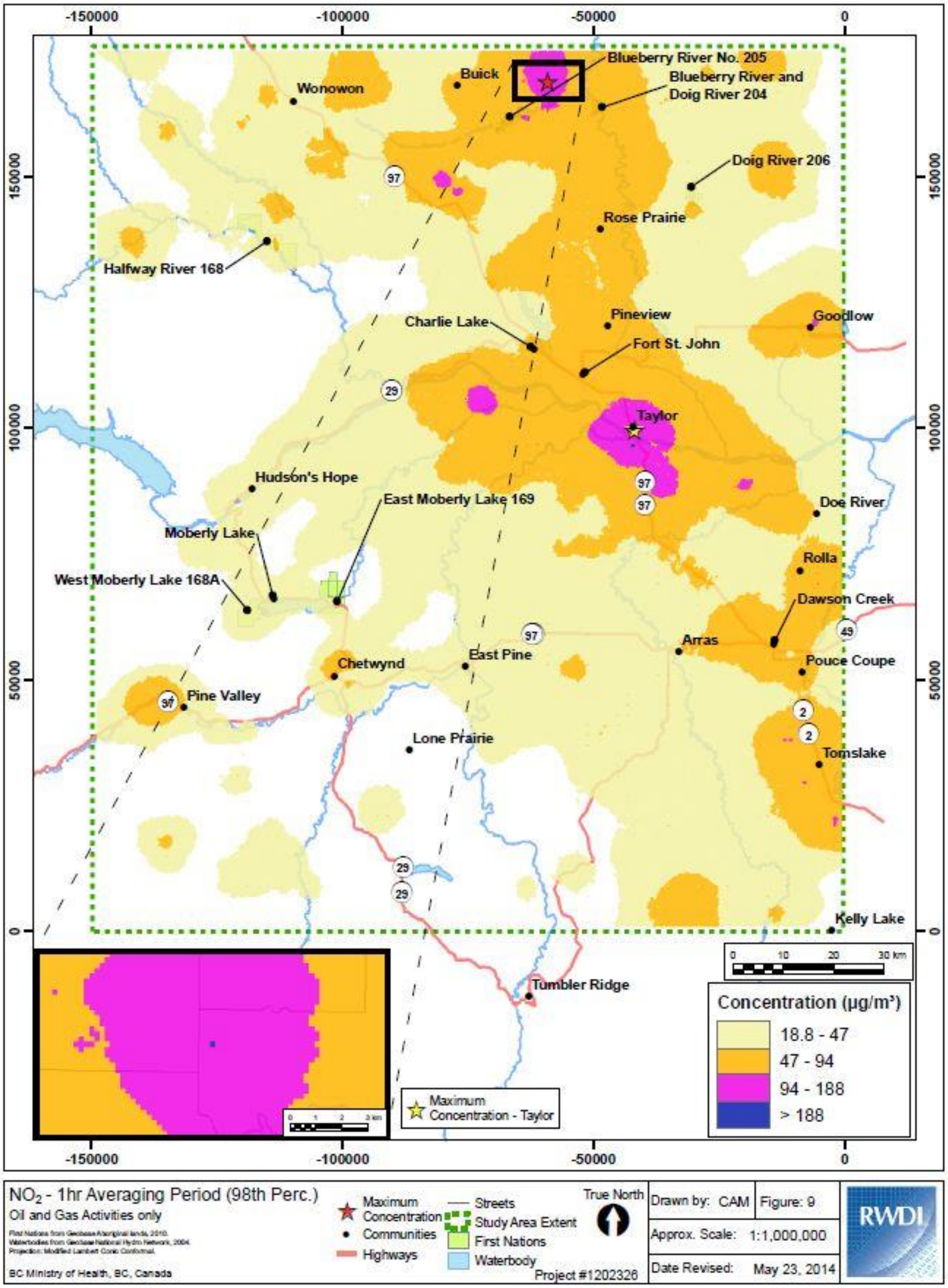

Figure 24 Predictions of maximum NO2 concentrations, 98th percentile, one hour averaging period, oil and gas emissions only

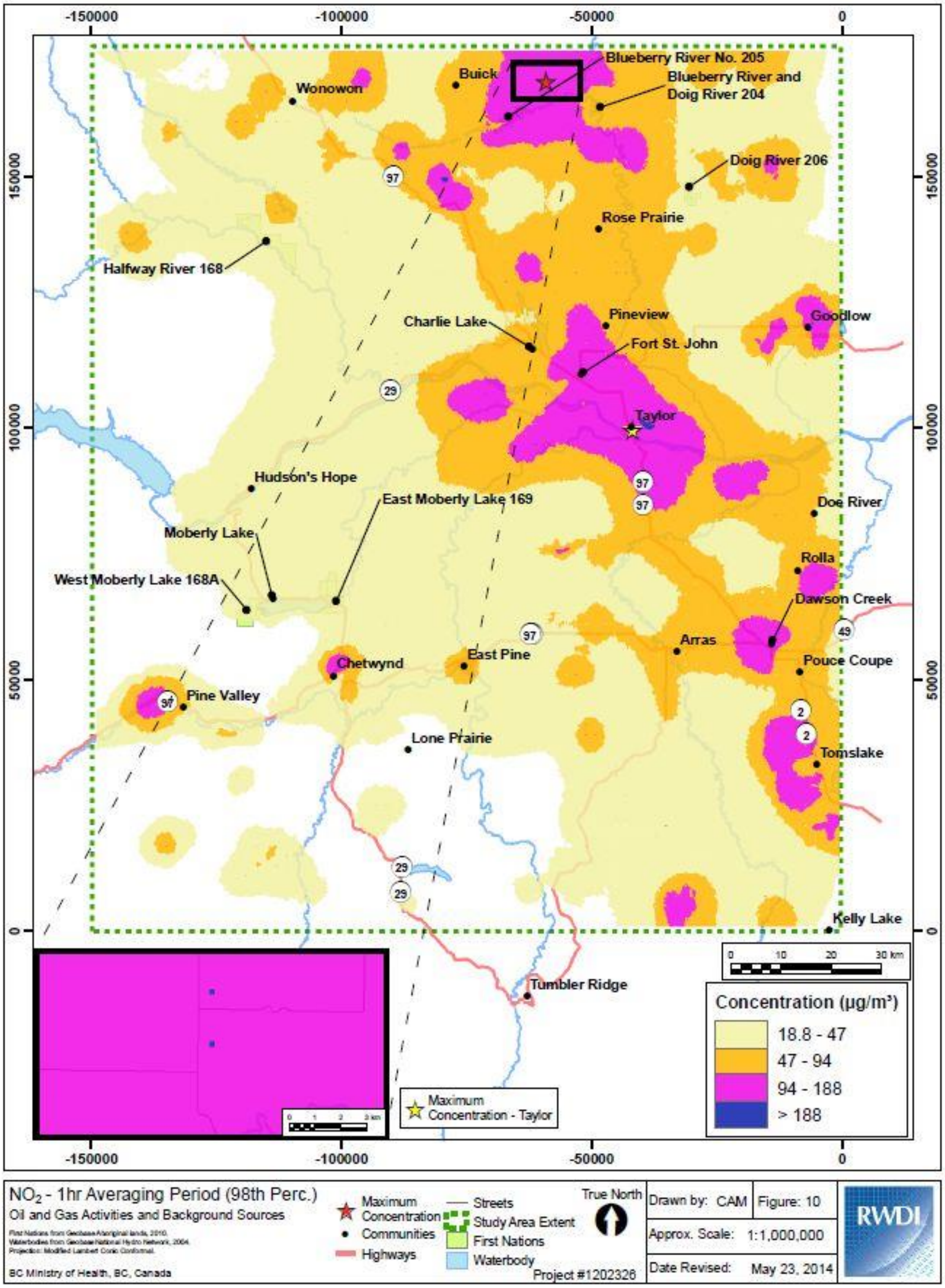

Figure 25 Predictions of NO2 concentrations, 98th percentile, one hour averaging period, cumulative scenario

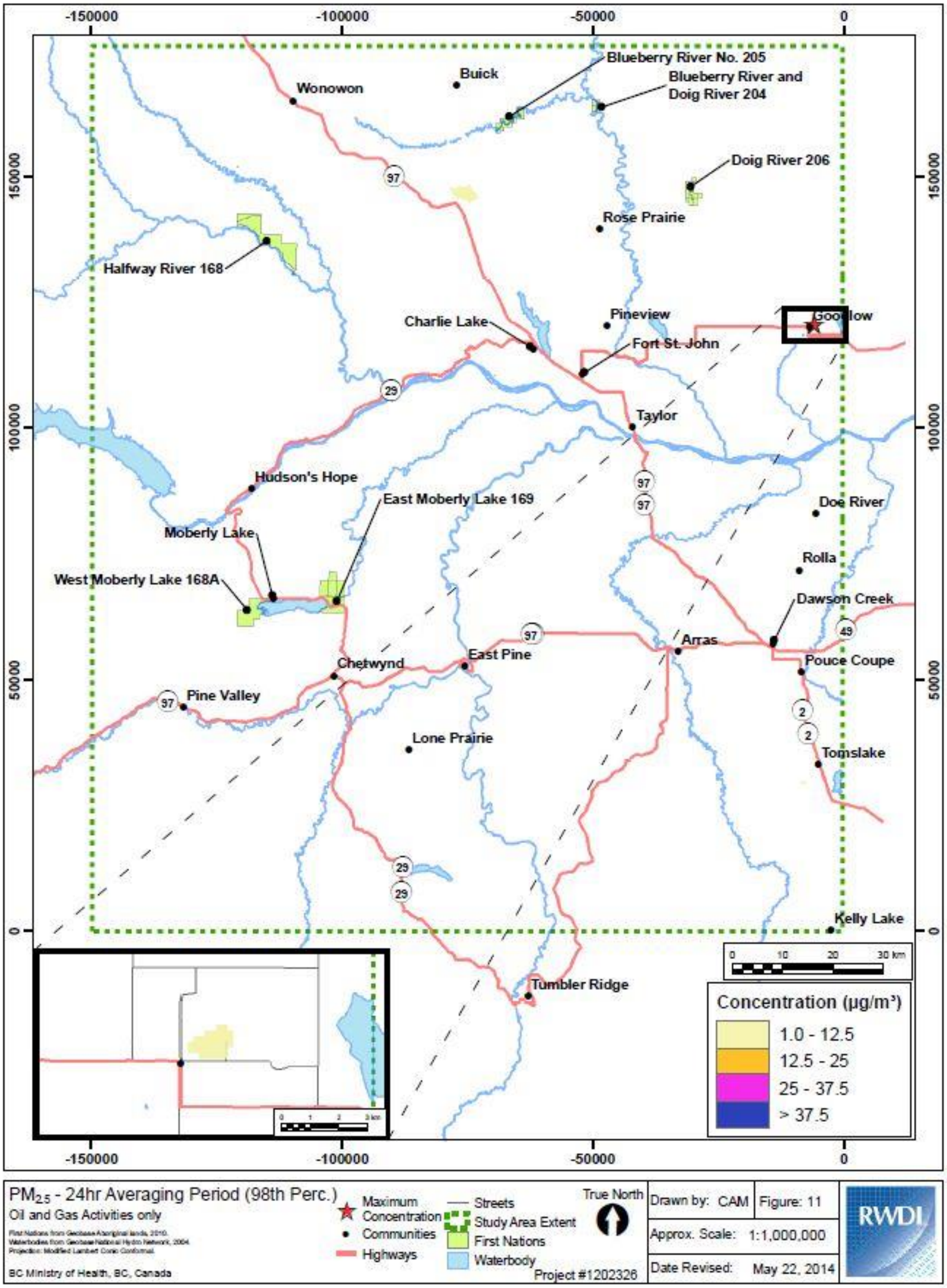

Figure 26 Predictions of maximum PM2.5 concentrations, 24 hour averaging period, oil and gas emissions only

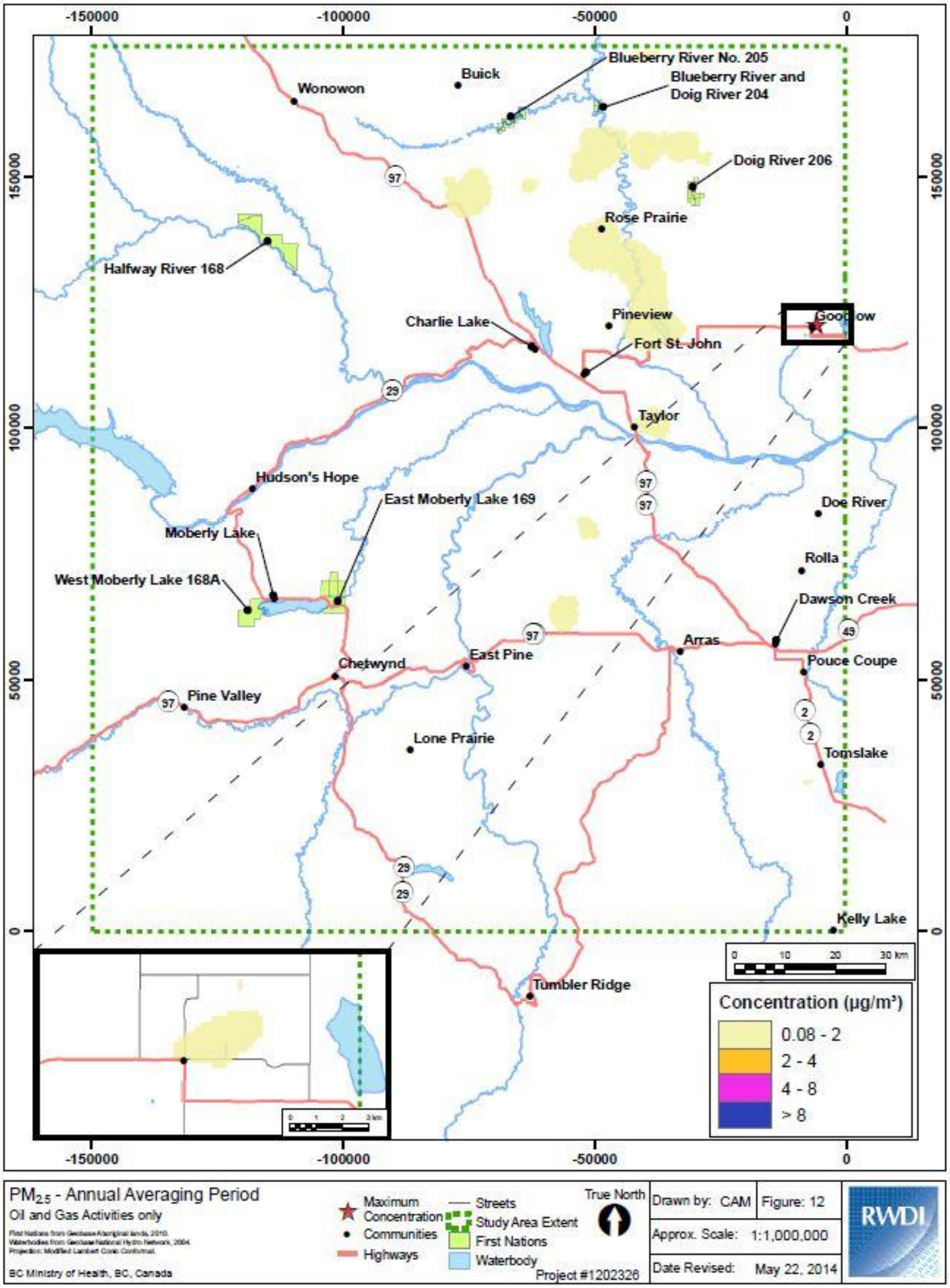

Figure 27 Predictions of annual average PM2.5 concentrations, oil and gas emissions only

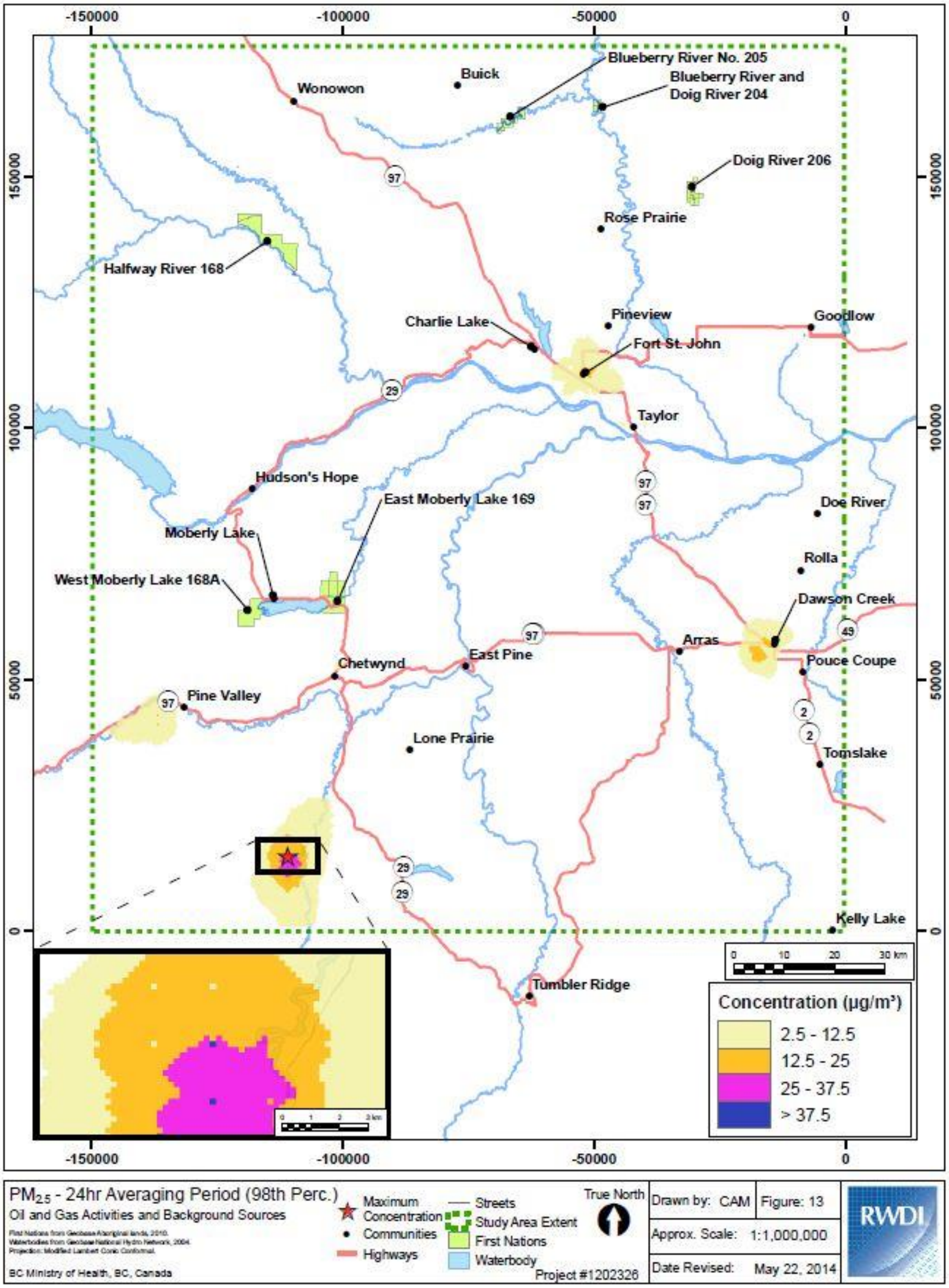

Figure 28 Predictions of PM2.5 concentrations, 24 hour averaging period, cumulative scenario

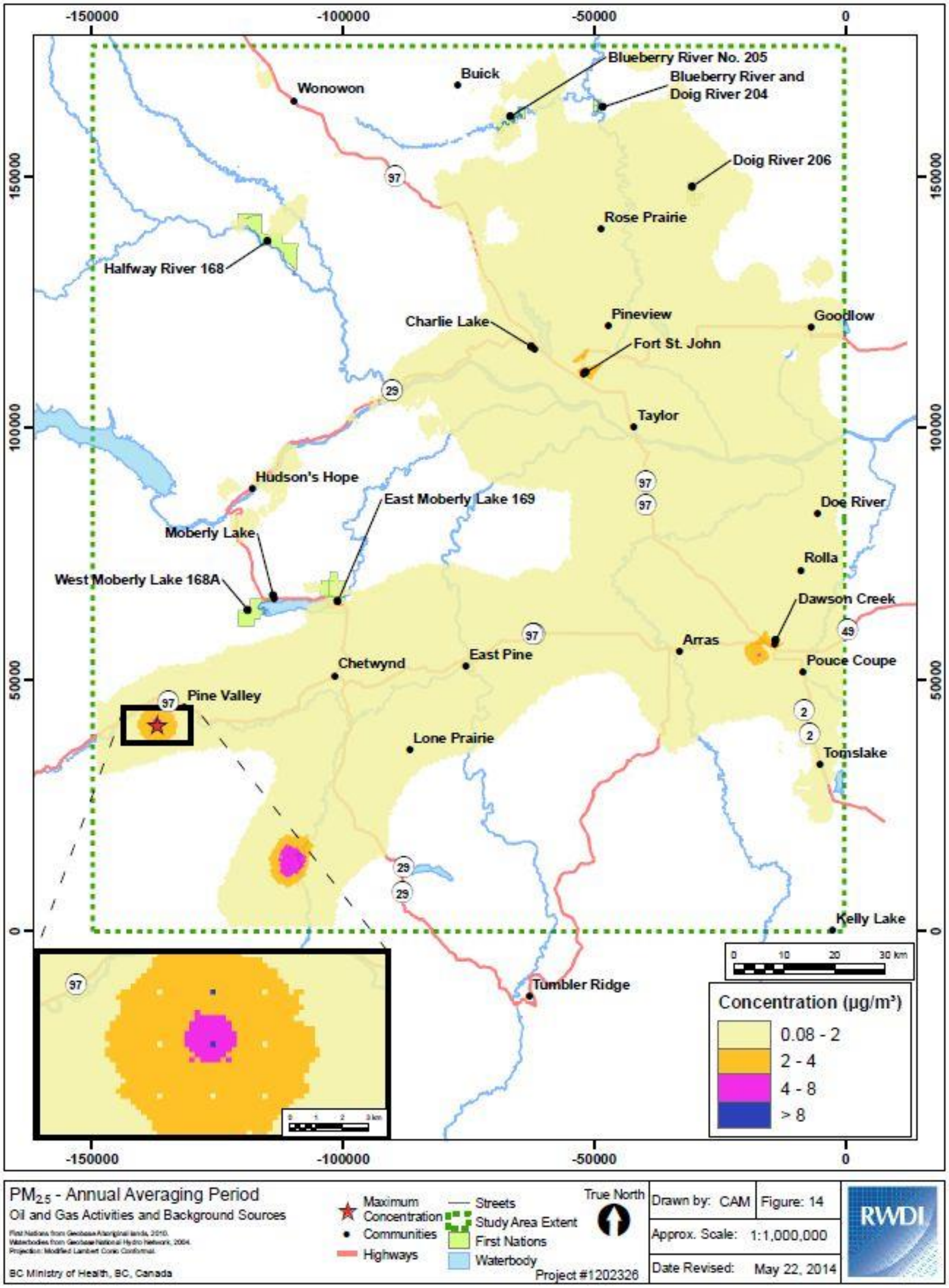

Figure 29 Predictions of PM2.5 concentrations, annual average, cumulative scenario

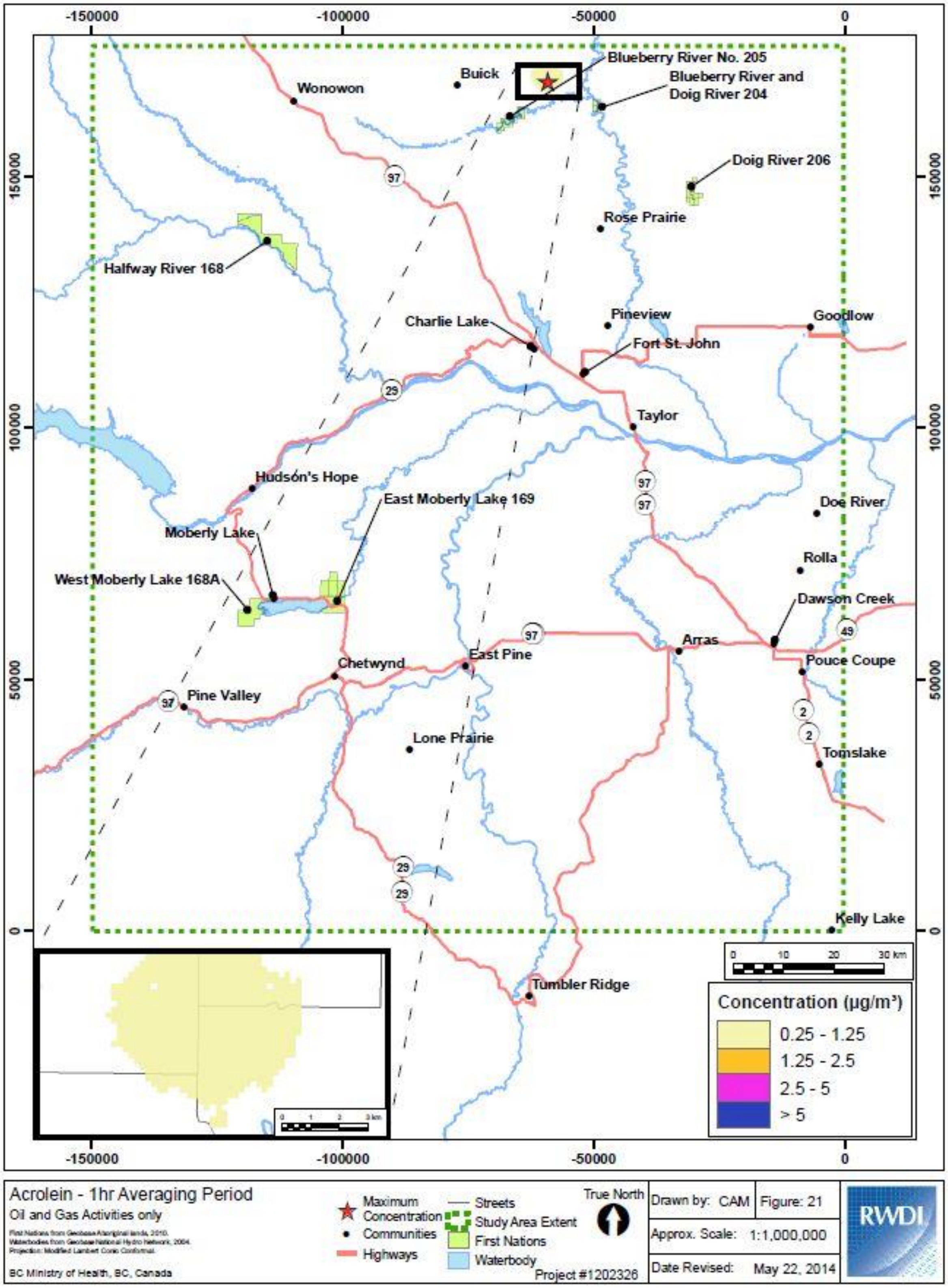

Figure 30 Predictions of maximum acrolein concentrations, one hour averaging period, oil and gas emissions only

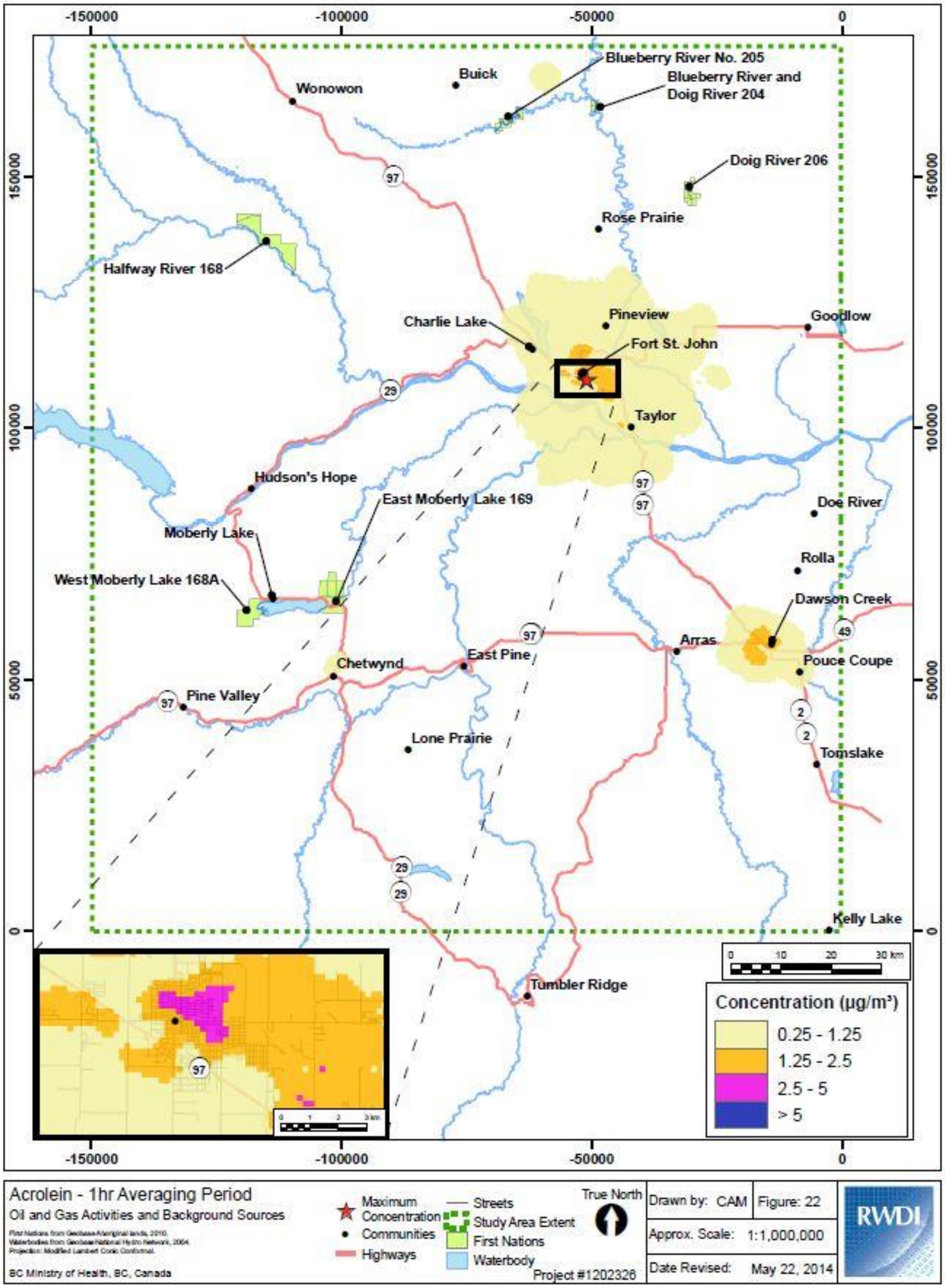

Figure 31 Predictions of maximum acrolein concentrations, one hour averaging period, cumulative scenario

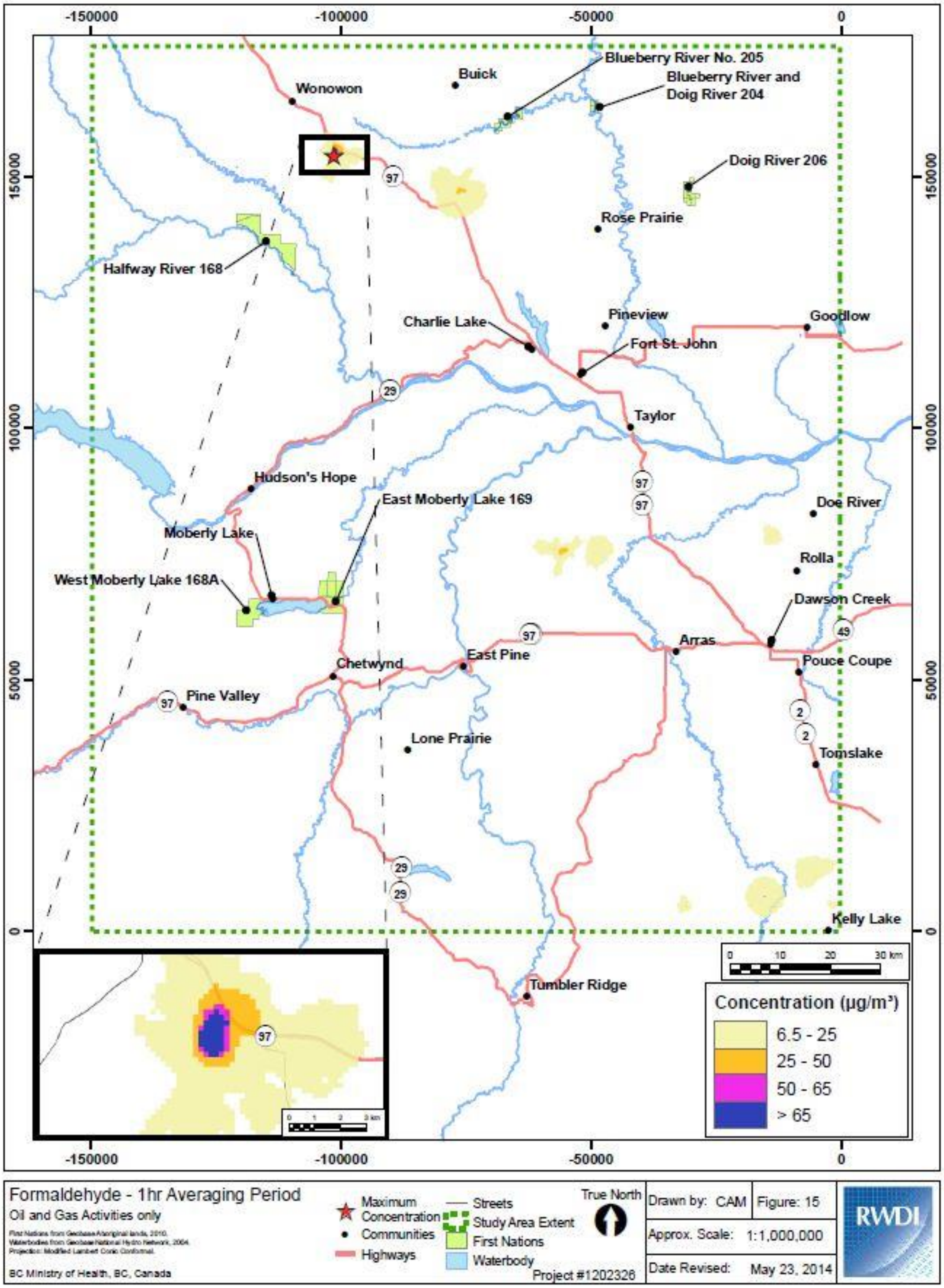

Figure 32 Predictions of maximum hourly formaldehyde concentrations, one hour averaging period, oil and gas emissions only

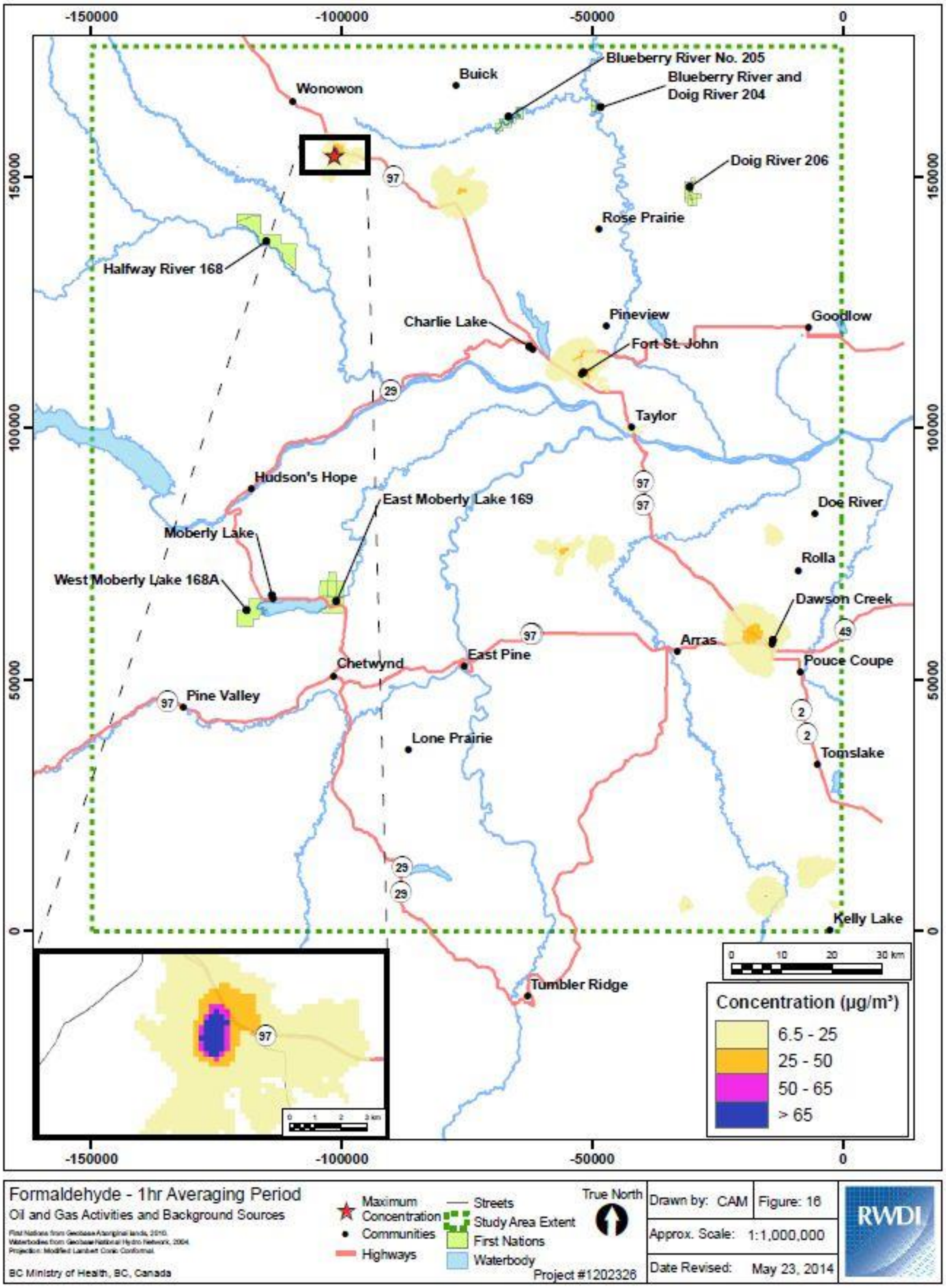

Figure 33 Predictions of maximum formaldehyde concentrations, one hour averaging period, cumulative scenario

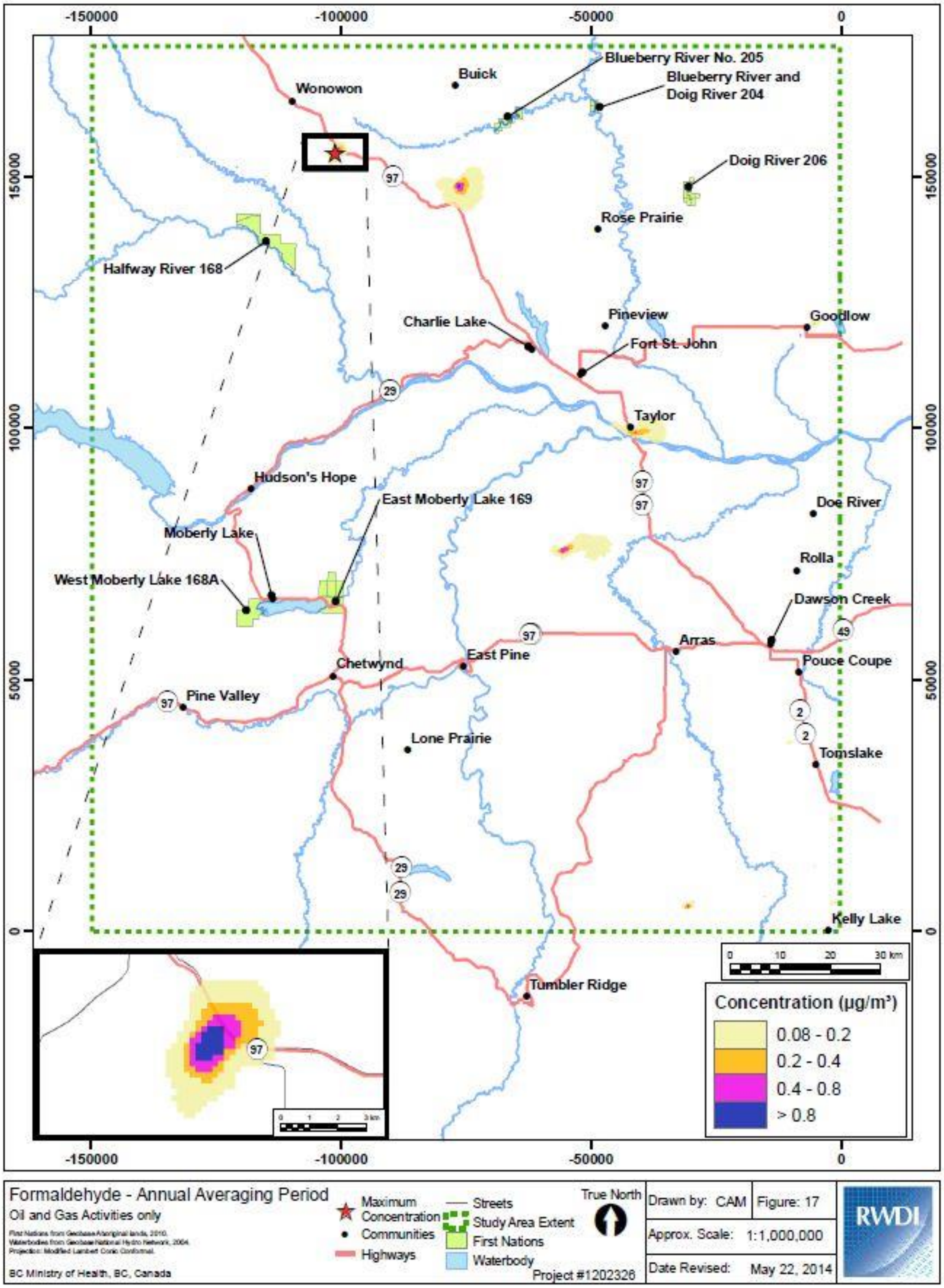

Figure 34 Predictions of formaldehyde concentrations, annual averaging period, oil and gas emissions only

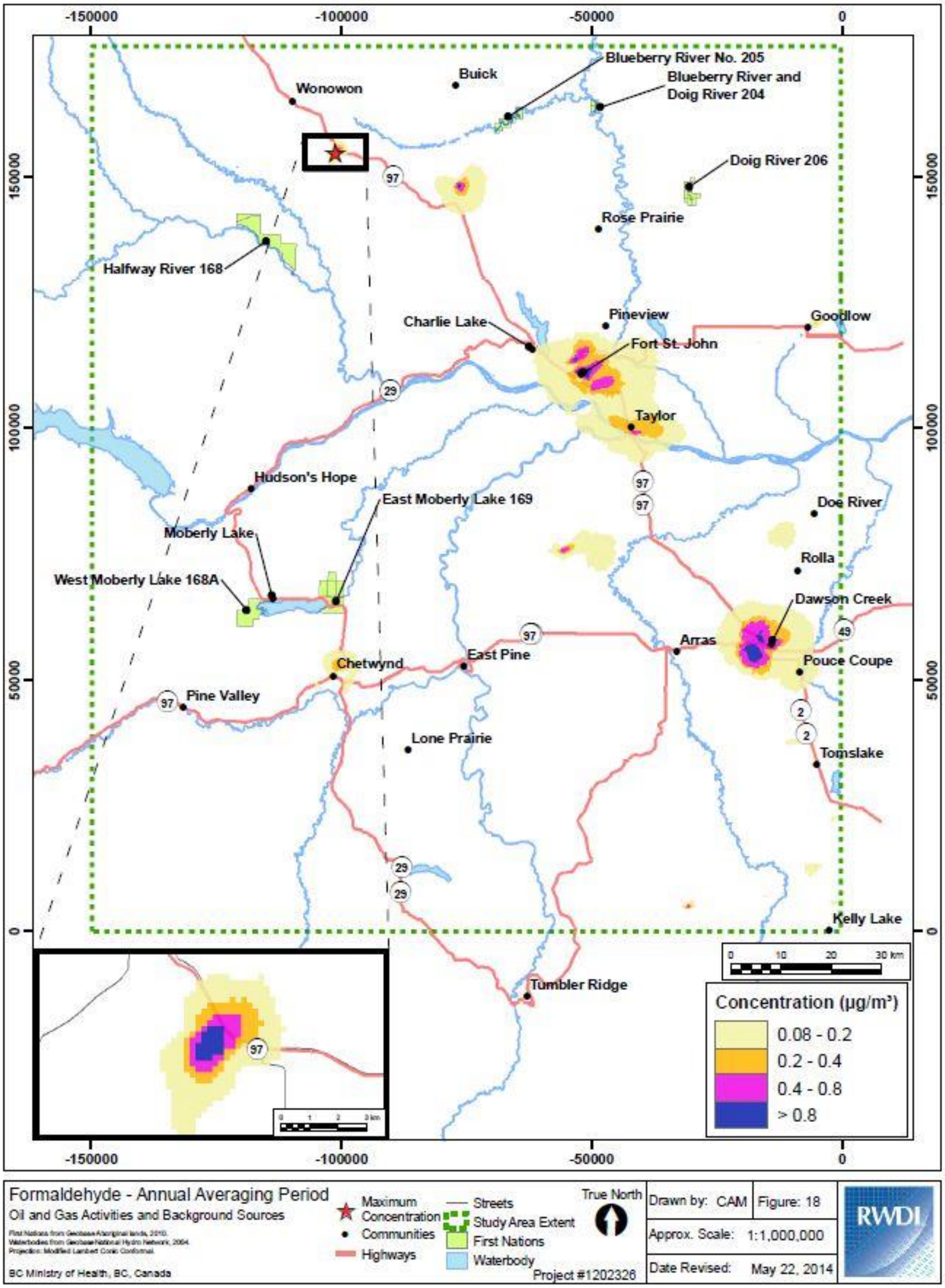

Figure 35 Predictions of formaldehyde concentrations, one hour averaging period, cumulative scenario

Appendix 4 Emission sources from oil and gas activities

Emission sources of air pollutants in the oil and gas sector include condensate tanks, gas processing facilities, compressor stations, construction activity, dehydrators, vehicles, engines and venting and flaring. Significant pollutant types emitted from these and other oil and gas industry sources include:

- 1,3-butadiene
- acetaldehyde
- acrolein
- benzene, toluene, ethylbenzene and xylene (BTEX) and other volatile organic compounds (VOCs)
- carbon monoxide
- cyclohexane
- formaldehyde
- isopropylbenzene (cumene)
- methane
- n-hexane
- nitrogen oxides
- ozone (a secondary pollutant)
- particulate matter
- sulfur dioxide and sulfur trioxide (SOx)
- total reduced sulfur (TRS)[9]

Key pollutants emitted from the wood products (Environment Canada 2014-2) include:

- acelatdehyde
- acrolein
- carbon monoxide (CO)
- formaldehyde
- methanol
- nitrogen oxides (NOx)
- particulate matter (PM10 and PM2.5)
- volatile organic compounds (VOCs)

[9] **Ambient TRS and H2S measurement:** Hydrogen sulphide (H2S) is a colourless gas with a rotten egg odour. Total reduced sulphur (TRS) includes hydrogen sulphide, mercaptans, dimethyl sulphide, dimethyl disulphide and other sulphur compounds. H2S is measured continuously by pulsed fluorescence (the same principle as the SO2 analyzer). Initially, all SO2 in the air sample is scrubbed out so that it does not interfere with the measured H2S concentration. The remaining H2S in the sample is then converted to SO2. The sample is then drawn through a sample chamber where it is irradiated with pulses of ultra-violet light. Any SO2 in the sample is excited to a higher energy level and upon returning to its original state, light or fluorescence is released. The amount of fluorescence measured is proportional to the SO2 (converted from H2S or TRS) concentration. The TRS analyzer works on exactly the same principle as the H2S analyzer. The only difference is that the conversion of sulphur compounds to SO2, occurs at a much higher temperature. Therefore there is a more complete conversion of sulphur compounds to SO2 (Clean Air Strategic Alliance 2015-1).

Appendix 5 Permitting Sources and Ambient Monitoring

Environmental permits for BC oil and gas operations are issued either by the Oil and Gas Commission or the Ministry of Environment under the *Environmental Management Act* (*EMA*). Operations that do not require National Energy Board (NEB) approval are permitted by the Commission. Those that require NEB approval are permitted by MoE.

Environmental monitoring is one of the common conditions to appear in EMA permits. In NE BC several oil and gas facilities are required to install and maintain monitoring facilities for meteorology and ambient H2S and SO2. These stations are routinely audited to ensure data validity. Example language included in a permit is as follows:

There are some situations where facilities have elected to perform meteorological and ambient monitoring in the absence of permit conditions. Data from these stations is also included in this assessment.

Table 8 Summary of Air monitoring stations installed by industry in the Pease area of NE BC

Agency	Facility	Notes
MoE	Taylor Townsite & Taylor South Hill Spectra	Permits require meteorological monitoring and ambient TRS and SO2.
MoE	Hasler & Pine Plant Spectra	Permit requires meteorological monitoring and ambient TRS and SO2. Two stations are required under the single MoE permit.
OGC	Doe River Spectra	Company is monitoring meteorology, TRS and SO2 voluntarily.
MoE	Dawson Spectra	Permit requires meteorological monitoring and ambient TRS and SO2.
OGC	Buick Creek CNRL	Permit does not require ambient monitoring. Company is monitoring meteorology, TRS and SO2 voluntarily.
MoE	Kwoen Gas Plant	Permit requires meteorological monitoring.

Copies of all EMA permits are available online at:
http://www2.gov.bc.ca/gov/topic.page?id=DF89089126D042FD96DF5D8C1D8B1E41

There are two other pertinent components for ensuring that accurate ambient data is acquired – auditing and validation. Twice a year, the Ministry of Environment's air audit team audits every air quality monitoring station in BC that falls under provincial jurisdiction. This includes both ministry-operated sties and monitoring stations that are regulated under industry permits, such as continuous emissions monitors for industrial stacks and ambient monitors. Human review and analysis of the ambient data is done by the MoE air validation team and is typically a three-month process before the data is archived as valid data. For more information see http://www.bcairquality.ca/assessment/air-monitoring-data.html

Appendix 6 Quality Control and Quality Assurance of Data

Auditing of monitors and data validation ensures accurate ambient concentration data. Twice a year, the Ministry of Environment's air audit team inspects every air quality monitoring station in BC that falls under provincial jurisdiction. This includes stations for monitoring ambient concentrations as well as stack emissions. The stations listed in Appendix 5 for NE BC along with the three new portable stations are audited by MoE.

Further information can be found at: http://www.bcairquality.ca/industry-resources/audit-air-monitoring.htm

Human review and analysis of the ambient data is done by the MoE air validation team and is typically a three-month process before the data is archived as valid data. For more information see http://www.bcairquality.ca/assessment/air-monitoring-data.html

Appendix 7 HHRA extreme modelling results for cumulative scenario

Table 9 Maximum Air Quality Modelling Results for the Upstream Oil and Gas Sources and the Background Sources (µg/m3). HHRA results were provided by the BC Ministry of Health. The dispersion modelling used CALPUFF to predict concentrations within the dispersion modelling study area. Maximum air quality modelling results for upstream oil and gas sources in the study area are presented in this table, as well as, for select species and time averaging periods, 99th or 98th percentiles over an entire year.

Representative_Receptor	X (m)	Y (m)	Receptor ID	1 H so_2(ug/m3)	24 H so_2(ug/m3)	Ann so_2(ug/m3)	1 H pm_25(ug/m3)	24 H pm_25(ug/m3)	Ann pm_25(ug/m3)	1 H h2_s(ug/m3)	24 H h2_s(ug/m3)	Ann h2_s(ug/m3)	99p 1h SO2	98 p 1h NOx	98 p 1h NO2	98p 24h PM2.5	no2_1h (ug/m3)	no2_24 h (ug/m3)
Criteria				450	160	25	80	25	8	7	3	-	196	-	188	25	400	200
Criteria Source				BCAAQO	BCAAQO	BCAAQO	AAAQO	BCAAQO	BCAAQO	BCAAQO	BCAAQO		US EPA		US EPA	BCAAQO	NAAQO	NAAQO
MPOI				1062.2	185.68	15.457	1552.8	239.3	28.894	26.368	5.3104	1.0256	503.9	1664.6	292.8693	112.65	535.3293	88.91237
MPOI Location (Receptor X m)				-76.875	-73	-101	-111	-111	-137	-76.375	-76.375	-76.375	-76.875	-59	-59	-111	-73	-5.625
MPOI Location (Receptor Y m)				146.875	157	163	15	15	41	147.125	148.125	148.125	146.875	169	169	15	105	120.625
			Receptor ID (for QA)	14541	5756	5965	532	532	1468	14572	14692	14692	14541	6208	6208	532	3856	13531
Tumbler Ridge	-63000	1000	44	7.0227	1.9778	0.12013	0.68143	0.15585	0.013376	0.049341	0.011534	0.000584	5.4499	8.8193	8.8193	0.088737	18.2	6.0332
Kelly Lake	-3000	1000	74	10.99	1.6349	0.13846	0.32046	0.095026	0.01064	0.27761	0.024987	0.00103	9.4072	14.042	14.042	0.054251	20.561	4.28
Charlie Lake (Community)	-61000	115000	4226	36.958	6.9236	0.93664	11.856	5.1801	0.48561	0.34983	0.072015	0.006413	31.766	75.316	75.316	1.8867	137.41	44.43357
Tomslake	-5125	33875	8163	9.911	2.0848	0.38165	1.6939	0.72019	0.10747	0.081719	0.009998	0.001045	7.6296	92.983	92.983	0.35263	145.8203	38.36
Lone Prairie	-86625	35875	8358	19.01	4.456	0.63814	2.1491	0.5397	0.11075	0.067199	0.01666	0.001967	12.304	14.868	14.868	0.37112	20.438	12.875
Pine Valley	-132375	44875	9062	90.333	7.7857	0.43952	26.759	3.1289	0.29905	0.33383	0.050537	0.002474	49.234	49.887	49.887	1.4471	79.522	16.153
Chetwynd	-101625	50875	9275	54.781	9.8148	1.5549	16.755	4.191	1.04	0.18818	0.033318	0.004021	32.768	163.13	142.7223	2.9412	147.6643	44.38337
Pouce Coupe	-8375	51625	9320	12.851	2.9956	0.80209	12.22	3.7543	0.72837	0.10965	0.018112	0.001625	10.79	90.783	90.783	2.5945	137.62	42.66887
East Pine	-75625	52875	9349	21.978	3.5427	0.91136	2.4984	1.0597	0.21286	0.088153	0.025171	0.002579	13.927	81.858	81.858	0.66617	103.57	42.28467
Arras	-32625	55875	9478	15.375	4.2458	0.66821	4.1893	0.96255	0.15414	0.16144	0.027304	0.002115	13.455	54.027	54.027	0.57331	85.966	34.542
Dawsons Creek	-13875	57375	9563	26.579	10.412	2.3655	80.839	26.961	4.8464	0.15794	0.021544	0.002073	23.612	389.86	165.3953	17.697	178.8473	55.31837
West Moberly Lake 168a	-117875	63125	9795	42.714	4.5932	0.45061	3.1289	0.75958	0.075569	0.097717	0.026144	0.002138	21.449	22.63	22.63	0.3315	38.114	17.943
Moberly Lake	-111875	65625	10065	17.398	3.5411	0.41189	2.6838	0.73367	0.059661	0.07101	0.024053	0.002069	13.422	21.343	21.343	0.28136	35.936	15.628

Representative_Receptor	X (m)	Y (m)	Receptor ID	1 H so_2(ug/m3)	24 H so_2(ug/m3)	Ann so_2(ug/m3)	1 H pm_25(ug/m3)	24 H pm_25(ug/m3)	Ann pm_25(ug/m3)	1 H h2_s(ug/m3)	24 H h2_s(ug/m3)	Ann h2_s(ug/m3)	99p 1h SO2	98 p 1h NOx	98 p 1h NO2	98p 24h PM2.5	no2_1h (ug/m3)	no2_24 h (ug/m3)
East Moberly Lake 169	-101875	67125	10201	36.645	6.3818	0.73258	2.7923	0.98284	0.17849	0.23329	0.028707	0.002601	20.023	37.281	37.281	0.55363	45.885	26.212
Rolla	-8875	71875	10447	34.2	4.3315	0.68605	2.4392	0.81433	0.10747	0.30925	0.045196	0.003254	16.244	54.071	54.071	0.50559	124.26	28.568
Doe River	-5375	82875	10895	30.506	4.4484	0.80518	1.396	0.71055	0.085228	0.13252	0.039437	0.004303	14.906	40.502	40.502	0.37439	58.778	27.598
Hudsons Hope	-118125	88125	11076	45.111	4.9381	0.47898	2.4339	0.92795	0.11859	0.10622	0.02736	0.002438	22.632	33.009	33.009	0.44859	43.632	26.985
Taylor	-42125	100125	11806	327.71	36.091	1.5035	11.572	3.5802	0.85925	0.39545	0.065647	0.005074	134.81	1045.2	230.9293	2.4902	367.5593	72.48737
Fort St. John	-52125	110625	12494	365.72	26.575	3.5079	104.33	34.641	6.0238	2.108	0.26529	0.008527	182.49	470.34	173.4433	20.383	190.3663	59.45437
Pineview	-47125	119875	13446	78.947	10.301	0.91053	6.3507	2.3048	0.23303	0.46508	0.11245	0.007601	51.036	77.15	77.15	0.97903	108.69	43.02897
Goodlow	-6875	119875	13454	56.185	8.2345	1.1427	3.774	0.62501	0.13714	2.5984	0.3933	0.026119	44.792	121.83	121.83	0.4213	145.3793	35.492
Halfway River 168	-114375	137625	14051	47.531	5.1388	0.69966	1.8485	0.7721	0.12097	0.23373	0.045547	0.003056	18.691	42.617	42.617	0.33799	134.81	23.496
Rose Prairie	-50125	139875	14168	21.417	4.9978	0.65257	4.0823	2.2261	0.22093	0.38664	0.061785	0.006662	18.535	93.609	93.609	0.69169	114.8	44.32687
Doig River 206	-30375	147125	14587	119.34	13.867	0.95678	3.3737	1.0481	0.12719	0.31168	0.062774	0.009062	16.645	50.649	50.649	0.40368	140.8873	38.775
Blueberry River No. 205	-66375	161625	15541	72.681	14.613	1.097	2.6494	1.0551	0.12076	1.0314	0.20088	0.007911	44.76	156.56	142.0653	0.45677	199.5503	46.76347
Blueberry River And Doig River 204	-49375	164375	15650	13.038	3.8922	0.52485	2.3458	1.2641	0.065959	0.22238	0.052167	0.004412	11.15	69.004	69.004	0.34416	160.7453	43.80997
Wonowon	-110375	165625	15675	18.21	3.8617	0.38841	0.85041	0.336	0.041696	0.13625	0.060747	0.002502	12.638	35.798	35.798	0.19717	65.434	18.141
Buick	-77375	167875	15676	18.174	4.1359	0.68805	1.5645	0.64461	0.1098	0.32906	0.060024	0.004307	15.851	116.2	116.2	0.35328	145.1383	42.11767
Charlie Lake (Waterbody)	-61000	121000	4442	40.378	5.8722	0.72107	3.8079	2.0298	0.14407	0.42403	0.089139	0.007541	30.121	44.619	44.619	0.68222	56.399	35.619

Appendix 8

Contact information:
BC Government programs and services - Enquiry BC: 1-800-663-7867
BC Oil & Gas Commission:

Emergency Contact 24 hour Incident Reporting 1-800-663-3456
Fort St John Reception and 24 hour complaint line – 24 hours: 250-794-5200
Victoria Reception: 250-419-4400

Additional information may be available from the BC Oil and Gas Commission and other sources that have yet to be analyzed in this report.