APPENDIX E
AIR QUALITY AND CLIMATE

INTRODUCTION TO SECTION 3 ATTACHMENTS

Section 3 of the Springbank Off-Stream Reservoir Project Environmental Impact Assessment (EIA) is the valued component (VC) chapter related to air quality, light, and greenhouse gas (GHG). Volume 3A, Section 3 assesses potential effects during construction and dry operations, and Volume 3B, Section 3 assesses potential effects during flood and post-flood operations.

There are seven attachments provided and one technical data report:

Attachment 3A provides the air source and emission inventory for construction activities and dry operations. The emissions are used to estimate ground-level concentrations using an air quality model. Attachment 3A also provides air source and emission inventory for other sources in the local assessment area (LAA); these include existing traffic along the Trans-Canada Highway No. 1.

Attachment 3B describes the meteorological information used by the air quality model to estimate ground-level concentrations resulting from air emissions due to SR1 construction. Meteorology determines the transport and dispersion of industrial emissions and, hence, largely determines air quality downwind of emission sources. Attachment 3B also provides the technical details and options used to apply CALMET (a diagnostic 3-dimensional meteorological model) for the air quality assessment.

Attachment 3C describes the CALPUFF air quality model that predicts changes to the ambient air quality (ground-level concentrations) resulting from air emissions during construction. The CALPUFF model was also used to predict the deposition of substances that are related to construction air emissions. The CALPUFF model uses mathematical equations to simulate transport, dispersion, transformation, and deposition processes in the atmosphere.

Attachment 3D describes the background ambient air quality concentrations that were used for the assessment. Background concentrations are the contributions from emissions not included in the modelling (i.e., emissions from sources located outside the LAA, smaller sources inside the LAA, and natural sources). In Volume 3A, Section 3, the assessment of construction emissions involves adding background values (for the substances of interest) to the model predictions prior to comparison to the ambient air quality objectives.

Attachment 3E provides 78 isopleth maps (also known as concentration and deposition plots) that summarize the maximum ground-level ambient air quality concentrations (and deposition) predicted by the CALPUFF model for construction air emissions. Isopleth maps are used to illustrate the spatial variation of ambient air quality. Isopleth maps are prepared for different time averaging periods that correspond to the ambient air quality objective for each substance of interest.

Attachment 3F provides the methods and results for the GHG emissions from the stationary and mobile equipment used for various construction activities.

Attachment 3G provides a series of daytime and nighttime photographs describing baseline conditions at four locations. These daytime and nighttime panoramic views are used for the light assessment in the Volume 3A, Section 3.

Dispersion Modelling for Wind-eroded Sediment from the Off-stream Reservoir Technical Data Report provides an assessment for the effects of fugitive dust emissions from wind erosion of deposited sediment in the off-stream reservoir during post-flood operations (after draining of the reservoir water back into the Elbow River).

Attachment 3A EMISSIONS DURING CONSTRUCTION

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Abbreviations

AADT	average annual daily traffic
ASDT	average summer daily traffic
BSFC	brake specific fuel consumption
CAC	criteria air contaminant
CGSB	Canadian General Standard Board
CNG	compressed natural gas
CO	carbon monoxide
ECCC	Environment and Climate Change Canada
EF	emission factor
g/s	grams per second
GVW	gross vehicle weight
kg/d	kilograms per day
LAA	local assessment area
LF	load factor
MOVES	Motor Vehicle Emission Simulator
NO_X	oxides of nitrogen
NPRI	National Pollutant Release Inventory
PAH	polycyclic aromatic hydrocarbon
PDA	project development area

PM	particulate matter
PM_{10}	particulate matter with aerodynamic particle size ≤ 10 µm
$PM_{2.5}$	particulate matter with aerodynamic particle size ≤ 2.5 µm
RFG	reformulated gasoline
RVP	Reid vapour pressure
SO_2	sulphur dioxide
t/y	tonnes per year
TF	transportable fraction
TSP	total suspended particulates
UF	utilization factor
U.S. EPA	United States Environmental Protection Agency
VMT	vehicle miles travelled
VOC	volatile organic compound

3A.1 INTRODUCTION

For the ambient air quality assessment, it is necessary to estimate emissions associated with project construction activities and emissions associated with other sources located in the local assessment area (LAA). The latter allows the combined effects of the Project and existing sources to be evaluated.

3A.1.1 CAC and VOC substances

The air quality assessment focuses on criteria air contaminants (CACs) that can potentially cause harm to health, the environment and property. These substances are called criteria because the Alberta Government, and Environment and Climate Change Canada have ambient air quality objectives, guidelines, or standards for these substances. CACs of interest for this Project are:

- nitrogen oxides (NO_X)
- sulphur dioxide (SO_2)
- carbon monoxide (CO)
- particulate matter with aerodynamic diameter less or equal to 2.5 µm ($PM_{2.5}$)
- total suspended particulates with aerodynamic diameter less or equal to 30 µm (TSP)

The gaseous CACs (NO_X, SO_2, CO) and $PM_{2.5}$ are associated with exhaust emissions from construction equipment. Fugitive dust emissions from surface disturbance activities result in particulate matter emissions of various sizes (e.g. $PM_{2.5}$, TSP). Although not considered a CAC, total particulate matter deposition (dustfall) is calculated for the accumulation of particulate matter on soils.

This air quality assessment includes specific VOC (volatile organic compound), polycyclic aromatic hydrocarbon (PAH) and metal substances. VOCs and PAHs result from construction equipment exhausts. Metals are in construction equipment exhaust and are carried on windblown dust.

Emission rates are estimated for 10 VOC, 15 PAH and 5 metal substances. Of these, there are ambient air quality criteria for 7 VOCs, 2 PAHs and 4 metals. Predicted concentrations and deposition for the 10 VOC, 7 PAHs and 5 metal substances are provided to the human health and ecological risk assessment team for use in Section 15.

3A.1.2 Dispersion Model Context

Maximum representative hourly and annual average substance emission rates are required for the dispersion model assessment. Ambient concentration predictions associated with maximum hourly emission rates are compared to short-term ambient criteria based on averaging periods shorter than a year (e.g., 1-hour, 24-hour, 30-day). Ambient concentration predictions associated with annual emission rates are compared to annual ambient criteria.

3A.1.3 Project Schedule Assumptions

Depending on conditions, an expected construction period of 275 days could be spread out over two to three years. During the construction period, construction activities and intensities will not be uniform. Most of the construction is expected to occur during non-winter periods when the ground is not frozen or covered with snow.

Some construction activities will occur 24-hours per day and others will be restricted to the daylight portion of the day (assumed to be a 12-hour period 7 am to 7 pm). The maximum 1-hour emission rate assumptions relating to the project schedule are as follows:

- Construction activities that occur 24 hours per day (e.g., off-stream dam) are conservatively assumed to occur simultaneously. The associated maximum 1-hour emission rates are assumed to be uniform for the construction duration (214 days, April to October), and they are used to predict maximum 1-hour and 24-hour average concentrations. The 214-day value is based on a 7-month construction season between April and October.
- Construction activities that occur for 12 hours per day (e.g., road realignments) are also conservatively assumed to occur simultaneously. The associated maximum 1-hour emission rates are assumed to be uniform for 12-hours during the day for all days of the year, and they are used to predict associated maximum 1-hour and 24-hour average concentrations.

While these 1-hour emission rates are appropriate to estimate short-term 1-hour and 24-hour average concentrations, they will overstate annual average emission rates and associated annual average concentrations and deposition. The 1-hour average emission rates are, therefore, reduced from the 1-hour emission rates using the ratio of 1) the expected working days per year for an activity to 2) the construction duration. The following are assumed for the calculation of annual emission rates during construction:

- Construction activities that occur for 24 hours per day will continue for 214 days per year. The 214-day value is based on a 7-month construction season between April and October. Depending on the activity, the number of working days can vary from 25 days to 214 days. For the 25-day activity, the annual average emission rates are 25/214 times the associated maximum 1-hour emission rates. The associated annual average emission rates are uniform over the day for all hours of the construction duration (214 days, April to October), and they are used to predict annual average concentrations.

- Construction activities that occur for 12 hours per day will continue for 365 days per year. The 365-day value is means that an activity can take place at any time during the year. Depending on the activity, the number of working days can vary from 10 days to 240 days. The maximum work days (240 days) are based on 6 work days per week for a maximum of 40 weeks. For a 240-day activity, the annual average emission rates are 240/365 times the associated maximum 1-hour emission rate.

Based on these schedule assumptions, a worst-case emission rate scenario is modelled where most total emissions for the project construction (approximately 78%) are allocated in one year instead of equally distributed over the construction period (e.g., two to three years).

The other LAA regional emissions are assumed to be continuous throughout the year and, therefore, the hourly and annual emission rates are the same.

3A.1.4 Project General Assumptions

The following general and operational assumptions are used to estimate project emissions due to combustion sources:

- Construction equipment complies with Tier 3 emission standards for off-road engines.
- Power ratings (hp) for off-road construction equipment are based on manufacturer specifications using the assumed manufacturers and models.
- Utilization (load) factors for off-road construction equipment from the U.S. EPA NONROAD model (U.S. EPA, 2005).
- 80% is the utilization factor for haul trucks.

The following general and operational assumptions are used to estimate project fugitive dust emissions:

- Seventy-five percent is the dust control efficiency on haul roads during the summer, corresponding to application of water twice daily (U.S. EPA, 2006a). Summer is assumed to be March to October.
- Ninety percent is the natural mitigation efficiency on haul roads during winter (Golder Associates, 2012). Winter is assumed to be November to February.
- Fugitive dust control not applied during bulldozing and grading, off-road equipment in transition, truck loading and unloading, and material transfer to and from the temporary top soil and overburden stockpile.

- Temporary top soil and overburden stockpile is stabilized when inactive for extended periods of time.
- Seventy-five percent transportable fraction (TF) is applied to estimate fugitive dust emissions. The TF accounts for the near-source removal of fugitive dust emissions due to micro-scale turbulence and impact on nearby vegetation. The emission fraction that is removed due to local source removal factors is defined as "capture fraction". The emission fraction that is not removed is defined as "transportable fraction". The transportable fraction is the correction factor for the deficiency of dispersion models, and it accounts for the near-source removal mechanisms for fugitive dust. A Transportable Fraction of 75% corresponds to the grassland land use category (Pouliot et al. 2010).

3A.1.5 Emission Factor and Emission Rate Units

In the following sections, emission factors and emission rates are presented in mixed metric and imperial units because most emission factors used for emission estimation originate from the U.S. EPA AP-42 Fifth Edition Compilation of Air Pollutant Emission Factors (U.S. EPA, 1998), which are in imperial units. The emission summaries are presented in metric units (e.g., g/s, kg/d and t/y).

The emission summaries presented in the following sections show the maximum hourly and annual average emission rates in units of grams per second (g/s) for direct input to the dispersion model. Total daily emissions in units of kilograms per day (kg/d) and total annual emissions in units of tonnes per year (t/y) are also presented. Daily emissions are based on the hourly emission rates and the work hours per day for each construction activity.

3A.2 EMISSION SUMMARY

The ambient air quality assessment addresses three cases:

- Base Case is defined by existing emissions in the LAA.
- Project Case considers only project emissions.
- Application Case considers the combined effect of the Base Case and the Project Case.

Background contributions (from emission sources outside the LAA) are considered for the Base Case and Application Case.

3A.2.1 Base Case Emission Rates

Base Case emissions in the LAA include traffic exhaust and road dust emissions from nearby roadways, and a compressor station located in the northwest sector of the LAA. Traffic emission rates are determined for the TransCanada Highway (Highway 1), Highway 22, Highway 8, and the Springbank Road. Traffic and road dust emissions on regional roads are estimated for winter and summer periods based on winter and summer-specific traffic volumes and emission factors.

A summary of Base Case emission rates is provided in Table 3A-1. NO_X, SO_2, CO and VOC emissions are associated with combustion sources only. $PM_{2.5}$ emission rates associated with combustion sources and with fugitive dust sources are similar in magnitude. TSP emission rates associated with fugitive dust sources are much greater than those associated with combustion emissions. The Base Case emission rates in Table 3A-1 do not include combustion emissions associated with residential heating or fugitive dust associated with agricultural operations. The background values that are added to the model predictions indirectly account for these sources.

3A.2.2 Project Case Emission Rates

Project Case emissions during construction are associated with the operation of the off-road construction equipment and earth moving activities for constructing the major components of the Project, including the road realignments and modifications. The Project results in two types of air emissions: combustion exhaust emissions from construction equipment and fugitive dust emissions from surface disturbance activities. The following emission sources due to construction activities are estimated:

- diesel combustion exhaust emissions from off-road construction equipment and haul trucks
- fugitive dust emissions from scraping, bulldozing and grading of top soil and overburden
- mechanically-generated dust by off-road equipment in transition
- fugitive dust emissions from truck loading and unloading
- mechanically-generated dust by truck traffic along haul roads
- fugitive dust emissions from wind erosion of top soil and overburden stockpile

Exhaust emissions from off-road diesel equipment are based on the Canadian off-road compression-ignition engine emission standards (ECCC, 2005). Project construction equipment is assumed to comply with Tier 3 emission standards.

Fugitive dust emissions from construction equipment activities and wind erosion are estimated using emission factors from various chapters of the U.S. EPA AP-42 Fifth Edition Compilation of Air Pollutant Emission Factors (U.S. EPA, 1998).

Emissions associated with on-highway vehicles transporting workers and materials to and from the site are not included in the project emission inventory because it is assumed they are of short duration and on paved roads.

A summary of project emissions is provided in Table 3A-2. NO_X, SO_2, CO and VOC emissions are associated with combustion sources only. The annual equivalent emission rates for these substances are about 74% of the corresponding the maximum daily emission rates. Most of the $PM_{2.5}$ and TSP emissions are associated with the fugitive haul road dust emissions. The associated annual equivalent emissions rates are about 90% to 95% of the corresponding maximum daily emission rates.

3A.2.3 Application Case Emission Rates

The Application Case emission rates are the sum of the Base Case and Project Case emission rates. Table 3A-3 shows the daily emission rates for the three cases. The project contribution is 91% to 95% (i.e., the Base Case contributes 5% to 9%) for particulate emissions and 40% to 68% (i.e., the Base Case contributes 32% to 60%) for gaseous emissions. These comparisons are based on the larger daily emission rates. On an annual basis (not shown in the table), the project contribution ranges from 90% to 95% for particulate emissions and 33% to 61% for gaseous emissions.

3A.2.4 Emission Uncertainty and Conservatism

The Base Case and Project Case vehicle exhaust emissions are based on local traffic data and accepted industry emission factors. The level-of-confidence associated with the estimates for gaseous CAC emission rates (e.g., NO_X, SO_2, CO and VOC) from these sources is greater than that estimates for TSP, $PM_{2.5}$ and metal emission rates. PAH emissions are estimated as a sum of their gaseous and particle fraction and, therefore, PAH emission estimates inherit the uncertainty in estimating gaseous and particulate CAC emissions.

Fugitive TSP (and associated $PM_{2.5}$) emission rates depend on the properties of the surface material, the occurrence and history of surface disturbances, and meteorological conditions. While the air quality assessment uses emission algorithms developed by the U.S. EPA, there is considerable uncertainty associated with estimating these emissions. This will result in uncertainties in the associated ambient TSP and $PM_{2.5}$ concentrations and dustfall deposition predictions. In response to the difficulty in estimating fugitive road dust emissions, the New York State Department of Environmental Conservation rates fugitive dust estimates using the U.S. EPA approach as “indeterminate” (NYSDOEC, 2013). They find that the approach has many shortcomings and the estimates do not correlate with ambient monitoring.

Nonetheless, fugitive dust emissions using U.S. EPA approach are estimated for the Base Case and Project sources and used in the assessment to obtain an approximate understanding of potential magnitude, geographic extent, and frequency of the maximum concentrations in the LAA due to project construction.

The maximum hourly emission rates depend indirectly on the total construction duration because the required number of equipment units and loaded truck trips per day are estimated for the material volume that is moved per year. Although the construction could take place over two to three years, it is conservatively assumed that the construction emissions are not evenly distributed over this period. Instead, approximately 78% of total construction emissions are allocated to a single year. Therefore, the project emission rates and the predicted air quality changes are conservative (i.e., they likely overpredict concentrations).

Table 3A-1 Base Case Emission Rates

Emission Source	Length (km)	AADT [a] (vehicle/day)	ASDT [b] (vehicle/day)	Winter Emission Rates [c] (kg/d)						Summer Emission Rates (kg/d)					
				NO_x	SO_2	CO	$PM_{2.5}$	TSP	VOC	NO_x	SO_2	CO	$PM_{2.5}$	TSP	VOC
Road Traffic - Combustion Emissions															
Highway 1	20.3	23,330	27,630	348	2.09	964	13.3	18.4	44.6	366	1.25	1,247	11.7	17.2	43.8
Highway 22	22.4	12,800	13,760	207	1.25	564	7.96	11	26.5	197	0.673	667	6.4	9.4	23.3
Highway 8	12.1	7,130	8,380	70.3	0.378	153	2.61	3.6	7.84	74.5	0.244	201	2.43	3.51	6.81
Springbank Road	8.8	5,260	6,150	18.8	0.198	77.6	0.939	1.72	4.13	18.8	0.096	101	0.767	1.63	4.47
Total Emissions				**644**	**3.92**	**1,759**	**24.8**	**34.7**	**83.1**	**657**	**2.26**	**2,217**	**21.3**	**31.7**	**78.4**
Road Traffic - Fugitive Dust Emissions															
Highway 1	20.3	23,330	27,630	—	—	—	12.9	270	—	—	—	—	14.6	306	—
Highway 22	22.4	12,800	13,760	—	—	—	7.5	157	—	—	—	—	7.72	162	—
Highway 8	12.1	7,130	8,380	—	—	—	9.31	195	—	—	—	—	5.58	117	—
Springbank Road	8,.8	5,260	6,150	—	—	—	3.18	66.7	—	—	—	—	1.9	39.7	—
Total Emissions				**—**	**—**	**—**	**32.9**	**689**	**—**	**—**	**—**	**—**	**29.8**	**624**	**—**
Point Source Emissions															
Compressor Station	—	—	—	68.2	—	—	—	—	—	68.2	—	—	—	—	—
TOTAL EMISSIONS				**712**	**3.92**	**1,759**	**57.7**	**723**	**83.1**	**725**	**2.26**	**2,217**	**51.1**	**656**	**78.4**

NOTES:
AADT - average annual daily traffic (vehicle/day). Two-way traffic for period January 1 to December 31 (365 days)
ASDT - average summer daily traffic (vehicle/day). Two-way traffic for period of May 1 to September 30 (153 days)
[a] AADT used in calculation of winter emissions
[b] ASDT used in calculation of summer emissions
[c] For traffic combustion emissions, winter is defined as the 6-month period October to March. For road dust emissions, winter is defined as the 4-month period November to February.

Table 3A-2 Project Case Emission Rates

Emission Source	Daily Emission Rates [a] (kg/d)						Annual Emission Rates [b] (kg/d)					
	NO_X	SO_2	CO	$PM_{2.5}$	TSP	VOC	NO_X	SO_2	CO	$PM_{2.5}$	TSP	VOC
Diesel exhaust emissions from off-road equipment	1,524	3.9	1,450	83.8	86.4	124	1,134	2.8	1,074	62.6	64.5	93.0
Fugitive dust emissions from bulldozing and grading	—	—	—	36.9	351	—	—	—	—	20.3	193	—
Fugitive dust emissions from off-road equipment in transition	—	—	—	4.4	154	—	—	—	—	1.9	67.6	—
Fugitive dust emissions from material loading and unloading	—	—	—	5.8	80.9	—	—	—	—	5.2	71.9	—
Fugitive dust emissions from truck traffic on haul roads	—	—	—	368 [c]	12,875[c]	—	—	—	—	356 [c]	12,476[c]	—
Fugitive dust emissions from wind erosion [d]	—	—	—	0.728 [e]	6.1 [e]	—	—	—	—	0.728 [e]	6.1[e]	—
TOTAL EMISSIONS	**1,524**	**3.9**	**1,450**	**499**	**13,554**	**124**	**1,134**	**2.8**	**1,074**	**447**	**12,879**	**93.0**

NOTES:

[a] Daily emission rates are based on maximum hourly emission rates and the work hours per day for each activity

[b] Annual emission rates are based on scaled (reduced) hourly emission rates and the work hours per day for each activity

[c] Daily emission rates for haul roads represent emissions during summer with applied dust control efficiency (75%) corresponding to water application twice daily

[d] Wind erosion emissions represent emissions at hourly average wind speed greater than 10.8 m/s. For wind speeds less than 10.8 m/s, no wind erosion emissions are generated.

[e] Emission rate estimated based on 0.37% probability of hourly average wind speed greater than 10 m/s, extracted from CALMET for the location of the temporary top soil and overburden stockpile.

Table 3A-3 Comparison of Base Case, Project Case, and Application Case Emission Rates

Assessment Case	Emission Source	Daily Emission Rate (kg/d)					
		NO_X	SO_2	CO	$PM_{2.5}$	TSP	VOC
Base Case (summer [a])	road traffic combustion emissions	657	2.26	2,217	21.3	31.7	78.4
	road traffic fugitive dust emissions	—	—	—	29.8	624	—
	compressor station (Shell Jumping Pound 5-7)	68.2	—	—	—	—	—
	Emission Total	**725**	**2.26**	**2,217**	**51.1**	**656**	**78.4**
Project Case	diesel exhaust emissions from off-road equipment	1,524	3.9	1,450	83.8	86.4	124
	fugitive dust emissions from bulldozing and grading	—	—	—	36.9	351	—
	fugitive dust emissions from off-road equipment in transition	—	—	—	4.4	154	—
	fugitive dust emissions from truck traffic on haul roads [b]	—	—	—	368	12,875	—
	fugitive dust emissions from material loading/unloading	—	—	—	5.8	80.9	—
	fugitive dust emissions from wind erosion	—	—	—	0.728	6.1	—
	Emission Total	**1,524**	**3.9**	**1,450**	**499**	**13,554**	**124**
Application Case	Base Case emissions	725	2.26	2,217	51.1	656	78.4
	Project Case emissions	1,524	3.9	1,450	499	13,554	124
	Emission Total	**2,249**	**6.16**	**3,667**	**551**	**14,210**	**202**
Project Contribution (%) to Application Case Emissions:		**68%**	**63%**	**40%**	**91%**	**95%**	61%

NOTES:

[a] For traffic combustion emissions, summer is defined as the 6-month period April to September. For road dust emissions, summer is defined as the 8-month period March to October.

[b] Daily emission rates for haul roads represent emissions during summer with applied dust control efficiency (75%) corresponding to water application twice daily. For haul road dust emissions, summer is defined as the 8-month period March to October.

3A.3 PROJECT EMISSIONS

3A.3.1 Emission Sources

The project emission sources are typical for a construction site that involves surface disturbance and associated earth moving activities (e.g., the construction of a large subdivision or highway). The major components of the Project include the diversion channel, the off-stream dam, and the floodplain berm. Additional components of the Project include road realignments and modifications, such as raising Highway 22 and Highway 22 bridge construction above the off-stream reservoir, and the construction of Highway 22 bridge and Township Road 242 bridge above the diversion channel.

Major Components of the Project

The construction of the major components of the Project includes movement of 6.80 million m^3 of earth material, including overburden and top soil, within the project development area (PDA). Earth material for the construction of the off-stream dam will be borrowed primarily from the diversion channel excavation (4.75 million m^3). Additional earth material (1.09 million m^3) will be borrowed from a designated area within the PDA (Borrow Area 1). A smaller volume of earth material (0.08 million m^3) will be excavated along the off-stream dam and placed as an embankment. A small volume of earth material will be excavated along the diversion channel (0.20 million m^3) and placed as an embankment at the diversion channel. Earth material for the floodplain berm will be excavated along the berm (0.06 million m^3) and borrowed from the diversion channel (0.04 million m^3). A smaller volume of earth material (0.02 million m^3) will be excavated along the floodplain berm and placed as an embankment.

Overburden and top soil from the major components of the Project will be stored at a temporary stockpile located near the diversion structure. Overburden and top soil from the temporary stockpile will be reused as a top layer for the project structures. Overburden from the diversion channel will be used for the construction of the off-stream dam. Top soil from the diversion channel, off-stream dam, and floodplain berm that will be stored at the temporary stockpile are estimated to be 0.32, 0.22 and 0.02 million m^3, respectively.

Emissions for the construction of the major components of the Project are associated with the operation of the off-road construction equipment and with earth moving activities. Wind erosion emissions might be generated at the temporary overburden and top soil stockpile during strong winds. The earth material will be transported with haul trucks. Most fugitive dust emissions are associated with haul trucks travelling on unpaved haul roads within the PDA. The highest truck traffic along the haul road from the diversion channel to the off-stream dam is estimated at 33 loaded trucks per hour, equivalent to one truck passing every minute.

Road Realignments and Modifications

The construction of the road realignments and modifications includes movement of 0.40 million m^3 of earth material for raising Highway 22 and Highway 22 bridge construction above the off-stream dam. Earth material for raising Highway 22 will be primarily excavated along the Highway 22 construction area (0.40 million m^3). A smaller volume of earth material (0.004 million m^3) will be borrowed from a designated area within the PDA (Borrow Area 2). The construction of Highway 22 bridge and Township Road 242 bridge above the diversion channel does not require earth moving activities. It is assumed that approximately 25% of the construction equipment units required for raising Highway 22 and Highway 22 bridge construction above the off-stream dam is allocated for the construction of Highway 22 bridge and Township Road 242 bridge above the diversion channel.

Emissions for the road realignments and modifications are associated with the operation of the off-road construction equipment and earth moving activities for raising Highway 22 above the off-stream dam. The earth material for raising Highway 22 will be transported with haul trucks along the Highway 22 construction area. Most fugitive dust emissions are associated with scraping, bulldozing and grading along the Highway 22 construction area.

3A.3.2 Diesel Exhaust Emissions from Off-Road Equipment

3A.3.2.1 CAC Emissions

Emission Rate Approach

Exhaust emissions from off-road diesel equipment are based on the Canadian off-road compression-ignition engine emission standards (ECCC, 2005). The Canadian Off-Road Compression-Ignition Engine Emission Regulations (ECCC, 2005) mirror the corresponding U.S. Code of Federal Regulation (CFR; (U.S. EPA, 2016a)). Emission standards are set forth in a tiered approach, depending on the engine manufacture year. Prior to 1996, off-road engines were not regulated. The first emission standards, known as Tier 1 standards, began to be phased in by power rating in 1996. Tier 2 standards began in 2001, Tier 3 standards in 2006 and Tier 4 standards in 2014. Table 3A-4 shows the off-road diesel engine emission standards by engine power rating and engine tier (ECCC, 2005/U.S. EPA, 2016a). The project construction equipment ranges in power rating from 30 hp (portable light generator) to 500 hp (scrapper tractor). Table 3A-4 includes only the engine power range applicable to the Project. In Table 3A-4, the emission standards used for the assessment are highlighted in grey colour. Although the actual off-road equipment fleet used during construction might be newer (Tier 4), for this assessment the project construction equipment is conservatively assumed to be Tier 3 compliant.

Emissions of NO_X, CO, PM and VOC for each off-road equipment type are determined from:

$$ER_h\ (g/s) = Number\ of\ Units \times Engine\ Power\ (hp) \times Emission\ Factor\ \left(\frac{g}{hp\ hr}\right) \times Engine\ Load\ Factor\ (\%) \times Unit\ Conversion\ \left(\frac{hr}{3600\ s}\right)$$

Equation 3A.1

where

ER_h	-	Hourly emission rate (g/s)
Engine Power	-	Power rating of equipment (hp)
Emission Factor	-	Canadian off-road compression-ignition engine emission standards (g/hp-hr) based on Tier 3 engines (ECCC, 2005)
Load Factor	-	Equipment load factor (%) by equipment type based on U.S. EPA NONROAD model documentation (U.S. EPA, 2010b). Defined as the fraction of actual engine output relative to maximum rated power, taking into account that engines are operating somewhere between idle speed and full power.

The engine power rating associated with each piece of equipment is sourced from manufacturer information.

The engine load factor (LF) is a measure of the fraction of actual engine output relative to maximum rated power. Equipment engine load factors from the NONROAD model documentation (U.S. EPA, 2010b) are used to calculate project emissions. An 80% LF is used for haul trucks, which is truck utilization by accounting for time for loading/unloading and time for breaks.

Emissions of SO_2 for each off-road equipment type are determined using the following equation, assuming that all diesel sulphur is oxidized:

$$ER_h\ (g/s) = Number\ of\ Units \times Fuel\ Consumption\ \left(\frac{L\ diesel}{hr}\right) \times Emission\ Factor\ \left(\frac{g}{L}\right) \times Unit\ Conversion\ \left(\frac{hr}{3600\ s}\right)$$

Equation 3A.2

where

ER_h	-	Hourly emission rate (g/s)
Fuel Consumption	-	Fuel consumption of equipment (L/hr)
Emission Factor	-	SO_2 emission factor per litre of fuel consumption (g/L).

The fuel consumption for each construction equipment unit is calculated using the following equation:

$$Fuel\ Consumption\ (L/hr) = Engine\ Power\ (hp) \times BSFC\ \left(\frac{lb\ diesel}{hp\ hr}\right) \times Unit\ Conversion\ \left(\frac{kg}{2.205\ lb}\right) \times \frac{1}{Diesel\ Density\ (0.85\ \frac{kg}{L})}$$

Equation 3A.3

where

Engine Power	-	Power rating of equipment (hp)
BSFC	-	Brake Specific Fuel Consumption (BSFC) by engine power rating (lb diesel/hp-hr) based on U.S. EPA NONROAD model documentation (U.S. EPA, 2010a, Table A4)
Diesel Density	-	Density of diesel fuel (0.85 kg/L).

Brake specific fuel consumptions (BSFC) by engine power rating are obtained from the U.S. EPA NONROAD model documentation (U.S. EPA, 2010a, Table A4). The BSFC provides the fuel consumption for each type of equipment in relation to the power rating of the equipment (lb fuel/hp-hr).

Table 3A-5 summarizes the off-road vehicle fleet information used in the calculation of CAC emission rates from diesel engines. Table 3A-6 summarizes the Project CAC emission rates from off-road equipment diesel exhaust.

Emission Factors

The off-road diesel engine emission standards (ECCC, 2005) specific to engine power rating and corresponding to Tier 3 equipment are applied as emission factors for NO_X, CO, PM and VOC. Where emission standards are provided for combined NO_X and HC emissions (NO_X+HC), the pollutant-specific emission standards for NO_X and HC are based on the recommended split in the NONROAD model documentation for Tier 2 and Tier 3 engines (U.S. EPA, 2010a, Table 8). VOC emission factors are based on the HC emission factor, by subtracting the methane (CH_4) fraction (assumed to be 9.8% of HC emissions) and applying a VOC-to-NMHC ratio of 1.233, based on the MOVES2014a/ NONROAD model speciation profiles (U.S. EPA, 2016b, Table 10). All particulate matter emissions are assumed to be smaller than 10 microns (PM_{10}) and 97% of the PM is assumed to be smaller than 2.5 microns ($PM_{2.5}$) (U.S. EPA, 2010a).

The U.S. EPA NONROAD model (U.S. EPA, 2005) calculates the SO_2 emission factors based on the sulphur content in diesel fuel and equipment-specific fuel consumption rates. The Sulphur in Diesel Fuel Regulations (ECCC, 2002) set a maximum limit of 15 mg/kg for sulphur contained in off-road diesel fuels in Canada effective 2010. The sulphur content of the diesel fuel can vary but cannot exceed the 15 mg/kg limit; this assessment conservatively uses the maximum limit. The emission factor for SO_2 is converted to g/L using the density of diesel (0.85 kg/L).

The SO_2 emission factor is calculated using the following equation:

$$EF\ (g/L) = Sulphur\ Content\ \left(\frac{mg}{kg}\right) \times Conversion\ Factor\ \left(2\ \frac{S}{SO_2}\right) \times Unit\ Conversion \left(\frac{g}{1000mg}\right) \times Diesel\ Density\ (0.85\ \frac{kg}{L})$$

Equation 3A.4

where

EF	-	Emission factor (g/L)
Sulphur Content	-	Sulphur content in off-road diesel fuel (mg/kg) assumed equal to the maximum suplhur limit (15 mg/kg) based on the Sulphur in Diesel Regulations (ECCC, 2002).
Conversion Factor (2)	-	Conversion factor equal to the ratio of molecular weights of SO_2 and S: SO_2/S=64/32=2.
Diesel Density	-	Density of diesel fuel (0.85 kg/L).

Temporal Allocation

The estimated maximum 1-hour emission rates are assumed to be uniform over the work hours per day (24 hours for the major components of the Project and 12 hours for the road realignments and modifications) of the construction duration (214 days for the major components of the Project and 365 days for the road realignments and modifications), and they are used to predict maximum 1-hour and 24-hour average concentrations.

The annual emission rates are scaled from the hourly emission rates based on the ratio of work days per year for an activity versus the construction duration (days per year) using the following equation:

$$ER_a\ (g/s) = ER_a\ (g/s) \times \frac{Work\ Days\ (d/a)}{Construction\ Duration\ (d/a)}$$

Equation 3A.5

The annual emission rates account for a project activity that may have a shorter work days than the construction duration. For example, the scraper (38 m³ capacity) at the diversion channel is expected to work for 25 days out of the 214 days construction duration. In this case, the annual emission rate for the scraper at the diversion channel is scaled from the hourly emission rate by the ratio of (25/214).

The annual average emission rates are assumed to be uniform over the day for all hours of the construction duration (214 days for the major components of the Project and 365 days for the road realignments and modifications), and they are used to predict annual average concentrations.

Table 3A-4 Canadian Off-Road Compression-Ignition Engines: Tier 1, 2, 3 and 4 Emission Standards (ECCC, 2005)

Engine Power (hp)	Tier	Model Year	Emission Factors (g/hp-hr)					
			$HC+NO_X$	NO_x [a]	HC [a]	CO	PM	VOC [b]
≥25 to <50	Tier 1	1999–2003	7.1	-	-	4.1	0.60	-
	Tier 2	2004–2007	5.6	5.0	0.6	4.1	0.45	0.67
	Tier 4 transitional	2008–2012	-	-	-	-	0.22	-
	Tier 4 final	2013+	3.5	-	-	-	0.02	-
≥50 to <75	Tier 1	1998–2003	-	6.9	-	-	-	-
	Tier 2	2004–2007	5.6	5.2	0.4	3.7	0.30	0.44
	Tier 3	2008–2012	3.5	3.3	0.2	3.7	-	0.22
	Tier 4 transitional	2008–2012	-	-	-	-	0.22	-
	Tier 4 final	2013+	3.5	-	-	-	0.02	-
≥75 to <100	Tier 1	1998–2003	-	6.9	-	-	-	-
	Tier 2	2004–2007	5.6	5.2	0.4	3.7	0.30	0.44
	Tier 3	2008–2011	3.5	3.3	0.2	3.7	-	0.22
	Tier 4 transitional	2012–2013	-	0.3	0.14	-	0.01	0.16
	Tier 4 final	2014+	-	0.3	0.14	-	0.01	0.16
≥100 to <175	Tier 1	1997–2000	-	6.9	-	-	-	-
	Tier 2	2003–2006	4.9	4.5	0.4	3.7	0.22	0.44
	Tier 3	2007–2011	3.0	2.8	0.2	3.7	-	0.22
	Tier 4 transitional	2012–2013	-	0.3	0.14	-	0.01	0.16
	Tier 4 final	2014+	-	0.3	0.14	-	0.01	0.16

Table 3A-4 Canadian Off-Road Compression-Ignition Engines: Tier 1, 2, 3 and 4 Emission Standards (ECCC, 2005)

Engine Power (hp)	Tier	Model Year	Emission Factors (g/hp-hr)					
			$HC+NO_X$	NO_X [a]	HC [a]	CO	PM	VOC [b]
≥175 to <300	Tier 1	1996–2002	-	8.5	1.0	8.5	0.4	1.11
	Tier 2	2003–2005	4.9	4.5	0.4	2.6	0.15	0.44
	Tier 3	2006–2010	3.0	2.8	0.2	2.6	-	0.22
	Tier 4 transitional	2011–2013	-	-	0.14	-	0.01	0.16
	Tier 4 final	2014+	-	-	0.14	-	0.01	0.16
≥300 to <600	Tier 1	1996–2000	-	8.5	1.0	8.5	0.4	1.11
	Tier 2	2001–2005	4.8	4.5	0.3	2.6	0.15	0.33
	Tier 3	2006-2010	3.0	2.8	0.2	2.6	-	0.22
	Tier 4 transitional	2011–2013	-	0.3	0.14	-	0.01	0.16
	Tier 4 final	2014+	-	0.3	0.14	-	0.01	0.16

NOTES:

[a] Pollutant-specific NO_X and HC emission standards for Tier 2 and Tier 3 engines derived based on the recommended split of ($HC+NO_X$) emission standard in the NONROAD model documentation (U.S. EPA, 2010a, Table 8).

[b] VOC emission standards derived from the HC emission standard, by subtracting the CH_4 fraction (assumed to be 9.8%) of HC emissions and applying a VOC-to-NMHC ratio of 1.233, based on the MOVES2014a/NONROAD model speciation profiles (U.S. EPA, 2016b, Table 10).

AAAAA - Emission standards used for the assessment

SOURCES:

Canadian Off-Road Compression-Ignition Engine Emission Regulations (ECCC, 2005)

Nonroad Compression-Ignition Engines - Exhaust Emission Standards (U.S. EPA, 2016a)

Table 3A-5 Off-Road Equipment Parameters for CAC Emission Rate Calculation

Construction Activity and Equipment Type	Manufacturer	Model	Fuel Type	Number of Units	Engine Power (hp)	Work Hours per Day (h/d)	Work Days per Year (d/y)	Constr. Duration (d/y)	BSFC (lb fuel/ hp-hr)	Fuel Usage (L/hr)	Load Factor (%)	Emission Factors (g/hp-hr)						Emission Factors (g/L)
												NO_x	CO	TSP	PM_{10}	$PM_{2.5}$	VOC	SO_2
Diversion Channel																		
Articulated dump truck (17 m³ capacity)	CAT	740	Diesel	2	464	24	214	214	0.367	91.4	80%	2.80	2.60	0.15	0.15	0.15	0.22	0.025
Backhoe	CAT	450	Diesel	2	144	24	214	214	0.367	28.4	21%	2.80	3.70	0.22	0.22	0.21	0.22	0.025
Scraper (38 m³ capacity)	CAT	637G (Tractor)	Diesel	5	500	24	214	214	0.367	98.5	59%	2.80	2.60	0.15	0.15	0.15	0.22	0.025
	CAT	637G (Scraper)	Diesel	5	283	24	214	214	0.367	55.8	59%	2.80	2.60	0.15	0.15	0.15	0.22	0.025
Off-Stream Dam																		
Articulated dump truck (17 m³ capacity)	CAT	740	Diesel	28	464	24	214	214	0.367	91.4	80%	2.80	2.60	0.15	0.15	0.15	0.22	0.025
Bulldozer	CAT	D6	Diesel	2	170	24	214	214	0.367	33.5	59%	2.80	3.70	0.22	0.22	0.21	0.22	0.025
Vibratory soil compactors	CAT	CP56B	Diesel	2	157	24	214	214	0.367	30.9	59%	2.80	3.70	0.22	0.22	0.21	0.22	0.025
Water Truck	Peterbilt	348 with Paccar PX-9 engine	Diesel	1	380	24	214	214	0.367	74.9	59%	2.80	2.60	0.15	0.15	0.15	0.22	0.025
Portable light generator	CAT	QX20	Diesel	48	30	24	214	214	0.408	6.6	43%	5.00	4.10	0.45	0.45	0.44	0.67	0.025
Borrow Area 1																		
Backhoe	CAT	450	Diesel	2	144	24	214	214	0.367	28.4	21%	2.80	3.70	0.22	0.22	0.21	0.22	0.025
Portable light generator	CAT	QX20	Diesel	21	30	24	214	214	0.408	6.6	43%	5.00	4.10	0.45	0.45	0.44	0.67	0.025
Floodplain Berm																		
Articulated dump truck (17 m³ capacity)	CAT	740	Diesel	4	464	12	60	214	0.367	91.4	80%	2.80	2.60	0.15	0.15	0.15	0.22	0.025
Bulldozer	CAT	D6	Diesel	2	170	12	60	214	0.367	33.5	59%	2.80	3.70	0.22	0.22	0.21	0.22	0.025
Concrete truck	Peterbilt & McNeilus	357 with Cummins ISM350 Engine	Diesel	1	350	12	10	214	0.367	69.0	43%	2.80	2.60	0.15	0.15	0.15	0.22	0.025
River Reroute at Diversion Structure																		
Articulated dump truck (17 m³ capacity)	CAT	740	Diesel	2	464	12	45	365	0.367	91.4	80%	2.80	2.60	0.15	0.15	0.15	0.22	0.025
Excavators	CAT	325FL	Diesel	2	161	12	45	365	0.367	31.7	53%	2.80	3.70	0.22	0.22	0.21	0.22	0.025
Front end loader	CAT	982M	Diesel	1	436	12	45	365	0.367	85.9	48%	2.80	2.60	0.15	0.15	0.15	0.22	0.025
Bulldozer	CAT	D6	Diesel	1	170	12	45	365	0.367	33.5	59%	2.80	3.70	0.22	0.22	0.21	0.22	0.025

Table 3A-5 Off-Road Equipment Parameters for CAC Emission Rate Calculation

Construction Activity and Equipment Type	Manufacturer	Model	Fuel Type	Number of Units	Engine Power (hp)	Work Hours per Day (h/d)	Work Days per Year (d/y)	Constr. Duration (d/y)	BSFC (lb fuel/ hp-hr)	Fuel Usage (L/hr)	Load Factor (%)	Emission Factors (g/hp-hr)						Emission Factors (g/L)
												NO_X	CO	TSP	PM_{10}	$PM_{2.5}$	VOC	SO_2
Diversion Structure																		
Truck-mounted crane	Peterbilt & Altec	365 with Cummins ISX engine	Diesel	1	425	12	10	365	0.367	83.7	43%	2.80	2.60	0.15	0.15	0.15	0.22	0.025
Concrete truck	Peterbilt & McNeilus	357 with Cummins ISM350 Engine	Diesel	1	350	12	60	365	0.367	69.0	43%	2.80	2.60	0.15	0.15	0.15	0.22	0.025
Portable diesel generator	CAT	QX35	Diesel	2	44	12	275	365	0.408	9.6	43%	5.00	4.10	0.45	0.45	0.44	0.67	0.025
Low Level Outlet Works																		
Truck-mounted crane	Peterbilt & Altec	365 with Cummins ISX engine	Diesel	1	425	12	15	365	0.367	83.7	43%	2.80	2.60	0.15	0.15	0.15	0.22	0.025
Concrete truck	Peterbilt & McNeilus	357 with Cummins ISM350 Engine	Diesel	1	350	12	5	365	0.367	69.0	43%	2.80	2.60	0.15	0.15	0.15	0.22	0.025
Raising Highway 22 and Highway 22 Bridge Construction																		
Dump trucks	CAT	CT681	Diesel	20	430	12	240	365	0.367	84.7	80%	2.80	2.60	0.15	0.15	0.15	0.22	0.025
Scrapers	John Deere	9470R	Diesel	3	470	12	240	365	0.367	92.6	59%	2.80	2.60	0.15	0.15	0.15	0.22	0.025
Backhoes	CAT	450	Diesel	2	144	12	240	365	0.367	28.4	21%	2.80	3.70	0.22	0.22	0.21	0.22	0.025
Dozers	CAT	D6	Diesel	2	170	12	240	365	0.367	33.5	59%	2.80	3.70	0.22	0.22	0.21	0.22	0.025
Excavators	CAT	325FL	Diesel	2	161	12	240	365	0.367	31.7	53%	2.80	3.70	0.22	0.22	0.21	0.22	0.025
Skid steers	CAT	272D	Diesel	2	95	12	240	365	0.408	20.8	23%	3.30	3.70	0.30	0.30	0.29	0.22	0.025
Water trucks	Peterbilt	348 with Paccar PX-9 engine	Diesel	2	380	12	240	365	0.367	74.9	59%	2.80	2.60	0.15	0.15	0.15	0.22	0.025
Graders (large)	John Deere	872G	Diesel	2	300	12	240	365	0.367	59.1	59%	2.80	2.60	0.15	0.15	0.15	0.22	0.025
Vibratory soil compactors	CAT	CP56B	Diesel	2	157	12	240	365	0.367	30.9	59%	2.80	3.70	0.22	0.22	0.21	0.22	0.025
Smooth drum rollers	CAT	CP56B	Diesel	2	157	12	240	365	0.367	30.9	59%	2.80	3.70	0.22	0.22	0.21	0.22	0.025
Asphalt paver	CAT	AP500F	Diesel	1	142	12	90	365	0.367	28.0	59%	2.80	3.70	0.22	0.22	0.21	0.22	0.025
Tandem vibratory rollers/compactor	CAT	CB64B	Diesel	1	142	12	90	365	0.367	28.0	59%	2.80	3.70	0.22	0.22	0.21	0.22	0.025
Mini backhoe (trenching)	CASE	580N EP	Diesel	1	74	12	60	365	0.408	16.2	21%	3.30	3.70	0.30	0.30	0.29	0.22	0.025
Hydraulic impact pile drivers	BRUCE & CAT	CAT 326 FL	Diesel	2	200	12	14	365	0.367	39.4	43%	2.80	2.60	0.15	0.15	0.15	0.22	0.025
Truck-mounted crane	Peterbilt & Altec	365 with Cummins ISX engine	Diesel	1	425	12	180	365	0.367	83.7	43%	2.80	2.60	0.15	0.15	0.15	0.22	0.025
Concrete truck	Peterbilt & McNeilus	357 with Cummins ISM350 Engine	Diesel	1	350	12	180	365	0.367	69.0	43%	2.80	2.60	0.15	0.15	0.15	0.22	0.025

Table 3A-5 Off-Road Equipment Parameters for CAC Emission Rate Calculation

Construction Activity and Equipment Type	Manufacturer	Model	Fuel Type	Number of Units	Engine Power (hp)	Work Hours per Day (h/d)	Work Days per Year (d/y)	Constr. Duration (d/y)	BSFC (lb fuel/ hp-hr)	Fuel Usage (L/hr)	Load Factor (%)	Emission Factors (g/hp-hr)						Emission Factors (g/L)
												NO_X	CO	TSP	PM_{10}	$PM_{2.5}$	VOC	SO_2
Highway 22 Bridge and Township Road 242 Bridge Construction																		
Scrapers	John Deere	9470R	Diesel	1	470	12	240	365	0.367	92.6	59%	2.80	2.60	0.15	0.15	0.15	0.22	0.025
Backhoes	CAT	450	Diesel	1	144	12	240	365	0.367	28.4	21%	2.80	3.70	0.22	0.22	0.21	0.22	0.025
Dozers	CAT	D6	Diesel	1	170	12	240	365	0.367	33.5	59%	2.80	3.70	0.22	0.22	0.21	0.22	0.025
Excavators	CAT	325FL	Diesel	1	161	12	240	365	0.367	31.7	53%	2.80	3.70	0.22	0.22	0.21	0.22	0.025
Skid steers	CAT	272D	Diesel	1	95	12	240	365	0.408	20.8	23%	3.30	3.70	0.30	0.30	0.29	0.22	0.025
Graders (large)	John Deere	872G	Diesel	1	300	12	240	365	0.367	59.1	59%	2.80	2.60	0.15	0.15	0.15	0.22	0.025
Vibratory soil compactors	CAT	CP56B	Diesel	1	157	12	240	365	0.367	30.9	59%	2.80	3.70	0.22	0.22	0.21	0.22	0.025
Smooth drum rollers	CAT	CP56B	Diesel	1	157	12	240	365	0.367	30.9	59%	2.80	3.70	0.22	0.22	0.21	0.22	0.025
Asphalt paver	CAT	AP500F	Diesel	1	142	12	90	365	0.367	28.0	59%	2.80	3.70	0.22	0.22	0.21	0.22	0.025
Tandem vibratory rollers/compactor	CAT	CB64B	Diesel	1	142	12	90	365	0.367	28.0	59%	2.80	3.70	0.22	0.22	0.21	0.22	0.025
Mini backhoe (trenching)	CASE	580N EP	Diesel	1	74	12	60	365	0.408	16.2	21%	3.30	3.70	0.30	0.30	0.29	0.22	0.025
Hydraulic impact pile drivers	BRUCE & CAT	CAT 326 FL	Diesel	2	200	12	10	365	0.367	39.4	43%	2.80	2.60	0.15	0.15	0.15	0.22	0.025
Truck-mounted crane	Peterbilt & Altec	365 with Cummins ISX engine	Diesel	1	425	12	180	365	0.367	83.7	43%	2.80	2.60	0.15	0.15	0.15	0.22	0.025
Concrete truck	Peterbilt & McNeilus	357 with Cummins ISM350 Engine	Diesel	1	350	12	180	365	0.367	69.0	43%	2.80	2.60	0.15	0.15	0.15	0.22	0.025

Table 3A-6 CAC Emission Rates for Off-Road Diesel Equipment

				Hourly Emission Rates (g/s)							Annual Emission Rates (g/s)						
Construction Activity and Equipment Type	**Manufacturer**	**Model**	**# Units**	**SO_2**	**NO_X**	**CO**	**TSP**	**PM_{10}**	**$PM_{2.5}$**	**VOC**	**SO_2**	**NO_X**	**CO**	**TSP**	**PM_{10}**	**$PM_{2.5}$**	**VOC**
Diversion Channel																	
Articulated dump truck (17 m³ capacity)	CAT	740	2	0.001	0.577	0.536	0.031	0.031	0.03	0.046	0.0013	0.577	0.536	0.031	0.031	0.03	0.046
Backhoe	CAT	450	2	0.0004	0.047	0.062	0.004	0.004	0.004	0.004	0.0004	0.047	0.062	0.004	0.004	0.004	0.004
Scraper (38 m³ capacity)	CAT	637G (Tractor)	5	0.003	1.147	1.065	0.061	0.061	0.06	0.091	0.0004	0.134	0.124	0.007	0.007	0.007	0.011
	CAT	637G (Scraper)	5	0.002	0.649	0.603	0.035	0.035	0.034	0.052	0.0002	0.076	0.07	0.004	0.004	0.004	0.006
Off-Stream Dam																	
Articulated dump truck (17 m³ capacity)	CAT	740	28	0.018	8.084	7.506	0.433	0.433	0.42	0.642	0.018	8.084	7.506	0.433	0.433	0.42	0.642
Bulldozer	CAT	D6	2	0.0005	0.156	0.206	0.012	0.012	0.012	0.012	0.0005	0.156	0.206	0.012	0.012	0.012	0.012
Vibratory soil compactors	CAT	CP56B	2	0.0004	0.144	0.19	0.011	0.011	0.011	0.011	0.0004	0.144	0.19	0.011	0.011	0.011	0.011
Water truck	Peterbilt	348 with Paccar PX-9 engine	1	0.001	0.174	0.162	0.009	0.009	0.009	0.014	0.0005	0.174	0.162	0.009	0.009	0.009	0.014
Portable light generator	CAT	QX20	48	0.0022	0.860	0.705	0.077	0.077	0.075	0.115	0.0011	0.430	0.353	0.039	0.039	0.038	0.057
Borrow Area 1																	
Backhoe	CAT	450	2	0.0004	0.047	0.062	0.004	0.004	0.004	0.004	0.0004	0.047	0.062	0.004	0.004	0.004	0.004
Portable light generator	CAT	QX20	21	0.0010	0.376	0.309	0.034	0.034	0.033	0.050	0.0005	0.188	0.154	0.017	0.017	0.016	0.025
Floodplain Berm																	
Articulated dump truck (17 m³ capacity)	CAT	740	4	0.003	1.155	1.072	0.062	0.062	0.06	0.092	0.0007	0.324	0.301	0.017	0.017	0.017	0.026
Bulldozer	CAT	D6	2	0.0005	0.156	0.206	0.012	0.012	0.012	0.012	0.0001	0.044	0.058	0.003	0.003	0.003	0.003
Concrete truck	Peterbilt & McNeilus	357 with Cummins ISM350 Engine	1	0.0005	0.117	0.109	0.006	0.006	0.006	0.009	0.00002	0.005	0.005	0.0003	0.0003	0.0003	0.0004
River Reroute at Diversion Structure																	
Articulated dump truck (17 m³ capacity)	CAT	740	2	0.001	0.577	0.536	0.031	0.031	0.03	0.046	0.0002	0.071	0.066	0.004	0.004	0.004	0.006
Excavators	CAT	325FL	2	0.0004	0.133	0.175	0.01	0.01	0.01	0.011	0.0001	0.016	0.022	0.001	0.001	0.001	0.001
Front end loader	CAT	982M	1	0.001	0.163	0.151	0.009	0.009	0.008	0.013	0.0001	0.02	0.019	0.001	0.001	0.001	0.002
Bulldozer	CAT	D6	1	0.0002	0.078	0.103	0.006	0.006	0.006	0.006	0.00003	0.01	0.013	0.001	0.001	0.001	0.001

Table 3A-6 CAC Emission Rates for Off-Road Diesel Equipment

Construction Activity and Equipment Type	Manufacturer	Model	# Units	Hourly Emission Rates (g/s)						Annual Emission Rates (g/s)					
				SO_2	NO_X	CO	TSP	PM_{10}	$PM_{2.5}$	VOC	SO_2	NO_X	CO	TSP	PM_{10}	$PM_{2.5}$	VOC
Diversion Structure																	
Truck-mounted crane	Peterbilt & Altec	365 with Cummins ISX engine	1	0.001	0.142	0.132	0.008	0.008	0.007	0.011	0.00002	0.004	0.004	0.0002	0.0002	0.0002	0.0003
Concrete truck	Peterbilt & McNeilus	357 with Cummins ISM350 Engine	1	0.0005	0.117	0.109	0.006	0.006	0.006	0.009	0.0001	0.019	0.018	0.001	0.001	0.001	0.002
Portable diesel generator	CAT	QX35	2	0.0001	0.053	0.043	0.005	0.005	0.005	0.007	0.0001	0.04	0.032	0.004	0.004	0.003	0.005
Low Level Outlet Works																	
Truck-mounted crane	Peterbilt & Altec	365 with Cummins ISX engine	1	0.001	0.142	0.132	0.008	0.008	0.007	0.011	0.00002	0.006	0.005	0.0003	0.0003	0.0003	0.0005
Concrete truck	Peterbilt & McNeilus	357 with Cummins ISM350 Engine	1	0.0005	0.117	0.109	0.006	0.006	0.006	0.009	0.00001	0.002	0.001	0.0001	0.0001	0.0001	0.0001
Raising Highway 22 and Highway 22 Bridge Construction																	
Dump trucks	CAT	CT681	20	0.012	5.351	4.969	0.287	0.287	0.278	0.425	0.0078	3.519	3.267	0.188	0.188	0.183	0.28
Scrapers	John Deere	9470R	3	0.002	0.647	0.601	0.035	0.035	0.034	0.051	0.0013	0.425	0.395	0.023	0.023	0.022	0.034
Backhoes	CAT	450	2	0.0004	0.047	0.062	0.004	0.004	0.004	0.004	0.0003	0.031	0.041	0.002	0.002	0.002	0.002
Dozers	CAT	D6	2	0.0005	0.156	0.206	0.012	0.012	0.012	0.012	0.0003	0.103	0.136	0.008	0.008	0.008	0.008
Excavators	CAT	325FL	2	0.0004	0.133	0.175	0.01	0.01	0.01	0.011	0.0003	0.087	0.115	0.007	0.007	0.007	0.007
Skid Steers	CAT	272D	2	0.0003	0.04	0.045	0.004	0.004	0.004	0.003	0.0002	0.026	0.03	0.002	0.002	0.002	0.002
Water trucks	Peterbilt	348 with Paccar PX-9 engine	2	0.001	0.349	0.324	0.019	0.019	0.018	0.028	0.0007	0.229	0.213	0.012	0.012	0.012	0.018
Graders (large)	John Deere	872G	2	0.001	0.275	0.256	0.015	0.015	0.014	0.022	0.0005	0.181	0.168	0.01	0.01	0.009	0.014
Vibratory soil compactors	CAT	CP56B	2	0.0004	0.144	0.19	0.011	0.011	0.011	0.011	0.0003	0.095	0.125	0.007	0.007	0.007	0.008
Smooth drum rollers	CAT	CP56B	2	0.0004	0.144	0.19	0.011	0.011	0.011	0.011	0.0003	0.095	0.125	0.007	0.007	0.007	0.008
Asphalt paver	CAT	AP500F	1	0.0002	0.065	0.086	0.005	0.005	0.005	0.005	0.00005	0.016	0.021	0.001	0.001	0.001	0.001
Tandem vibratory rollers/compactor	CAT	CB64B	1	0.0002	0.065	0.086	0.005	0.005	0.005	0.005	0.00005	0.016	0.021	0.001	0.001	0.001	0.001
Mini backhoe (trenching)	CASE	580N EP	1	0.0001	0.014	0.016	0.001	0.001	0.001	0.001	0.00002	0.002	0.003	0.0002	0.0002	0.0002	0.0002
Hydraulic impact pile drivers	BRUCE & CAT	CAT 326 FL	2	0.0006	0.134	0.124	0.007	0.007	0.007	0.011	0.00002	0.005	0.005	0.0003	0.0003	0.0003	0.0004

Table 3A-6 CAC Emission Rates for Off-Road Diesel Equipment

Construction Activity and Equipment Type	Manufacturer	Model	# Units	Hourly Emission Rates (g/s)							Annual Emission Rates (g/s)						
				SO_2	NO_X	CO	TSP	PM_{10}	$PM_{2.5}$	VOC	SO_2	NO_X	CO	TSP	PM_{10}	$PM_{2.5}$	VOC
Truck-mounted crane	Peterbilt & Altec	365 with Cummins ISX engine	1	0.0006	0.142	0.132	0.008	0.008	0.007	0.011	0.0003	0.07	0.065	0.004	0.004	0.004	0.006
Concrete truck	Peterbilt & McNeilus	357 with Cummins ISM350 Engine	1	0.0005	0.117	0.109	0.006	0.006	0.006	0.009	0.0002	0.058	0.054	0.003	0.003	0.003	0.005
Highway 22 Bridge and Township Road 242 Bridge Construction																	
Scrapers	John Deere	9470R	1	0.001	0.216	0.2	0.012	0.012	0.011	0.017	0.0004	0.142	0.132	0.008	0.008	0.007	0.011
Backhoes	CAT	450	1	0.0002	0.024	0.031	0.002	0.002	0.002	0.002	0.0001	0.015	0.02	0.001	0.001	0.001	0.001
Dozers	CAT	D6	1	0.0002	0.078	0.103	0.006	0.006	0.006	0.006	0.0002	0.051	0.068	0.004	0.004	0.004	0.004
Excavators	CAT	325FL	1	0.0002	0.066	0.088	0.005	0.005	0.005	0.005	0.0001	0.044	0.058	0.003	0.003	0.003	0.003
Skid steers	CAT	272D	1	0.0001	0.02	0.022	0.002	0.002	0.002	0.001	0.0001	0.013	0.015	0.001	0.001	0.001	0.001
Graders (large)	John Deere	872G	1	0.0004	0.138	0.128	0.007	0.007	0.007	0.011	0.0003	0.091	0.084	0.005	0.005	0.005	0.007
Vibratory soil compactors	CAT	CP56B	1	0.0002	0.072	0.095	0.006	0.006	0.005	0.006	0.0001	0.047	0.063	0.004	0.004	0.004	0.004
Smooth drum rollers	CAT	CP56B	1	0.0002	0.072	0.095	0.006	0.006	0.005	0.006	0.0001	0.047	0.063	0.004	0.004	0.004	0.004
Asphalt paver	CAT	AP500F	1	0.0002	0.065	0.086	0.005	0.005	0.005	0.005	0.00005	0.016	0.021	0.001	0.001	0.001	0.001
Tandem vibratory rollers/compactor	CAT	CB64B	1	0.0002	0.065	0.086	0.005	0.005	0.005	0.005	0.00005	0.016	0.021	0.001	0.001	0.001	0.001
Mini backhoe (trenching)	CASE	580N EP	1	0.0001	0.014	0.016	0.001	0.001	0.001	0.001	0.00002	0.002	0.003	0.0002	0.0002	0.0002	0.0002
Hydraulic impact pile drivers	BRUCE & CAT	CAT 326 FL	2	0.0006	0.134	0.124	0.007	0.007	0.007	0.011	0.00002	0.004	0.003	0.0002	0.0002	0.0002	0.0003
Truck-mounted crane	Peterbilt & Altec	365 with Cummins ISX engine	1	0.0006	0.142	0.132	0.008	0.008	0.007	0.011	0.0003	0.07	0.065	0.004	0.004	0.004	0.006
Concrete truck	Peterbilt & McNeilus	357 with Cummins ISM350 Engine	1	0.0005	0.117	0.109	0.006	0.006	0.006	0.009	0.0002	0.058	0.054	0.003	0.003	0.003	0.005
TOTAL EMISSION RATE			**g/s**	**0.063**	**24.26**	**23.17**	**1.40**	**1.40**	**1.36**	**2.00**	**0.04**	**16.19**	**15.42**	**0.922**	**0.922**	**0.894**	**1.32**
			kg/d	**3.90**	**1,524**	**1,450**	**86.4**	**86.4**	**83.8**	**124**	**2.76**	**1,134**	**1,074**	**64.5**	**64.5**	**62.6**	**93.0**

3A.3.2.2 VOC, PAH and Metal Emissions

Emission factors for individual VOC, PAH, and metal substances for off-road diesel equipment are based on the U.S. EPA Motor Vehicle Emission Simulator (MOVES) model version 2014a (MOVES2014a; (U.S. EPA, 2015)). The MOVES2014a model creates emission factors and emission inventories for both, on-road motor vehicles and off-road equipment, under a wide range of user-defined conditions. MOVES2014a incorporates the NONROAD2008 model for estimating CAC emissions from off-road equipment. Starting with version 2014a, the model has the additional capability of estimating air toxic emissions from off-road equipment.

The MOVES2014a-NONROAD model was originally developed for the United States and it contains built-in equipment population totals by region (e.g., at the U.S. county level) and default data distributions such as engine age distribution. To run the model for a region outside the United States, a representative U.S. county with similar characteristics needs to be selected. To be consistent with the MOVES2014a run for estimating regional emissions from highway and regional road traffic (Section A.4.2), Marion County, Indiana was selected as a representative region for the project location based on the similar fuel type usage and the similar population of the county capital city, Indianapolis, compared to Calgary.

Emissions are conservatively estimated for year 2012 to represent construction equipment prior to Tier 4 emission standard (Tier 4 standard for off-road engines comes into effect in 2014). The model run uses the default NONROAD data distributions and fuel formulations, except for daily temperature and daily relative humidity profiles which are based on the Canadian Climate Normals from Springbank airport station (ECCC 2010a). Two model runs are executed – one for a typical winter day in January and one for a typical summer day in July. All running and evaporative emission processes are included in the model. Table 3A-7 summarizes the inputs to the MOVES2014a-NONROAD model. Table 3A-8 presents the hourly temperature and hourly relative humidity profiles used in the model.

The model generates emission totals for the selected region (i.e., Marion County). The model output is additionally post-processed using an internal processing script (*EmissionFactors_per_hphr_by_Equipment.sql*) to generate emission factors per engine horsepower (g/hp-hr). The emission factors are aggregated over all ranges of engine power which generates speciation profiles that are representative of a “typical” construction fleet.

The MOVES2014a-NONROAD model estimates emission factors for a number of VOC, PAH and metal substances. The emission factors of the individual substances are scaled from the total VOC or total TSP emission factor depending on whether the substance is in gaseous or particulate phase, respectively. These ratios are used to estimate ambient concentrations of the individual substances from the dispersion model predictions for total VOC and PM. Scaling ratios for individual VOC, PAH and metal substances are derived by dividing the emission factor for each individual substance by the emission factor of total VOC or total PM. Individual VOC substances are scaled from the total VOC emission factor. Individual PAH substances are scaled from both, total VOC and total TSP emission factors, based on the gaseous and particulate fractions of each PAH substance as it exists in the atmosphere. Of the five metal substances that are identified in diesel exhaust, only elemental and divalent mercury can exist in gaseous phase and are scaled from total VOC; all other metals are scaled from total TSP.

Table 3A-9 presents the fractions of individual VOC substances from total VOC in units of grams per kilogram (g/kg). Table 3A-10 presents the partitioning of PAH in gaseous and particulate phases and the corresponding PAH fractions from total VOC and total TSP in mg/kg. Table 3A-11 presents the metal fractions from total VOC (mercury) and total TSP, in mg/kg. The individual VOC, PAH and metals emission fractions from total VOC and total TSP for winter and summer are calculated to be identical.

Table 3A-7 Input Parameters for the MOVES2014a-NONROAD Model

Model Parameter	Selected Option for the Project Assessment
Scale	
Model	nonroad
Calculation type	inventory
Time Spans	
Time aggregation level	day
Years	2012
Months	January, July
Days	weekdays
Geographic Bounds	
Region	county
State	Indiana
County	Marion County
Equipment	
Fuels	nonroad diesel fuel
Sectors	construction

Table 3A-7 Input Parameters for the MOVES2014a-NONROAD Model

Model Parameter	Selected Option for the Project Assessment
Substances and Processes	
Substances	total gaseous hydrocarbons non-methane hydrocarbons non-methane organic gases total organic gases volatile organic compounds methane (CH_4) carbon monoxide (CO) oxides of nitrogen (NO_X) primary exhaust $PM_{2.5}$ – Total primary exhaust PM_{10} – Total sulphur dioxide (SO_2) brake specific fuel consumption (BSFC) benzene ethanol MTBE 1,3-butadiene formaldehyde acrolein additional air toxics polycyclic aromatic hydrocarbons (PAH) metals
Processes	running exhaust crankcase running exhaust evaporation tank permeation evaporation hose permeation diurnal fuel vapor venting hot soak fuel vapor venting running loss fuel vapour venting
General Output	
Mass Units	grams
Energy Units	Joules
Output Emissions Detail	
Output Grouped By	time, location, hp class, substance
Time	day
Location	county

Table 3A-8 Hourly Temperature and Relative Humidity Profiles used in MOVES2014a-NONROAD

Hour	Winter Profiles			Summer Profiles		
	Temperature		Relative Humidity	Temperature		Relative Humidity
	(ºC)	(ºF)	(%)	(ºC)	(ºF)	(%)
12 am – 1 am	-11.7	10.9	65.0	10.6	51.1	72.4
1 am – 2 am	-12.5	9.5	65.7	9.7	49.5	75.0
2 am – 3 am	-13.1	8.5	66.4	9.1	48.3	77.6
3 am – 4 am	-13.5	7.7	67.1	8.6	47.4	80.2
4 am – 5 am	-13.8	7.1	67.8	8.2	46.8	82.7
5 am – 6 am	-14.2	6.5	68.5	7.8	46.0	85.3
6 am – 7 am	-14.5	5.9	69.2	7.4	45.3	87.9
7 am – 8 am	-14.2	6.4	68.0	7.7	45.9	83.6
8 am – 9 am	-12.7	9.2	66.8	9.6	49.2	79.3
9 am – 10 am	-10.1	13.8	65.7	12.5	54.5	75.0
10 am – 11 am	-7.5	18.5	64.5	15.6	60.0	70.7
11 am – 12 pm	-5.3	22.5	63.3	18.1	64.6	66.4
12 pm – 1 pm	-3.3	26.0	62.1	20.4	68.7	62.1
1 pm – 2 pm	-2.3	27.9	61.0	21.7	71.0	57.8
2 pm – 3 pm	-1.9	28.6	59.8	22.1	71.7	53.5
3 pm – 4 pm	-1.8	28.8	58.6	22.2	72.0	49.2
4 pm – 5 pm	-2.1	28.3	59.3	21.9	71.4	51.8
5 pm – 6 pm	-2.8	27.0	60.0	21.1	69.9	54.4
6 pm – 7 pm	-4.1	24.7	60.7	19.6	67.2	56.9
7 pm – 8 pm	-5.7	21.7	61.4	17.6	63.7	59.5
8 pm – 9 pm	-7.3	18.8	62.1	15.7	60.3	62.1
9 pm – 10 pm	-8.8	16.2	62.8	14.1	57.3	64.7
10 pm – 11 pm	-9.8	14.4	63.5	12.9	55.2	67.3
11 pm – 12 am	-10.8	12.6	64.3	11.7	53.1	69.8

NOTES:
Hourly temperature and relative humidity profiles based on Canadian Climate Normals from Springbank airport station (ECCC, 2010a). Daily minimum and maximum temperatures and relative humidity converted to hourly profiles using the MOVES2014a meteorological converter tool (*meteorologicaldataconverter_mobile6.xls*). Winter profiles derived from January Climate Normals data. Summer profiles derived from July Climate Normals data.
Climate Normals temperatures converted from ºC to ºF for input in the MOVES2014a-NONROAD model.

Table 3A-9 Individual VOC Substance Fractions from Total VOC (Off-Road Equipment)

Volatile Organic Compound	Mass Fraction of Total VOC [a] (g/kg)
Benzene	33.3
1,3-Butadiene	1.78
Formaldehyde	245
Acetaldehyde	86.6
Acrolein	20.8
2,2,4-Trimethylpentane	7.73
Ethyl Benzene	5.88
Propionaldehyde	22.3
Toluene	25.7
Xylene	17.9

NOTE:
[a] The speciation profiles for winter and summer are the same

Table 3A-10 Individual PAH Substance Fractions from Total TSP and Total VOC (Off-Road Equipment)

Polycyclic Aromatic Compound	PAH Partition (%)		Mass Fraction [a] (mg/kg)	
	Particle	Gaseous	Total TSP	Total VOC
Naphthalene	0	100	0	4,573
Dibenzo(a,h)anthracene	100	0	1.167	0
Fluoranthene	26	74	35.14	79.16
Acenaphthene	0	100	0	616
Acenaphthylene	0	100	0	747
Anthracene	28	72	35.15	73.65
Benz(a)anthracene	49	51	5.422	4.61
Benzo(a)pyrene	100	0	4.078	0
Benzo(b)fluoranthene	100	0	6.032	0
Benzo(g,h,i)perylene	55	45	4.204	2.716
Benzo(k)fluoranthene	100	0	4.643	0

Table 3A-10 Individual PAH Substance Fractions from Total TSP and Total VOC (Off-Road Equipment)

Polycyclic Aromatic Compound	PAH Partition (%)		Mass Fraction [a] (mg/kg)	
	Particle	Gaseous	Total TSP	Total VOC
Chrysene	63	37	9.446	4.544
Fluorene	0	100	0	784
Phenanthrene	0	100	0	1,272
Pyrene	0	100	0	91.77

NOTE:
[a] The speciation profiles for winter and summer are the same

Table 3A-11 Individual Metal Substance Fractions from Total TSP and Total VOC (Off-Road Equipment)

Metal	Mass Fraction [a] (mg/kg)	
	Total TSP	Total VOC
Mercury	0.005	0.024
Arsenic	2.648	0
Chromium 6+	0.054	0
Manganese	4.905	0
Nickel	8.529	0

NOTE:
[a] The speciation profiles for winter and summer are identical

3A.3.3 Fugitive Dust Emissions from Bulldozing and Grading

Emission Rate Approach

Fugitive dust emissions from scraping, bulldozing, and grading of top soil and overburden are estimated using U.S. EPA AP-42 emission factors from Chapter 11.9 Western Surface Coal Mining (U.S. EPA, 1998). The following equation is used to estimate fugitive TSP, PM_{10} and $PM_{2.5}$ emissions:

$$ER_h\ (g/s) = Number\ of\ Units \times Emission\ Factor\ \left(\frac{lb}{hr}\right) \times Utilization\ Factor (\%) \times Transportable\ Fraction\ (\%) \times Unit\ Conversion\ \left(\frac{kg}{2.205\ lb}\right) \times\ Unit\ Conversion \left(\frac{1000\ g}{kg}\right) \times Unit\ Conversion\ \left(\frac{hr}{3600\ s}\right)$$

Equation 3A.6

where

ER_h	-	Hourly emission rate (g/s)
Emission Factor	-	Particle size-specific emission factor for bulldozing of overburden (lb/hr).
Utilization Factor (UF)	-	Utilization factor defined as the ratio of net operating time versus gross operating time. The utilization factor accounts for the intermittent bulldozing during the operating hours. The utilization factor is assumed equal to the equipment load factor (LF) which is based on U.S. EPA NONROAD model documentation (U.S. EPA, 2010b).
Transportable Fraction (TF)=75%	-	An adjustment factor to account for near-source removal of fugitive dust emissions due to micro scale turbulence and impaction on buildings and vegetative surfaces. The emission fraction that is not removed by the near-source removal factors is defined as “Transportable Fraction”. Assumed Transportable Fraction equal to 75% corresponding to grassland (Pouliot et al., 2010).

Equation 3A.6 is used to model fugitive dust emissions using emission factors based on the duration of bulldozing and grading. A utilization factor is applied to account for bulldozing and grading being intermittent during operating hours. The utilization factor is assumed equal to the equipment LF which is based on U.S. EPA NONROAD model documentation (U.S. EPA, 2010b). It is assumed that no fugitive dust control will be applied for these activities.

Table 3A-12 summarizes the emission parameters used in the calculation of fugitive dust emissions from bulldozing and grading. Table 3A-13 summarizes the PM emission rates from bulldozing and grading.

Emission Factors

The size-specific emission factors are determined using the equations:

$$Emission\ Factor\ (\,TSP) = 5.7 \times \frac{s^{1.2}}{M^{1.3}}$$
$$Emission\ Factor\ (\,PM_{10}) = 0.75\ \times 1.0 \times \frac{s^{1.5}}{M^{1.4}}$$
$$Emission\ Factor\ (\,PM_{2.5}) = 0.105\ \times 5.7 \times \frac{s^{1.2}}{M^{1.3}}$$

Equation 3A.7

Where:

Emission Factor	-	Particle size-specific emission factor for bulldozing of overburden (lb/hr).
s=6.9%	-	Silt content assumed equal to 6.9% corresponding to mean silt content of overburden (U.S. EPA, 1998, Table 11.9-3).
M=7.9%	-	Moisture content assumed equal to 7.9% corresponding to mean moisture content of overburden (U.S. EPA, 1998, Table 11.9-3).

The bulldozing emission factors are applied to scrapers, bulldozers, graders and soil compactors at the construction site.

Temporal Allocation

The estimated maximum 1-hour emission rates are assumed to be uniform over the work day (24 hours for the major components of the Project and 12 hours for the road realignments and modifications) during construction (214 days for the major components of the Project and 365 days for the road realignments and modifications), and they are used to predict maximum 1-hour and 24-hour average concentrations.

The annual emission rates are scaled from the hourly emission rates based on the ratio of 1) work days per year for an activity to 2) the construction duration (days per year) using the following equation:

$$ER_a\ (g/s) = ER_a\ (g/s) \times \frac{Work\ Days\ (d/a)}{Construction\ Duration\ (d/a)}$$

Equation 3A.8

The annual emission rates account for a project activity that may have shorter work days than the construction duration. For example, bulldozing at the floodplain berm is expected to take place for 60 work days out of the 214 days construction duration. In this case, the annual emission rate for bulldozing at the floodplain berm is scaled from the hourly emission rate by the ratio of (60/214).

The annual average emission rates are assumed to be uniform over the day for all hours of the construction duration (214 days for the major components of the Project and 365 days for the road realignments and modifications), and they are used to predict annual average concentrations.

Table 3A-12 Activity Parameters and Emission Factors for Bulldozing and Grading

Construction Activity and Equipment Type	Manuf.	Model	Fuel Type	# Units	Engine Power (hp)	Work Hours (h/d)	Work Days (d/y)	Constr. Duration (d/y)	UF (%)	TF (%)	Emission Factors (lb/hr)		
											TSP	PM_{10}	$PM_{2.5}$
Diversion Channel													
Scraper (38 m^3 capacity)	CAT	637G	Diesel	5	500	24	25	214	59%	75%	3.94	0.75	0.41
Off-Stream Dam													
Bulldozer	CAT	D6	Diesel	2	170	24	214	214	59%	75%	3.94	0.75	0.41
Vibratory soil compactors	CAT	CP56B	Diesel	2	157	24	214	214	59%	75%	3.94	0.75	0.41
Floodplain Berm													
Bulldozer	CAT	D6	Diesel	2	170	12	60	214	59%	75%	3.94	0.75	0.41
River Reroute at Diversion Structure													
Bulldozer	CAT	D6	Diesel	1	170	12	45	365	59%	75%	3.94	0.75	0.41
Raising Highway 22 and Highway 22 Bridge Construction													
Scrapers	John Deere	9470R	Diesel	3	470	12	240	365	59%	75%	3.94	0.75	0.41
Dozers	CAT	D6	Diesel	2	170	12	240	365	59%	75%	3.94	0.75	0.41
Graders (large)	John Deere	872G	Diesel	2	300	12	240	365	59%	75%	3.94	0.75	0.41
Vibratory soil compactors	CAT	CP56B	Diesel	2	157	12	240	365	59%	75%	3.94	0.75	0.41
Smooth drum rollers	CAT	CP56B	Diesel	2	157	12	240	365	59%	75%	3.94	0.75	0.41

Table 3A-12 Activity Parameters and Emission Factors for Bulldozing and Grading

Construction Activity and Equipment Type	Manuf.	Model	Fuel Type	# Units	Engine Power (hp)	Work Hours (h/d)	Work Days (d/y)	Constr. Duration (d/y)	UF (%)	TF (%)	Emission Factors (lb/hr)		
											TSP	PM_{10}	$PM_{2.5}$
Highway 22 Bridge and Township Road 242 Bridge Construction													
Scrapers	John Deere	9470R	Diesel	1	470	12	240	365	59%	75%	3.94	0.75	0.41
Dozers	CAT	D6	Diesel	1	170	12	240	365	59%	75%	3.94	0.75	0.41
Graders (large)	John Deere	872G	Diesel	1	300	12	240	365	59%	75%	3.94	0.75	0.41
Vibratory soil compactors	CAT	CP56B	Diesel	1	157	12	240	365	59%	75%	3.94	0.75	0.41
Smooth drum rollers	CAT	CP56B	Diesel	1	157	12	240	365	59%	75%	3.94	0.75	0.41

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Table 3A-13 Particulate Emission Rates from Bulldozing and Grading

Construction Activity and Equipment Type	Manufacturer	Model	Number of Units	Hourly Emission Rates (g/s)			Annual Emission Rates (g/s)		
				TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$
Diversion Channel									
Scraper (38 m^3 capacity)	CAT	637G	5	1.099	0.210	0.115	0.128	0.025	0.013
Off-Stream Dam									
Bulldozer	CAT	D6	2	0.439	0.084	0.046	0.439	0.084	0.046
Vibratory soil compactors	CAT	CP56B	2	0.439	0.084	0.046	0.439	0.084	0.046
Floodplain Berm									
Bulldozer	CAT	D6	2	0.439	0.084	0.046	0.123	0.024	0.013
River Reroute at Diversion Structure									
Bulldozer	CAT	D6	1	0.220	0.042	0.023	0.027	0.005	0.003
Raising Highway 22 and Highway 22 Bridge Construction									
Scrapers	John Deere	9470R	3	0.659	0.126	0.069	0.433	0.083	0.046
Dozers	CAT	D6	2	0.439	0.084	0.046	0.289	0.055	0.030
Graders (large)	John Deere	872G	2	0.439	0.084	0.046	0.289	0.055	0.030
Vibratory soil compactors	CAT	CP56B	2	0.439	0.084	0.046	0.289	0.055	0.030
Smooth drum rollers	CAT	CP56B	2	0.439	0.084	0.046	0.289	0.055	0.030

Table 3A-13 Particulate Emission Rates from Bulldozing and Grading

Construction Activity and Equipment Type	Manufacturer	Model	Number of Units	Hourly Emission Rates (g/s)			Annual Emission Rates (g/s)		
				TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$
Highway 22 Bridge and Township Road 242 Bridge Construction									
Scrapers	John Deere	9470R	1	0.220	0.042	0.023	0.144	0.028	0.015
Dozers	CAT	D6	1	0.220	0.042	0.023	0.144	0.028	0.015
Graders (large)	John Deere	872G	1	0.220	0.042	0.023	0.144	0.028	0.015
Vibratory soil compactors	CAT	CP56B	1	0.220	0.042	0.023	0.144	0.028	0.015
Smooth drum rollers	CAT	CP56B	1	0.220	0.042	0.023	0.144	0.028	0.015
TOTAL EMISSION RATE			**g/s**	**6.152**	**1.175**	**0.646**	**3.469**	**0.663**	**0.364**
			kg/d	**351**	**67.1**	**36.9**	**193**	**36.9**	**20.3**

3A.3.4 Fugitive Dust Emissions from Off-Road Equipment in Transition

Emission Rate Approach

Fugitive dust emissions generated during off-road equipment in transition are estimated using U.S. EPA AP-42 emission factors from Chapter 13.2.2 Unpaved Roads (U.S. EPA, 2006a). Off-road equipment, except for haul trucks, is assumed to be primarily stationary, with minimum transition from one work area to another. PM emissions are estimated for excavators, backhoes, loaders, skid steers, hydraulic pile drivers and concrete trucks assuming small transition distances (200 m) within an hour. It is assumed that fugitive dust emissions from cranes are negligible because cranes are stationary for extended periods of time. It is also assumed that fugitive dust emissions generated from water trucks on haul roads are negligible because of the wet road surface due to water application.

The following equation is used to estimate TSP, PM_{10} and $PM_{2.5}$ fugitive emissions from off-road equipment movement on unpaved surfaces:

$$ER_h\ (g/s) = Number\ of\ Units \times Distance\ Travelled\ \left(\frac{km}{h}\right) \times Emission\ Factor\ \left(\frac{lb}{VMT}\right) \times Transportable\ Fraction\ (\%) \times Unit\ Conversion\ \left(281.9\,\frac{g/VKT}{lb/VMT}\right) \times \left(\frac{hr}{3{,}600\ s}\right)$$ **Equation 3A.9**

Where:

ER_h	-	Hourly emission rate (g/s)
Distance Travelled	-	Average distance travelled per hour by each equipment unit in transition (km). Assumed a distance of 0.200 km travelled per hour for excavators, backhoes, loaders and concrete trucks.
Emission Factor	-	Particle size-specific emission factor for unpaved roads (lb/VMT).
Transportable Fraction (TF)=75%	-	An adjustment factor to account for near-source removal of fugitive dust emissions due to micro scale turbulence and impaction on buildings and vegetative surfaces. The emission fraction that is not removed by the near-source removal factors is defined as “Transportable Fraction”. Assumed Transportable Fraction equal to 75% corresponding to grassland (Pouliot et al., 2010).

It is assumed that no fugitive dust control will be applied for equipment in transition.

Table 3A-15 summarizes the emission parameters used in the calculation of fugitive dust emissions generated from off-road equipment in transition. Table 3A-16 summarizes the PM emission rates from off-road equipment in transition.

Emission Factors

Size-specific emission factors are determined using the following equation:

$$Emission\ Factor\ (EF) = k\left(\frac{s}{12}\right)^{a}\left(\frac{W}{3}\right)^{b}$$ **Equation 3A.10**

Where:

EF	-	Particle size-specific emission factor (lb/VMT).
s=8.5%	-	Surface material silt content assumed equal to 8.5% corresponding to mean silt content of construction sites (U.S. EPA, 2006a, Table 13.2.2-1).
W	-	Average vehicle weight (tons). The average vehicle weight is estimated as an average of the fully loaded and empty vehicle, for equipment with payload capacity.
k, a, b	-	Size-specific empirical constants

The size-specific empirical constants corresponding to industrial roads are given in Table 3A-14.

Table 3A-14 Constants for Emission Factors from Unpaved Roads

Constants	Industrial Roads		
	$PM_{2.5}$	PM_{10}	TSP
k (lb/VMT)	0.15	1.5	4.9
a	0.9	0.9	0.7
b	0.45	0.45	0.45

Temporal Allocation

The estimated maximum 1-hour emission rates are assumed to be uniform over the work day (24 hours for the major components of the Project and 12 hours for the road realignments and modifications) for the construction duration (214 days for the major components of the Project and 365 days for the road realignments and modifications), and they are used to predict maximum 1-hour and 24-hour average concentrations.

The annual emission rates are scaled from the hourly emission rates based on the ratio of 1) work days per year for an activity to 2) the construction duration (days per year) using the following equation:

$$ER_a\ (g/s) = ER_a\ (g/s) \times \frac{Work\ Days\ (d/a)}{Construction\ Duration\ (d/a)}$$

Equation 3A.11

The annual emission rates account for a project activity that may have a shorter work days than the construction duration. For example, the excavator (CAT 325FL) for river reroute at the diversion structure is expected to work for 45 days out of the 365 days construction duration. In this case, the annual emission rate for the excavator is scaled from the hourly emission rate by the ratio of (45/365).

The annual average emission rates are assumed to be uniform over the day for all hours of the construction duration (214 days for the major components of the Project and 365 days for the road realignments and modifications), and they are used to predict annual average concentrations.

Table 3A-15 Activity Parameters and Emission Factors for Off-Road Equipment in Transition

Construction Activity and Equipment Type	Manuf.	Model	# Units	Engine Power (hp)	Work Hours (h/d)	Work Days (d/y)	Constr. Duration (d/y)	Dist. Travel (km/h)	Vehicle Weight (tonne)	TF (%)	Emission Factor (lb/VMT)		
											TSP	PM_{10}	$PM_{2.5}$
Diversion Channel													
Backhoe	CAT	450	2	144	24	214	214	0.200	12.3	75%	7.59	2.17	0.22
Borrow Area 1													
Backhoe	CAT	450	2	144	24	214	214	0.200	12.3	75%	7.59	2.17	0.22
Floodplain Berm													
Concrete truck	Peterbilt & McNeilus	357 with Cummins ISM350	1	350	12	10	214	0.200	70.0	75%	16.60	4.74	0.47
River Reroute at Diversion Structure													
Excavators	CAT	325FL	2	161	12	45	365	0.200	25.9	75%	10.61	3.03	0.30
Front end loader	CAT	982M	1	436	12	45	365	0.200	45.2	75%	13.63	3.89	0.39
Diversion Structure													
Concrete truck	Peterbilt & McNeilus	357 with Cummins ISM350 Engine	1	350	12	60	365	0.200	70.0	75%	16.60	4.74	0.47

Table 3A-15 Activity Parameters and Emission Factors for Off-Road Equipment in Transition

Construction Activity and Equipment Type	Manuf.	Model	# Units	Engine Power (hp)	Work Hours (h/d)	Work Days (d/y)	Constr. Duration (d/y)	Dist. Travel (km/h)	Vehicle Weight (tonne)	TF (%)	Emission Factor (lb/VMT)		
											TSP	PM_{10}	$PM_{2.5}$
Low Level Outlet Works													
Concrete truck	Peterbilt & McNeilus	357 with Cummins ISM350 Engine	1	350	12	5	365	0.200	70.0	75%	16.60	4.74	0.47
Raising Highway 22 and Highway 22 Bridge Construction													
Backhoes	CAT	450	2	144	12	240	365	0.200	12.3	75%	7.59	2.17	0.22
Excavators	CAT	325FL	2	161	12	240	365	0.200	25.9	75%	10.61	3.03	0.30
Skid steers	CAT	272D	2	95	12	240	365	0.200	3.7	75%	4.44	1.27	0.13
Mini backhoe (trenching)	CASE	580N EP	1	74	12	60	365	0.200	7.2	75%	5.95	1.70	0.17
Hydraulic impact pile drivers	BRUCE & CAT	CAT 326 FL	2	200	12	14	365	0.200	30.1	75%	11.34	3.24	0.32
Concrete truck	Peterbilt & McNeilus	357 with Cummins ISM350 Engine	1	350	12	180	365	0.200	70.0	75%	16.60	4.74	0.47

Table 3A-15 Activity Parameters and Emission Factors for Off-Road Equipment in Transition

Construction Activity and Equipment Type	Manuf.	Model	# Units	Engine Power (hp)	Work Hours (h/d)	Work Days (d/y)	Constr. Duration (d/y)	Dist. Travel (km/h)	Vehicle Weight (tonne)	TF (%)	Emission Factor (lb/VMT)		
											TSP	PM_{10}	$PM_{2.5}$
Highway 22 Bridge and Township Road 242 Bridge Construction													
Backhoes	CAT	450	1	144	12	240	365	0.200	12.3	75%	7.59	2.17	0.22
Excavators	CAT	325FL	1	161	12	240	365	0.200	25.9	75%	10.61	3.03	0.30
Skid steers	CAT	272D	1	95	12	240	365	0.200	3.7	75%	4.44	1.27	0.13
Mini backhoe (trenching)	CASE	580N EP	1	74	12	60	365	0.200	7.2	75%	5.95	1.70	0.17
Hydraulic impact pile drivers	BRUCE & CAT	CAT 326 FL Excavator	2	200	12	10	365	0.200	30.1	75%	11.34	3.24	0.32
Concrete truck	Peterbilt & McNeilus	357 with Cummins ISM350 Engine	1	350	12	180	365	0.200	70.0	75%	16.60	4.74	0.47

Table 3A-16 Particulate Emission Rates from Off-Road Equipment in Transition

Construction Activity and Equipment Type	Manufacturer	Model	Number of Units	Hourly Emission Rates (g/s)			Annual Emission Rates (g/s)		
				TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$
Diversion Channel									
Backhoe	CAT	450	2	0.178	0.051	0.005	0.178	0.051	0.005
Borrow Area 1									
Backhoe	CAT	450	2	0.178	0.051	0.005	0.178	0.051	0.005
Floodplain Berm									
Concrete truck	Peterbilt & McNeilus	357 Truck with Cummins ISM350 Engine	1	0.195	0.056	0.006	0.009	0.003	0.000
River Reroute at Diversion Structure									
CAT 325 FL excavators	CAT	325FL	2	0.249	0.071	0.007	0.031	0.009	0.001
CAT 982 M front end loader	CAT	982M	1	0.160	0.046	0.005	0.020	0.006	0.001
Diversion Structure									
Concrete truck	Peterbilt & McNeilus	357 Truck with Cummins ISM350 Engine	1	0.195	0.056	0.006	0.032	0.009	0.001
Low Level Outlet Works									
Concrete truck	Peterbilt & McNeilus	357 Truck with Cummins ISM350 Engine	1	0.195	0.056	0.006	0.003	0.001	0.000

Table 3A-16 Particulate Emission Rates from Off-Road Equipment in Transition

Construction Activity and Equipment Type	Manufacturer	Model	Number of Units	Hourly Emission Rates (g/s)			Annual Emission Rates (g/s)		
				TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$
Raising Highway 22 and Highway 22 Bridge Construction									
Backhoes	CAT	450	2	0.178	0.051	0.005	0.117	0.033	0.003
Excavators	CAT	325FL	2	0.249	0.071	0.007	0.164	0.047	0.005
Skid steers	CAT	272D	2	0.104	0.030	0.003	0.069	0.020	0.002
Mini backhoe (trenching)	CASE	580N EP	1	0.070	0.020	0.002	0.011	0.003	0.000
Hydraulic impact pile drivers	BRUCE & CAT	CAT 326 FL Excavator	2	0.266	0.076	0.008	0.010	0.003	0.000
Concrete truck	Peterbilt & McNeilus	357 Truck with Cummins ISM350 Engine	1	0.195	0.056	0.006	0.096	0.027	0.003
Highway 22 Bridge and Township Road 242 Bridge Construction									
Backhoes	CAT	450	1	0.089	0.025	0.003	0.059	0.017	0.002
Excavators	CAT	325FL	1	0.125	0.036	0.004	0.082	0.023	0.002
Skid steers	CAT	272D	1	0.052	0.015	0.001	0.034	0.010	0.001
Mini backhoe (trenching)	CASE	580N EP	1	0.070	0.020	0.002	0.011	0.003	0.000
Hydraulic impact pile drivers	BRUCE & CAT	CAT 326 FL Excavator	2	0.266	0.076	0.008	0.007	0.002	0.000
Concrete truck	Peterbilt & McNeilus	357 Truck with Cummins ISM350 Engine	1	0.195	0.056	0.006	0.096	0.027	0.003
TOTAL EMISSION RATE			**g/s**	**3.211**	**0.917**	**0.092**	**1.208**	**0.345**	**0.035**
			kg/d	**154**	**44.0**	**4.40**	**67.6**	**19.3**	**1.9**

3A.3.5 Fugitive Dust Emissions from Material Loading and Unloading

The following are activities in the PDA that will generate dust:

- moving top soil from diversion channel, off-stream dam and floodplain berm to a temporary stockpile located near the diversion structure
- moving overburden from diversion channel and floodplain berm to a temporary stockpile located near the diversion structure
- moving soil from the diversion channel to the off-stream dam and floodplain berm
- moving overburden from temporary stockpile to off-stream dam and floodplain berm
- moving top soil from temporary stockpile to diversion channel, off-stream dam and floodplain berm
- moving soil from from Borrow Area 1 to the off-stream dam
- excavating soil and placing it on site as embankment at diversion channel, off-stream dam, floodplain berm and Highway 22 realignment and modification
- moving soil from Borrow Area 2 for raising Highway 22

The material volume movements are described in Table 3A-17, where the volumes are before shrinkage at the receiving areas. It is assumed that soil for the embankments is excavated and placed on site by shovels. All other material is transported by haul trucks.

Table 3A-17 Project Material Movement Volumes

Project Area	Construction Process	Volume (m^3)
Diversion channel	strip, stockpile, and place topsoil	321,000
	excavate and place as access embankment	195,500
	excavate and place as spoil	960,000
Off-stream dam	strip, stockpile, and place topsoil	215,000
	excavate and place as embankment	75,000
	from diversion channel and place as embankment	3,792,043
	from Borrow Area 1 and place	1,086,782
Floodplain berm	strip, stockpile, and place topsoil	16,000
	excavate and place as embankment	19,350
	excavate and place as spoil	45,350
	borrow from diversion channel and place as embankment	41,458

Table 3A-17 Project Material Movement Volumes

Project Area	Construction Process	Volume (m^3)
River reroute at diversion structure	excavate and place as embankment	30,404
Raising Highway 22	excavate and place as embankment	395,000
	Borrow from Borrow Area 2 and place	4,000
TOTAL MATERIAL TRANSFER VOLUME		**7,196,887**
NOTE: The total material volume includes only one of the loading and unloading operations.		

Emission Rate Approach

Fugitive dust emissions from material loading and unloading operations are estimated using U.S. EPA AP-42 emission factors from Chapter 13.2.4 Aggregate Handling and Storage Piles (U.S. EPA, 2006b). Only one of the loading and unloading operations is included for material movement to/from the temporary storage pile since it is assumed that material will be stored at the stockpile for prolonged period of time (more than a year) and transport of material to and from the stockpile will not occur at the same time.

Fugitive TSP, PM_{10} and $PM_{2.5}$ emissions from material loading and unloading are estimated from:

$$ER_h\ (g/s) = Material\ \left(\frac{tonne}{hr}\right) \times Emission\ Factor\ \left(\frac{kg}{tonne}\right) \times Transportable\ Fraction\ (\%) \times Unit\ Conversion\ \left(\frac{1000\ g}{kg}\right) \times \left(\frac{hr}{3{,}600\ s}\right)$$

Equation 3A.12

where:

ER_h	-	Hourly emission rate (g/s)
Material	-	Loaded/unloaded material (tonne/hr)
Emission Factor	-	Particle size-specific emission factor
Transportable Fraction (TF)=75%	-	An adjustment factor to account for near-source removal of fugitive dust emissions due to micro scale turbulence and impaction on buildings and vegetative surfaces. The emission fraction that is not removed by the near-source removal factors is defined as “Transportable Fraction”. Assumed Transportable Fraction equal to 75% corresponding to grassland (Pouliot et al., 2010).

The material volumes in m^3 is converted to tonnes using a bulk density of 1.6 kg/m^3 for soil. It is assumed that no fugitive dust control will be applied for material loading and unloading.

Table 3A-19 summarizes the emission parameters used in the calculation of fugitive dust emissions generated from material loading and unloading. Table 3A-20 summarizes the PM emission rates from material loading and unloading.

Emission Factors

The size-specific emission factors are determined using the equation:

$$Emission\ Factor\ (EF) = k(0.0016)\frac{\left(\frac{U}{2.2}\right)^{1.3}}{\left(\frac{M}{2}\right)^{1.4}}$$

Equation 3A.13

where:

EF	-	Particle size-specific emission factor (kg/tonne).
U=3.8 m/s	-	Mean wind speed (m/s). Used average wind speed of 3.8 m/s based on the last 3 years (2014-2016) of meteorological data from Springbank airport station.
M=3.4%	-	Material moisture content (%). Moisture content assumed equal to 3.4% corresponding to mean moisture content of exposed ground (U.S. EPA 2006b, Table 13.2.4-1).
k	-	Particle size multiplier (dimensionless)

The particle size multiplier (k) for different particle size ranges is given in Table 3A-18.

Table 3A-18 Aerodynamic Particle Size Multiplier for Material Loading/Unloading Emission Factor

Aerodynamic Particle Size Multiplier (k)				
PM_{30}	PM_{15}	PM_{10}	PM_{5}	$PM_{2.5}$
0.74	0.48	0.35	0.20	0.053

Temporal Allocation

The estimated maximum 1-hour emission rates are assumed to be uniform over the work hours per day (24 hours for the major components of the Project and 12 hours for the road realignments and modifications) for the construction duration (214 days for the major components of the Project and 365 days for the road realignments and modifications), and they are used to predict maximum 1-hour and 24-hour average concentrations.

The annual emission rates are scaled from the hourly emission rates based on the ratio of 1) work days per year for an activity to 2) the construction duration (days per year) using the following equation:

$$ER_a\ (g/s) = ER_a\ (g/s) \times \frac{Work\ Days\ (d/a)}{Construction\ Duration\ (d/a)}$$

Equation 3A.14

The annual emission rates account for a project activity that may have shorter work days than the construction duration. For example, earth material unloading at Highway 22 construction area takes place for 240 work days out of the 365 days for construction duration. In this case, the annual emission rate for the earth unloading at Highway 22 construction zone is scaled from the hourly emission rate by the ratio of (240/365).

The annual average emission rates are assumed to be uniform over the work day for construction duration (214 days for the major components of the Project and 365 days for the road realignments and modifications), and they are used to predict annual average concentrations.

Table 3A-19 Activity Parameters and Emission Factors for Material Loading and Unloading

Activity Description	Material Movement				Work Hours per Day (h/d)	Work Days per Year (d/y)	Constr. Duration (d/y)	TF (%)	Emission Factor (kg/tonne)		
	Total Volume (m^3)	Volume per Day (m^3/d)	Volume per Hour (m^3/h)	Mass per Hour (t/h)					TSP	PM_{10}	$PM_{2.5}$
Diversion Channel											
Soil loading for off-stream dam	3,792,043	13,789	575	919	24	214	214	75%	1.15E-03	5.42E-04	8.21E-05
Soil loading for floodplain berm	41,458	691	58	92	24	60	214	75%	1.15E-03	5.42E-04	8.21E-05
Loading of overburden	960,000	3,491	145	233	24	214	214	75%	1.15E-03	5.42E-04	8.21E-05
Top soil for stockpile	321,000	1,167	49	78	24	214	214	75%	1.15E-03	5.42E-04	8.21E-05
Soil loading for access embankment	195,500	711	30	47	24	214	214	75%	1.15E-03	5.42E-04	8.21E-05
Soil unloading for access embankment	195,500	711	30	47	24	214	214	75%	1.15E-03	5.42E-04	8.21E-05
Borrow Area 1											
Soil loading for off-stream dam	1,086,782	3,952	165	263	24	214	214	75%	1.15E-03	5.42E-04	8.21E-05
Off-Stream Dam											
Soil unloading from diversion channel	3,792,043	13,789	575	919	24	214	214	75%	1.15E-03	5.42E-04	8.21E-05
Unloading of overburden from diversion channel	960,000	1,745	73	116	24	214	214	75%	1.15E-03	5.42E-04	8.21E-05
Soil unloading from borrow area 1	1,086,782	3,952	165	263	24	214	214	75%	1.15E-03	5.42E-04	8.21E-05

Table 3A-19 Activity Parameters and Emission Factors for Material Loading and Unloading

Activity Description	Material Movement				Work Hours per Day (h/d)	Work Days per Year (d/y)	Constr. Duration (d/y)	TF (%)	Emission Factor (kg/tonne)		
	Total Volume (m^3)	Volume per Day (m^3/d)	Volume per Hour (m^3/h)	Mass per Hour (t/h)					TSP	PM_{10}	$PM_{2.5}$
Top soil for stockpile	215,000	782	33	52	24	214	214	75%	1.15E-03	5.42E-04	8.21E-05
Soil loading for embankment	75,000	273	11	18	24	214	214	75%	1.15E-03	5.42E-04	8.21E-05
Soil unloading for embankment	75,000	273	11	18	24	214	214	75%	1.15E-03	5.42E-04	8.21E-05
Floodplain Berm											
Soil unloading from diversion channel	41,458	691	58	92	12	60	214	75%	1.15E-03	5.42E-04	8.21E-05
Top Soil for stockpile	16,000	267	22	36	12	60	214	75%	1.15E-03	5.42E-04	8.21E-05
Overburden for stockpile	45,350	756	63	101	12	60	214	75%	1.15E-03	5.42E-04	8.21E-05
Soil loading for embankment	19,350	323	27	43	12	60	214	75%	1.15E-03	5.42E-04	8.21E-05
Soil unloading for embankment	19,350	323	27	43	12	60	214	75%	1.15E-03	5.42E-04	8.21E-05
River Reroute at Diversion Structure											
Soil loading for river reroute	30,404	676	56	90	12	45	365	75%	1.15E-03	5.42E-04	8.21E-05
Soil unloading for river reroute	30,404	676	56	90	12	45	365	75%	1.15E-03	5.42E-04	8.21E-05

Table 3A-19 Activity Parameters and Emission Factors for Material Loading and Unloading

Activity Description	Material Movement				Work Hours per Day (h/d)	Work Days per Year (d/y)	Constr. Duration (d/y)	TF (%)	Emission Factor (kg/tonne)		
	Total Volume (m³)	Volume per Day (m³/d)	Volume per Hour (m³/h)	Mass per Hour (t/h)					TSP	PM_{10}	$PM_{2.5}$
Temporary Stockpile											
Top soil unloading from diversion channel	321,000	1,167	49	78	24	214	214	75%	1.15E-03	5.42E-04	8.21E-05
Top soil unloading from off-stream dam	215,000	782	33	52	24	214	214	75%	1.15E-03	5.42E-04	8.21E-05
Top soil unloading from floodplain berm	16,000	267	22	36	24	60	214	75%	1.15E-03	5.42E-04	8.21E-05
Overburden unloading from floodplain berm	45,350	756	63	101	24	60	214	75%	1.15E-03	5.42E-04	8.21E-05
Borrow Area 2											
Soil loading for raising highway 22	4,000	17	1	2	12	240	365	75%	1.15E-03	5.42E-04	8.21E-05
Raising Highway 22											
Soil unloading from borrow area 2	4,000	17	1	2	12	240	365	75%	1.15E-03	5.42E-04	8.21E-05
Soil loading for embankment	395,000	1,646	137	219	12	240	365	75%	1.15E-03	5.42E-04	8.21E-05
Soil unloading for embankment	395,000	1,646	137	219	12	240	365	75%	1.15E-03	5.42E-04	8.21E-05

Table 3A-20 Particulate Emission Rates from Material Loading and Unloading

Activity Description	Material Movement		Hourly Emission Rates (g/s)			Annual Emission Rates (g/s)		
	Total Volume (m^3)	Mass per Hour (t/h)	TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$
Diversion Channel								
Soil loading for off-stream dam	3,792,043	919	0.220	0.104	0.016	0.220	0.104	0.016
Soil loading for floodplain berm	41,458	92	0.022	0.010	0.002	0.006	0.003	0.000
Overburden for stockpile	960,000	233	0.056	0.026	0.004	0.056	0.026	0.004
Top soil for stockpile	321,000	78	0.019	0.009	0.001	0.019	0.009	0.001
Soil loading for access embankment	195,500	47	0.011	0.005	0.001	0.011	0.005	0.001
Soil unloading for access embankment	195,500	47	0.011	0.005	0.001	0.011	0.005	0.001
Borrow Area 1								
Soil loading for off-stream dam	1,086,782	263	0.063	0.030	0.005	0.063	0.030	0.005
Off-Stream Dam								
Soil unloading from diversion channel	3,792,043	919	0.220	0.104	0.016	0.220	0.104	0.016
Soil unloading from diversion channel overburden	960,000	233	0.056	0.026	0.004	0.056	0.026	0.004
Soil unloading from borrow area	1,086,782	263	0.063	0.030	0.005	0.063	0.030	0.005
Top soil for stockpile	215,000	52	0.012	0.006	0.001	0.012	0.006	0.001
Soil loading for embankment	75,000	18	0.004	0.002	0.000	0.004	0.002	0.0003
Soil unloading for embankment	75,000	18	0.004	0.002	0.000	0.004	0.002	0.0003

Table 3A-20 Particulate Emission Rates from Material Loading and Unloading

Activity Description	Material Movement		Hourly Emission Rates (g/s)			Annual Emission Rates (g/s)		
	Total Volume (m^3)	Mass per Hour (t/h)	TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$
Floodplain Berm								
Soil unloading from diversion channel	41,458	92	0.022	0.010	0.002	0.006	0.003	0.0004
Top soil for stockpile	16,000	36	0.008	0.004	0.001	0.002	0.001	0.0002
Overburden for stockpile	45,350	101	0.024	0.011	0.002	0.007	0.003	0.0005
Soil loading for embankment	19,350	43	0.010	0.005	0.001	0.003	0.001	0.0002
Soil unloading for embankment	19,350	43	0.010	0.005	0.001	0.003	0.001	0.0002
River Reroute at Diversion Structure								
Soil loading for river reroute	30,404	90	0.022	0.010	0.002	0.003	0.001	0.0002
Soil unloading for river reroute	30,404	90	0.022	0.010	0.002	0.003	0.001	0.0002
Temporary Stockpile								
Top soil unloading from diversion channel	321,000	78	0.019	0.009	0.001	0.019	0.009	0.001
Top soil unloading from off-stream dam	215,000	52	0.012	0.006	0.001	0.012	0.006	0.001
Top soil unloading from floodplain berm	16,000	36	0.008	0.004	0.001	0.002	0.001	0.0002
Overburden unloading from floodplain berm	45,350	101	0.024	0.011	0.002	0.007	0.003	0.0005
Borrow Area 2								
Soil loading for raising Highway 22	4,000	2	0.001	0.0003	0.00004	0.0003	0.0002	0.00002

Table 3A-20 Particulate Emission Rates from Material Loading and Unloading

Activity Description	Material Movement		Hourly Emission Rates (g/s)			Annual Emission Rates (g/s)		
	Total Volume (m³)	Mass per Hour (t/h)	TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$
Raising Highway 22								
Soil unloading from Borrow Area 2	4,000	2	0.001	0.0003	0.00004	0.0003	0.0002	0.00002
Soil loading for embankment	395,000	219	0.052	0.025	0.004	0.034	0.016	0.002
Soil unloading for embankment	395,000	219	0.052	0.025	0.004	0.034	0.016	0.002
TOTAL EMISSION RATE		**g/s**	**1.048**	**0.496**	**0.075**	**0.881**	**0.417**	**0.063**
		kg/d	**80.9**	**38.2**	**5.8**	**71.9**	**34.0**	**5.2**

3A.3.6 Fugitive Dust Emissions from Truck Traffic on Haul Roads

Most fugitive dust emissions for the Project is generated by truck traffic on unpaved haul roads. The major truck traffic will occur between the diversion channel and the off-stream dam (33 round trips per hour) for transporting excavated soil from the diversion channel to construction of the off-stream dam. The following project components are connected by haul roads for transporting of soil:

- diversion channel to top soil and overburden stockpile
- diversion channel to off-stream dam
- off-stream dam to top soil and overburden stockpile
- Borrow Area 1 to off-stream dam
- diversion channel to floodplain berm
- floodplain berm to top soil and overburden stockpile
- diversion structure for river reroute
- Borrow Area 2 for raising Highway 22
- along Highway 22 construction between construction sites

Off-road CAT 740 articulated haul trucks with a payload capacity of 17.4 m^3 will be used to transport material for the major components. On-highway CAT 681 haul trucks with a payload capacity of 9.9 m^3 will be used to transport material for raising Highway 22.

Emission Rate Approach

Fugitive dust emissions generated by truck traffic on haul roads are estimated using U.S. EPA AP-42 emission factors from Chapter 13.2.2 Unpaved Roads (U.S. EPA, 2006a). The haul roads will be watered during windy summer days to reduce the generation of fugitive dust emissions. A control efficiency of 75% during summer is assumed, corresponding to road watering twice daily (U.S. EPA, 2006a). Summer is defined as the 8-month period March to October. During winter, much less fugitive dust will be generated due to snow, snow cover and freezing temperatures. A natural mitigation efficiency of 90% is assumed during winter accounting for these factors (Golder Associates, 2012). Winter is considered 4 months in the dispersion model – January to December. Winter control efficiency is applied only for haul roads to Highway 22 construction since construction activities associated with raising of Highway 22 and bridge construction are assumed to take place during winter while the construction of the major components of the Project is assumed to take place only in summer between April and October.

Fugitive TSP, PM_{10} and $PM_{2.5}$ emissions from haul roads are estimated from:

$$ER_h\ (g/s) = Number\ of\ Units \times Road\ Length\ (km) \times Round\ Trip\ Factor(2) \times Number\ of\ Trips \left(\frac{trips}{hr}\right) \times Emission\ Factor\ \left(\frac{lb}{VMT}\right) \times Control\ Efficiency\ (\%) \times Transportable\ Fraction\ (\%) \times Unit\ Conversion\ \left(281.9\frac{g/VKT}{lb/VMT}\right) \times \left(\frac{hr}{3{,}600\ s}\right)$$

Equation 3A.15

Where:

ER_h	-	Hourly emission rate (g/s)
Number of Units	-	Number of trucks
Road Length	-	Haul road length (km)
Number of Trips	-	Number of trips per truck per hour (trips/h)
Round Trip Factor (2)	-	A factor of 2 accounting for a round trip distance
Emission Factor	-	Particle size-specific emission factor (lb/VMT).
Control Efficiency	-	Control efficiency (%). Assumed 75% control efficiency in summer corresponding to watering twice daily (U.S. EPA, 2006a) and 90% natural mitigation efficiency in winter (Golder Associates, 2012).
Transportable Fraction (TF)=75%	-	An adjustment factor to account for near-source removal of fugitive dust emissions due to micro scale turbulence and impaction on buildings and vegetative surfaces. The emission fraction that is not removed by the near-source removal factors is defined as “Transportable Fraction”. Assumed Transportable Fraction equal to 75% corresponding to grassland (Pouliot et al., 2010).

Table 3A-22 summarizes the emission parameters used in the calculation of fugitive dust emissions generated truck traffic on haul roads. Table 3A-23 summarizes the Project PM emission rates from haul roads.

Emission Factors

The size-specific emission factors are determined using the following equation:

$$Emission\ Factor\ (EF) = k\ \left(\frac{s}{12}\right)^a\ \left(\frac{W}{3}\right)^b$$

Equation 3A.16

Where:

EF	-	Particle size-specific emission factor (lb/VMT).
s = 8.5%	-	Surface material silt content assumed equal to 8.5% corresponding to mean silt content of construction sites (U.S. EPA, 2006a, Table 13.2.2-1).

W	-	Average vehicle weight (tons). The average vehicle weight is estimated as an average of the fully loaded and empty truck.
k, a, b	-	Size-specific empirical constants

The size-specific empirical constants corresponding to industrial roads are given in Table 3A-21.

Table 3A-21 Constants for Emission Factors from Unpaved Roads

Constants	Industrial Roads		
	$PM_{2.5}$	PM_{10}	TSP
k (lb/VMT)	0.15	1.5	4.9
a	0.9	0.9	0.7
b	0.45	0.45	0.45

Temporal Allocation

The estimated maximum 1-hour emission rates are assumed to be uniform over the work day (24 hours for the major components of the Project and 12 hours for the road realignments and modifications) for the construction duration (214 days for the major components of the Project and 365 days for the road realignments and modifications), and they are used to predict maximum 1-hour and 24-hour average concentrations.

The annual emission rates are scaled from the hourly emission rates based on the ratio of 1) work days per year for an activity to 2) the construction duration (days per year) using the following equation:

$$ER_a\ (g/s) = ER_a\ (g/s) \times \frac{Work\ Days\ (d/a)}{Construction\ Duration\ (d/a)}$$

Equation 3A.17

The annual emission rates account for a project activity that may have a shorter work days than the construction duration. For example, truck haul on the haul road from the diversion channel to the floodplain berm takes place for 60 work days out of the 214 days' construction duration. In this case, the annual emission rate for the haul road from the diversion channel to the floodplain berm is scaled from the hourly emission rate by the ratio of (60/214).

The annual average emission rates are assumed to be uniform over the day for all hours of the construction duration (214 days for the major components of the Project and 365 days for the road realignments and modifications), and they are used to predict annual average concentrations.

Table 3A-22 Activity Parameters and Emission Factors for Haul Roads

Haul Road	Road Length (km)	Truck Model	# of Units	Truck Capacity (m^3)	Operating Hours per Day	Operating Days per Year	Total Days per Year	Hauled Material			Number of Trips per Hour	Number of Trips per Hour per Unit	Control and Natural Mitigation Efficiency (%)		TF (%)	Emission Factors (lb/VMT)		
								Total m^3	m^3/d	m^3/h			Summer[a]	Winter[b]		TSP	PM_{10}	$PM_{2.5}$
Diversion Channel																		
Haul road from diversion channel to top soil and overburden stockpile	3.60	CAT 740	2	17.4	24	214	214	321,000	1,167	49	3	1.40	75%	—	75%	14.50	4.14	0.41
Off-Stream Dam																		
Haul road from diversion channel to off-stream dam	6.78	CAT 740	18	17.4	24	214	214	3,792,043	13,789	575	33	1.83	75%	—	75%	14.50	4.14	0.41
Haul road from off-stream dam to top soil and overburden stockpile	6.78	CAT 740	6	17.4	24	214	214	1,175,000	4,273	178	10	1.71	75%	—	75%	14.50	4.14	0.41
Haul road from Borrow Area 1 to off-stream dam	3.24	CAT 740	4	17.4	24	214	214	1,086,782	3,952	165	9	2.37	75%	—	75%	14.50	4.14	0.41
Floodplain Berm																		
Haul road from diversion channel to floodplain berm	2.34	CAT 740	2	17.4	12	60	214	41,458	691	58	3	1.65	75%	—	75%	14.50	4.14	0.41
Haul road from topsoil stockpile to floodplain berm	2.34	CAT 740	2	17.4	12	60	214	61,350	1,023	85	5	2.45	75%	—	75%	14.50	4.14	0.41
River Reroute at Diversion Structure																		
Haul road for river reroute at diversion structure	0.50	CAT 740	2	17.4	12	45	365	30,404	676	56	3	1.62	75%	—	75%	14.50	4.14	0.41
Raising of Highway 22 and Bridge Construction																		
Haul road from Borrow Area 2 to Highway 22 construction	3.24	CAT 681	1	9.9	12	240	365	4,000	17	1.39	0.14	0.14	75%	90%	75%	10.69	3.05	0.31
Haul road along Highway 22 construction	1.36 [c]	CAT 681	19	9.9	12	240	365	395,000	1,646	137	14	0.73	75%	90%	75%	10.69	3.05	0.31

NOTES:
[a] Summer is defined as the 8-month period March to October
[b] Winter is defined as the 4-month period November to February
[c] Assumed three groups of trucks distributed along Highway 22 construction area and each truck moving within 600 m on site: 1.36 km / 3 + 0.100 km = 0.600 km
"—" Indicates that activity does not occur in winter

Table 3A-23 Particulate Emission Rates from Haul Roads

Haul Road	Road Length (km)	Truck Model	Number of Trips per Hour	# of Units	Hourly Emission Rates (g/s)						Annual Emission Rates (g/s)					
					Summer [a]			Winter [b]			Summer [a]			Winter [b]		
					TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$
Diversion Channel																
Haul road from diversion channel to top soil and overburden stockpile	3.60	CAT 740	3	2	4.284	1.224	0.122	—	—	—	4.284	1.224	0.122	—	—	—
Off-Stream Dam																
Haul road from diversion channel to off-stream dam	6.78	CAT 740	33	18	95.31	27.23	2.72	—	—	—	95.31	27.23	2.72	—	—	—
Haul road from off-stream dam to top soil and overburden stockpile	6.78	CAT 740	10	6	29.53	8.44	0.844	—	—	—	29.53	8.44	0.844	—	—	—
Haul road from Borrow Area 1 to off-stream dam	3.24	CAT 740	9	4	13.05	3.73	0.373	—	—	—	13.05	3.73	0.373	—	—	—
Floodplain Berm																
Haul road from diversion channel to floodplain berm	2.34	CAT 740	3	2	3.30	0.942	0.094	—	—	—	0.924	0.264	0.026	—	—	—
Haul road from topsoil stockpile to floodplain berm	2.34	CAT 740	5	2	4.88	1.394	0.139	—	—	—	1.368	0.391	0.039	—	—	—
River Reroute at Diversion Structure																
Haul road for river reroute at diversion structure	0.50	CAT 740	3	2	2.755	0.787	0.079	—	—	—	0.340	0.097	0.010	—	—	—
Raising of Highway 22 and Bridge Construction																
Haul road from Borrow Area 2 to Highway 22 construction	3.24	CAT 681	0.14	1	0.14	0.041	0.004	0.057	0.016	0.002	0.094	0.027	0.003	0.038	0.011	0.001
Haul road along Highway 22 construction	1.36	CAT 681	14	19	2.61	0.746	0.075	1.044	0.298	0.030	1.716	0.490	0.049	0.686	0.196	0.020
TOTAL EMISSION RATE				**g/s**	**156**	**44.5**	**4.45**	**1.10**	**0.315**	**0.031**	**147**	**41.9**	**4.19**	**0.724**	**0.207**	**0.021**
				kg/d	**12,875**	**3,679**	**368**	**47.6**	**13.6**	**1.36**	**12,476**	**3,565**	**356**	**31.3**	**8.9**	**0.89**

NOTES:
[a] Summer is defined as the 8-month period March to October
[b] Winter is defined as the 4-month period November to February
"—" Indicates that activity does not occur in winter

3A.3.7 Fugitive Dust Emissions from Wind Erosion on Temporary Top Soil and Overburden Stockpile

The stripped top soil and overburden from the diversion channel, off-stream dam and floodplain berm will be stored at a temporary stockpile located northwest of the diversion structure. Overburden and top soil from the off-stream dam and floodplain berm will be reused as a top layer at the dam and berm once their construction is completed. Overburden from the diversion channel that is stored at the stockpile will be used for the construction of the off-stream dam. Top soil from the diversion channel that is stored at the stockpile will be reused as a top layer for the diversion channel after its construction.

The surface of the stockpile is characterized by finite availability of erodible material referred to as erosion potential. Emissions generated by wind erosion are dependent on the frequency of disturbance of the erodible surface, if its erosion potential is restored every time the surface is disturbed. A disturbance is defined as an action that results in the exposure of fresh surface material.

The erosion potential increases with increasing wind speed. The hourly mean wind speeds are typically not sufficient to sustain wind erosion. Therefore, wind erosion emissions are related to wind gusts of high magnitude. The fastest mile wind is a meteorological variable that reflects the magnitude of wind gusts. Wind erosion emissions are dependent on the magnitude and frequency of the fastest mile winds at the site.

Emission Rate Approach

Fugitive dust emissions due to wind erosion at the temporary top soil and overburden stockpile were estimated using U.S. EPA AP-42 emission factors from Chapter 13.2.5 Industrial Wind Erosion (U.S. EPA, 2006c).

Fugitive TSP, PM_{10} and $PM_{2.5}$ emissions from wind erosion on the temporary top soil and overburden stockpile are estimated from:

$$ER_h\ (g/s) = Disturbed\ Area\ (m^2) \times Number\ of\ Disturbances\ \times Emission\ Factor\ \left(\frac{g}{m^2}\right) \times Transportable\ Fraction\ (\%) \times Unit\ Conversion \left(\frac{hr}{3{,}600\ s}\right)$$

Equation 3A.18

where:

ER_h	-	Hourly emission rate (g/s)
Disturbed Area=800 m²	-	Disturbed area of the top soil and overburden stockpile assumed equal to 800 m². The disturbed area was calculated based on 8 trucks loading material to the stockpile per hour, and approximately 10 m x 10 m area disturbed by each truck.
Number of Disturbances	-	Number of disturbances per hour calculated from the number of truck loadings per hour.
Emission Factor	-	Particle size-specific emission factor for wind erosion on overburden from Table 3A-25.
Transportable Fraction (TF)=75%	-	An adjustment factor to account for near-source removal of fugitive dust emissions due to micro scale turbulence and impaction on buildings and vegetative surfaces. The emission fraction that is not removed by the near-source removal factors is defined as “Transportable Fraction”. Assumed Transportable Fraction equal to 75% corresponding to grassland (Pouliot et al., 2010).

Wind erosion emissions for the temporary top soil and overburden stockpile are estimated only for the periods when the surface of the stockpile is disturbed by either loading or unloading of material. It is assumed that once top soil and overburden are fully loaded at the stockpile, the stockpile will be undisturbed for approximately a year before material is reclaimed for the major components of the Project. It is assumed that the stockpile will be stabilized between loading and unloading activities, by means of vegetating or covering the surface, and the stockpile will, therefore, not be a source of wind erosion emissions during inactive periods. Loading and unloading activities at the stockpile can occur at the same time with other construction activities (e.g. excavation of the diversion channel and hauling of earth material to the off-stream dam). Therefore, wind erosion emissions are assumed to occur simultaneously with other construction emissions.

It is assumed that no fugitive dust control will be applied for wind erosion emissions from the top soil and overburden stockpile.

Table 3A-26 summarizes the emission parameters used to calculate fugitive dust emissions generated from wind erosion on the temporary top soil and overburden stockpile. Table 3A-27 summarizes the particulate emission rates from wind erosion on the stockpile.

Emission Factors

The size-specific emission factors for wind-generated particulate emissions are determined using the equation:

$$Emission\ Factor\ (EF) = k \sum_{i=1}^{N} P_i$$

Equation 3A.19

where:

EF	-	Particle size-specific emission factor (g/m²).
k	-	Particle size multiplier
N	-	Number of disturbances per emission period
P_i	-	Erosion potential corresponding to the observed fastest mile of wind for the i^{th} period between disturbances (g/m²)

The particle size multiplier varies with aerodynamic particle size. Particle size multipliers for wind erosion particulate emissions are given in Table 3A-21.

Table 3A-24 Particle Size Multipliers for Emission Factors from Wind Erosion

Particle Size Multiplier	Wind Erosion			
	$PM_{2.5}$	PM_{10}	PM_{15}	TSP
k (g/m²)	0.075	0.5	0.6	1.0

The erosion potential function for a dry exposed surface is calculated using the following equation:

$$P = 58(u^* - u_t{}^*)^2 + 25(u^* - u_t{}^*)$$

Equation 3A.20

$$P = 0\ for\ u^* \le u_t{}^*$$

where:

u^*	-	Surface friction velocity (m/s). The friction velocity is a measure of wind shear stress on the erodible surface.
$u_t^*=1.02$	-	Threshold friction velocity assumed equal to 1.02 m/s corresponding to overburden (U.S. EPA, 2006c, Table 13.2.5-2).

Wind erosion emissions are generated when the surface wind friction velocity is greater than the threshold friction velocity (P>0).

Wind erosion emissions are calculated for six wind speed categories defined in the dispersion model. The hourly average wind speeds at reference height (10 m) for each wind speed category are converted to fastest mile wind speeds using a correction factor of 1.26, based on Durst's graph (Durst 1960). The Durst graph gives the ratio of probable maximum wind speed averaged over *t* seconds to hourly mean speed. The correction factor of 1.26 corresponds to a fastest mile wind speed of 72 mph (averaging time of 50 seconds). This correction factor is conservative since a very small percent (0.37%) of the predicted hourly winds are greater than 10.8 m/s.

$$u_{fm} = 1.26 \times u$$ **Equation A.21**

The surface friction velocity for each wind speed category is calculated from the fastest mile wind speed using the logarithmic wind speed profile equation:

$$u_{fm}(z) = \frac{u^*}{0.4} \ln \frac{z}{z_0}$$ **Equation 3A.22**

$$u^* = 0.049 \times u_{fm}$$

where:

u_{fm}	-	Fastest mile wind speed at reference height z (cm/s)
u*	-	Surface friction velocity (cm/s). The friction velocity is a measure of wind shear stress on the erodible surface.
z=10 m	-	Reference height above surface equal to 10 m, corresponding to wind reference height used in the dispersion model.
z0=0.3 cm	-	Roughness height assumed equal to 0.3 cm corresponding to overburden (U.S. EPA, 2006c, Table 13.2.5-2).
0.4	-	von Karman constant, dimensionless

Table 3A-25 provides the calculation of size-specific emissions factors per disturbance in g/m² of disturbed area for the six wind speed categories. The fastest mile wind speed and corresponding friction velocity are conservatively calculated for the upper limit of each wind speed category. An upper limit of 20 m/s is assumed for wind speed category 6 since this category has no upper limit in the dispersion model. As presented in Table 3A-25, there is wind erosion potential at the top soil and overburden stockpile only for wind speeds in wind speed category 6 (wind speeds greater than 10.8 m/s).

Table 3A-25 Size-Specific Emission Factors for Wind Erosion of Overburden

Wind Speed Category	Hourly Wind Speed (m/s)		U_{fm}	U*	U* - U_t*	P_i	Size-Specific Emission Factor (g/m²/disturbance)		
	Lower Limit	Upper Limit	(m/s)	(m/s)	—	(g/m²)	TSP	PM_{10}	$PM_{2.5}$
1	0	1.54	1.94	0.10	0.00	0.00	0.00	0.00	0.00
2	1.54	3.09	3.89	0.19	0.00	0.00	0.00	0.00	0.00
3	3.09	5.14	6.48	0.32	0.00	0.00	0.00	0.00	0.00
4	5.14	8.23	10.37	0.51	0.00	0.00	0.00	0.00	0.00
5	8.23	10.8	13.61	0.67	0.00	0.00	0.00	0.00	0.00
6	10.8	20	25.20	1.24	0.22	8.44	8.44	4.22	0.63

Temporal Allocation

The estimated maximum 1-hour emission rates are assumed to occur when the wind speed is greater than 10.8 m/s, for the construction duration (214 days), and they are used to predict maximum 1-hour and 24-hour average concentrations.

The annual emission rates are the same as the hourly emission rates because wind erosion is assumed to occur for the full period of the construction duration (214 days) when the stockpile is being accessed for storage or for use.

Table 3A-26 Activity Parameters and Emission Factors for Wind Erosion

Wind Speed Category	Disturbed Area	Material Movement			Truck Capacity	Number of Disturbances		Work Hours per Day	Work Days per Year	Constr. Duration (d/y)	TF	Emission Factor (g/m²/disturbance)		
	m²	Total Volume (m³)	Volume per Day (m³/d)	Volume per Hour (m³/h)	m³	Per Day	Per Hour				%	TSP	PM_{10}	$PM_{2.5}$
Temporary Top Soil and Overburden Stockpile														
1	800	1,557,350	5,663	236	17.4	325	14	24	214	214	75%	0.00	0.00	0.00
2	800	1,557,350	5,663	236	17.4	325	14	24	214	214	75%	0.00	0.00	0.00
3	800	1,557,350	5,663	236	17.4	325	14	24	214	214	75%	0.00	0.00	0.00
4	800	1,557,350	5,663	236	17.4	325	14	24	214	214	75%	0.00	0.00	0.00
5	800	1,557,350	5,663	236	17.4	325	14	24	214	214	75%	0.00	0.00	0.00
6	800	1,557,350	5,663	236	17.4	325	14	24	214	214	75%	8.44	4.22	0.63

Table 3A-27 Particulate Emission Rates from Wind Erosion

Wind Speed Category	Disturbed Area	Number of Disturbances		Hourly Emission Rates (g/s)			Annual Emission Rates (g/s)		
	m²	Per Day	Per Hour	TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$
Temporary Top Soil and Overburden Stockpile									
1	800	325	14	0.00	0.00	0.00	0.00	0.00	0.00
2	800	325	14	0.00	0.00	0.00	0.00	0.00	0.00
3	800	325	14	0.00	0.00	0.00	0.00	0.00	0.00
4	800	325	14	0.00	0.00	0.00	0.00	0.00	0.00
5	800	325	14	0.00	0.00	0.00	0.00	0.00	0.00
6	800	325	14	19.08	15.30	2.29	19.08	15.30	2.29
TOTAL EMISSION RATE			**g/s**	**19.08**	**15.30**	**2.29**	**19.08**	**15.30**	**2.29**
			kg/d	**6.06**	**4.86**	**0.728**	**6.06**	**4.86**	**0.728**

NOTE:

[a] Annual emission rate estimated based on 0.37% probability of hourly average wind speed greater than 10 m/s, predicted for the location of the temporary top soil and overburden stockpile.

3A.3.8 Metal Emissions in Fugitive Dust

Metal mass fractions in fugitive dust are based on laboratory analysis of five soil samples collected near the PDA. The maximum concentration from the five samples is conservatively used for the speciation profile. Metals with concentrations less than the detection limit in all five samples are considered not present in the soil. Metal mass fractions are applied to fugitive dust TSP emissions.

Table 3A-28 presents the metal mass fractions of total TSP in fugitive dust in mg/kg. The same metal fractions are used for winter and summer.

Table 3A-28 Metal Mass Fractions from Total TSP (Fugitive Dust)

Metal	Mass Fraction (mg/kg)
	Total TSP
Arsenic	6.93
Barium	286
Beryllium	1.03
Cadmium	0.60
Chromium	26.1
Cobalt	8.93
Copper	22.1
Lead	13.1
Mercury	0.0301
Molybdenum	1.10
Nickel	24.5
Uranium	3.07
Vanadium	42.3
Zinc	124

3A.4 REGIONAL EMISSIONS

3A.4.1 Emission Sources

Traffic emissions from regional roads within the Project LAA are the major regional emission sources included in the Base Case emission inventory. Emissions associated with a compressor station located in the northwest sector of the LAA are included. The following regional emissions are quantified for the Base Case:

- traffic combustion exhaust emissions from TransCanada Highway, Highway 22, Highway 8, and Springbank Road
- road dust emissions from TransCanada Highway, Highway 22, Highway 8, and Springbank Road
- emissions from the Shell Jumping Pound 5-7 Compressor Station

3A.4.2 Vehicular Traffic Emissions

Traffic emission rates are determined for TransCanada Highway, Highway 22, Highway 8, and the Springbank Road based on traffic counts provided by Alberta Transportation and on the application of the U.S. EPA Motor Vehicle Emission Simulator (MOVES) traffic emission model version 2014a (MOVES2014a; (U.S. EPA, 2015)). Traffic emissions on regional roadways are estimated for winter and summer periods based on winter and summer-specific emission factors derived from MOVES2014a.

3A.4.2.1 Traffic Counts

Traffic counts are extracted from Alberta TransportationTraffic Data Mapping (Alberta Transportation, 2015) for the most recent year (2015). Directional traffic counts from the most representative traffic control locations within the LAA are used to estimate the traffic volumes on TransCanada Highway, Highway 22, Highway 8, and the Springbank Road. Figure 3A-1 presents a snapshot of Alberta Transportation – Traffic Data Mapping (Alberta Transportation, 2015) within the LAA with highlighted traffic control locations used for the assessment. The following traffic control intersections are used to extract traffic counts for the regional roadways in the LAA:

- TransCanada Highway – Intersection of TransCanada Highway and Highway 22, Reference # 59200
- Highway 22 – Intersection of TransCanada Highway and Highway 22, Reference # 59200

- Highway 8 – Intersection of Highway 8 and Range Road 41, Reference # 70000190
- Springbank Road – Intersection of TransCanada Highway and Range Road 33, Reference # 59204

Traffic counts are provided by Alberta Transportation as an average annual daily traffic (AADT) count and an average summer daily traffic (ASDT) count. The summer traffic counts for all regional roadways are higher than the average annual traffic counts which indicates that traffic volume in summer is higher than traffic in winter. Therefore, the AADT count is applied to winter emissions and the ASDT count is applied to summer emissions. For traffic combustion emissions, winter is defined as the six-month period October to March.

Figure 3A-2 to Figure 3A-4 present diagrams of directional traffic counts at the representative intersections used in the assessment. Representative directional traffic counts are used to characterize the traffic volume on the road segments located within the LAA. There is no Alberta Transportation traffic control along Springbank Road in the LAA. Therefore, traffic count from Range Road 33, at the intersection with TransCanada Highway north of Springbank Road, is used to represent the traffic volume on Springbank Road.

The directional traffic counts on the representative intersection diagrams are subdivided for five vehicle classes (A to E):

- A: passenger vehicle
- B: recreational vehicle
- C: bus
- D: single unit truck
- E: tractor trailer unit

These five vehicle classes are mapped to the 13 vehicle classes from MOVES2014a using the default U.S. national vehicle population distribution. The mapping of Alberta Transportation traffic counts to the MOVES2014a vehicle classes is presented in Table 3A-29. For this mapping, all busses are represented by the MOVES2014a intercity bus category and single unit trucks are represented by single unit short-haul and long-haul trucks.

The Alberta Transportation traffic counts for the nearby roadways are summarized in Table 3A-30. The Alberta Transportation traffic counts for the nearby roadways are allocated to MOVES2014a vehicle classes in Table 3A-31.

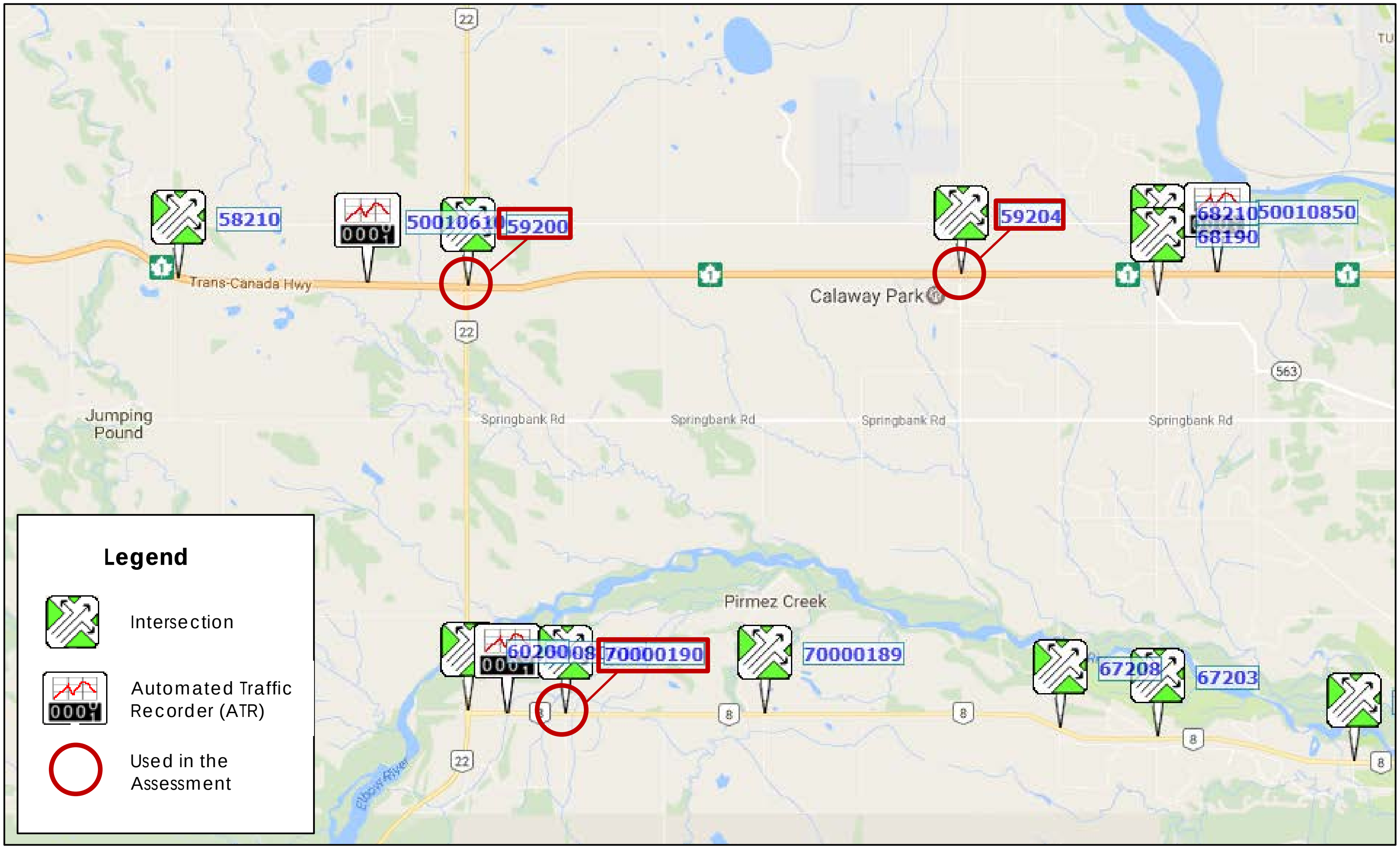

Figure 3A-1 Alberta Transportation Traffic Data Mapping in the Project LAA (Alberta Transportation 2015)

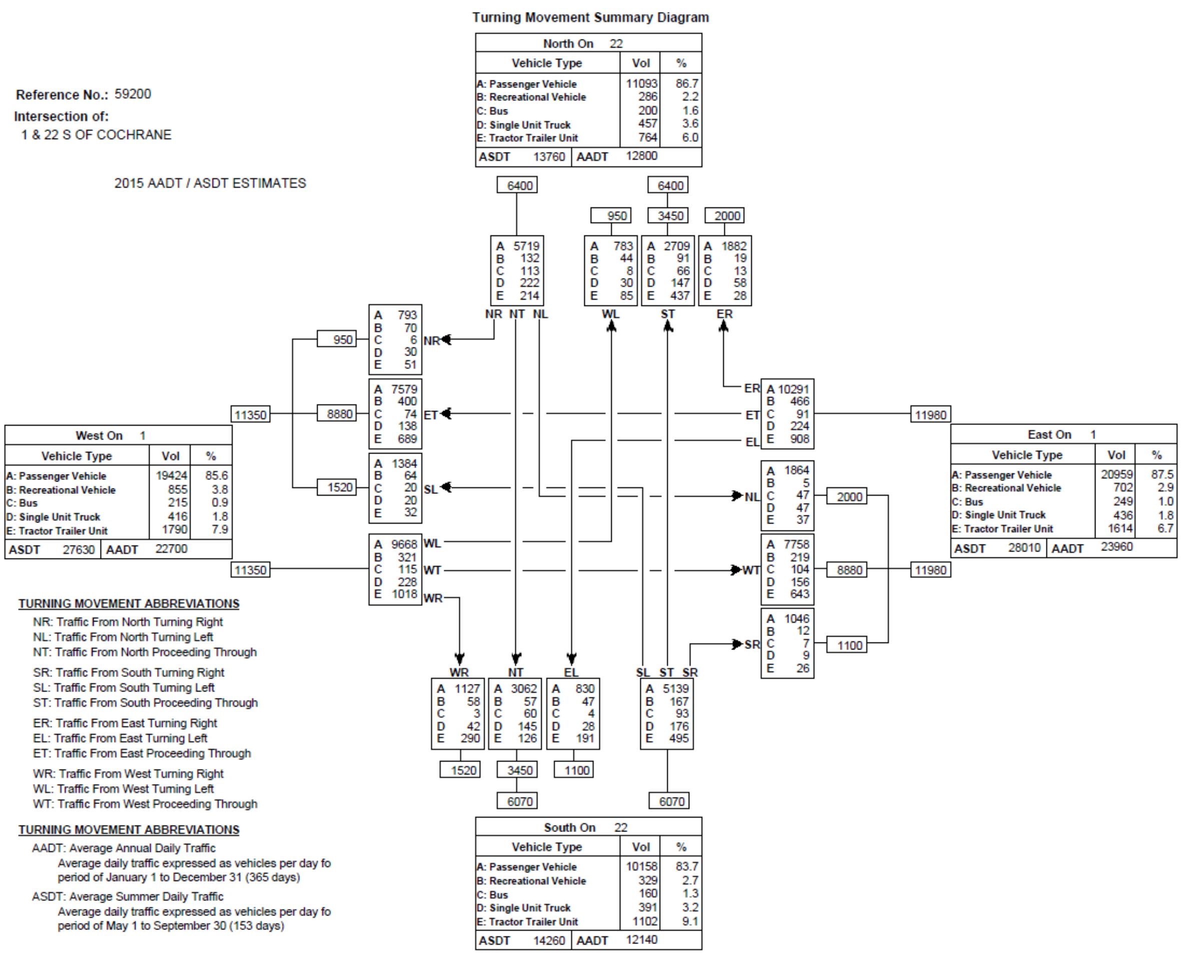

Figure 3A-2 Directional Traffic Count at the Intersection of TransCanada Highway and Highway 22 (Ref # 59200)

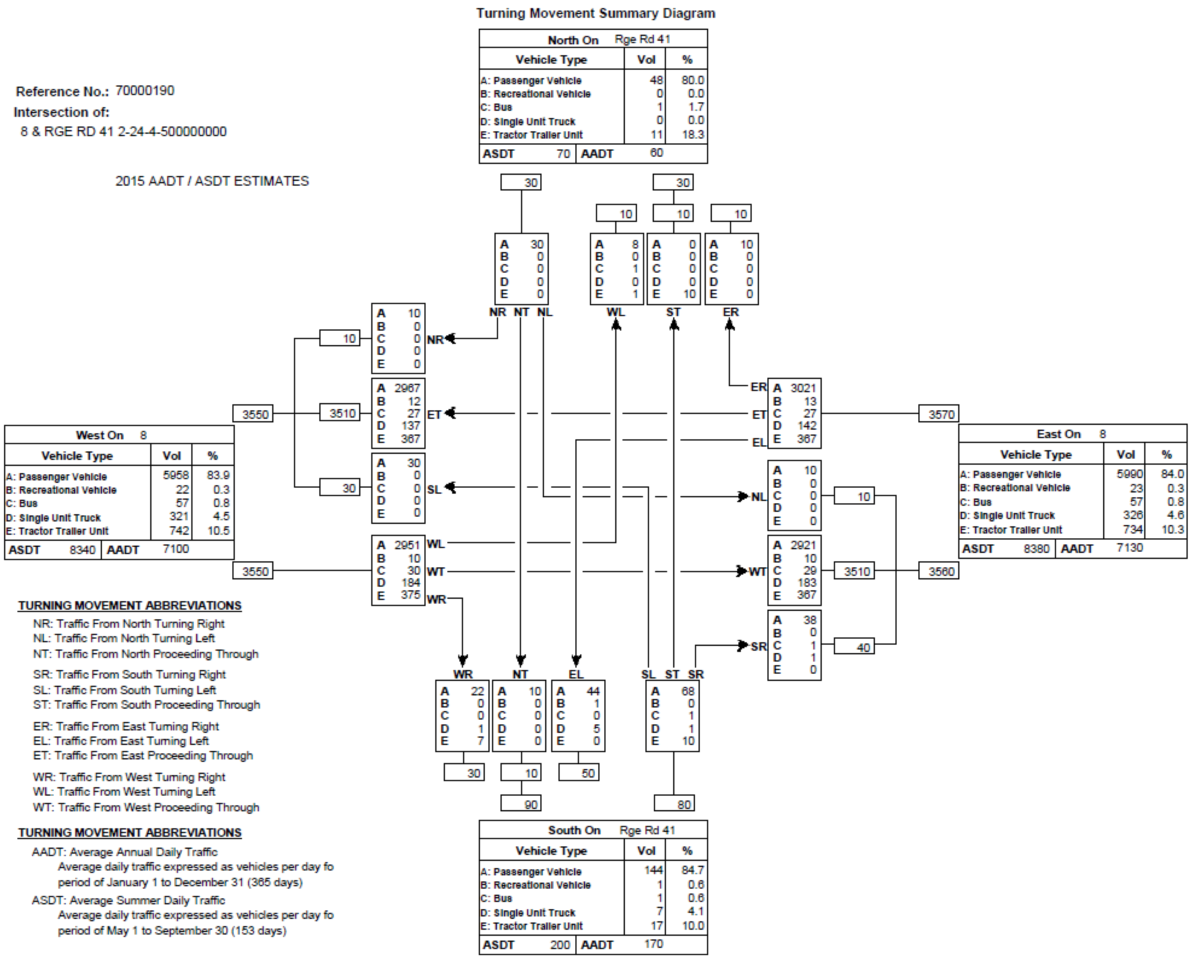

Figure 3A-3 Directional Traffic Count at the Intersection of Highway 8 and Range Road 41 (Ref # 70000190)

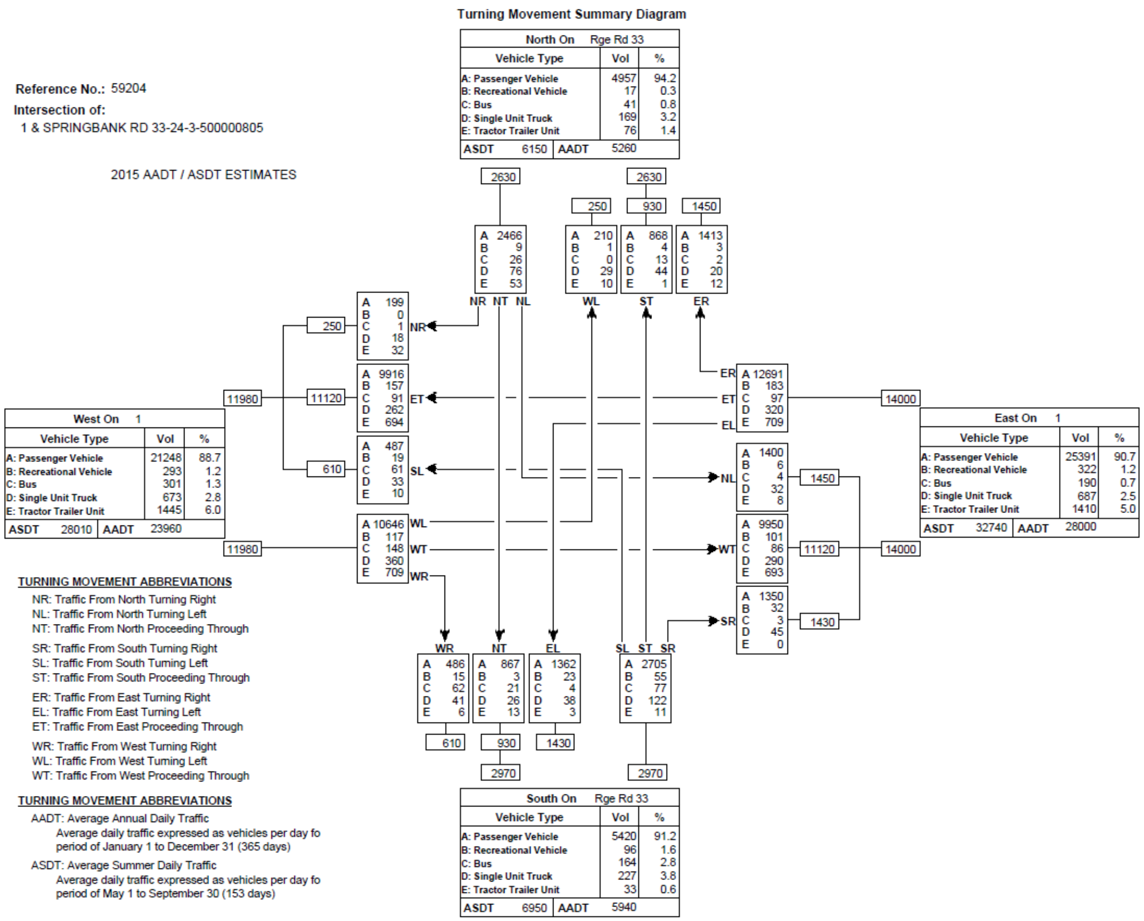

Figure 3A-4 Directional Traffic Count at the Intersection of TransCanada Highway and Range Road 33 (Ref # 59204)

Table 3A-29 Mapping of Alberta Transportation Traffic Counts to MOVES2014a Vehicle Classes

Alberta Transportation		MOVES2014a		Vehicle Fraction [a]
Class ID	**Vehicle Class**	**Class ID**	**Vehicle Class**	
A	Passenger Vehicle	11	Motorcycle	0.04
		21	Passenger Car	0.52
		31	Passenger Truck	0.35
		32	Light Commercial Truck	0.09
		Total:		**1.00**
B	Recreational Vehicle	54	Motor Home	1.00
		Total:		**1.00**
C	Bus [b]	41	Intercity Bus	1.00
		Total:		**1.00**
D	Single Unit Truck [c]	52	Single Unit Short-haul Truck	0.96
		53	Single Unit Long-haul Truck	0.04
		Total:		**1.00**
E	Tractor Trailer Unit	61	Combination Short-haul Truck	0.47
		62	Combination Long-haul Truck	0.53
		Total:		**1.00**

NOTES:

[a] Mapping of Alberta Transportation traffic counts to MOVES2014a vehicle classes based on MOVES2014a U.S. national vehicle population distribution.

[b] Vehicle class C (bus) mapped to MOVES2014a intercity bus category.

[c] Vehicle class D (single unit truck) mapped to MOVES2014a single unit short-haul and long-haul truck categories.

Table 3A-30 Alberta Transportation Traffic Counts (vehicles/day) at the Regional Roadways

Vehicle Class ID	Alberta Transportation Vehicle Class	TransCanada Highway		Highway 22		Highway 8		Springbank Road	
		AADT	ASDT	AADT	ASDT	AADT	ASDT	AADT	ASDT
A	passenger vehicle	20,192	23,913	11,093	11,925	5,990	7,040	4,957	5,796
B	bus	232	275	200	215	57	67	41	48
C	single unit truck	426	505	457	491	326	383	169	198
D	recreational vehicle	779	922	286	307	23	27	17	20
E	tractor trailer unit	1,702	2,016	764	821	734	863	76	89
Total Traffic Count:		**23,330**	**27,630**	**12,800**	**13,760**	**7,130**	**8,380**	**5,260**	**6,150**

Table 3A-31 Traffic Counts Allocated to MOVES2014a Vehicle Class

Vehicle Class ID	MOVES2014a Vehicle Class	TransCanada Highway		Highway 22		Highway 8		Springbank Road	
		AADT	ASDT	AADT	ASDT	AADT	ASDT	AADT	ASDT
11	motorcycle	732	867	402	432	217	255	180	210
21	passenger car	10,542	12,485	5,792	6,226	3,127	3,676	2,588	3,026
31	passenger truck	7,122	8,435	3,913	4,206	2,113	2,483	1,749	2,044
32	light commercial truck	1,795	2,125	986	1,060	532	626	441	515
Total Passenger Vehicles:		**20,192**	**23,913**	**11,093**	**11,925**	**5,990**	**7,040**	**4,957**	**5,796**
41	intercity bus	232	275	200	215	57	67	41	48
Total Buses:		**232**	**275**	**200**	**215**	**57**	**67**	**41**	**48**
52	single unit short-haul truck	409	485	439	472	313	368	162	190
53	single unit long-haul truck	17	20	18	19	13	15	7	8
Total Single Unit Trucks:		**426**	**505**	**457**	**491**	**326**	**383**	**169**	**198**
54	motor home	779	922	286	307	23	27	17	20
Total Recreational Vehicles:		**779**	**922**	**286**	**307**	**23**	**27**	**17**	**20**

Table 3A-31 Traffic Counts Allocated to MOVES2014a Vehicle Class

Vehicle Class ID	MOVES2014a Vehicle Class	TransCanada Highway		Highway 22		Highway 8		Springbank Road	
		AADT	ASDT	AADT	ASDT	AADT	ASDT	AADT	ASDT
61	combination short-haul truck	807	955	362	389	348	409	36	42
62	combination long-haul truck	895	1,060	402	432	386	454	40	47
Total Tractor Trailer Units:		**1,702**	**2,016**	**764**	**821**	**734**	**863**	**76**	**89**
Total Traffic Count:		**23,330**	**27,630**	**12,800**	**13,760**	**7,130**	**8,380**	**5,260**	**6,150**

3A.4.2.2 MOVES2014a Emission Factors

The MOVES2014a model generates emission factors and emission inventories for on-road motor vehicles for four road types and under a wide range of user-defined conditions. The four road types defined in MOVES2014a are:

- off-network
- rural restricted access
- rural unrestricted access
- urban restricted access
- urban unrestricted access

Restricted access road types refer to highways that can only be accessed by an entrance ramp. Additionally, the MOVES2014a model allows separating the emission rates for the entrance ramps alone and the restricted access roads without the ramp. TransCanada Highway, Highway 22 and Highway 8 are classified as a rural restricted road type and emission rates are estimated without including the ramps. The Springbank Road is classified as a rural unrestricted road type.

The MOVES2014a model was originally developed for the United States and it contains built-in vehicle population totals by region (e.g. U.S. county), and default data distributions such as vehicle-miles-travelled (VMT) and vehicle type population distribution, VMT fraction per road type, vehicle age distribution and vehicle speed distribution. To run the model for a region outside the United States, a representative U.S. county with similar characteristics needs to be selected. For the assessment, Marion County, Indiana is a representative region for the project location based on the following factors:

1. Indiana is one of the U.S. East Coast states that use Reformulated Gasoline (RFG) fuel and are under a controlled fuel program, similar to Canada (Renewable Fuels Regulations SOR/2010-189; (ECCC, 2010b)) and Alberta (Renewable Fuels Standard Regulation 29/2010; (AEP, 2010)).
2. Indianapolis has a similar population (approximately 0.85 million) to the population of Calgary, Alberta (approximately 1.24 million) and, therefore, the vehicle population and vehicle population distribution in Marion County is similar to the vehicle population in Calgary and the Project LAA;

The MOVES2014a model is run for the most current year (2016) and using most of the default data distributions for Marion County. The input data for the model is customized for the fuel formulations to reflect Canada and Alberta fuels, and for hourly temperature and hourly relative humidity profiles based on the Canadian Climate Normals from Springbank airport station. Two model runs are executed – one for a typical winter day in January and one for a typical summer day in July. Winter and summer-specific emission factors are derived from the typical winter day run and the typical summer day run, respectively. For traffic combustion emissions, winter is defined as the six-month period October to March.

Running and evaporative emission processes are included in the model. Start exhaust and extended idle exhaust processes are not included because it is assumed that most of the traffic in the LAA is through traffic with minimum stops and no extensive idling. Table 3A-32 summarizes the inputs to the MOVES2014a model. Table 3A-33 presents the customized fuel formulations used in the model to reflect fuels used in Canada and Alberta.

The model generates emission inventory aggregated on county level (i.e. Marion County). The model output is additionally post-processed using an internal processing script (*EmissionRates.sql*) to generate emission factors per VMT (g/VMT). The emission factors are grouped by road type and vehicle class corresponding to the breakdown of traffic counts. Table 3A-34 lists the emission factors by vehicle class generated by MOVES2014a for the rural restricted and rural unrestricted road types.

Table 3A-32 Input Parameters for the MOVES2014a Model

Model Parameter	Selected Option for the Project Assessment
Scale	
Model	onroad
Domain	county
Calculation Type	inventory
Time Spans	
Time Aggregation Level	hour
Years	2016
Months	January, July
Days	weekdays
Start Hour	00:00
End Hour	23:00
Geographic Bounds	
Region	county
State	Indiana
County	Marion County
On-Road Vehicles	
Fuels	compressed natural gas (CNG), diesel fuel, electricity, ethanol (E-85), gasoline
Source use types [a]	combination long-haul truck, combination short-haul truck, intercity bus, light commercial truck, motor home, motorcycle, passenger car, passenger truck, single unit long-haul truck, single unit short-haul truck
Road Types	
Road types	rural restricted access, rural unrestricted access

Table 3A-32 Input Parameters for the MOVES2014a Model

Model Parameter	Selected Option for the Project Assessment
Substances and Processes	
Substances	total gaseous hydrocarbons non-methane hydrocarbons non-methane organic gases total organic gases volatile organic compounds methane (CH_4) carbon monoxide (CO) oxides of nitrogen (NO_X) Primary Exhaust $PM_{2.5}$ – total Primary Exhaust $PM_{2.5}$ – species Primary Exhaust $PM_{2.5}$ – brakewear particulate Primary Exhaust $PM_{2.5}$ – tirewear particulate Primary Exhaust PM_{10} – total Primary Exhaust PM_{10} – brakewear particulate Primary Exhaust PM_{10} – tirewear particulate sulphur dioxide (SO_2) total energy consumption benzene ethanol MTBE 1,3-butadiene formaldehyde acrolein additional air toxics polycyclic aromatic hydrocarbons (PAH) metals
Processes	running exhaust brakewear tirewear evaporative permeation evaporative fuel vapour venting evaporative fuel leaks crankcase running exhaust refueling displacement vapour loss refueling spillage loss

Table 3A-32 Input Parameters for the MOVES2014a Model

Model Parameter	Selected Option for the Project Assessment
General Output	
Mass Units	grams
Energy Units	Joules
Distance Units	miles
Activity	distance traveled
Output Emissions Detail	
Output Grouped By	time, location, road type, source use type [a], substance
Time	hour
Location	county

NOTE:
[a] Source use type in MOVES2014a refers to vehicle type

Table 3A-33 Fuel Formulations used in the MOVES2014a Model

Fuel Type	Fuel Formulation ID	Market Share (%)	RVP (psi)	Sulphur (ppm)	Ethanol (vol %)	Aromatics (vol %)	Olefins (vol %)	Benzene (vol %)	E200 (vol %)	E300 (vol %)	Biodiesel Ester (vol %)
Gasoline	4000 [a]	97	10.2 [b]	10 [c]	5 [d]	25.0 [e]	10.1 [e]	0.67 [e]	50.25 [e]	86.13 [e]	—
	3341	3	10.2 [b]	10 [c]	10 [d]	25.0 [e]	10.1 [e]	0.67 [e]	50.25 [e]	86.13 [e]	—
Diesel	25005	100	—	15	2 [d]	—	—	—	—	—	5
Ethanol (E85)	27002	100	10.2 [b]	10 [c]	74	—	—	—	49.9	89.5	—
Compressed natural gas (CNG)	28001	100	—	15 [c]	—	—	—	—	—	—	—

NOTES:

[a] New gasoline formulation defined in the model to reflect fuel properties specific to Canada and Alberta gasoline fuels.

[b] Reid vapour pressure (RVP) based on supplier reported Canada-wide and provincial gasoline properties from Benzene in Canadian Gasoline Report 2010-2012 (ECCC, 2015) and Canadian General Standard Board (CGSB) Automotive Gasoline Standard CGSB-3.5-2016 (CGSB, 2004) (maximum RVP of gasoline = 72 kPa; maximum RVP of gasoline that contains ethanol = 72 + 7 kPa).

[c] Sulphur content in gasoline fuel based on Canadian Sulphur in Gasoline Fuel Regulations (ECCC, 1999). Sulphur content in diesel fuel based on Canadian Sulphur in Diesel Fuel Regulations (ECCC, 2002).

[d] Ethanol content set to 5% by volume in the gasoline formulation with the greatest market share, and set to 2% by volume in diesel fuel, based on Canadian Renewable Fuels Regulations (ECCC, 2010b) and Alberta Renewable Fuels Standard Regulation (AEP, 2010). Ethanol content set to 10% by volume in the gasoline formulation with the lower market share.

[e] Aromatics, olefins, benzene, E200 and E300 contents in gasoline fuel based on supplier reported Canada-wide and provincial gasoline properties from Benzene in Canadian Gasoline Report 2010-2012 (ECCC, 2015).

Other values are default values from the MOVES2014a model for Marion County, Indiana

Table 3A-34 MOVES2014a CAC Emission Factors for Traffic Exhaust Emissions on Regional Roadways

Class ID	Vehicle Class	Winter Emission Factors (g/VMT)						Summer Emission Factors (g/VMT)					
		SO_2	NO_X	CO	VOC	PM_{10} [a]	$PM_{2.5}$	SO_2	NO_X	CO	VOC	PM_{10} [a]	$PM_{2.5}$
Rural Restricted Road Type (without Ramps)													
11	motorcycle	0.008	0.915	14.089	0.921	0.045	0.036	0.003	0.896	14.663	1.016	0.033	0.025
21	passenger car	0.006	0.259	1.939	0.061	0.029	0.018	0.002	0.203	2.268	0.065	0.017	0.008
31	passenger truck	0.008	0.555	3.282	0.107	0.032	0.021	0.003	0.413	3.808	0.115	0.020	0.010
32	light commercial truck	0.007	0.574	3.106	0.101	0.031	0.020	0.003	0.414	3.649	0.100	0.021	0.011
41	intercity bus	0.010	12.573	2.283	0.522	0.478	0.405	0.015	12.066	2.209	0.000	0.462	0.391
52	single unit short-haul truck	0.008	2.516	3.609	0.293	0.151	0.106	0.006	2.197	3.261	0.128	0.141	0.097
53	single unit long-haul truck	0.005	2.318	2.446	0.294	0.168	0.116	0.006	2.224	2.274	0.069	0.158	0.107
54	motor home	0.012	3.884	15.770	0.628	0.213	0.165	0.007	3.339	14.138	0.594	0.147	0.107
61	combination short-haul truck	0.010	6.844	1.400	0.303	0.272	0.210	0.014	6.558	1.357	0.000	0.265	0.204
62	combination long-haul truck	0.010	7.502	1.566	0.337	0.310	0.243	0.015	7.191	1.519	0.000	0.303	0.236
Rural Unrestricted Road Type													
11	motorcycle	0.007	0.878	13.817	1.103	0.052	0.037	0.002	0.859	14.379	1.186	0.040	0.026
21	passenger car	0.006	0.233	1.740	0.068	0.041	0.019	0.002	0.186	2.020	0.074	0.030	0.009
31	passenger truck	0.008	0.477	2.750	0.110	0.044	0.021	0.003	0.365	3.173	0.120	0.033	0.011
32	light commercial truck	0.008	0.513	2.711	0.109	0.044	0.021	0.003	0.379	3.164	0.106	0.035	0.013
41	intercity bus	0.010	12.198	2.715	0.658	0.657	0.513	0.014	11.687	2.627	0.000	0.638	0.495
52	single unit short-haul truck	0.009	2.839	4.278	0.409	0.222	0.136	0.007	2.478	3.860	0.169	0.212	0.128
53	single unit long-haul truck	0.006	2.729	2.858	0.405	0.249	0.151	0.007	2.601	2.666	0.095	0.239	0.143

Table 3A-34 MOVES2014a CAC Emission Factors for Traffic Exhaust Emissions on Regional Roadways

Class ID	Vehicle Class	Winter Emission Factors (g/VMT)						Summer Emission Factors (g/VMT)					
		SO_2	NO_X	CO	VOC	PM_{10} [a]	$PM_{2.5}$	SO_2	NO_X	CO	VOC	PM_{10} [a]	$PM_{2.5}$
54	motor home	0.013	3.888	14.902	0.827	0.251	0.169	0.007	3.319	13.334	0.710	0.201	0.125
61	combination short-haul truck	0.010	7.034	1.609	0.360	0.396	0.269	0.014	6.726	1.561	0.000	0.388	0.261
62	combination long-haul truck	0.011	7.833	1.806	0.402	0.454	0.315	0.015	7.489	1.752	0.000	0.445	0.306

NOTE:
[a] Total PM emission is assumed to be comprised entirely of particles with size less or equal to 10 microns (PM_{10}) in the MOBILE2014a model

3A.4.2.3 CAC Emissions

CAC vehicle traffic emissions on the regional roadways are estimated using the following equation:

$$\begin{aligned} ER_h\ (g/s) = {} & Road\ Length\ (km) \\ & \times \sum_{vehicle\ class} \left(Average\ Daily\ Traffic\ (vpd) \times Emission\ Factor\ \left(\frac{g}{VMT}\right)\right) \\ & \times Unit\ Conversion\ \left(\frac{mile}{1.61\ km}\right) \times \left(\frac{day}{24\ hr}\right) \times \left(\frac{hr}{3{,}600\ s}\right) \end{aligned}$$

Equation 3A.19

where:

ER_h	-	Hourly emission rate (g/s)
Road Length	-	Road length (km)
Average Daily Traffic	-	Two-way daily traffic count per vehicle class (vpd). AADT used for calculating winter emissions and ASDT used for calculating summer emissions.
Emission Factor	-	Emission factor from MOVES2014a specific for a vehicle class, road type, and winter or summer.

The equation estimates CAC emissions from vehicle traffic on regional roadways using emission factors based on the two-way traffic count and the length of the road segment within the Project LAA.

Table 3A-35 summarizes the CAC emission rates from vehicle traffic on regional roadways.

Temporal Allocation

The regional vehicle traffic emissions are assumed to be continuous throughout the year and therefore the hourly and annual emission rates are the same. Different emission rates are applied in the winter and summer periods. For traffic combustion emissions, winter is defined as the six-month period October to March.

Table 3A-35 CAC Emission Rates from Vehicle Traffic on Regional Roadways

Regional Road	Length (km)	Traffic Count		Winter Emission Rates (g/s)						Summer Emission Rates (g/s)					
		AADT	ASDT	SO_2	NO_X	CO	VOC	PM_{10}	$PM_{2.5}$	SO_2	NO_X	CO	VOC	PM_{10}	$PM_{2.5}$
TransCanada Highway	20.2	23,330	27,630	0.024	4.03	11.16	0.516	0.213	0.154	0.014	4.23	14.44	0.507	0.199	0.135
Highway 22	22.4	12,800	13,760	0.015	2.40	6.53	0.307	0.127	0.092	0.008	2.29	7.72	0.270	0.109	0.074
Highway 8	12.0	7,130	8,380	0.004	0.814	1.77	0.091	0.042	0.030	0.003	0.862	2.33	0.079	0.041	0.028
Springbank Road	8.8	5,260	6,150	0.002	0.217	0.898	0.048	0.020	0.011	0.001	0.217	1.173	0.052	0.019	0.009
TOTAL EMISSION RATE			**g/s**	**0.045**	**7.45**	**20.36**	**0.962**	**0.402**	**0.287**	**0.026**	**7.60**	**25.66**	**0.908**	**0.367**	**0.246**
			kg/d	**3.92**	**644**	**1,759**	**83.1**	**34.7**	**24.8**	**2.26**	**657**	**2,217**	**78.4**	**31.7**	**21.3**

NOTE:
[a] Total TSP emission is assumed to be comprised entirely of particles with size less or equal to 10 microns (PM_{10}) in the MOBILE2014a model

3A.4.2.4 VOC, PAH, and Metal Emissions

The MOVES2014a model (U.S. EPA, 2015) estimates emission factors for a selection of VOC, PAH and metal substances. The emission factors of the individual substances are scaled from the total VOC or total TSP emission factor, depending on whether the substance is in gaseous or particulate phase, respectively. These ratios are used to estimate ambient concentrations of the individual substances from the dispersion model predictions for total VOC and total TSP.

Scaling ratios for individual VOC, PAH and metal substances are derived by dividing the emission factor for each individual substance by the emission factor of total VOC or total TSP. The VOC, PAH and metals scaling fractions are aggregated to a weighted average using the VMT per vehicle class as the weights. Individual VOC substances are scaled from the total VOC emission factor. Individual PAH substances are scaled from both, total VOC and total TSP emission factors, based on the gaseous and particulate fractions of each PAH substance as it exists in the atmosphere. Of the five metals that are identified in vehicle exhaust, only elemental and divalent mercury can exist in gaseous phase and are scaled from total VOC; all other metals are scaled from total TSP.

Table 3A-36 presents the fractions of individual VOC substances from total VOC in units of g/kg. Table 3A-37 presents the partitioning of PAH in gaseous and particulate phases, and the corresponding PAH fractions from total VOC and total TSP in mg/kg. Table 3A-38 lists the metal fractions from total VOC (mercury) and total TSP, in mg/kg. The VOC, PAH and metals emission fractions from total VOC and total TSP are the maximum of the calculated winter and summer fractions.

Table 3A-36 VOC Substance Fractions from Total VOC (On-Road Vehicles)

Volatile Organic Substance	Mass Percent of Total VOC [a] (mg/kg)
Benzene	27.1
1,3-Butadiene	1.88
Formaldehyde	27.3
Acetaldehyde	11.4
Acrolein	1.95
2,2,4-Trimethylpentane	25.5
Ethyl Benzene	17.6
Propionaldehyde	1.54

Table 3A-36 VOC Substance Fractions from Total VOC (On-Road Vehicles)

Volatile Organic Substance	Mass Percent of Total VOC [a] (mg/kg)
Toluene	115
Xylene	64.9
NOTE: [a] The emission fractions are the maximum of the calculated winter and summer fractions	

Table 3A-37 PAH Substance Fractions from Total TSP and Total VOC (On-Road Vehicles)

Polycyclic Aromatic Substance	PAH Partition (%)		Mass Fraction [a] (mg/kg)	
	Particle	Gaseous	TSP	VOC
Naphthalene	0.3	99.7	21	3,225
Dibenzo(a,h)anthracene	100	0	4.1	0
Fluoranthene	28	72	104	104
Acenaphthene	0	100	0	84
Acenaphthylene	1.3	98.7	6.3	195
Anthracene	14.1	85.9	28	67
Benz(a)anthracene	77.5	22.5	99	12
Benzo(a)pyrene	99.8	0.2	165	0.14
Benzo(b)fluoranthene	94.6	5.4	78	1.9
Benzo(g,h,i)perylene	99.9	0.1	409	0.18
Benzo(k)fluoranthene	94.3	5.7	74	1.9
Chrysene	82.9	17.1	75	6.5
Fluorene	0	100	0	147
Phenanthrene	0	100	0	269
Pyrene	0	100	0	123
NOTE: [a] The mass fractions are the maximum of the calculated winter and summer fractions				

Table 3A-38 Metal Fractions from Total TSP and Total VOC (On-Road Vehicles)

Metal	Mass Fraction [a] (mg/kg)	
	TSP	VOC
Mercury	0.011	0.854
Arsenic	46	0
Chromium 6+	0.237	0
Manganese	31	0
Nickel	39	0

NOTE:
[a] The mass fractions are the maximum of the calculated winter and summer fractions

3A.4.3 Road Dust Emissions

3A.4.3.1 CAC Emissions

Emission Rate Approach

Road dust emissions from vehicle traffic on the regional roadways are estimated using U.S. EPA AP-42 emission factors from Chapter 13.2.1 Paved Roads (U.S. EPA, 2011). Fugitive TSP, PM_{10} and $PM_{2.5}$ emissions from the regional roadways are estimated from:

$$
\begin{aligned}
ER_h\ (g/s) = {} & Road\ Length\ (km) \times Average\ Daily\ Traffic\ (vpd) \times Emission\ Factor\ \left(\frac{g}{VMT}\right) \\
& \times Control\ Efficiency\ (\%) \times Transportable\ Fraction\ (\%) \\
& \times Unit\ Conversion\ \left(\frac{miles}{1.61\ km}\right) \times \left(\frac{day}{24\ hr}\right) \times \left(\frac{hr}{3{,}600\ s}\right)
\end{aligned}
$$

Equation 3A.23

where:

ER_h	-	Hourly emission rate (g/s)
Road Length	-	Road length (km)
Average Daily Traffic	-	Two-way daily traffic count (vpd). AADT used for calculating winter emissions and ASDT used for calculating summer emissions.
Emission Factor	-	Particle size-specific emission factor (g/VMT).
Control Efficiency	-	Natural mitigation efficiency (%). Estimated 5% natural mitigation efficiency in winter and 9% natural mitigation efficiency in summer, based on number of “wet” days with at least 0.254 mm of precipitation in winter and summer.

Transportable Fraction (TF)=75%	-	An adjustment factor to account for near-source removal of fugitive dust emissions due to micro scale turbulence and impaction on buildings and vegetative surfaces. The emission fraction that is not removed by the near-source removal factors is defined as “Transportable Fraction”. Assumed Transportable Fraction equal to 75% corresponding to grassland (Pouliot et al., 2010).

For fugitive road dust emissions, winter is defined as the four-month period November to February.

Natural mitigation efficiency is applied to both winter and summer road dust emissions based on the number of “wet” days with at least 0.254 mm of precipitation in the winter and summer periods. Natural mitigation efficiency is estimated on a daily basis from:

$$Mitigation\ Efficiency\ (\%) = \frac{P}{4N} \times 100$$ **Equation 3A.24**

where:

Mitigation Efficiency	-	Natural mitigation efficiency (%)
P	-	Number of “wet” days with at least 0.254 mm of precipitation during winter and summer. Number of days per month with at least 0.254 mm precipitation extracted from Canadian Climate Normals from Springbank airport station.
N	-	Number of days in the averaging period. 120 days in winter (4 months) and 245 days in summer (8 months).

Based on the Climate Normals data, a natural mitigation efficiency of 5% is estimated for winter and 9% - for summer.

Table 3A-41 summarizes the emission parameters used in the calculation of fugitive dust emissions from vehicle traffic on regional roadways. Table 3A-42 summarizes the PM emission rates from vehicle traffic on regional roadways.

Emission Factors

The size-specific emission factors are determined from:

$$Emission\ Factor\ (EF) = k(sL)^{0.91} \times (W)^{1.02}$$ **Equation 3A.25**

Where:

EF	-	Particle size-specific emission factor (g/VMT).
k	-	Particle size multiplier (g/VMT)
sL	-	Road surface silt loading (g/m²).
W	-	Average weight of the vehicles travelling on the road (tons). The average weight is estimated as a traffic count-weighted average of the Gross Vehicle Weights (GVW) for individual vehicle classes.

The particle size multiplier (k) for different particle size ranges is given in Table 3A-39.

During winter, the road surface silt loading increases due to the periodic application of antiskid material during months with snowfall. Table 3A-40 provides the default silt loadings for normal conditions and a “winter multiplier” which account for the increased silt loading during winter. The silt loading depends on the average daily traffic. The silt loading is generally greater for lower traffic volumes. The default winter and summer silt loadings in Table 3A-40 are used to estimate winter and summer fugitive dust emissions on the regional roadways depending on the AADT and ASDT.

The average vehicle weight (W) used in the emission factor calculation is the average weight of all vehicles travelling on the road. The average vehicle weight (W) is calculated from the average Gross Vehicle Weights (GVW) of the individual vehicle classes (e.g. passenger car, light commercial truck) weighted by the traffic count (AADT or ASDT) for each vehicle class.

Temporal Allocation

The regional road dust emissions are assumed to be continuous throughout the year and, therefore, the hourly and annual emission rates are the same. Different emission rates are applied in the winter and summer periods. For road dust emissions, winter is defined as the four-month period November to February.

Table 3A-39 Aerodynamic Particle Size Multiplier for Paved Road Dust Emission Factor

Aerodynamic Particle Size Multiplier (k)			
PM_{30}	**PM_{15}**	**PM_{10}**	**$PM_{2.5}$**
0.74	0.48	0.35	0.053

Table 3A-40 Default Silt Loadings and Winter Multipliers

AADT		Default Baseline Silt Loading (g/m^2)	Winter Baseline Silt Loading Multiplier [a]
Lower Limit	Upper Limit		
0	500	0.6	4
500	5,000	0.2	3
5,000	10,000	0.06	2
> 10,000	—	0.03	1

NOTES:
[a] To account for application of antiskid material during winter periods with frozen precipitation.
AADT: Annual Average Daily Traffic

SOURCE: U.S. EPA AP-42, Section 13.2.1, Table 13.2.1-2

Table 3A-41 Activity Parameters and Emission Factors for Road Dust Emission Rates

Regional Road	Length (km)	Traffic Count (vehicles/day)		Silt Loading (g/m²)		W (ton)	TF (%)	Natural Mitigation Efficiency (%)		Winter Emission Factors (g/VMT)			Summer Emission Factors (g/VMT)		
		AADT	ASDT	Winter	Summer			Winter	Summer	TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$
TransCanada Highway	20.2	23,330	27,630	0.03	0.03	5.77	75	5	9	1.289	0.246	0.061	1.289	0.246	0.061
Highway 22	22.4	12,800	13,760	0.03	0.03	5.55	75	5	9	1.238	0.236	0.059	1.238	0.236	0.059
Highway 8	12.0	7,130	8,380	0.12	0.06	6.49	75	5	9	5.129	0.979	0.245	2.730	0.521	0.130
Springbank Road	8.8	5,260	6,150	0.12	0.06	4.16	75	5	9	3.255	0.621	0.155	1.732	0.331	0.083

Table 3A-42 Particulate Emission Rates from Vehicle Traffic on Regional Roadways

Regional Road	Length (km)	Traffic Count		Winter Emission Rates (g/s)			Summer Emission Rates (g/s)		
		AADT	ASDT	TSP	PM_{10}	$PM_{2.5}$	TSP	PM_{10}	$PM_{2.5}$
TransCanada Highway	20.2	23,330	27,630	3.121	0.596	0.149	3.541	0.676	0.169
Highway 22	22.4	12,800	13,760	1.819	0.347	0.087	1.873	0.357	0.089
Highway 8	12.0	7,130	8,380	2.259	0.431	0.108	1.354	0.258	0.065
Springbank Road	8.8	5,260	6,150	0.772	0.147	0.037	0.460	0.088	0.022
TOTAL EMISSION RATE			**g/s**	**7.97**	**1.52**	**0.380**	**7.23**	**1.38**	**0.345**
			kg/d	**689**	**131**	**32.9**	**624**	**119**	**29.8**

NOTES:
Winter defined as the four-month period November to February
Summer defined as the eight-month period March to October

3A.4.3.2 Metal Emissions in Road Dust

Emission fractions for metals in road dust are based on laboratory analysis of five soil samples collected near the PDA. The maximum concentration from the five samples is conservatively used for the speciation profile. Metals with concentrations less than the detection limit in all five samples are considered not present in the soil. Metal mass fractions from total fugitive PM emissions are expressed in units of mg/kg.

3A.4.4 Regional Facility Emissions

There is one industrial facility located in the northwest quadrant of the Project LAA, the Shell Canada Limited, Jumping Pound 5-7 Compressor Station. The compressor station reports NO_X emissions to the National Pollutant Release Inventory (NPRI). The reported NO_X emission rate (24.9 t/y) in NPRI for 2014 is used in the dispersion model. Other combustion emissions from the compressor station are considered negligible and are not estimated.

It is assumed that NO_X emissions are released from two stacks, one compressor stack and one heater stack. Table 3A-43 lists the stack parameters and NO_X emission rates from the compressor station. Typical stack parameters are assumed for dispersion modelling.

Table 3A-43 NO_X Emissions from Shell Jumping Pound 5-7 Compressor Station

Source Identification Number		C-1	H-1
Unit description		Compressor	Heater
Temporal variation		Continuous	Continuous
Stack Location (UTM Zone 11, NAD 83)			
UTM easting [a]	m E	671,061	671,061
UTM northing [a]	m N	5,665,810	5,665,810
Base elevation	m ASL	1,250	1,250
Stack Parameters [b]			
Stack height	m	7.50	7.50
Stack diameter	m	0.50	0.40
Exit velocity	m/s	30	10
Exit temperature	°C	527	327
	°K	800	600

Table 3A-43 NO_x Emissions from Shell Jumping Pound 5-7 Compressor Station

Source Identification Number		C-1	H-1
Emission Rates [c]			
NO_x	g/s	0.592	0.197
	kg/d	51.2	17.1

NOTES:
[a] Compressor station location approximated from Google Earth Professional®. Assumed both stacks at the same location.
[b] Assumed typical stack parameters
[c] Emission rates based on 2014 NPRI reporting

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Attachment 3B METEOROLOGICAL MODELLING USING CALMET

Table of Contents

LIST OF FIGURES

Abbreviations

AEP	Alberta Environment and Parks
CDED	Canadian Digital Elevation Data
ECCC	Environment and Climate Change Canada
GEO.DAT	geophysical data
LAA	local assessment area
NALCMS	North American Land Change Monitoring System
NTDB	National Topographic Data Base
the Project	the Springbank Off-stream Reservoir Project

3B.1 INTRODUCTION

This appendix provides an overview of the meteorological information used for the Springbank Off-stream Reservoir Project (the Project) assessment. Also provided are the technical details and options that used to apply the CALMET model for the assessment.

Meteorology determines the transport and dispersion of industrial emissions and, hence, largely determines air quality downwind of emission sources. Meteorological data for the five-year period from 2002 to 2006 are used to define transport and dispersion parameters. The selection of a five-year period is consistent with the Alberta Environment and Parks (AEP) Air Quality Model Guideline (AEP 2013), which requires data for a five-year period when using output from a meteorological model (e.g., CALMET).

Meteorological characteristics vary with time (e.g., season and time of day) and location (e.g., height above ground, terrain features, and land cover properties). Historically, meteorological data measured at one location have been used and extrapolated to reflect conditions across a model domain. For large model domains, this approach fails to recognize that meteorological conditions for any given hour can vary significantly across the domain due to terrain and geophysical differences. Curvilinear airflow can also result from mesoscale and synoptic-scale weather patterns.

Meteorological models are used to provide spatially and temporally varying wind and temperature fields across a model domain to overcome the limitations associated with the use of single station measurements. The CALMET meteorological pre-processing program is used to provide temporally and spatially varying meteorological parameters required by the CALPUFF model.

The CALMET pre-processor is available from the web site of the model developer (i.e., Exponent Inc. - http://www.src.com/calpuff/calpuff1.htm). As of August 2017, the most recent Exponent version of CALMET was Version 6.5.0 level 150223, released June 22, 2015. The corresponding current U.S. EPA version of CALMET is Version 5.8.5, level 151214. Consistent with the AEP Air Quality Model Guideline, Version 6.5.0 was adopted.

3B.2 MODEL DOMAIN

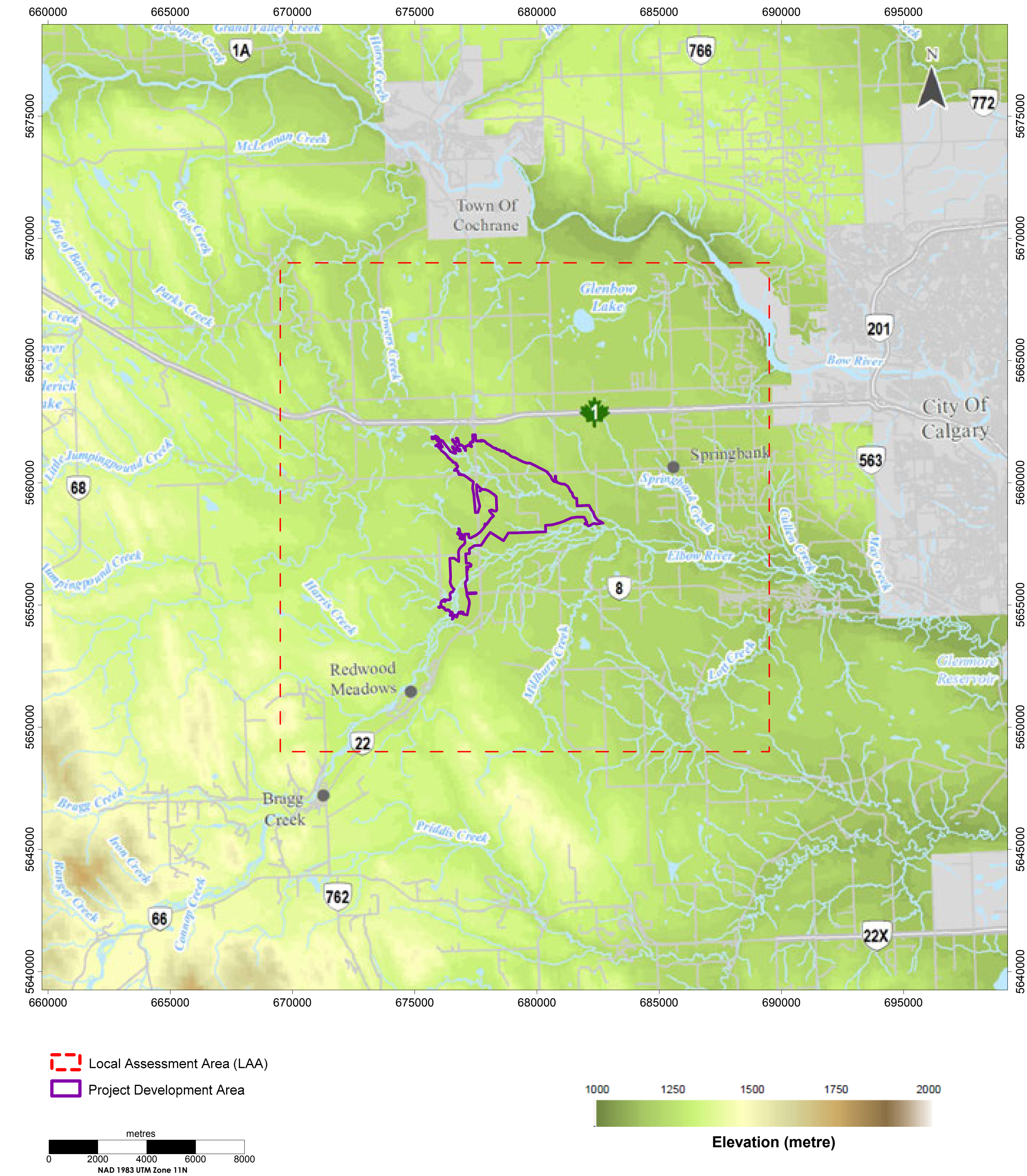
3B.2.1 Boundaries

The model domain adopted for this assessment extends from 50.8806 degrees latitude to 51.2275 degrees latitude (resulting in a north south extent of 40 km), and from 114.7326 degrees longitude to 114.1426 degrees longitude (resulting in an east west extent of 40 km), as shown in Figure 3B-1. The study domain covers a 1,600 km^2 area, the extent of which is provided in Table 3B-1. A horizontal grid spacing of 500 m is used for the CALMET simulation. The modelled area, therefore, corresponds to 80 rows by 80 columns. With this grid spacing, it was possible to maximize run time and file size efficiencies while still capturing terrain feature influences on wind flow patterns. The model domain is larger than the air quality local assessment area (LAA), which is a 20 km north-south extent and 20 km east-west extent (shown in Figure 3B-1).

To simulate transport and dispersion processes, it is important to simulate the representative vertical profiles of wind direction, wind speed, temperature, and turbulence intensity within the atmospheric boundary layer (i.e., the layer within about 2,000 m above the Earth's surface). To capture this vertical structure, twelve vertical layers are selected. CALMET defines a vertical layer as the midpoint between two faces (i.e., thirteen faces correspond to twelve layers, with the lowest layer always being ground level or 10 m). The vertical faces used in this study are 0 m, 20 m, 40 m, 80 m, 120 m, 280 m, 520 m, 880 m, 1,320 m, 1,820 m, 2,380 m, 3,000 m, and 4,000 m.

Table 3B-1 Model Domain (40 km by 40 km) Coordinates (UTM Zone 11; NAD 83)

Domain Corner	Easting (m)	Northing (m)
Southwest	659500	5639000
Northwest	659500	5679000
Southeast	699500	5639000
Northeast	699500	5679000



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Terrain in CALMET Model Domain

3B.2.2 Topography

The valley and elevated terrain features in the model domain affect surface wind flow patterns. The terrain data used to define these features were obtained from Canadian Digital Elevation Data (CDED 2016). The source data for CDED at scales of 1:50,000 and 1:250,000 were extracted from the hypsographic and hydrographical elements of the National Topographic Data Base (NTDB) and from various scaled positional data acquired from the provinces and territories. These data have a horizontal resolution of about 30 m, which is more than sufficient for air quality assessment purposes.

A general overview of the terrain in the model domain is presented in Figure 3B-1. Broadly speaking, the higher elevations are towards the northwest and southeast of the domain, and the lowest elevations are near the southeastern portion of the domain.

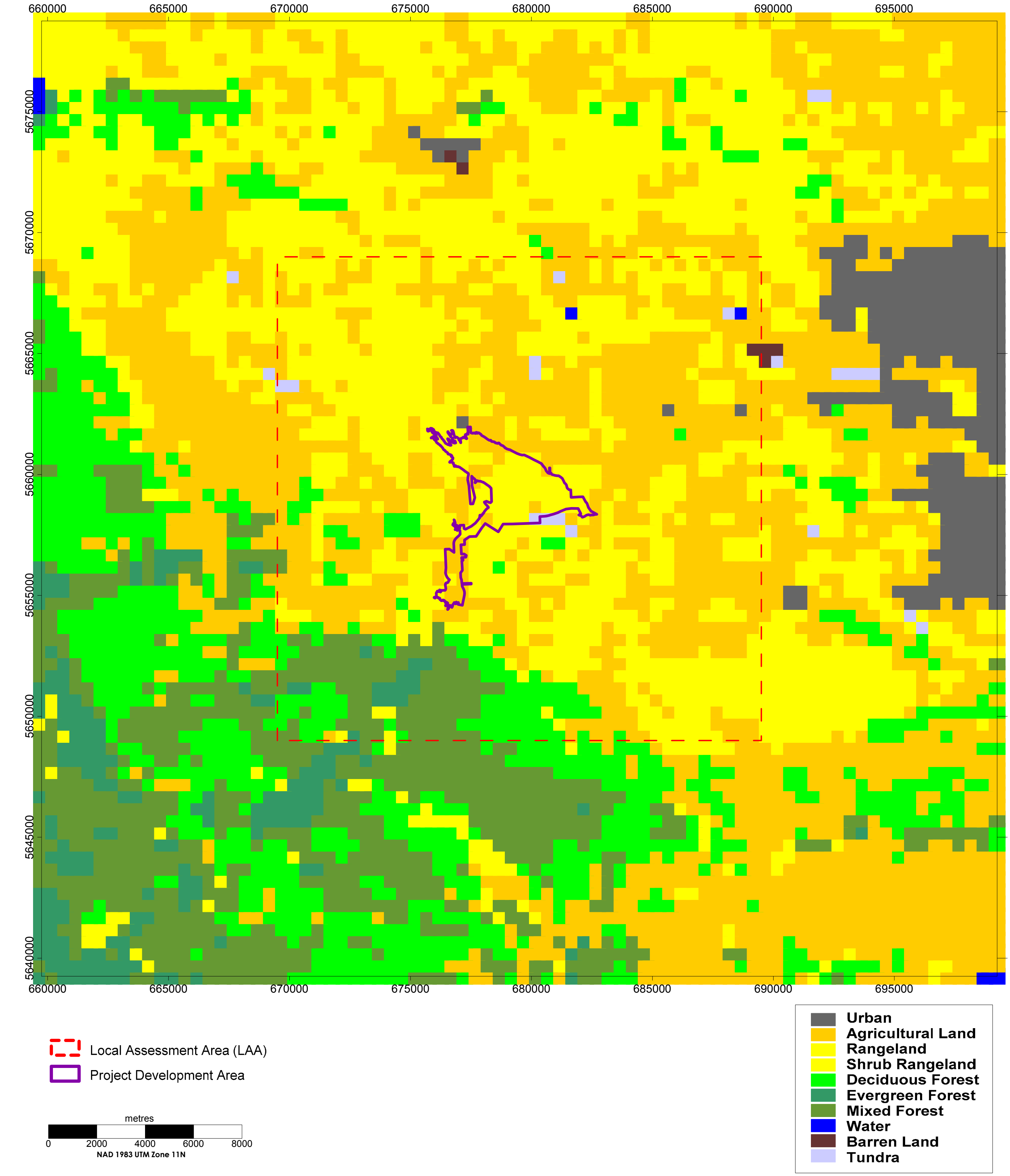
3B.2.3 Land-Cover Types

The North American land-cover data (Commission for Environmental Cooperation 2016) is used to initialize land-cover categories in the CALMET model. The 2005 North American land-cover dataset was produced as part of the North American Land Change Monitoring System (NALCMS), a trilateral effort between the Canada Centre for Remote Sensing, the United States Geological Survey, and three Mexican organizations (National Institute of Statistics and Geography, National Commission for the Knowledge and Use of the Biodiversity, and the National Forestry Commission of Mexico). This dataset has a 250 m resolution.

The 2005 North American land-cover data were extracted and then converted into the fractional land-use format accepted by the CALMET MAKEGEO pre-processor. MAKEGEO creates the geophysical data file (GEO.DAT) for CALMET. The 250 m resolution data are grouped on a 1 km grid basis and the land-cover type assigned to the larger grid cell is based on the dominant land-cover type for that grid cell.

The mapping from the North American land-cover dataset to the CALMET land-use categories is listed in Table 3B-2. Tables 3B-3 to 3B-6 describe the seasonal values for surface roughness (z_0), albedo, Bowen ratio, soil heat flux, anthropogenic heat flux, and leaf area index (LAI) defined according to the Guidelines for AEP Air Quality Model Guideline (AEP 2013) and the CALMET User Guide (Scire et al. 2000).

Land-cover in the CALMET domain is mainly cropland (see Figure 3B-2 for the land cover on a 500 m resolution basis). Based on the 500 m resolution data, the domain comprises 35.5 percent cropland, 30.9 percent rangeland, 14.3 percent deciduous forest, 11.8 percent mixed forest, 4.1 percent urban land, 2.8 percent evergreen forest, 0.3 percent tundra, 0.1 percent barren land, and 0.1 percent water.



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Land-use Classes within the Model Domain

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3B-2

Table 3B-2 Mapping from the North American Land-cover Data to CALMET Land-Use Categories

Land Cover Code	Land Cover Type	CALMET Code	CALMET Land Use Category
1	Temperate or sub-polar needleleaf forest	42	Evergreen Forest Land
2	Sub-polar taiga needleleaf forest	42	Evergreen Forest Land
3	Tropical or sub-tropical broadleaf evergreen forest	42	Evergreen Forest Land
4	Tropical or sub-tropical broadleaf deciduous forest	41	Deciduous Forest Land
5	Temperate or sub-polar broadleaf deciduous forest	41	Deciduous Forest Land
6	Mixed forest	43	Mixed Forest Land
7	Tropical or sub-tropical shrubland	32	Shrub Rangeland
8	Temperate or sub-polar shrubland	32	Shrub Rangeland
9	Tropical or sub-tropical grassland	30	Rangeland
10	Temperate or sub-polar grassland	30	Rangeland
11	Sub-polar or polar shrubland-lichen-moss	80	Tundra
12	Sub-polar or polar grassland-lichen-moss	80	Tundra
13	Sub-polar or polar barren-lichen-moss	80	Tundra
14	Wetland	60	Wet Land
15	Cropland	20	Agricultural Land
16	Barren lands	70	Barren Land
17	Urban	10	Urban or Build-up
18	Water	50	Water
19	Snow and Ice	90	Snow or Ice

Table 3B-3 Land-cover Characterization and Associated Geophysical Parameters for the Winter Season

NALCMS Code	Surface Roughness (m)	Albedo	Bowen Ratio	Soil Heat Flux (fraction)	Anthropogenic Heat Flux (W/m²)	Leaf Area Index	CALMET Code	CALMET Land Cover Type
1	0.900	0.130	2.000	0.100	0.000	4.500	42	Evergreen Forest
2	0.900	0.130	2.000	0.100	0.000	4.500	42	
3	0.900	0.130	2.000	0.100	0.000	4.500	42	
4	0.550	0.210	2.000	0.100	0.000	0.100	41	Deciduous Forest
5	0.550	0.210	2.000	0.100	0.000	0.100	41	
6	1.200	0.170	2.000	0.100	0.000	2.300	43	Mixed Forest
7	0.050	0.250	1.000	0.150	0.000	0.500	32	Shrub Rangeland
8	0.050	0.250	1.000	0.150	0.000	0.500	32	
9	0.150	0.750	2.000	0.100	0.000	0.800	30	Rangeland
10	0.150	0.750	2.000	0.100	0.000	0.800	30	
11	0.200	0.300	0.500	0.150	0.000	0.000	80	Tundra
12	0.200	0.300	0.500	0.150	0.000	0.000	80	
13	0.200	0.300	0.500	0.150	0.000	0.000	80	
15	0.150	0.750	2.000	0.100	0.000	0.800	20	Agricultural Land
16	0.150	0.450	6.000	0.150	0.000	0.050	70	Barren Land
17	1.000	0.180	1.500	0.250	16.000	0.200	10	Urban or Build-up
18	0.001	0.750	0.000	1.000	0.000	0.000	50	Water

NOTES:
Winter = December, January, and February
W/m² = watts per square metre

Table 3B-4 Land-cover Characterization and Associated Geophysical Parameters for the Spring Season

NALCMS Code	Surface Roughness (m)	Albedo	Bowen Ratio	Soil Heat Flux (fraction)	Anthropogenic Heat Flux (W/m^2)	Leaf Area Index	CALMET Code	CALMET Land Cover Type
1	0.900	0.110	1.500	0.100	0.000	5.200	42	Evergreen Forest
2	0.900	0.110	1.500	0.100	0.000	5.200	42	
3	0.900	0.110	1.500	0.100	0.000	5.200	42	
4	0.750	0.150	1.500	0.100	0.000	1.000	41	Deciduous Forest
5	0.750	0.150	1.500	0.100	0.000	1.000	41	
6	1.200	0.130	1.500	0.100	0.000	3.300	43	Mixed Forest
7	0.050	0.250	1.000	0.150	0.000	0.500	32	Shrub Rangeland
8	0.050	0.250	1.000	0.150	0.000	0.500	32	
9	0.220	0.200	0.400	0.100	0.000	2.200	30	Rangeland
10	0.220	0.200	0.400	0.100	0.000	2.200	30	
11	0.200	0.300	0.500	0.150	0.000	0.000	80	Tundra
12	0.200	0.300	0.500	0.150	0.000	0.000	80	
13	0.200	0.300	0.500	0.150	0.000	0.000	80	
15	0.220	0.200	0.400	0.100	0.000	2.200	20	Agricultural Land
16	0.300	0.300	3.000	0.150	0.000	0.050	70	Barren Land
17	1.000	0.180	1.500	0.250	14.000	0.200	10	Urban or Build-up
18	0.001	0.100	0.000	1.000	0.000	0.000	50	Water

NOTES:
Spring = March, April, and May
W/m^2 = watts per square metre

Table 3B-5 Land-cover Characterization and Associated Geophysical Parameters for the Summer Season

NALCMS Code	Surface Roughness (m)	Albedo	Bowen Ratio	Soil Heat Flux (fraction)	Anthropogenic Heat Flux (W/m^2)	Leaf Area Index	CALMET Code	CALMET Land Cover Type
1	0.800	0.080	1.400	0.100	0.000	5.200	42	Evergreen Forest
2	0.800	0.080	1.400	0.100	0.000	5.200	42	
3	0.800	0.080	1.400	0.100	0.000	5.200	42	
4	1.050	0.150	0.600	0.100	0.000	3.400	41	Deciduous Forest
5	1.050	0.150	0.600	0.100	0.000	3.400	41	
6	1.150	0.120	0.900	0.100	0.000	4.500	43	Mixed Forest
7	0.050	0.250	1.000	0.150	0.000	0.500	32	Shrub Rangeland
8	0.050	0.250	1.000	0.150	0.000	0.500	32	
9	0.500	0.200	0.400	0.100	0.000	2.800	30	Rangeland
10	0.500	0.200	0.400	0.100	0.000	2.800	30	
11	0.200	0.300	0.500	0.150	0.000	0.000	80	Tundra
12	0.200	0.300	0.500	0.150	0.000	0.000	80	
13	0.200	0.300	0.500	0.150	0.000	0.000	80	
15	0.500	0.200	0.400	0.100	0.000	2.800	20	Agricultural Land
16	0.300	0.280	4.000	0.150	0.000	0.050	70	Barren Land
17	1.000	0.180	1.500	0.250	8.000	0.200	10	Urban or Build-up
18	0.001	0.100	0.000	1.000	0.000	0.000	50	Water

NOTES:
Summer = June, July, and August
W/m^2 = watts per square metre

Table 3B-6 Land-cover Characterization and Associated Geophysical Parameters for the Fall Season

NALCMS Code	Surface Roughness (m)	Albedo	Bowen Ratio	Soil Heat Flux (fraction)	Anthropogenic Heat Flux (W/m²)	Leaf Area Index	CALMET Code	CALMET Land Cover Type
1	0.900	0.080	1.400	0.100	0.000	4.700	42	Evergreen Forest
2	0.900	0.080	1.400	0.100	0.000	4.700	42	
3	0.900	0.080	1.400	0.100	0.000	4.700	42	
4	0.950	0.150	0.600	0.100	0.000	0.100	41	Deciduous Forest
5	0.950	0.150	0.600	0.100	0.000	0.100	41	
6	1.150	0.120	0.900	0.100	0.000	2.300	43	Mixed Forest
7	0.050	0.250	1.000	0.150	0.000	0.500	32	Shrub Rangeland
8	0.050	0.250	1.000	0.150	0.000	0.500	32	
9	0.320	0.200	0.400	0.100	0.000	0.300	30	Rangeland
10	0.320	0.200	0.400	0.100	0.000	0.300	30	
11	0.200	0.300	0.500	0.150	0.000	0.000	80	Tundra
12	0.200	0.300	0.500	0.150	0.000	0.000	80	
13	0.200	0.300	0.500	0.150	0.000	0.000	80	
15	0.320	0.200	0.400	0.100	0.000	0.300	20	Agricultural Land
16	0.300	0.280	6.000	0.150	0.000	0.050	70	Barren Land
17	1.000	0.180	1.500	0.250	12.000	0.200	10	Urban or Build-up
18	0.001	0.100	0.000	1.000	0.000	0.000	50	Water

NOTES:
Fall = September, October, and November
W/m² = watts per square metre

3B.3 METEOROLOGICAL MEASUREMENTS

Meteorological data include a wide range of parameters: ambient air temperature, precipitation, relative humidity, visibility, solar radiation, wind, severe weather, and thermal inversions. Selected parameters at the nearby Environment and Climate Change Canada (ECCC) Springbank Airport climate station are reviewed in the following subsections.

3B.3.1 Ambient Air Temperature

Table 3B-7 summarizes the historical monthly and annual mean air temperatures at the Springbank Airport for the period of 1981 to 2010. Annual average ambient temperature is 3.1°C at this station.

Table 3B-7 Historical Monthly and Annual Mean Daily Temperatures at Springbank Airport (1981 to 2010)

Month	Mean Daily Temperature (°C)
January	-8.2
February	-6.7
March	-2.7
April	3.4
May	8.1
June	12.1
July	14.8
August	13.7
September	9.5
October	3.9
November	-3.8
December	-7
ANNUAL	3.1
SOURCE: National Climate Data and Information Archive http://climate.weather.gc.ca/climate_normals/index_e.html	

3B.3.2 Precipitation

Table 3B-8 summarizes monthly mean total precipitation, rainfall, and snowfall at the Springbank Airport. The average total precipitation at the Springbank Airport was 469.6 mm/y. The driest months are during the winter, while the wettest month is June.

Table 3B-8 Mean Monthly and Annual Total Precipitation, Rainfall, and Snowfall at Fort Springbank Airport (1981 to 2010)

Month	Total Precipitation (mm)	Total Rainfall (mm)	Snowfall (cm)
January	9.9	0.2	12.7
February	11.5	0	14.7
March	17.6	0.4	21.7
April	25.4	9.3	19.0
May	61.1	49.5	12.4
June	106.7	106.7	0
July	66.9	66.9	0.1
August	78.0	78.0	0
September	50.3	45.5	5.3
October	16.3	7.0	11.6
November	16.3	2.4	17.4
December	9.8	0.3	12.4
Annual	469.6	366.0	127.0

3B.3.3 Atmospheric Pressure

The normal atmospheric pressure at sea level is 101.325 kPa. Atmospheric pressure decreases with increasing elevation. The normal atmospheric pressure at the project site, which is at an average elevation of 1,205 m asl, is 87.7 kPa. Atmospheric pressure also changes with the passing of synoptic scale weather systems that are associated with high and low pressure regions. The nearest meteorological station with valid atmospheric pressure measurements is Calgary International Airport. The monthly mean atmospheric pressures at Calgary International Airport range from 88.7 kPa to 89.2 kPa (ECCC 2016).

3B.4 CALMET INPUT DATA

The CALMET model was applied using gridded 3-D meteorological data generated by the MM5 model (a mesoscale meteorological model produced by Penn State/NCAR). The MM5 data were obtained from AEP and were used as an initial guess field to generate vertical wind and temperature profiles across the model domain on a 12 km grid resolution for the five-year period 2002 to 2006 (i.e., for 43,824 hours). Figure 3B-3 shows the MM5 grid point locations based on the 12 km grid resolution in the CALMET model domain.

There are no surface stations with concurrent hourly data for the 2002-2006 period within the model domain. Also, there are no upper air station in the model domain. For this reason, the CALMET model was applied in the no-observation mode.

3B.5 CALMET PREDICTIONS

To evaluate the MM5-CALMET model approach for this assessment, the CALMET surface and elevated wind, surface temperature, mixing height, and PG stability class data were extracted for the Project Site.

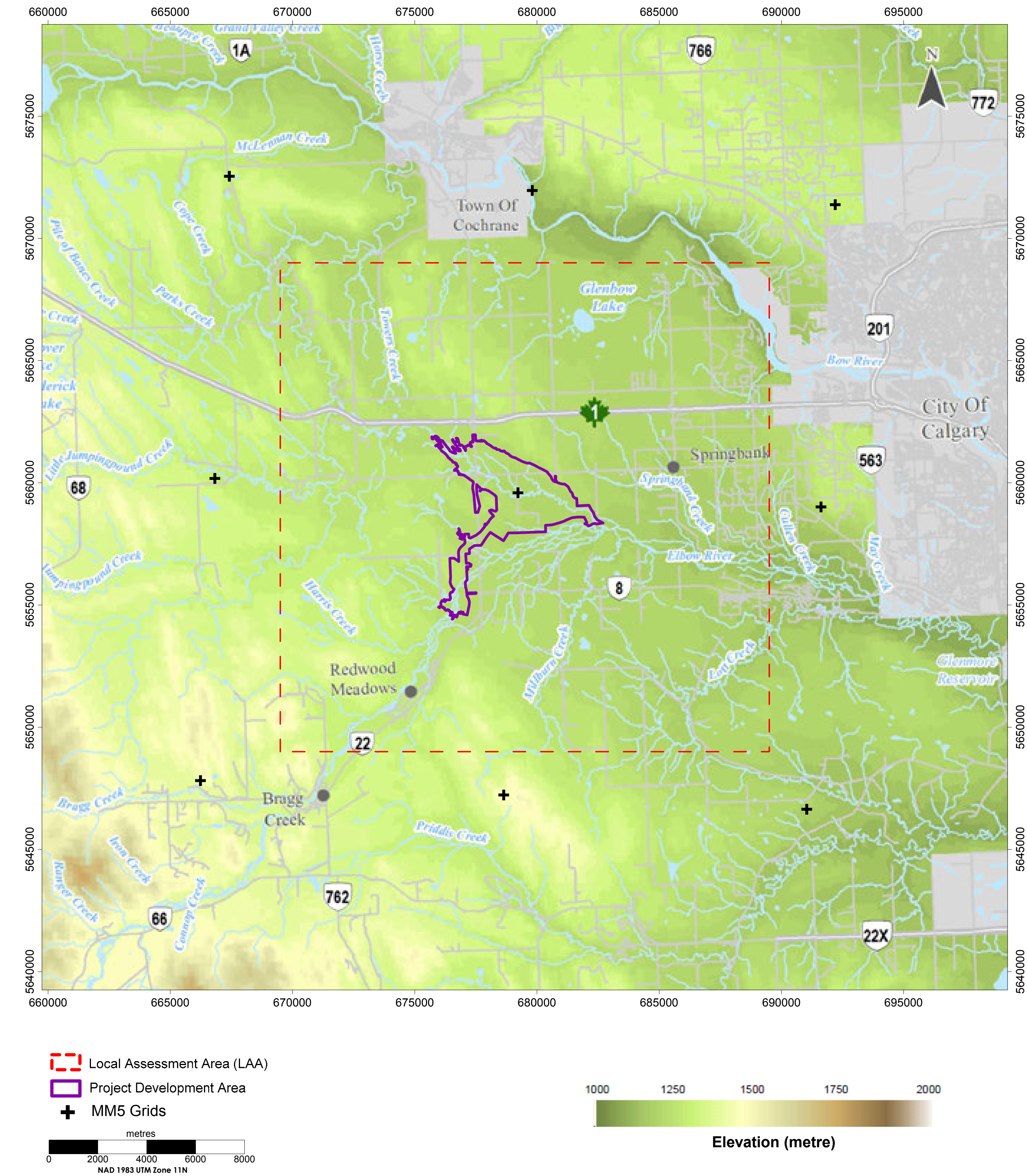
3B.5.1 Predicted Winds

3B.5.1.1 Predicted Surface Winds (2002-2006)

Figure 3B-4 shows individual year joint wind direction and wind speed frequency distributions (i.e., wind roses) predicted by CALMET for the project site 10 m above the ground for the 5-year period. While, the results indicate some variation from year to year, the winds are predicted to be mainly from the west and northwest sectors and least frequent winds are from the northeast sector.

3B.5.1.2 Predicted Elevated Winds (2002-2006)

Figure 3B-5 shows wind roses predicted by CALMET for the project site at 30 m, 60 m, 100 m and 200 m above ground. The results indicate a tendency for increasing wind speed, with increasing height above the ground.



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Locations of the 12 km Resolution MM5 Grid Points

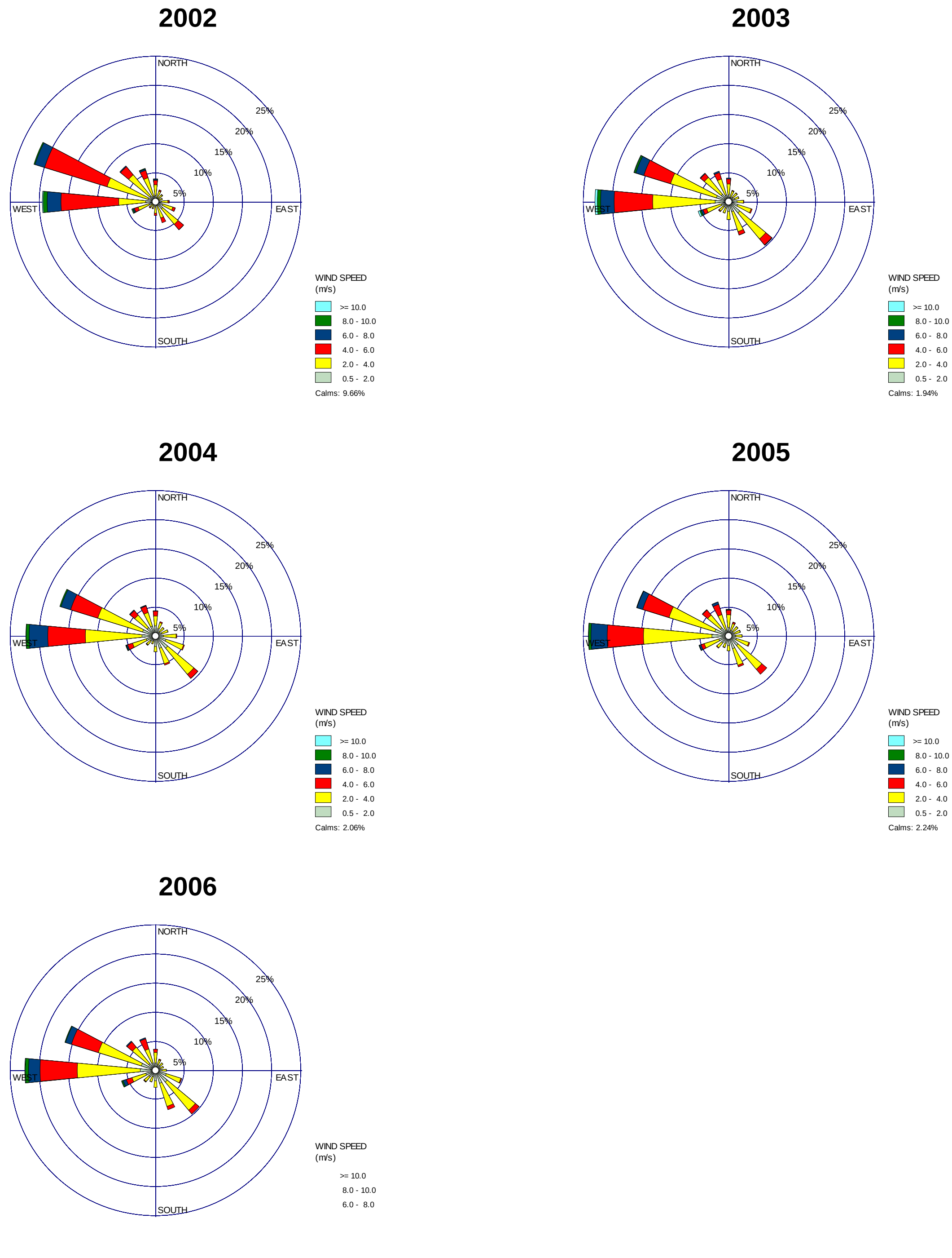


Figure 3B-4 Predicted 10 m Level Wind Roses for the Project Site (2002 to 2006)

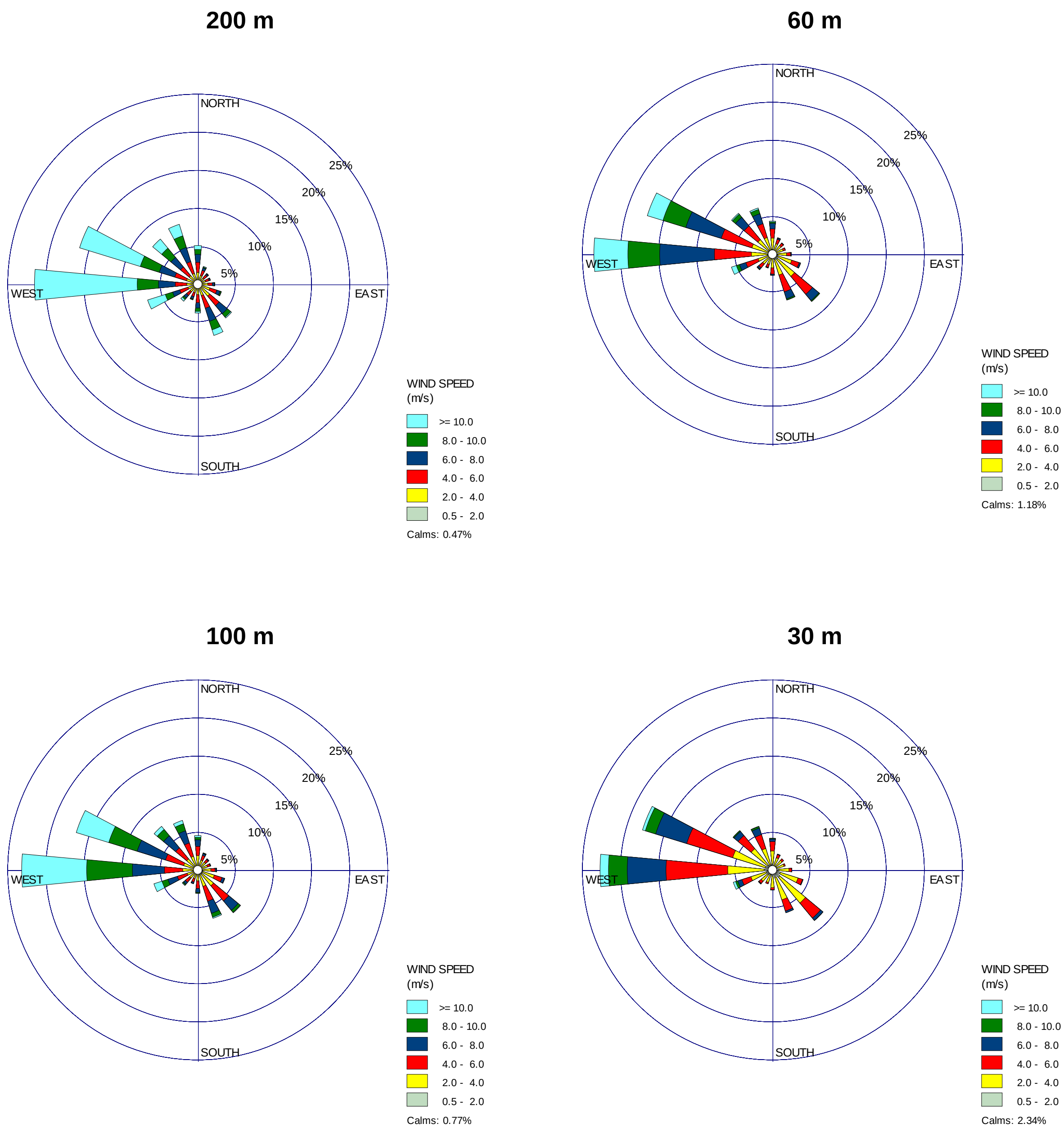


Figure 3B-5 Predicted Elevated Level Wind Roses for the Project Site (2002 to 2006)

3B.5.2 Predicted Surface Temperatures

Figure 3B-6 shows the monthly average surface temperatures predicted by CALMET for the project site. The predicted monthly temperatures indicate reasonable seasonal surface temperature variations (i.e., compare with Table 3B-7).

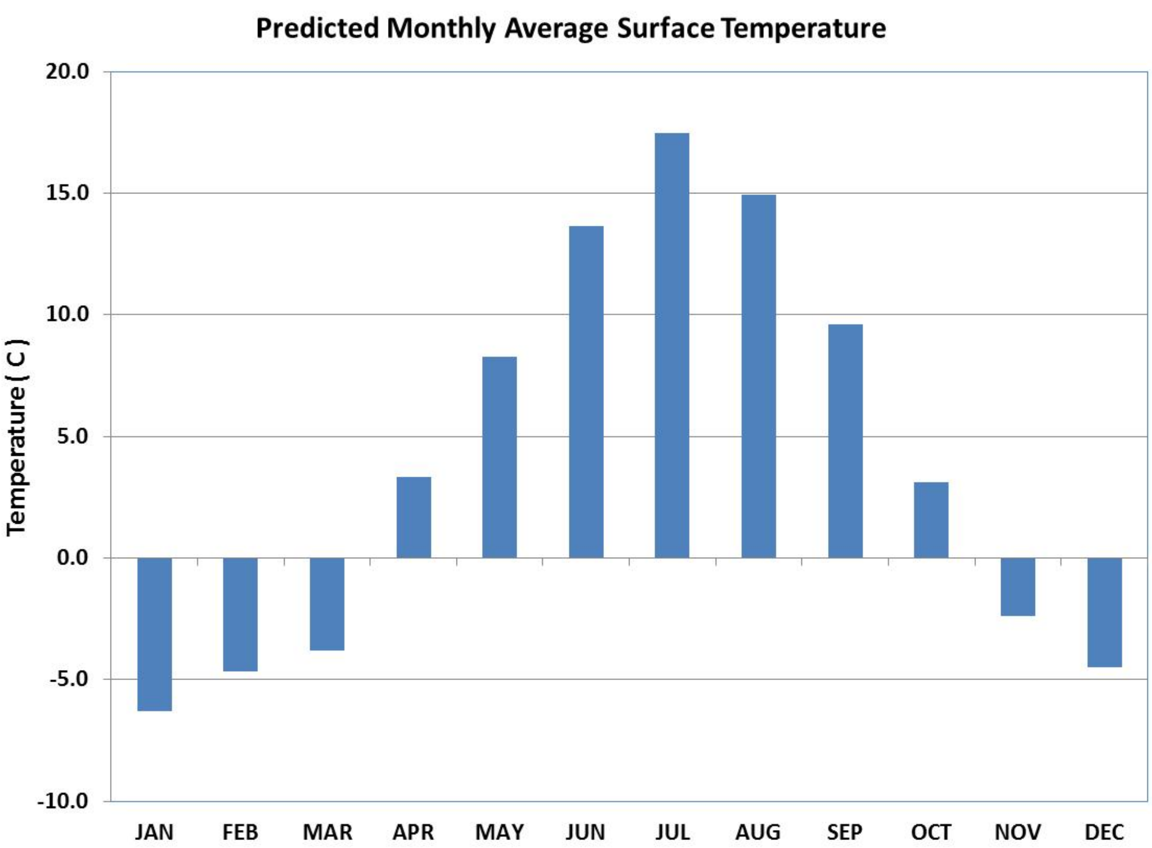


Figure 3B-6 Predicted Monthly Average Surface Temperatures for the Project Site (2002 to 2006)

3B.5.3 Predicted Precipitation

There are two options with respect to precipitation data: the first uses measured (observed) precipitation data and the second uses predicted data from MM5. The MM5 approach is used since it allows the precipitation field to vary across the domain; this approach generally predicts enhanced precipitation over elevated terrain.

Table 3B-9 compares the annual total precipitation observed at the Springbank Airport for the 2002 to 2006 period with the associated predictions based on the MM5-CALMET models. The Springbank Airport data were obtained from ECCC (Environment and Climate Change Canada 2016). In general, the values predicted by the MM5-CALMET models at this location are greater than the observed values by 38% for the 5-year average. The best comparison is for 2002 and 2005 based on the closer agreement (i.e. less than ± 10% range) between observations and predictions. The worst comparison was in 2003, which the model over-predicted by 77%.

The MM5-CALMET predicted precipitation is used by the CALPUFF model to calculate wet deposition.

Table 3B-9 Comparison of Observed and MM5-CALMET Predicted Annual Total Precipitation at the Springbank Airport (2002 to 2006)

Year	Observed Total Precipitation (mm)	Predicted Total Precipitation) (mm)	Over/Under Prediction (mm)	Over/Under Prediction (%)
2002	396	355	-41	-10
2003	353	624	271	77
2004	456	688	233	51
2005	664	719	56	8
2006	390	634	244	63
Average	**452**	**604**	**152**	**38**

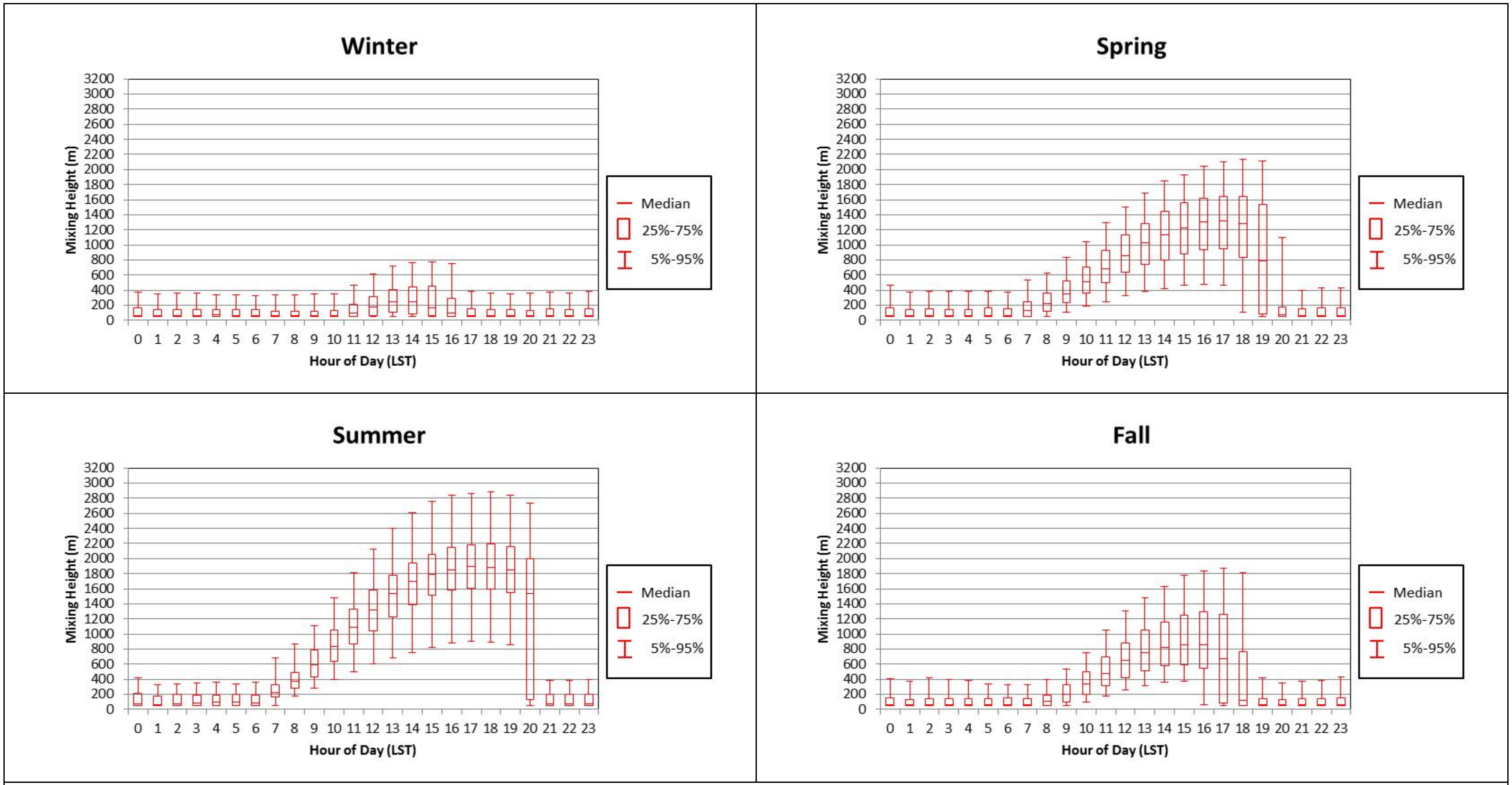
3B.5.4 Predicted Mixing Heights

The presence of an elevated inversion can trap effluents discharged into the atmosphere in the layer between the surface and the base of the inversion layer; this can increase ground-level ambient concentrations relative to the absence of an inversion layer. Mixing heights are usually the highest (i.e., in the 1,000 m to 2,000 m range) during daytime periods that are characterized by strong solar heating, and the lowest (i.e., about 100 m) during the night. High wind speeds can also produce well-mixed layers.

For this assessment, the CALMET post-processor was used to extract the mixing heights from CALMET output files, and the mixing height predictions for the project site are provided in Figure 3B-7. The results show:

- winter—the maximum median value is about 300 m
- spring—the maximum median afternoon value is about 1,300 m
- summer—the maximum median afternoon value about 1,890 m
- fall—the maximum median afternoon values are about 960 m

The minimum values for each season are predicted to occur during the night. During the night, the mixing height tends to be determined by mechanical mixing processes, with higher wind speeds resulting in a deeper mixed layer. The convective mixing process dominates during the day, leading to maximum mixed layer depths during the afternoon. The CALMET model, as applied, sets the minimum mixing height to 50 m.



NOTE: **Winter**: December, January, and February. **Spring**: March, April, and May.
Summer: June, July, and August. **Fall**: September, October, and November.

Figure 3B-7 Predicted Mixing Heights for Different Seasons and Times of Day for the Project Site (2002 to 2006)

3B.5.5 Predicted Atmospheric Stability Class

Atmospheric dispersion is caused by atmospheric turbulence, which can be related to atmospheric stability. Meteorologists define six stability classes (referred to as the Pasquill Gifford [PG] classes):

- Stability classes A, B and C occurs during the day, when solar radiation heats the ground. The air next to the ground is heated and tends to rise, enhancing vertical motions. This is referred to as an unstable atmosphere.
- Stability classes E and F occur during the night, when the ground cools due to long-wave radiation losses. The air next to the ground cools, suppressing vertical motions. This is referred to as a stable atmosphere.
- Stability class D is associated with completely overcast conditions (day or night) when there is no net heating or cooling of the ground, transitional periods between stable and unstable conditions, or during high wind speed periods (winds greater than 6 m/s [or 22 km/h]). This is referred to as a neutral atmosphere.

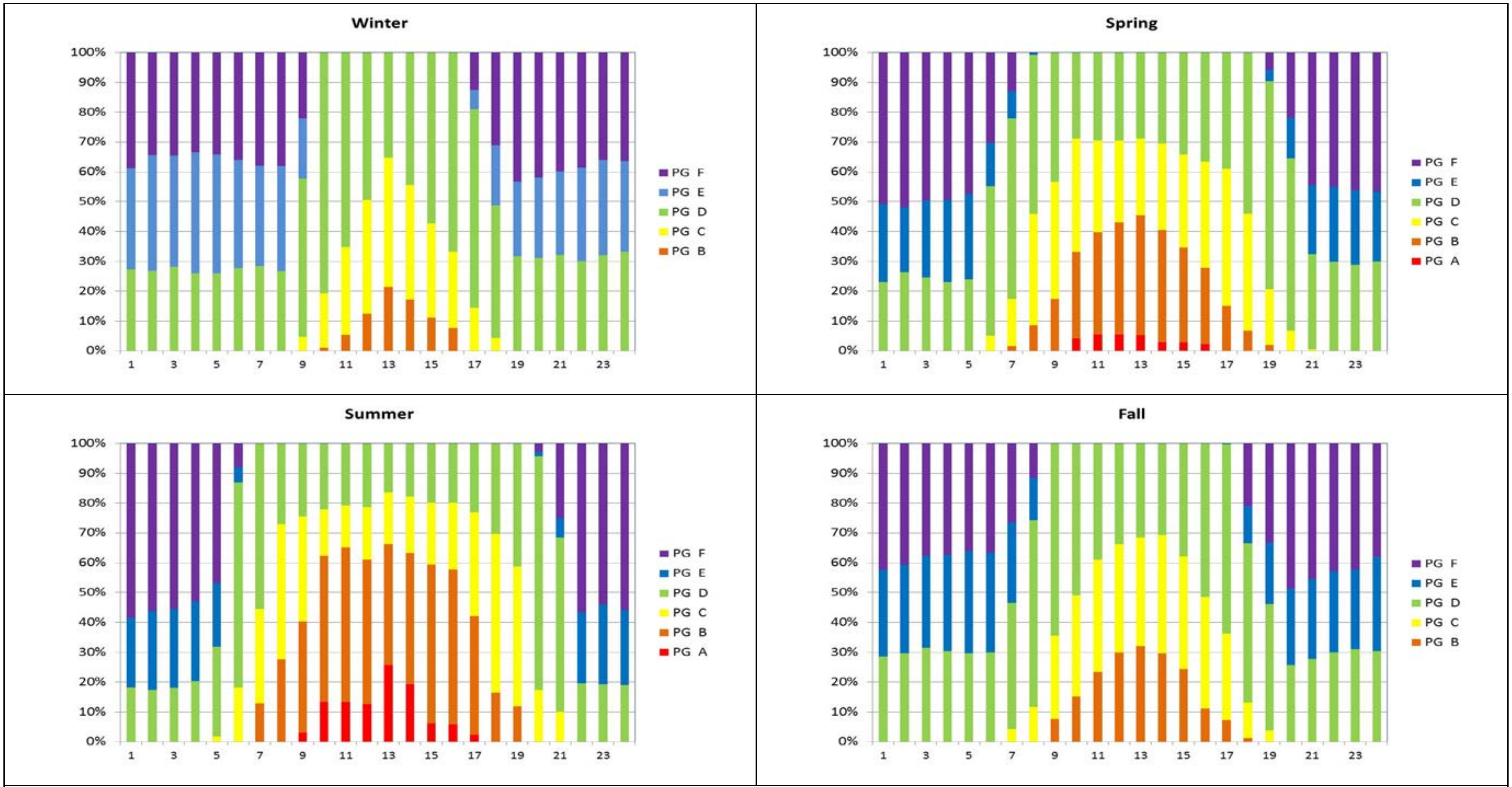
Stability classes undergo a significant daily variation, and they have a seasonal dependence. Stability classes can be determined from routine airport observations using the method devised by Turner (1963). A stability classification algorithm is also included in the CALMET model; this approach is based on the Turner approach using wind speed and cloud cover information for each grid point in the domain.

Table 3B-10 compares the stability class frequency distributions based on the CALMET model predictions for the project site. Figure 3B-8 shows the frequency distributions of predicted seasonal PG stability classes for the project site on a diurnal basis. Unstable conditions are more frequent during the summer and during daytime periods. Stable conditions are more frequent during nighttime periods.

Table 3B-10 Predicted Stability Class Frequency Distributions (%) at the Project Site (2002 to 2006)

PG Class	Project Site
A	1.5
B	10.7
C	15.0
D	36.3
E	14.5
F	21.9
Total	100.0

NOTE:
PG – Pasquill-Gifford.



NOTE: **Winter**: December, January, and February. **Spring**: March, April and May.
Summer: June, July, and August. **Fall**: September, October and November.

Figure 3B-8 Seasonal Frequency of Predicted PG Stability Class for the Project Site (2002 to 2006)

3B.6 CALMET MODEL OPTIONS

The input parameters for the CALMET control file used for the assessment are provided in Tables 3B-11 to 3B-17. The AEP Air Quality Model Guideline (AEP 2013) indicates that default assumptions and switches are to be used. Although not specified in the Model Guideline, it is assumed that the default values are defined in the CALMET user manual (Scire et al. 2000). The Model Guideline also indicates some specific values that are to be used instead of the default values; the AEP values are highlighted by orange shading in the tables. All AEP recommended default switch selections are applied. The default values and the values adopted for this assessment are identified in the tables

Table 3B-11 Input Groups in the CALMET Control File

Input Group	Description	Applicable to Project
0	Input and output file names	Yes
1	General run control parameters	Yes
2	Grid control parameters	Yes
3	Output Options	Yes
4	Meteorological data options	Yes
5	Wind Field Options and Parameters	Yes
6	Mixing Height, Temperature and Precipitation Parameters	Yes
7	Surface meteorological station parameters	No
8	Upper air meteorological station parameters	No
9	Precipitation parameters	No

Table 3B-12 CALMET Model Options Groups 0 and 1

Parameter	Default	Project	Comment
Input Group 0: Input and Output File Names			
NUSTA	-	0	Number of upper air stations
NOWSTA	-	0	Number of overwater meteorological stations
MM3D	-	60	Number of MM5.DAT files (one for each month)
NIGF	-	0	Number of IGF-CALMET.DAT files
Input Group 1: General Run Control Parameters			
IBYR	-	2002	Starting year
IBMO	-	1	Starting month
IBDY	-	1	Starting day
IBHR	-	0	Starting hour
IBSEC	-	0	Starting second
IEYR	-	2007	Ending year
IEMO	-	1	Ending month
IEDY	-	1	Ending day
IEHR	-	0	Ending hour
IESEC	-	0	Ending second
ABTZ	-	UTC-0700	UTC time zone
NSECDT	3,600	3,600	Length of modeling time-step (seconds)
IRTYPE	1	1	Run type = 1 computes wind fields and micro-meteorological fields. Run type = 1 required for CALPUFF.
LCALGRD	T	T	LCALGRD = 1 stores the special data fields required by CALPUFF.
ITEST	2	2	Flag to stop run after SETUP phase
MREG	-	0	Test options specified to see if they conform to regulatory values 0 = NO checks are made

Table 3B-13 CALMET Model Options Group 2: Grid control parameters

Parameter	Default	Project	Comment
PMAP	UTM	UTM	Map projection
IUTMZN	-	11	UTM Zone
UTMHEM	N	N	Hemisphere for UTM projection
DATUM	WGS-84	NAR-C	The NORTH AMERICAN 1983 GRS 80 Spheroid datum is used for output coordinates to be consistent with the applied CDED terrain data
NX	-	80	Number of X grid cells
NY	-	80	Number of Y grid cells
DGRIDKM	-	0.5	Horizontal grid spacing (km)
XORIGKM	-	659.5	Reference coordinate of SW corner of grid cell (1,1) -X coordinate (km)
YORIGKM	-	5639.0	Reference coordinate of SW corner of grid cell (1,1) -Y coordinate (km)
NZ	-	12	Vertical grid definition: Number of vertical layers as per the AEP Model Guideline.
ZFACE	-	0, 20, 40, 80, 120, 280, 520, 880, 1320, 1820, 3000 and 4000	Vertical grid definition: Cell face heights (m) as per the AEP Model Guideline.

Table 3B-14 CALMET Model Options Group 3: Output Options

Parameter	Default	Project	Comment
Disk Output:			
LSAVE	T	T	Save meteorological fields in the unformatted output files
IFORMO	1	1	Unformatted output file suitable for input into CALPUFF is generated
Line Printer Output:			
LPRINT	F	F	LPRINT = F, do not print meteorological fields
IPRINF	1	1	Print intervals (h); used only if LPRINT = T.
IUVOUT (NZ)	NZ*0	12*0	Specify which layers of U, V wind component to print
IWOUT (NZ)	NZ*0	12*0	Specify which level of the w wind component to print
ITOUT (NZ)	NZ*0	12*0	Specify which levels of the 3-D temperature field to print
Meteorological fields to print:			
Variable		**0 = don't print 1 = print**	**Comment**
STABILITY		1	PGT stability; used only if LPRINT = T.
USTAR		0	Friction velocity; used only if LPRINT = T.
MONIN		0	Monin-Obukhov length; used only if LPRINT = T.
MIXHT		1	Mixing height; used only if LPRINT = T.
WSTAR		0	Convective velocity scale; used only if LPRINT = T.
PRECIP		1	Precipitation rate; used only if LPRINT = T.
SENSHEAT		0	Sensible heat flux; used only if LPRINT = T.
CONVZI		0	Convective mixing height; used only if LPRINT = T.
Testing and debug print options for micrometeorological module:			
LDB	F	F	Print input meteorological data and internal variables
NN1	1	1	First time step for which debug data are printed
NN2	1	1	Last time step for which debug data are printed
LDBCST	F	F	Print distance to land internal variables
Testing and debug print options for wind field module:			
Variable		**0 = don't write 1 = write**	**Comment**
IOUTD	0	0	Control variable for writing the test/debug wind fields to disk files
NZPRN2	1	1	Number of levels to print, starting at surface,

Table 3B-14 CALMET Model Options Group 3: Output Options

Parameter	Default	Project	Comment
IPR0	0	0	Print the interpolated wind components
IPR1	0	0	Print the terrain adjusted surface wind components
IPR2	0	0	Print the smoothed wind components and the initial divergence fields
IPR3	0	0	Print the final wind speed and direction
IPR4	0	0	Print the final divergence fields
IPR5	0	0	Print the winds after kinematic effects are added
IPR6	0	0	Print the winds after the Froude number adjustment is made
IPR7	0	0	Print the winds after slope flows are added
IPR8	0	0	Print the final wind field components

Table 3B-15 CALMET Model Options Group 4: Meteorological Data Options

Parameter	Default	Project	Comment
NOOBS	-	2	No observation mode is used when MM5 data is only used as per AEP Model Guideline
Number of Surface & Precipitation Meteorological Stations:			
NSSTA	-	0	Number of surface stations used
NPSTA	-	-1	Precipitation stations not used
Cloud Data Options:			
ICLDOUT	-	Not applicable	output a CLOUD.DAT file (yes or no) 1=yes
MCLOUD	4	4	Use AEP MM5 gridded cloud data as per AEP Model Guideline preference.
File Formats:			
IFORMS	2	2	Used free-formatted surface meteorological data file
IFORMP	2	Not applicable	Precipitation data file format
IFORMC	2	Not applicable	Cloud data file format

Table 3B-16 CALMET Model Option Group 5: Wind Field Options and Parameters

Parameter	Default	Project	Comment
Wind Field Model Options:			
IWFCOD	1	1	Model selection variables
IFRADJ	1	1	Compute Froude number adjustment
IKINE	0	0	Compute kinematic effects
IOBR	0	0	Use O'Brien procedure for adjustment of the vertical velocity
ISLOPE	1	1	Compute slope flow effects
IEXTRP	-4	-4	Extrapolate surface wind observations to upper layers (similarity theory used with layer 1 data at upper air stations ignored)
ICALM	0	0	Extrapolate surface winds even if calm
BIAS	NZ*0	12*0	Layer-dependent biases modifying the weights of surface and upper air stations Zero BIAS leaves weights unchanged
RMIN2	4	4	Minimum distance from nearest upper air station to surface station for which extrapolation of surface winds at surface station will be allowed
IPROG	14	14	Use gridded prognostic wind field model output fields as input to the diagnostic wind field model. Set to 14 as MM5 gridded model data was used as the main input to CALMET model for this assessment. As per the AEP Model Guideline.
ISTEPPGs	3600	3600	Time step (seconds) of the prognostic model input data
IGFMET	0	0	Use coarse CALMET fields as initial guess fields
Radius of Influence Parameters:			
LVARY	F	F	Use varying radius of influence
RMAX1	24	Not Applicable	Maximum radius of influence over land in the surface layer (km) set to twice the AEP MM5 grid resolution (12 km) as per the AEP MODEL Guideline suggestion.
RMAX2	24	Not Applicable	Maximum radius of influence over land aloft (km) set to twice the AEP MM5 grid resolution (12 km) as per the AEP MODEL Guideline suggestion.
RMAX3	24	Not Applicable	Maximum radius of influence over water set to twice the AEP MM5 grid resolution (12 km) as per the AEP MODEL Guideline suggestion.

Table 3B-16 CALMET Model Option Group 5: Wind Field Options and Parameters

Parameter	Default	Project	Comment
Other Wind Field Input Parameters:			
RMIN	0.1	0.1	Minimum radius of influence used in the wind field interpolation (km)
TERRAD	-	3	Radius of influence of terrain features (km) based on local topographic conditions near the Project Site
R1	6	Not Applicable	Relative weighting of the first guess field and observations in the surface layer (km) set to one-half the AEP MM5 grid resolution (12 km) as per the AEP MODEL Guideline suggestion.
R2	6	Not Applicable	Relative weighting of the first guess field and observations in the layers aloft (km) set to one-half the AEP MM5 grid resolution (12 km) as per the AEP MODEL Guideline suggestion.
RPROG	-	0	Relative weighting parameter of the prognostic wind field data (km)
DIVLIM	5.0E-6	5.0E-6	Maximum acceptable divergence in the divergence minimization procedure
NITER	50	50	Maximum number of iterations in the divergence minimization procedure
NSMTH (NZ)	2, (MXNZ-1)*4	2, 11*4	Number of passes in the smoothing procedure For NZ level 1, the CALMET default value 2 was used for the Project. For other levels, value 4 was used as CALMET input 4km MM5 data already provided high resolution spatial wind fields
NINTR2	99	12*99	Maximum number of stations used in each layer for the interpolation of data to a grid point
CRITFN	1.0	1.0	Critical Froude number
ALPHA	0.1	0.1	Empirical factor controlling the influence of kinematic effects
FEXTR2(NZ)	NZ*0.0	12*0	Multiplicative scaling factor for extrapolation of surface observations to upper layers
Barrier Information:			
NBAR	0	0	Number of barriers to interpolation of the wind fields (The barrier option is not used)
KBAR	NZ	12	Level (1 to NZ) up to which barriers apply For this project, NZ=12
XBBAR	-	0	X coordinate of beginning of each barrier

Table 3B-16 CALMET Model Option Group 5: Wind Field Options and Parameters

Parameter	Default	Project	Comment
YBBAR	-	0	Y coordinate of beginning of each barrier
XEBAR	-	0	X coordinate of ending of each barrier
YEBAR	-	0	Y coordinate of ending of each barrier
Diagnostic Module Data Input Options:			
IDIOPT1	0	0	Surface temperature (0 = compute internally from hourly surface observation)
ISURFT	-	-1	use 2-D spatially varying surface temperatures
IDIOPT2	0	0	Domain-averaged temperature lapse (0 = compute internally from hourly surface observation)
IUPT	-	Not Applicable	Not applicable since no upper air stations are used
ZUPT	200	200	Depth through which the domain-scale lapse rate is computed (m)
IDIOPT3	0	0	Domain-averaged wind components
IUPWND	-1	Not Applicable	Not applicable since no upper air stations are used
ZUPWND	1., 1000	Not Applicable	Bottom and top of layer through which domain-scale winds are computed (m). Not applicable since it is only used if IDIOPT3 = 0, NOOBS > 0 and IUPWND > 0
IDIOPT4	0	0	Observed surface wind components for wind field module
IDIOPT5	0	Not Applicable	Observed upper air wind components for wind field module
Lake Breeze Information:			
LLBREZE	F	F	Lake breeze module is not used
NBOX	-	0	Number of lake breeze regions
XG1	-	0	X Grid line 1 defining the region of interest
XG2	-	0	X Grid line 2 defining the region of interest
YG1	-	0	Y Grid line 1 defining the region of interest
YG2	-	0	Y Grid line 2 defining the region of interest
XBCST	-	0	X Point defining the coastline in kilometres (Straight line)
YBCST	-	0	Y Point defining the coastline in kilometres (Straight line)
XECST	-	0	X Point defining the coastline in kilometres (Straight line)
YECST	-	0	Y Point defining the coastline in kilometres (Straight line)
NLB	-	0	Number of stations in the region
METBXID	-	0	Station ID’s in the region

Table 3B-17 CALMET Model Option Group 6: Mixing Height, Temperature and Precipitation Parameters

Parameter	Default	Project	Comment
Empirical Mixing Height Constants:			
CONSTB	1.41	1.41	Neutral, mechanical equation
CONSTE	0.15	0.15	Convective mixing height equation
CONSTN	2400	2400	Stable mixing height equation
CONSTW	0.16	0.16	Over water mixing height equation
FCORIO	1.0E-4	1.0E-04	Absolute value of Coriolis parameter
Spatial Averaging of Mixing Heights:			
IAVEZI	1	1	Conduct spatial averaging
MNMDAV	1	1	Maximum search radius in averaging (grid cells)
HAFANG	30	30	Half-angle of upwind looking cone for averaging
ILEVZI	1	1	Layer of winds used in upwind averaging
Convective Mixing Heights Options:			
IMIXH	1	1	Method to compute the convective mixing height (Maul-Carson)
THRESHL	0.0	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 when 0<QH<THRESHL (overland) or 0<QH<THRESHW (overwater)
TZICRLX	800	800	Relaxation time of convective mixing height to equilibrium value Used only if IZICRLX = 1 and TZICRLX must be >= 1.
ITWPROG	0	0	Option for overwater lapse rates used in convective mixing height growth (1=use prognostic lapse rates)
ILUOC3D	16	16	Land use category ocean in 3D.DAT datasets
Other Mixing Height Variables:			
DPTMIN	0.001	0.001	Minimum potential temperature lapse rate in the stable layer above the current convective mixing height (K/m)
DZZI	200	200	Depth of layer above current convective mixing height through which lapse rate is computed (m)
ZIMIN	50	50	Minimum overland mixing height (m)

Table 3B-17 CALMET Model Option Group 6: Mixing Height, Temperature and Precipitation Parameters

Parameter	Default	Project	Comment
ZIMAX	3,000	4,000	Maximum overland mixing height (m) Increased to 4000 m to consistent with AEP recommended model layers which the highest ZFACE is 4000 m
ZIMINW	50	50	Minimum overwater mixing height (m)
ZIMAXW	3,000	4,000	Maximum overwater mixing height (m) Increased to 4000 m to consistent with AEP recommended model layers which the highest ZFACE is 4000 m
Overwater Surface Fluxes Method and Parameters:			
ICOARE	10	10	Overwater surface fluxes method Set to 10 means COARE with no wave parameterization
DSHELF	0	0	Coastal/Shallow water length scale (km)
IWARM	0	0	COARE warm layer computation
ICOOL	0	0	COARE cool skin layer computation
Relative Humidity Parameters:			
IRHPROG	1	1	Use the MM5 gridded relative humidity data as per the AEP Model Guideline.
Temperature Parameters:			
ITPROG	-	2	No surface or upper air observations Use the MM5 gridded surface temperature data as per the AEP Model Guideline.
IRAD	1	1	Interpolation type
TRADKM	24	24	Radius of influence for temperature interpolation (km) to be set at two times the MM5 12 km resolution as per the AEP Model Guideline
NUMTS	5	Not Applicable	Maximum number of stations to include in temperature interpolation
IAVET	1	1	Conduct spatial averaging of temperatures (1 = yes)
TGDEFB	-0.0098	-0.0098	Default temperature gradient below the mixing height over water (K/m)
TGDEFA	-0.0045	-0.0045	Default temperature gradient above the mixing height over water (K/m)
JWAT1	-	55	Beginning land use categories for temperature interpolation over water

Table 3B-17 CALMET Model Option Group 6: Mixing Height, Temperature and Precipitation Parameters

Parameter	Default	Project	Comment
JWAT2	-	55	Ending land use categories for temperature interpolation over water
Precipitation Interpolation Parameters:			
NFLAGP	2	Not Applicable	Method of interpolation
SIGMAP	100	Not Applicable	Radius of Influence (km) Not Applicable for this project as no precipitation station data were used
CUTP	0.01	Not Applicable	Minimum Precipitation rate cut-off (mm/h)

3B.7 REFERENCES

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Attachment 3C CALPUFF MODELLING FOR CONSTRUCTION

Stantec

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Abbreviations

$(NH_4)_2SO_4$	ammonium sulphate
µm	microns
AAAQG	Alberta Ambient Air Quality Guidelines
AAAQO	Alberta Ambient Air Quality Objectives
AEP	Alberta Environment and Parks
AQMG	Alberta Air Quality Model Guideline
ARM	ambient ratio method
ARM3	Acid Rain Mountain Mesocale Model
CAC	criteria air contaminant
CO	carbon monoxide
CTDM	complex terrain dispersion model
ESRD	Alberta Environment and Sustainable Resource Development
$g/m^2/s$	gram per square metre per second
g/m^3	gram per cubic metre
g/s	gram per second
H_2O_2	hydrogen peroxide
HNO_3	nitric acid
ISC	Industrial Source Complex
K	Degree Kelvin

K/m	degree Kelvin per meter
LAA	local assessment area
MP	McElroy-Pooler
MST	mountain standard time
NAD 83	North American Datum of 1983
NH_3	ammonia
NH_4NO_3	ammonium nitrate
NO	nitric oxide
NO_2	nitrogen dioxide
NO_3^-	nitrate
NO_3^-	inorganic nitrate
NO_X	oxides of nitrogen
O_3	ozone
OLM	ozone limiting method
PAH	polycyclic aromatic hydrocarbons
PDF	probability distribution function
PDF	probability density function
PG	Pasquill-Gifford
PM	particulate matter
PM_{10}	particulate matter 10 micrometers or less in diameter
$PM_{2.5}$	particles less than or equal to 10 micrometers in diameter
ppb	parts per billion

RAA	regional assessment area
RIVAD	regional impact in visibility and acid deposition
SO_2	sulphur dioxide
SO_4^{2-}	sulphate
SOA	secondary organic aerosol
SW	southwest
TCM	total conversion method
the Project	Springbank Off-stream Reservoir Project
TSP	total suspended particulate
U.S. EPA	United States Environmental Protection Agency
USEPA	United States Environmental Protection Agency
UTM	universal transverse Mercator
VOC	volatile organic compound
σ_v	standard deviation of lateral velocity
σ_w	standard deviation of vertical velocity

3C.1 INTRODUCTION

Ambient air quality models are used to predict air quality changes (i.e., changes to ambient concentrations or deposition) associated with current and future emission scenarios. This section discusses the selection and application of the primary dispersion model that used for the Springbank Off-stream Reservoir Project (the Project) air quality assessment.

3C.1.1 Model Types

Air quality simulation (or dispersion) models provide a scientific means of relating industrial and community emissions to air quality changes, by using mathematical equations to simulate transport, dispersion, transformation, and deposition processes in the atmosphere. Dispersion models can address a wide range of distance scales (hundreds of metres to hundreds of kilometres) and time scales (minutes to years). Typically, there are two modelling levels-of-effort:

- Screening models estimate maximum short-term (1-hour) average concentrations for a wide range of pre-selected meteorological conditions. These models are typically limited to single sources and downwind distances of less than 10 km (e.g., the U.S. Environmental Protection Agency [U.S. EPA] SCREEN3 and AERSCREEN models).
- Refined models use sequential hourly meteorological data for a one to five-year period (8,760 hours to 43,800 hours, respectively). These models can address multiple sources and predict hourly average concentrations for all source, meteorology, and receptor combinations. The hourly concentrations can be used to predict concentrations for averaging periods that are factors of 24 (i.e., 2, 3, 4, 6, 8, or 12 h), or for longer periods (i.e., seasonal or annual). Some refined models can also account for chemical transformation and deposition processes.

Regulatory agencies have relied on dispersion models as part of the approval process for industrial and infrastructure projects. Numerous models are available to predict ambient air quality changes and the appropriate selection depends on project-specific circumstances. In response to the regulatory use of these models, formal guidelines regarding the selection and application of these models have been developed (e.g., Alberta Environment and Sustainable Resource Development [ESRD] 2013a; U.S. EPA 2005a).

3C.1.2 Model Input and Output Files

The application of a dispersion model requires the preparation of input files and the analysis of output files. The input files include the following:

- control/option information to identify the model run, to select the available technical features, and to control the output options specific to the selected model
- source data that identify the locations, emission characteristics (e.g., stack height), and emission rates (e.g., oxides of nitrogen [NO_X] emission rate) for each source
- terrain elevations and surface characteristics to account for terrain influences on airflow and turbulence
- surface characteristics to provide the deposition properties for the vegetation canopy
- hourly meteorological data to characterize airflow and turbulence in the region

The output files can include:

- a summary file to identify the model run and to provide an overview of the run
- hourly concentration files for each receptor and meteorological combination
- hourly deposition files for each receptor and meteorological combination

Presentation software is used to provide concentrations and deposition contour plots that can be superimposed over base maps.

3C.2 MODEL SELECTION

3C.2.1 Requirements

For the atmospheric assessment, the selected model should have the ability to account for:

- multiple point, area, and volume sources
- flat and elevated terrain features
- secondary particulate matter with a mean aerodynamic diameter of 2.5 microns (µm) or smaller ($PM_{2.5}$) formation
- sulphur dioxide (SO_2) to sulphate (SO_4^{2-}) conversion
- NO_X to nitrate (NO_3^-) conversion
- wet, dry, gaseous, and particulate deposition processes

These features are required to predict ambient concentrations and deposition. Furthermore, the model selection and application needs to be consistent with the Alberta Air Quality Model Guideline (AQMG) (ESRD 2013a).

3C.2.2 Selected Model

Based on the review of the AQMG, the CALPUFF model is used to predict secondary $PM_{2.5}$ formation and deposition. CALPUFF has two options with respect to meteorological data:

- The simple mode assumes a uniform meteorological field over the model domain during a given hour. However, CALPUFF has the advantage of allowing the plume trajectories to vary from hour-to-hour in a systematic manner as the wind direction varies from hour-to-hour. This becomes more important to include when the model is applied to larger domains.
- The CALMET mode allows for three-dimensionally varying meteorological fields over the model domain during a given hour.

For this assessment, the CALPUFF model with the three-dimensional CALMET meteorological data fields is selected (see Attachment 3B).

The CALPUFF model is available from the web site of the model developer (i.e., Exponent Inc. - http://www.src.com/calpuff/calpuff1.htm). As of August 2017, the most recent Exponent version of CALPUFF was Version 7.2.1 level 150618, released June 22, 2015. The corresponding currently approved U.S. EPA version of CALPUFF is Version 5.8.5, level 151214. Consistent with the AEP Air Quality Model Guideline, Version 7.2.1 was adopted.

3C.2.3 CALPUFF Model Assumptions

The CALPUFF model (Scire et al. 2000) is a multi-layer, multi-species, non-steady state puff dispersion model that can simulate the effects of time and space-varying meteorological conditions on substance transport, transformation, and removal. CALPUFF contains algorithms for near-source effects such as building downwash, transitional plume rise, partial plume penetration, as well as longer-range effects such as chemical transformation and pollutant removal (wet scavenging and dry deposition). It can accommodate arbitrarily varying point source and area source emissions. Most of the algorithms contain options to treat physical processes at differing levels of detail depending on the requirements for the particular model application:

- Atmospheric dispersion—several options are provided in CALPUFF for the computation of dispersion coefficients:
  - similarity theory to estimate σ_v and σ_w from surface heat and momentum fluxes provided by CALMET

  - Pasquill-Gifford (PG) or McElroy-Pooler (MP) dispersion coefficients
  - dispersion equations based on the complex terrain dispersion model (CTDM)
  - hourly values of direct turbulence measurements (σ_v and σ_w)
- Chemical transformation—CALPUFF includes options to parameterize chemical transformation effects using:
  - the five species scheme (SO_2, SO_4^{2-}, NO_X, nitric acid [HNO_3], and NO^{3-}) employed in the MESOPUFF II model
  - a modified six-species scheme (SO_2, SO_4^{2-}, NO, NO_2, HNO_3, and NO^{3-}) adapted from the RIVAD/ARM3 (regional impact in visibility and acid deposition/acid rain mountain mesocale model) method
  - a set of user specified, diurnally-varying transformation rates, or ISORROPIA
  - an inorganic aerosol thermodynamic equilibrium model that can be used to improve the nitric acid/nitrate aerosol partition
- Dry deposition—this is a full resistance model provided to calculate dry deposition rates of gases and particulate matter as a function of geophysical parameters, meteorological conditions, and substance properties. Options are provided to allow user-specified, diurnally varying deposition velocities to be used for one or more pollutants instead of the resistance model (e.g., for sensitivity testing) or to bypass the dry deposition model completely.
- Wet deposition—this is an empirical scavenging coefficient approach used in CALPUFF to compute the depletion and wet deposition fluxes due to precipitation scavenging. The scavenging coefficients are specified as a function of the pollutant and precipitation type (i.e., frozen vs. liquid precipitation).

The following section describes the application of the CALPUFF model specific to the atmospheric assessment for the Project.

3C.3 MODEL APPLICATION

3C.3.1 Model Domain

The CALPUFF model requires the user to define the area where emissions sources are characterized, the meteorological conditions are characterized and the locations where the air quality changes are to be predicted. The CALPUFF model domain is a 20 km by 20 km centered on the PDA, and includes the communities of Springbank and Redwood Meadows. This area is also referred to as the local assessment area (LAA). Table 3C-1 provides the corner coordinates of the LAA.

Table 3C-1 Local Assessment Area Coordinates (UTM Zone 12; NAD 83)

	Easting (m)	Northing (m)
Model Domain		
Southwest Corner	669500	5649000
Northwest Corner	669500	5669000
Northeast Corner	689500	5669000
Southeast Corner	689500	5649000

3C.3.2 Receptor Locations

Two types of receptors within the model domain are defined: nested Cartesian grid points and discrete locations.

3C.3.2.1 Gridded Cartesian Receptors

Figure 3C-1 shows the nested receptor points that are used to provide spatial concentration and deposition patterns due to project emissions. The receptors are based on the following spacing:

- 20 m spacing along the project fenceline
- 20 m spacing within 100 m of the project fenceline
- 50 m spacing within 500 m of the project fenceline
- 250 m spacing within 2 km of the project fenceline
- 500 m spacing within 5 km of the project fenceline
- 1,000 m spacing beyond 5 km of the project fenceline

The grid density is the greatest near the PDA to allow the assessment to focus on project emissions. More distant from the Project, the resolution is sufficient to determine the additive effects of the project emissions with emissions from other sources and 365 gridded receptors with a 200-m spacing within the project fenceline are also included. These receptors are used to plot isopleths, but are not used to determine maximum predicted concentrations within the assessment area.

The above indicated spacing is depicted in Figure 3C-1 and the project centric receptor grid is sufficient to provide an indication of the magnitude and spatial concentrations from project emissions. The described grid consists of 11,360 receptor points.

3C.3.2.2 Discrete Receptors

In addition to gridded receptors, 58 discrete locations corresponding to specific sites of interest (e.g., residences and businesses) are included. Figure 3C-2 shows the locations and Table 3C-2 provides the coordinates of these discrete receptors.

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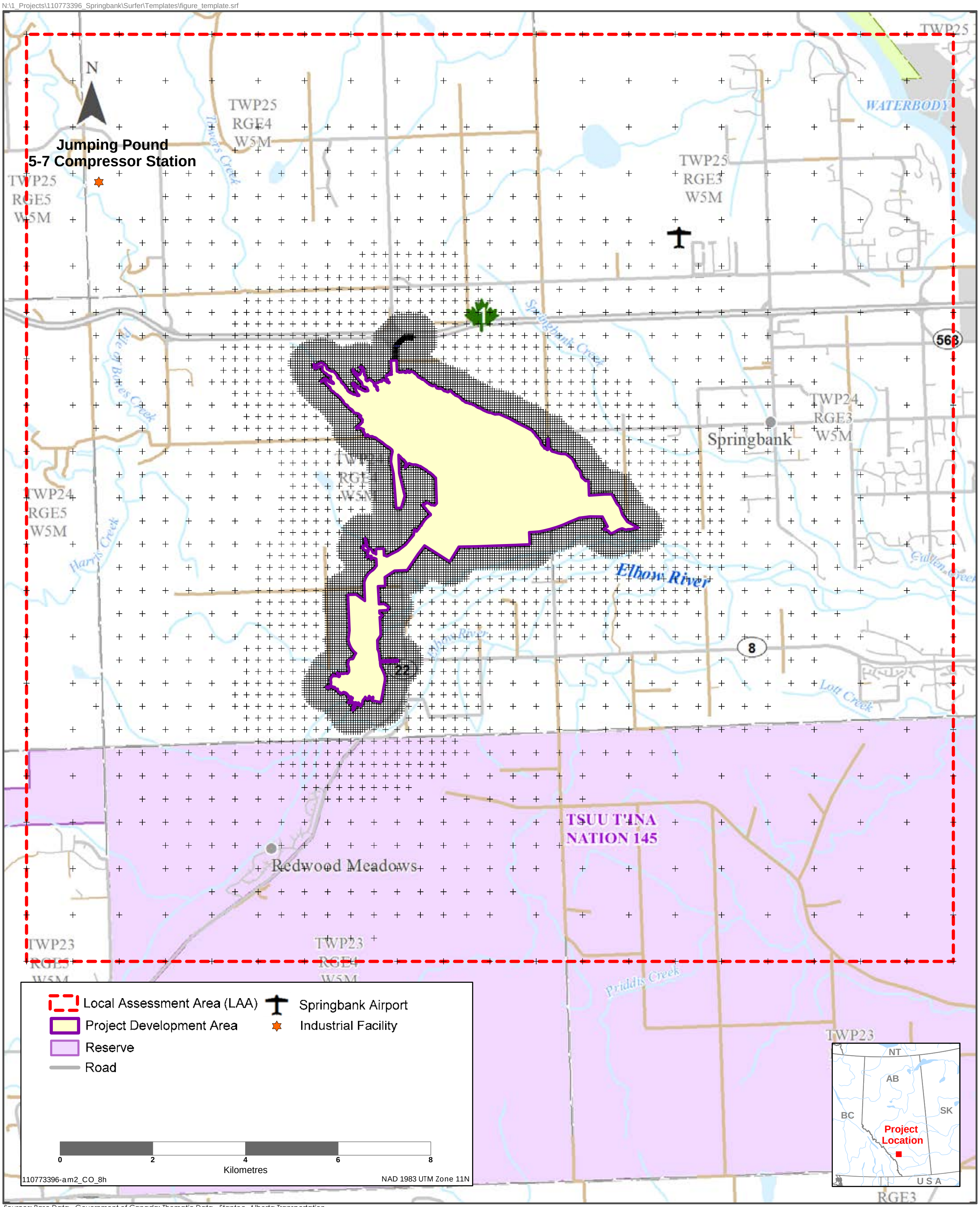

Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Cartesian Receptor Grid in the Local Assessment Area

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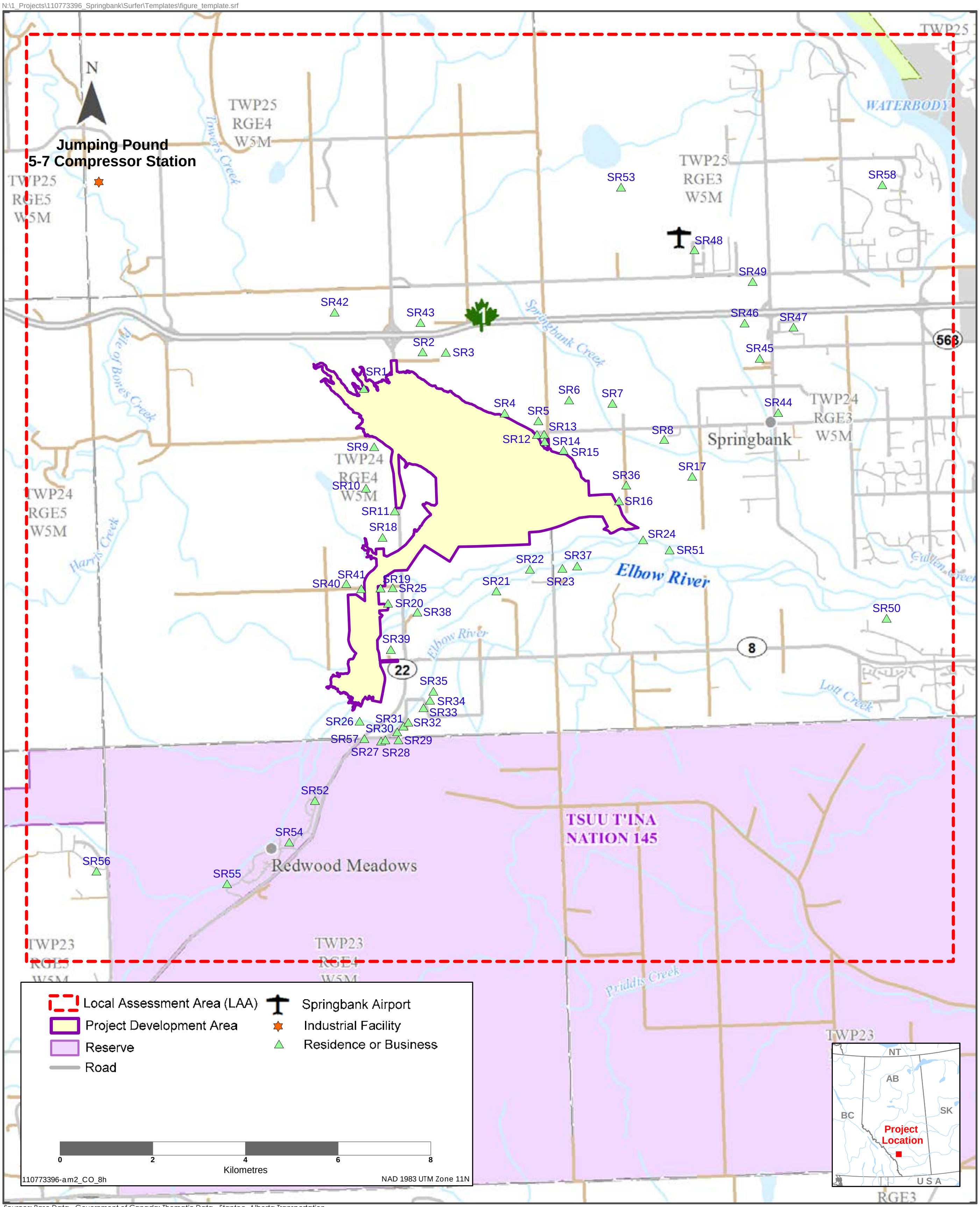

Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Discrete Receptors in the Local Assessment Area

Table 3C-2 Locations of Discrete Receptors

No.	Model ID	Description	Indigenous Receptor	UTM Easting (m)	UTM Northing (m)	Elevation (m)
1	11361	Residence	-	676781	5661331	1216
2	11362	Residence	-	678048	5662119	1221
3	11363	Residence	-	678552	5662110	1221
4	11364	Residence	-	679819	5660800	1212
5	11365	Residence	-	680547	5660633	1214
6	11366	Residence	-	681210	5661081	1211
7	11367	Residence	-	682145	5661009	1213
8	11368	Residence	-	683263	5660232	1218
9	11369	Residence	-	677002	5660073	1223
10	11370	Residence	-	676827	5659178	1239
11	11371	Residence	-	677449	5658687	1225
12	11375	Residence	-	680518	5660338	1217
13	11376	Residence	-	680670	5660342	1217
14	11377	Residence	-	680684	5660189	1220
15	11378	Residence	-	681089	5660000	1225
16	11379	Residence	-	682288	5658906	1231
17	11380	Residence	-	683867	5659434	1237
18	11381	Residence	-	677183	5658119	1217
19	11382	Residence	-	677141	5657023	1227
20	11383	Residence	-	677303	5656695	1231
21	11384	Residence	-	679639	5656960	1227
22	11385	Residence	-	680364	5657430	1220
23	11386	Residence	-	681065	5657450	1220
24	11387	Residence	-	682806	5658064	1216
25	3901	Commercial	-	677404	5657030	1227
26	2311	Residence	-	676688	5654153	1225
27	9459	Residence	✓	677153	5653723	1231
28	9459	Entheos Conference and Retreat Centre	✓	677243	5653750	1230
29	9460	Residence	✓	677526	5653748	1230
30	9477	Residence	-	677499	5653923	1225
31	9477	Residence	-	677635	5654046	1226

Table 3C-2 Locations of Discrete Receptors

No.	Model ID	Description	Indigenous Receptor	UTM Easting (m)	UTM Northing (m)	Elevation (m)
32	9492	Residence	-	677739	5654132	1225
33	9505	Residence	-	678067	5654443	1222
34	9519	Residence	-	678209	5654605	1221
35	9519	Residence	-	678281	5654797	1220
36	6468	Residence	-	682441	5659245	1239
37	9744	Residence	-	681384	5657499	1219
38	3651	Camping Ground	-	677934	5656505	1235
39	3252	Camping Ground	-	677362	5655699	1215
40	3922	Residence	-	676401	5657121	1226
41	3861	Residence	-	676726	5657009	1227
42	10119	Residence	-	676149	5662976	1241
43	9322	Residence	-	678003	5662753	1236
44	10555	School	-	685721	5660811	1212
45	10600	School	-	685324	5661980	1219
46	10617	Park	-	684997	5662740	1236
47	10618	Commercial	-	686053	5662653	1233
48	10673	Airport	-	683915	5664323	1277
49	10654	School	-	685171	5663637	1251
50	10467	Golf Club	-	688061	5656372	1236
51	9787	Golf Club	-	683378	5657845	1217
52	9394	Residence	-	675726	5652441	1303
53	10719	Residence	-	682331	5665673	1272
54	10262	Park	-	675169	5651545	1343
55	10228	Golf Club	-	673829	5650646	1311
56	10817	Golf Club	-	671010	5650919	1320
57	9457	Park	✓	676793	5653775	1229
58	10935	Golf Club	-	687967	5665726	1272

NOTE:
Model IDs of receptors 25 to 58 are based on nearest gridded receptors
✓ indicates that the receptor is identified as indigenous.
- Indicates that the receptor is not identified as indigenous

3C.3.3 Meteorology

The CALMET meteorological model is used to provide representative wind, temperature, and turbulence fields (see Attachment 3B). Five years (2002 to 2006) of hourly CALMET input files were prepared and used for this assessment. The meteorological inputs reflect seasonal variations in the land cover properties (see Attachment 3B).

3C.3.4 Dispersion

The CALPUFF model offers several dispersion options selected for this assessment:

- The selection of the similarity scaling approach to estimate σ_v and σ_w is viewed as using a more up-to-date understanding of dispersion in the boundary layer than the historical discrete PG dispersion approach. The similarity approach treats dispersion as a continuous function, whereas the PG approach considers discrete classes. For this reason, MDISP = 2 (Input group 2) is used to select the similarity approach and this selection is consistent with the AQMG.
- The probability distribution function (PDF) approach accounts for downdrafts and updrafts that occur under convective conditions. The PDF approach increases the predicted concentrations under convective conditions. For this assessment MPDF = 1 (PDF assumed) is selected and is consistent with the AQMG.
- Vertical wind shear accounts for the enhanced dispersion that can happen when the wind direction changes with increasing height above the ground. If vertical wind shear is adopted (MSHEAR = 1), the ambient concentrations can be larger than if vertical wind shear is not simulated (MSHEAR = 0). Scire (2009, pers. comm.), the developer of the CALPUFF model, indicates that there may be some problems with the vertical wind shear algorithms, and he recommends that MSHEAR = 0 be adopted until the issue can be further explored and evaluated. For this reason, the default MSHEAR = 0 (Input group 2) is selected, and this selection is consistent with the AQMG.

This discussion has been provided to indicate the selection of the dispersion details can have an influence on the model predictions.

3C.3.5 Chemical Transformation

The RIVAD/ARM3 (regional impact in visibility and acid deposition/acid rain mountain mesocale model) chemical scheme is selected (MCHEM = 3) to be consistent with the AQMG. The RIVAD/ARM3 chemistry scheme treats the NO and NO_2 conversion process in addition to the NO_2 to NO_3^- and SO_2 to SO_4^{2-} conversions, with equilibrium between gaseous HNO_3 and particulate ammonium nitrate (NH_4NO_3) (Scire et al. 2000). The selected chemical transformation scheme influences the predicted NO_2 and SO_2 concentrations due to the removal of nitrate and sulphate compounds.

The chemical transformation scheme requires NO and NO_2 emissions rates. Typically, only the NO_X emission rate is known, and this is expressed in terms of NO_2 mass equivalent. Based on the NO_X emission rate, the individual NO and NO_2 emission rates are calculated as follows:

- 90% NO and 10% NO_2 on a volume basis
- NO mass emission = 0.9*(30/46)*(NO_X mass emission)
- NO_2 mass emission = 0.1 *(46/46)*(NO_X mass emission)

These assumptions result in 85% NO and 15% NO_2 emission on a mass basis. The 90% NO and 10% NO_2 volume ratio is consistent with the ozone limiting method (See Section 3C.3.6).

3C.3.6 NO to NO_2 Conversion

The AQMG identifies several NO to NO_2 conversion approaches:

- total conversion method (TCM) assumes all NO is converted to NO_2
- CALPUFF predictions based on the RIVAD/ARM approach using representative ozone measurements
- ozone limiting method (OLM) using representative ozone measurements
- ambient ratio method (ARM)

The OLM assumes that the conversion of NO to NO_2 in the atmosphere is limited by the ambient O_3 concentration in the atmosphere. The approach assumes that 10 percent (on a volume basis) of the NO is converted to NO_2 prior to discharge into the atmosphere. For the remaining NO, the following is adopted:

- If 0.9 (NO_X) is greater than the ambient O_3 concentration then NO_2 = 0.1 (NO_X) + O_3. For this case, the conversion is not complete.
- If 0.9 (NO_X) is less than the ambient O_3 concentration then NO_2 = 0.1 (NO_X) + 0.9 (NO_X). This is equivalent to the total conversion approach, since there is sufficient ozone to effect the complete conversion.

In the application of the OLM, the concentrations are expressed as ppb.

The AQMG indicates that it is preferable to use onsite time-series of hourly O_3 data that matches the same time period as the meteorological data. The AQMG defines onsite as being “within the facility boundary”. While representative O_3 data are measured and are available for the model domain, none of it is collected onsite. Given the absence of onsite O_3 data, the default rural values listed in Appendix E of the AQMG are adopted. These data are based on measurements across Alberta (i.e., Anzac and Fort Chipewyan from northeast Alberta, as well as Beaverlodge, Caroline, Elk Island, Genessee, Tomahawk, and Violet Grove in central Alberta).

For this assessment, the OLM method is applied to the calculated NO_X concentrations predicted by the CALPUFF model using the indicated representative ozone concentration data. For purpose of comparison, the TCM results also are presented; this approach is conservative and does not account for combustion or atmospheric chemistry. The selection of the OLM with the TCM results is consistent with the AQMG.

3C.3.7 NH_3 Concentrations

The CALPUFF chemistry scheme requires ambient ammonia concentrations to predict nitrate and sulfate formation. Table 3C-3 provides the NH_3 values that are used for this assessment. The NH_3 concentrations vary on a monthly basis and are based on three years of continuous monitoring at Lethbridge monitoring station (January 2014 to September 2016) (AEP 2017).

Table 3C-3 Ambient NH_3 Concentrations Assumed for the Assessment Area

Year	Ammonia Concentration (ppb)											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
2014	3.25	1.76	2.97	3.40	5.42	4.37	8.17	7.88	4.20	4.87	3.17	13.8
2015	4.62	6.24	4.99	5.10	10.1	10.6	8.13	9.60	6.16	6.74	6.01	10.1
2016	10.5	7.82	-	8.52	8.85	4.04	6.98	7.39	4.27	-	-	-
Average	6.11	5.27	3.98	5.67	8.12	6.34	7.76	8.29	4.88	5.80	4.59	11.93

3C.3.8 Short-term Concentrations

The CALPUFF model predicts 1-hour average concentrations. Since an odour can be associated with a shorter time-period, associated odour peak concentrations can be greater than the 1 hour average concentration predictions by CALPUFF. Prior to comparing an hourly average concentration to an odour threshold, it is important to adjust the time average measurement (i.e., the mean or M) to the short-term exposure that can be associated with odour (i.e., the peak or P). Numerous approaches have been developed to account for the P/M ratio, which depends on factors such as the emission source type (e.g., a tall stack or a ground based release), the meteorological conditions (e.g., atmospheric stability), and the downwind distance from the emission source (i.e., travel time).

The AQMG recommends the following formula to calculate an impact factor and then multiply the impact factor by the maximum predicted 1-h concentration to obtain the relevant average concentration.

Impact factor = 1.1233 × (averaging period in hours)$^{-2.906}$

For this assessment, the odour peak calculation assumes an averaging period of three minutes. The application of above formula to calculate impact factor results in odour peaks that are 2.7 times the 1-h average prediction.

For this assessment, a value of 2.7 is adopted to account for this peak to mean (P/M) relationship. This factor is representative for relating 1-h average concentrations to shorter term peak values that are associated with the perception of odour.

3C.3.9 Particulate Formation

The CALPUFF model is used to predict secondary $PM_{2.5}$ formation due to precursor SO_2 and NO_X emissions. The model predicts particulate nitrate NO_3^-, which can exist as an aerosol (i.e., dissolved in a water droplet) or as a particle (e.g., NH_4NO_3). Similarly, sulphate SO_4^{2-} can also exist as an aerosol or as a particle (e.g., ammonium sulphate [$(NH_4)_2SO_4$]). NO_3^- and SO_4^{2-} are assumed to react with ambient ammonia (NH_3) to produce ammonium nitrate and ammonium sulphate, respectively. The predicted sulphate and nitrate are multiplied by the factors indicated in Table 3C-4 to account for these transformations.

The $PM_{2.5}$ predictions derived from the CALPUFF model include the primary $PM_{2.5}$ contribution plus the secondary sulphate and nitrate contributions.

Table 3C-4 $PM_{2.5}$ Multipliers for SO_4^{2-} and NO_3^-

Predicted Parameter	SO_4^{2-}	NO_3^-
Molecular Mass	96	62
End Product	**$(NH_4)_2SO_4$**	**NH_4NO_3**
Molecular Mass	132	80
Multiplier	1.375	1.290

NOTE:
Multiplier = (molecular mass of end product)/(molecular mass of predicted parameter)

3C.3.10 Deposition Calculation Approach

3C.3.10.1 Deposition Parameters

Deposition comprises dry and wet removal mechanisms. The dry and wet deposition rates depend on the phase of the compound being deposited (e.g., vapour or particle), and other physical and chemical properties of the compound. For this assessment, deposition is required to predict the following:

- deposition of dustfall (dry deposition of total suspended particulate (TSP)) because Alberta has an ambient air quality guideline for dustfall.
- deposition of metal compounds because these compounds can have potential adverse effects on environmental health and, subsequently, on human health.

Table 3C-5 provides a list of the CAC compound groups associated with the project emissions and provides the associated deposition assumptions. Table 3C-5 also indicates which compounds are vapour or particulate phase dominated. All metals are assumed to be associated with the particulate matter phase. Particulate matter (PM) is divided into three size ranges (i.e., 0 to 2.5 µm, 2.5 to 10 µm, and 10 to 30 µm) to account for larger particles being deposited close the emission source and smaller particles travelling further downwind before being deposited. The deposition values predicted with each size fraction are summed to calculate the total deposition.

For dry deposition, the compound groups are discussed in terms of the deposition options that are available in the CALPUFF model:

- For gaseous SO_2, NO, NO_2, and HNO_3, dry deposition is calculated using the CALPUFF internal vapour-phase resistance sub-model. The default resistance model input parameters are listed in Tables 3C-15 and 3C-16.
- For particulate SO_4^{-2} and NO_3^-, dry deposition is calculated using the CALPUFF internal particle-phase resistance sub-model. Default geometric mass mean diameters and standard deviations of 0.48 µm and 2 µm (respectively) based on the CALPUFF manual (Scire et al. 2000) are adopted.
- For PM size-based fractions, dry deposition is calculated using the CALPUFF internal particle-phase resistance sub-model. Geometric mass mean diameters and standard deviations for PM size-based fractions are listed in Table 3C-16 and are based on the US EPA’s Human Health Risk Assessment guidance document (USEPA 2005b).

The calculation of wet deposition requires wet scavenging coefficients that vary with substance phase (i.e., gas or particle) and form of the precipitation (i.e., liquid (rain) or solid (snow)). The CALPUFF model assumes the scavenging coefficient approach for both gases and particles. The following assumptions are made relative to these parameters:

- For nitrogen and sulphur compounds, the default wet scavenging coefficients listed in Table 3C-16 are used and these are based on the CALPUFF manual (Scire et al. 2000).
- For particle size fractions, the scavenging coefficients listed in Table 3C-16 are used and these are based on USEPA (1995).

Table 3C-5 Deposition Assumptions

Compound	Percent Vapour	Percent Particle	Dry Deposition
Common Air Contaminants			
SO_2	100	0	Gas Phase Resistance Model
SO_4^{-2}	0	100	Particle Phase Resistance Model
NO	100	0	Gas Phase Resistance Model
NO_2	100	0	Gas Phase Resistance Model
HNO_3	100	0	Gas Phase Resistance Model
NO_3^-	0	100	Particle Phase Resistance Model
$PM_{2.5}$ (Combustion product)	0	100	Particle Phase Resistance Model
$PM_{2.5}$ to PM_{10} range (Combustion product)	0	100	Particle Phase Resistance Model
PM_{10} to TSP (Combustion product)	0	100	Particle Phase Resistance Model
$PM_{2.5}$ (Fugitive dust)	0	100	Particle Phase Resistance Model
$PM_{2.5}$ to PM_{10} range (Fugitive dust)	0	100	Particle Phase Resistance Model
PM_{10} to TSP (Fugitive dust)	0	100	Particle Phase Resistance Model

3C.3.11 Source Parameters

Base Case and project emission sources are identified, characterized, and quantified in Attachment 3A. Depending on the nature of the source types, they can be described as one of the following: point source, line source or volume source. Differing input parameters are used to represent the source types relevant to the LAA.

3C.3.11.1 Point Sources

Industrial stacks are treated as point sources. Parameters required for each stack include stack location, stack base elevation, stack height, stack diameter, stacks gas exit temperature, stack gas exit velocity, and substance emissions rates. There are two stacks associated with a compressor station in the LAA. Parameters to represent these stacks are provided in Table 3C-6 and further discussed in Attachment 3A. The compressor station emission rates are assumed to be constant and continuous.

3C.3.11.2 Regional Highways

Traffic emissions from highways and major roads in the LAA are referred to as line sources and each line source is represented by multiple volume sources. The US EPA memorandum on haul road emissions (US EPA 2012) and AERMOD guidance document (US EPA 2004) are used to derive appropriate volume source parameters. Highway and roadway volume source parameters are provided in Table 3C-7. Key features include:

- Four highways and roadways are selected to represent the main traffic corridors in the LAA: TransCanada Highway (Highway 1), Highway 22, Highway 8, and the Springbank Road.
- The volume source spacing and the number of individual volume sources to represent each highway varies with distance from the Project. A smaller spacing (i.e., 50 m) is used to represent highway segments near the Project and a larger spacing (i.e., 200 m) is used to represent highway segments more distant from the Project.
- The volume source height (VH = 2 .0 m) and the top of the plume height (VP = 2.0 m), and the emission release height (RH = VP/2 = 1 .0 m) are related to the dimensions of a typical vehicle. The width of the volume source (VR) is related to the width of the highway (20 m).
- The turbulence generated by the vehicle wake zone is represented by initial lateral and vertical dimensions referred to a Sy and Sz, respectively. The Sy and Sz values are based on the recommendations provided in the AERMOD model user's guide (US EPA 2004).

This approach mimics an initially well-mixed plume associated with vehicle wake zones. The approach, however, does not calculate concentrations for distances less than the volume spacing distance. This disadvantage is not a limitation because locations of interest are farther downwind. Emission rates associated with highway and roadway sources are discussed and provided in Attachment 3A. The emission rates are assumed to be continuous and vary with season (the winter period being November to February and the summer period being March to October).

3C.3.11.3 Project Volume Sources

Project emissions from excavation, truck loading and unloading, bulldozing, concrete trucks, graders, backhoes, and truck mounted cranes are represented as volume sources. Associated volume source parameters are provided in Table 3C-8. Key features include:

- There are 10 project activities associated with these operations. Each activity is represented by 1 to 5 individual volume sources, depending on the activity.

- The volume source height (VH), the top of plume height (PH), and the emission release height (RH) are related to the dimensions of the dominant piece of equipment. The width of the volume source (PW) is also related to the dimensions of the equipment or the dimensions of the activity.
- The PH and RH are also based on the width and height of the piece of equipment used for the dominant operation.
- Initial Sy and Sz values are calculated based on AERMOD model user's guide (US EPA 2004).

Emission rates associated with the project sources are discussed and provided in Attachment 3A. The emission rates are limited to certain times of the year and to certain times of the day, depending on the activity.

3C.3.11.4 Project Haul Road Sources

Haul roads are line sources represented as multiple volume sources, similar to highway emission sources. Associated volume source parameters are provided in Table 3C-9. Key features include:

- Six haul roads are associated with the Project. Depending on the length of each haul road, 23 to 114 volume sources represent each haul road, with a volume source spacing of 60 m.
- The volume source height (VH), the top of plume height (PH), and the emission release height (RH) are related to the dimensions of the associated haul trucks. The width of the volume source (PW) is related to the width of the haul road (RW).
- The turbulence generated by the vehicle wake zone is represented by initial lateral and vertical dimensions referred to a Sy and Sz, respectively. The Sy and Sz values are based on the recommendations provided in the AERMOD model user’s guide (US EPA 2004).

Emission rates associated with the haul roads are discussed and provided in Attachment 3A. The emission rates are limited to certain times of the year and to certain times of the day, depending on the haul road.

3C.3.11.5 Project Temporary Overburden and Topsoil Stockpile

The Project will require a temporary overburden and topsoil stockpile. Wind erosion emissions from the stockpile are represented by an area source. Table 3C-10 shows area source parameters used for the overburden stockpile. Emission rates associated with the stockpile are discussed and provided in Attachment 3A. The emission rates depend on the wind speed.

Table 3C-6 Regional Point Source Parameters

Model Source ID	Source Description	Temporal Variation	Source Parameters						
			Location and Elevation			Stack Height	Stack Diameter	Stack Exit Temperature	Stack Exit Velocity
			m E	m N	m ASL	m	m	K	m/s
Compressor Station									
SHELL1	Compressor Engine	Continuous	671061	5665810	1,250	7.5	0.5	800	30
SHELL2	Heat Medium Heater	Continuous	671061	5665810	1,250	7.5	0.4	600	10

NOTES:
Location based on UTM Zone 16, NAD 83
Stacks are modelled as point sources.

Table 3C-7 Source Parameters for Regional Highway Sources

Model Source ID	Source Description	Temporal Variation	Source Parameters										
			Location and Base Elevation			VH and PH	PW	RH	Volume Spacing	Sy	Sz	Length of Road	Number
			m E	m N	m ASL	m	m	m	m	m	m	m	#
H1	Trans-Canada Highway	Seasonal (continuous source)	676558	5662620	1234	2.0	20	1.0	50	23.3	0.93	3053	62
			674114	5662537	1226	2.0	20	1.0	100	46.5	0.93	3947	39
			671402	5663034	1244	2.0	20	1.0	200	93.0	0.93	13259	65
H22	Highway 22	Seasonal (continuous source)	677524	5657764	1218	2.0	20	1.0	50	23.3	0.93	10080	202
			677312	5663710	1267	2.0	20	1.0	100	46.5	0.93	3993	39
			677210	5666637	1243	2.0	20	1.0	200	93.0	0.93	8327	40
H8	Highway 8	Seasonal (continuous source)	677848	5655532	1211	2.0	20	1.0	50	23.3	0.93	558	12
			679155	5655570	1207	2.0	20	1.0	100	46.5	0.93	2030	20
			684982	5655750	1175	2.0	20	1.0	200	93.0	0.93	9468	47
SR	Springbank Road	Seasonal (continuous source)	681356	5660509	1210	2.0	20	1.0	50	23.3	0.93	1327	27
			683033	5660559	1190	2.0	20	1.0	100	46.5	0.93	2060	20
			686890	5660695	1190	2.0	20	1.0	200	93.0	0.93	5410	27

NOTES:
Location based on UTM Zone 16, NAD 83
vehicle height (VH) = Top of plume height (PH) = 2.0 m
release height (RH) = 1/2 x VH = 1.0 m
plume width (PW) = 20 m (highway width)

Table 3C-8 Source Parameters for Project Volume Sources

Model Source ID	Source Description	Temporal Variation	Source Parameters								
			Location and Base Elevation			PH	PW	RH	Sy	Sz	Number
			m E	m N	m ASL	m	m	m	m	m	#
DCV [b]	diversion channel excavation	Monthly (April to October); 24 h per day	676665	5655984	1236	4.29	3.94	2.14	1.83	1.99	5
DV [c]	off-stream dam construction	Monthly (April to October)	679721	5658634	1205	7.07	3.43	3.53	1.60	3.29	3
BV [d]	floodplain berm construction	Monthly and Hourly (April to October; 7 am to 7 pm)	677067	5655202	1216	2.96	2.33	1.48	1.08	1.38	1
DCCSV [e]	river reroute and diversion channel concrete structure	Diurnal (7 am to 7 pm); 24 h per day	681412	5658924	1187	3.75	50.0	1.87	23.26	1.74	1
DOCSV [f]	low level outlet works construction	Diurnal (7 am to 7 pm; 24 h per day)	676781	5655847	1221	3.95	2.44	1.98	1.13	1.84	1
BP1V [g]	borrow area 1	Monthly (April to October); 24 h per day)	680588	5659822	1201	4.14	2.44	2.07	1.13	1.93	1
BP3V [g]	borrow area 2	Diurnal (7 am to 7 pm)	679234	5659410	1195	4.14	2.44	2.07	1.13	1.93	1
H22V [h]	raising highway 22 and bridge construction	Diurnal (7 am to 7 pm)	677386	5661382	1214	3.18	50.0	1.59	23.26	1.48	3
R242V [h]	Highway 22 bridge and Township Road 242 bridge construction	Diurnal (7 am to 7 pm)	677580	5657732	1218	3.18	50.0	1.59	23.26	1.48	2

Table 3C-8 Source Parameters for Project Volume Sources

Model Source ID	Source Description	Temporal Variation	Source Parameters: Location and Base Elevation			PH	PW	RH	Sy	Sz	Number
			m E	m N	m ASL	m	m	m	m	m	#
SPV [c]	temporary overburden and topsoil stockpile loading/unloading	Monthly (April to October); 24 h per day)	676648	5656585	1238	7.07	3.43	3.53	1.60	3.29	1

NOTES:

Location based on UTM Zone 16, NAD 83

[b] plume height (PH) and emission release height (RH) based on width and height of equipment used for dominant operation (Scraper). vehicle height (VH) = 4.29 m (CAT 637G Motor Scraper); release height (RH) = 1/2 x VH = 2.14 m; plume width (PW) = vehicle width (VW) = 3.94 m.

[c] plume height (PH) and emission release height(RH) based on width and height of equipment used for dominant operation (articulated dump truck). vehicle dump height (VH) = 7.07 m (CAT 740); release height (RH) = 1/2 x VH = 3.53 m; plume width (PW) = vehicle width (VW) = 3.43 m.

[d] plume height (PH) and emission release height (RH) based on width and height of equipment used for dominant operation (Bulldozer). vehicle height (VH) = 2.96 m (CAT D6); release height (RH) = 1/2 x VH = 1.87 m; plume width (PW)= vehicle width (VW) = 2.33 m.

[e] plume height (PH) and emission release height (RH) based on height of equipment used for dominant operation (articulated dump truck). vehicle height (VH) = 3.75 m (CAT 740); release height (RH) = 1/2 x VH = 1.87 m; plume width (PW) of 50 m based on where construction equipment will be spread out.

[f] plume height (PH) and emission release height(RH) based on height of equipment used for dominant operation (Truck mounted crane). vehicle height (VH) = 3.95 m (Altec Crane AC45-127S on Peterbilt 365 Truck); release height (RH) = 1/2 x VH = 1.98 m; plume width (PW) = vehicle width (VW) = 2.44 m.

[g] plume height (PH) and emission release height (RH) based on width and height of equipment used for dominant operation (backhoe); vehicle height (VH) = 4.14 m (CAT 450); release height (RH) = 1/2 x VH = 2.07 m; plume width (PW) = vehicle width (VW) = 2.44 m.

[h] plume height (PH) and emission release height (RH) based on height of equipment used for dominant operation (grader); vehicle height (VH) = 3.18 m (John Deere 872G); release height (RH) = 1/2 x VH = 1.59 m; vehicle width (VW) = 2.64 m; plume width (PW) of 50 m based on where construction equipment will be spread out.

Table 3C-9 Source Parameters for Haul Roads

Model Source ID	Source Description	Temporal Variation	Source Parameters										
			Location and Elevation			PH	PW	RH	Volume Spacing	Sy	Sz	Length of Road	Number
			m E	m N	m ASL	m	m	m	m	m	m	m	#
HR_DC [b d]	haul road from diversion channel to off-stream dam	Monthly (April to October); 24 h per day	676640	5655980	1237	6.37	30	3.18	60	27.91	2.96	6780	114
HR_BP1 [b d]	haul road from borrow area 1 to off-stream dam	Monthly (April to October); 24 h per day	679820	5660310	1200	6.37	30	3.18	60	27.91	2.96	3240	55
HR_B [b d]	haul road from diversion channel to floodplain berm	Monthly and Hourly (April to October; 7 am to 7 pm)	676949	5656976	1223	6.37	30	3.18	60	27.91	2.96	2340	40
HR_BP3 [c d]	haul road from borrow area 2 to highway 22	Diurnal (7 am to 7 pm); Monthly and diurnal for fugitives (January to December; 7am to 7pm)	679199	5659432	1195	6.22	30	3.11	60	27.91	2.89	3240	55
HR_SPDC [b d]	haul road from diversion channel to overburden and topsoil stockpile	Monthly (April to October); 24 h per day	676640	5655980	1237	6.37	30	3.18	60	27.91	2.96	3600	61

Table 3C-9 Source Parameters for Haul Roads

Model Source ID	Source Description	Temporal Variation	Source Parameters											
			Location and Elevation			PH	PW	RH	Volume Spacing	Sy	Sz	Length of Road	Number
			m E	m N	m ASL	m	m	m	m	m	m	m	#
HR_H22 [c d]	haul road along Highway 22 construction	Diurnal (7 am to 7 pm); Monthly and diurnal for fugitives (January to December; 7am to 7pm)	677423	5660200	1211	6.22	30	3.11	60	27.91	2.89	1320	23

NOTES:

Location based on UTM Zone 16, NAD 83

[b] plume height (PH) and emission release height (RH) based on U.S. EPA Memorandum on haul road modelling (U.S. EPA, 2012) and the haul truck height. Vehicle height (VH) = 3.745 m (CAT 740 mining truck). Top of plume height (PH) = 1.7 x VH = 6.37 m; release height (RH) = 1/2 x PH = 3.18 m.

[c] plume height (PH) and emission release height (RH) are calculated based on U.S. EPA Memorandum on haul road modelling (U.S. EPA, 2012) and the haul truck height. Vehicle height (VH) = 3.657 m (CAT CT681 mining truck). Top of plume height (PH) = 1.7 x VH = 6.22 m. Release height (RH) = 1/2 x PH = 3.11 m.

[d] Plume width (PW) based on U.S. EPA Memorandum on haul road modelling (U.S.EPA, 2012) and haul road width. Road width (RW) = 25 m for haul roads. Plume width (PW) = RW + 6 m. PW = 30 m (rounded) for haul roads. Volume source separation distance = 60 m (double of plume width).

Table 3C-10 Source Parameters for Area Source

Model ID	Source Description	Temporal Variation	Source Parameters						
			Location and Base Elevation			Area	Effective Height	Sz	Number
			m E	m N	m ASL	km²	m	m	#
SPA	Temporary Overburden and Topsoil Stockpile Wind Erosion	Variable with wind speed	676648	5656585	1240	0.125	3.33	0	1

NOTES:
Location based on UTM Zone 16, NAD 83
[a] Stockpile is modelled as area source
[b] Effective height is 2/3rd stockpile height. Stockpile height assumed to be 5.0 m.

3C.3.12 Interpretation of Predictions

3C.3.12.1 Comparison to Alberta Ambient Air Quality Objectives

The AQMG indicates that the eight highest 1-h predictions at each receptor location during any given year should be disregarded as they can be considered outliers. This means that the 1-h Alberta Ambient Air Quality Objectives (AAAQO) should be compared to the 9th highest 1-h prediction, not to the highest 1-h prediction. For a one-year period, the 9th highest 1-h value corresponds to the 99.9th percentile predicted 1-h concentration.

When effecting this comparison, AEP has the expectation that the 9th highest 1-h prediction corresponds to a realistic worst-case scenario. Although “realistic” is not defined, one can assume it refers to a normal maximum emissions case that could reasonably be expected during routine operations. Specifically, it does not appear to be associated with maximum emissions due to process upsets or due to pollution-control technology downtime.

AEP also indicates that the first-highest 24-h average prediction should be compared to the corresponding 24-h AAAQO (ESRD 2013b). The annual average concentration is compared directly to the annual AAAQO. When comparing the 24-h and annual average concentrations to the respective AAAQOs, the top eight 1-h average values are included.

3C.3.12.2 Contour Concentration and Deposition Plots

Ambient concentration and deposition predictions are displayed as contour plots superimposed over base maps for the local assessment area (LAA). The concentration contour plots are based on the maximum values from the five-year simulation period. The deposition contour plots are also based on the maximum values from the five-year period. In preparing these contour plots, a grid spacing of 200 m is used for the LAA contour plots. This may result in some “smoothing” of the contours. However, the tabular results are more accurately based directly on the model output and not smoothed data.

3C.4 SUMMARY AND CONCLUSIONS

The CALPUFF dispersion model (most recent Version 7.2.1, Level 150618) is used to predict ambient concentrations and deposition for the project air quality assessment. The following are adopted for the application of the model:

- 11,387 gridded and sensitive receptor points to assess criteria air contaminant (CAC), VOC, PAH and metal concentrations, and TSP and metal deposition for the 20 km by 20 km LAA.
- Five years of meteorological data for the period January 2002 to December 2006 to represent the wide range of weather conditions that could occur. The CALMET model (see Attachment 3B) provides the meteorological data for the CALPUFF model.
- The OLM estimates ambient NO_2 concentrations from the predicted NO_X values. The rural default O_3 concentrations from the AQMG are used for the chemical transformation needs of the model assessment.
- The CALPUFF model was applied to Project Only Case (Appendix 3E), Base Case, and Application Case emission scenarios using the source and emission inventory information described in Attachment 3A.

This approach and input parameters ae used to predict air quality changes due to the Project.

3C.5 CALPUFF MODEL OPTIONS

For the purposes of organization, the CALPUFF control file defines 20 input groups as identified in Table 3C-11. The input parameters for the CALPUFF control file are provided in Tables 3C-12 to 3C-19. The AQMG indicates that default assumptions and switches are to be used. Although not specified in the AQMG, the default values are assumed to be those defined in the CALPUFF user manual (Scire et al. 2000). The AQMG also explicitly indicates specific default values (ESRD 2013a). These values are highlighted by orange shading in the following tables. The default values and the values adopted for this updated assessment are identified in the tables.

Table 3C-11 Input Groups in the CALPUFF Control File

Input Group	Description	Applicable to Project?
0	Input and output file names	Yes
1	General run control parameters	Yes
2	Technical options	Yes
3	Species list	Yes
4	Map projection and grid control parameters	Yes
5	Output options	Yes
6	Sub grid scale complex terrain inputs	No
7	Dry deposition parameters for gases	Yes
8	Dry deposition parameters for particles	Yes
9	Miscellaneous dry deposition for parameters	Yes
10	Wet deposition parameters	Yes
11	Chemistry parameters	Yes
12	Misc. dispersion and computational parameters	Yes
13	Point source parameters	Yes
14	Area source parameters	No
15	Line source parameters	No
16	Volume source parameters	Yes
17	Flare source control parameters	No
18	Road emissions parameters	No
19	Emission rate scale-factor tables	Yes

Table 3C-12 CALPUFF Model Options Groups 1 and 2

Input Group 1: General Run Control Parameters

Parameter	Default	Project	Comments
METRUN	0	0	All model periods in met file(s) will be run
IBYR	-	2002	Starting year
IBMO	-	1	Starting month
IBDY	-	1	Starting day
IBHR	-	0	Starting hour
IEYR	-	2007	Ending year
IEMO	-	1	Ending month
IEDY	-	1	Ending day
IEHR	-	0	Ending hour
ABTZ		UTC-0700	Base time zone (7 = MST)
NSPEC	5	15	Number of chemical species
NSE	3	12	Number of chemical species to be emitted
ITEST	2	2	Program is executed after SETUP phase
MRESTART	0	0	Do not read or write a restart file during run
NRESPD	0	24	File updated every 24 periods
METFM	1	1	CALMET binary file (CALMET.MET)
AVET	60	60	Averaging time in minutes
PGTIME	60	60	PG Averaging time in minutes
IOUTU	1	1	Output units for binary concentration and flux files written in Dataset v2.2 or later formats. 1 = mass - g/m^3 (concentration) or g/m^2/s (deposition)

Input Group 2: Technical Options

Parameter	Default	Project	Comments
MGAUSS	1	1	Gaussian distribution used in near field
MCTADJ	3	3	Partial plume path terrain adjustment
MCTSG	0	0	Scale-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

Table 3C-12 CALPUFF Model Options Groups 1 and 2

Input Group 2: Technical Options (cont'd)

Parameter	Default	Project	Comments
MRISE	1	1	Method used to compute plume rise for point sources not subject to building downwash 1 = Briggs plume rise
MTIP_FL	0	0	No stack-tip downwash for flare sources
MRISE_FL	2	2	Plume rise module for flare sources; 2=Numerical plume rise
MBDW	1	2	PRIME Method is used to simulate building downwash as per the AQMG
MSHEAR	0	0	Vertical wind shear is not modelled as per the AQMG
MSPLIT	0	0	Puff splitting not used as per the AQMG
MCHEM	3	3	Transformation rates computed internally using (RIVID/ARM3) scheme as per the AQMG
MAQCHEM	0	0	Aqueous phase transformation not modelled
MLWC	1	1	Liquid Water Content flag (Used only if MAQCHEM = 1)
MWET	1	1	Wet removal modelled
MDRY	1	1	Dry deposition modelled
MTILT	**0**	**1**	**Gravitational settling (plume tilt) modelled for fugitive dust**
MDISP	3	2	Dispersion coefficients from internally calculated sigma v, sigma w using micrometeorological variables (u*, w*, L, etc.) as per the AQMG
MTURBVW	3	3	Use both σ_v and σ_w from PROFILE.DAT to compute σ_y and σ_z (n/a)
MDISP2	3	3	PG dispersion coefficients for rural areas (computed using ISCST3 approximation) and MP coefficients in urban areas when measured turbulence data is missing
MTAULY	0	0	Draxler default 617.284 (s)
MTAUADV	0	0	No turbulence advection
MCTURB	1	1	Standard CALPUFF subroutines
MROUGH	0	0	PG σ_y and σ_z is not adjusted for roughness
MPARTL	1	1	Partial plume penetration of elevated inversion
MPARTLBA	1	1	Partial plume penetration of elevated inversion modelled for the buoyant area sources as per the AQMG
MTINV	0	0	Strength of temperature inversion computed from default gradients
MPDF	0	1	The probability density function (PDF) to be used for dispersion under convective conditions as per the AQMG

Table 3C-12 CALPUFF Model Options Groups 1 and 2

Input Group 2: Technical Options (cont'd)

Parameter	Default	Project	Comments
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 regulatory values as per the AQMG

Table 3C-13 CALPUFF Model Options Groups 3 and 4

Input Group 3: Species List-Chemistry Options

CSPEC	Modelled[1]	Emitted[2]	Dry Deposition[3]	Output Group Number
SO_2	1	1	1	0
SO_4^{2-}	1	0	2	0
NO	1	1	1	0
NO_2	1	1	1	0
HNO_3	1	0	1	0
NO_3^-	1	0	2	0
NO_X	1	1	0	0
CO	1	1	0	0
VOC	1	1	0	0
$PM_{2.5}$ (Combustion product)	1	1	2	0
$PM_{2.5}$ to PM_{10} range (Combustion product)	1	1	2	0
PM_{10} to TSP (Combustion product)	1	1	2	0
$PM_{2.5}$ (Fugitive dust)	1	1	2	0
$PM_{2.5}$ to PM_{10} range (Fugitive dust)	1	1	2	0
PM_{10} to TSP (Fugitive dust)	1	1	2	0

NOTES:
[1] 0=no, 1=yes
[2] 0=no, 1=yes
[3] 0=none, 1=computed-gas, 2=computed particle, 3=user-specified

Input Group 4: Map Projection and Grid Control Parameters

Parameter	Default	Project	Comments
PMAP	UTM	UTM	Universal Transverse Mercator
FEAST	0	0	False Easting (km) at the projection origin
FNORTH	0	0	False Northing (km) at the projection origin
IUTMZN	-	11	UTM zone
UTMHEM	N	N	Northern Hemisphere for UTM projection
DATUM	WGS-84	NAR-C	NAR-C is applicable for this assessment. WGS-84 is just the datum for TRC demo case along with the CALPUFF release.

Table 3C-13 CALPUFF Model Options Groups 3 and 4

Input Group 4: Map Projection and Grid Control Parameters (cont'd)

Parameter	Default	Project	Comments
NX	-	80	Number of X grid cells in meteorological grid
NY		80	Number of Y grid cells in meteorological grid
NZ	No default	12	Vertical grid definition: Number of vertical layers as per the AEP Model Guideline.
DGRIDKM	-	0.5	Grid spacing (km) to match CALMET (see Appendix C)
ZFACE	No default	0, 20, 40, 80, 120, 280, 520, 880, 1320, 1820, 3000 and 4000	Vertical grid definition: Cell face heights (m) as per the ESRD Model Guideline.
XORIGKM	-	659.5	Reference X coordinate for SW corner of grid cell (1,1) of meteorological grid (km)
YORIGKM	-	5639	Reference Y coordinate for SW corner of grid cell (1,1) of meteorological grid (km)
IBCOMP	-	1	X index of lower left corner of the computational grid
JBCOMP	-	1	Y index of lower left corner of the computational grids
IECOMP	-	80	X index of the upper right corner of the computational grid
JECOMP	-	80	Y index of the upper right corner of the computational grid
LSAMP	T	F	Sampling grid is not used
IBSAMP	-	1	X index of lower left corner of the sampling grid
JBSAMP	-	1	Y index of lower left corner of the sampling grid
IESAMP	-	80	X index of upper right corner of the sampling grid
JESAMP	-	80	Y index of upper right corner of the sampling grid
MESHDN	1	1	Nesting factor of the sampling grid

Table 3C-14 CALPUFF Model Option Group 5

Input Group 5: Output Option

Parameter	Default	Project	Comments
ICON	1	1	Output file CONC.DAT containing concentrations is created
IDRY	1	1	Output file DFLX.DAT containing dry fluxes is created
IWET	1	1	Output file WFLX.DAT containing wet fluxes is created
IT2D	0	0	2D Temperature
IRHO	0	0	Density
IVIS	1	0	Output file containing relative humidity data is not created
LCOMPRS	T	T	Do not perform data compression in output file
IQAPLOT	1	1	Create a standard series of output files (e.g., locations of sources, receptors, grids ...) suitable for plotting
IMFLX	0	0	Do not calculate mass fluxes across specific boundaries
IPFTRAK	0	0	Puff locations and properties reported to PFTRAK.DAT file for postprocessing
IMBAL	0	0	Mass balances for each species are not reported hourly
ICPRT	0	0	Do not print concentration fields to the output list file
IDPRT	0	0	Do not print dry flux fields to the output list file
IWPRT	0	0	Do not print wet flux fields to the output list file
ICFRQ	1	24	Concentration fields are printed to output list file every 24-hour
IDFRQ	1	24	Dry flux fields are printed to output list file every 24-hour
IWFRQ	1	24	Wet flux fields are printed to output list file every 24-hour
IPRTU	1	3	Units for line printer output are in µg/m^3 for concentration and µg/m^2/s for deposition
IMESG	2	2	Messages tracking the progress of run are written on screen
LDEBUG	F	F	Logical value for debug output
IPFDEB	1	1	First puff to track
NPFDEB	1	1	Number of puffs to track
NN1	1	1	Meteorological period to start output
NN2	10	10	Meteorological period to end output

Table 3C-14 CALPUFF Model Option Group 5

Input Group 5: Output Option (cont'd)

Species	Concentrations Printed (0= no, 1 = yes)		Dry Fluxes Printed (0 = no, 1 = yes)		Wet Fluxes Printed (0 = no, 1 = yes)		Mass Flux	
	Printed	Saved to Disk	Printed	Saved to Disk	Printed	Saved to Disk	Printed	Saved to Disk
SO_2	0	1	0	1	0	1	0	1
SO_4^{2-}	0	1	0	1	0	1	0	1
NO	0	1	0	1	0	1	0	1
NO_2	0	1	0	1	0	1	0	1
HNO_3	0	1	0	1	0	1	0	1
NO_3^-	0	1	0	1	0	1	0	1
NO_X	0	1	0	1	0	1	0	1
CO	0	1	0	1	0	1	0	1
VOC	0	1	0	1	0	1	0	1
$PM_{2.5}$ (Combustion product)	0	1	0	1	0	1	0	1
$PM_{2.5}$ to PM_{10} range (Combustion product)	0	1	0	1	0	1	0	1
PM_{10} to TSP (Combustion product)	0	1	0	1	0	1	0	1
$PM_{2.5}$ (Fugitive dust)	0	1	0	1	0	1	0	1
$PM_{2.5}$ to PM_{10} range (Fugitive dust)	0	1	0	1	0	1	0	1
PM_{10} to TSP (Fugitive dust)	0	1	0	1	0	1	0	1

Table 3C-15 CALPUFF Model Option Groups 6 and 7

Input Group 6: Sub-Grid Scale Complex Terrain Inputs

Parameter	Default	Project	Comments
NHILL	0	0	Number of terrain features
NCTREC	0	0	Number of special complex terrain receptors
MHILL	-	2	Hill data created by OPTHILL & input below in Subgroup (6b); Receptor data in Subgroup (6c)
XHILL2M	1	1	Conversion factor for changing horizontal dimensions to metres
ZHILL2M	1	1	Conversion factor for changing vertical dimensions to metres
XCTDMKM	-	0	X origin of CTDM system relative to CALPUFF coordinate system (km)
YCTDMKM	-	0	Y origin of CTDM system relative to CALPUFF coordinate system (km)

Input Group 7: Dry Deposition Parameters for Gases

Species	Default	Project	Comments
SO_2	0.1509	0.1509	Diffusivity
	1000	1000	Alpha star
	8.0	8.0	Reactivity
	0.0	0.0	Mesophyll resistance
	0.4	0.4	Henry’s Law coefficient
NO	0.1345	0.1345	Diffusivity
	1.0	1.0	Alpha star
	2.0	2.0	Reactivity
	25	25	Mesophyll resistance
	18	18	Henry’s Law coefficient
NO_2	0.1656	0.1656	Diffusivity
	1.0	1.0	Alpha star
	8.0	8.0	Reactivity
	5.0	5.0	Mesophyll resistance
	3.5	3.5	Henry’s Law coefficient
HNO_3	0.1628	0.1628	Diffusivity
	1.0	1.0	Alpha star
	18.0	18.0	Reactivity
	0.0	0.0	Mesophyll resistance
	0.0000001	0.0000001	Henry’s Law coefficient

Table 3C-16 CALPUFF Model Option Groups 8, 9, 10, and 11

Input Group 8: Dry Deposition Parameters for Particles

Species	Default	Project	Comments
SO_4^{2-}	0.48	0.48	Geometric mass mean diameter of SO_4^{2-} [µm]
SO_4^{2-}	2.0	2.0	Geometric standard deviation of SO_4^{2-} [µm]
NO_3^-	0.48	0.48	Geometric mass mean diameter of NO_3^- [µm]
NO_3^-	2.0	2.0	Geometric standard deviation of NO_3^- [µm]
$PM_{2.5}$ (Combustion product)	-	1.6	Geometric mass mean diameter of PM [µm]
$PM_{2.5}$ (Combustion product)	-	0.0	Geometric standard deviation of PM [µm]
$PM_{2.5}$ to PM_{10} range (Combustion product)	-	6.9	Geometric mass mean diameter of PM [µm]
$PM_{2.5}$ to PM_{10} range (Combustion product)	-	0.0	Geometric standard deviation of PM [µm]
PM_{10} to TSP (Combustion product)	-	21.5	Geometric mass mean diameter of PM [µm]
PM_{10} to TSP (Combustion product)	-	0.0	Geometric standard deviation of PM [µm]
$PM_{2.5}$ (Fugitive dust)	-	1.6	Geometric mass mean diameter of PM [µm]
$PM_{2.5}$ (Fugitive dust)	-	0.0	Geometric standard deviation of PM [µm]
$PM_{2.5}$ to PM_{10} range (Fugitive dust)	-	6.9	Geometric mass mean diameter of PM [µm]
$PM_{2.5}$ to PM_{10} range (Fugitive dust)	-	0.0	Geometric standard deviation of PM [µm]
PM_{10} to TSP (Fugitive dust)	-	21.5	Geometric mass mean diameter of PM [µm]
PM_{10} to TSP (Fugitive dust)	-	0.0	Geometric standard deviation of PM [µm]
NOTES: Geometric mass mean diameter and geometric standard deviation pf different size fractions are derived from USEPA (2005b)			

Table 3C-16 CALPUFF Model Option Groups 8, 9, 10, and 11

Input Group 9: Miscellaneous Dry Deposition Parameters

Parameters	Default	Project	Comments
RCUTR	30	30	Reference cuticle resistance (s/cm)
RGR	10	10	Reference ground resistance (s/cm)
REACTR	8	8	Reference pollutant reactivity
NINT	9	9	Number of particle size intervals for effective particle deposition velocity
IVEG	1	1	Vegetation in non-irrigated areas is active and unstressed

Input Group 10: Wet Deposition Parameters

Species	Default	Project	Comments
SO_2	3.0E-05	3.0E-05	Scavenging coefficient for liquid precipitation [s^{-1}]
	0.0	0.0	Scavenging coefficient for frozen precipitation [s^{-1}]
SO_4^{2-}	1.0E-04	1.0E-04	Scavenging coefficient for liquid precipitation [s^{-1}]
	3.0E-05	3.0E-05	Scavenging coefficient for frozen precipitation [s^{-1}]
NO	-	2.9E-05	Scavenging coefficient for liquid precipitation [s^{-1}]
	-	0.0	Scavenging coefficient for frozen precipitation [s^{-1}]
NO_2	-	5.1E-05	Scavenging coefficient for liquid precipitation [s^{-1}]
	-	0.0	Scavenging coefficient for frozen precipitation [s^{-1}]
HNO_3	6.0E-05	6.0E-05	Scavenging coefficient for liquid precipitation [s^{-1}]
	0.0	0.0	Scavenging coefficient for frozen precipitation [s^{-1}]
NO_3^-	1.0E-04	1.0E-04	Scavenging coefficient for liquid precipitation [s^{-1}]
	0.00003	0.00003	Scavenging coefficient for frozen precipitation [s^{-1}]
$PM_{2.5}$ (Combustion product)	-	6.0E-05	Scavenging coefficient for liquid precipitation [s^{-1}]
	-	2.0E-05	Scavenging coefficient for frozen precipitation [s^{-1}]
$PM_{2.5}$ to PM_{10} range (Combustion product)	-	4.2E-04	Scavenging coefficient for liquid precipitation [s^{-1}]
	-	1.4E-04	Scavenging coefficient for frozen precipitation [s^{-1}]
PM_{10} to TSP (Combustion product)	-	6.6E-04	Scavenging coefficient for liquid precipitation [s^{-1}]
	-	2.2E-04	Scavenging coefficient for frozen precipitation [s^{-1}]
$PM_{2.5}$ (Fugitive dust)	-	6.0E-05	Scavenging coefficient for liquid precipitation [s^{-1}]
	-	2.0E-05	Scavenging coefficient for frozen precipitation [s^{-1}]
$PM_{2.5}$ to PM_{10} range (Fugitive dust)	-	4.2E-04	Scavenging coefficient for liquid precipitation [s^{-1}]
	-	1.4E-04	Scavenging coefficient for frozen precipitation [s^{-1}]

Table 3C-16 CALPUFF Model Option Groups 8, 9, 10, and 11

Input Group 10: Wet Deposition Parameters (cont'd)

Species	Default	Project	Comments
PM_{10} to TSP (Fugitive dust)	-	6.6E-04	Scavenging coefficient for liquid precipitation [s^{-1}]
	-	2.2E-04	Scavenging coefficient for frozen precipitation [s^{-1}]

NOTES:
NO and NO_2 scavenging coefficients are from RWDI (2005)
PM size fractions scavenging coefficients are from USEPA (1995)

Input Group 11: Chemistry Parameters

Parameters	Default	Project	Comments
MOZ	1	1	Rural hourly ozone values based on the Appendix E in the ESRD AQMG (ESRD 2013a)
BCKO3	12*80	Not used	Background ozone concentration (ppb)
MNH3	0	0	Ammonia data option (Used only if MCHEM = 6 or 7)
MAVGNH3	1	0	Use ammonia at puff centre height (Used only if MCHEM = 6 or 7, and MNH3 = 1)
BCKNH3	12*10	6.11, 5.27, 3.98, 5.67, 8.12, 6.34, 7.76, 8.29, 4.88, 5.80, 4.59, 11.93	Background ammonia concentration (ppb) (Based on measurements at Lethbridge monitoring station)
RNITE1	0.2	0.2	Night-time NO_2 loss rate in percent/hour
RNITE2	2	2	Night-time NO_X loss rate in percent/hour
RNITE3	2	2	Night-time HNO_3 loss rate in percent/hour
MH202	1	1	H_2O_2 data input option
BCKH202	12*1	12*1	Monthly background H_2O_2 concentrations (Aqueous phase transformations not modelled)
RH_ISRP	50	50	Minimum relative humidity used in ISORRPOIA computations (Used only if MCHEM = 6 or7)
SO4_ISRP	0.4	0.4	Minimum SO_4 used in ISORRPOIA computations (Used only if MCHEM = 6 or7)
BCKPMF	-	Not used	Fine particulate concentration for Secondary Organic Aerosol Option
OFRAC	-	Not used	Organic fraction of fine particulate for SOA Option
VCNX	-	Not used	VOC/NO_X ratio for SOA Option

Table 3C-17 CALPUFF Model Option Group 12

Input Group 12: Diffusion/Computational Parameters

Parameters	Default	Project	Comments
SYTDEP	550	550	Horizontal size of a puff in metres beyond which the time dependant dispersion equation of Heffter (1965) is used
MHFTSZ	0	0	Do not use Heffter formulas for sigma z
JSUP	5	5	Stability class used to determine dispersion rates for puffs above boundary layer
CONK1	0.01	0.01	Vertical dispersion constant for stable conditions
CONK2	0.1	0.1	Vertical dispersion constant for neutral/stable conditions
TBD	0.5	0.5	Use ISC transition point for determining the transition point between the Schulman-Scire (Schulman et al., 1998) to Huber-Snyder Building Downwash scheme
ISIGMAV	1	1	Sigma-v is read for lateral turbulence data
IMIXCTDM	0	0	Predicted mixing heights are used
XMXLEN	1	1	Maximum length of emitted slug in meteorological grid units
XSAMLEN	1	1	Maximum travel distance of slug or puff in meteorological grid units during one sampling unit
MXNEW	99	99	Maximum number of puffs or slugs released from one source during one time step
MXSAM	99	99	Maximum number of sampling steps during one time step for a puff or slug
NCOUNT	2	2	Number of iterations used when computing the transport wind for a sampling step that includes transitional plume rise
SYMIN	1	1	Minimum sigma y in metres for a new puff or slug
SZMIN	1	1	Minimum sigma z in metres for a new puff or slug
SZCAP_M	5.0E06	5.0E06	Maximum sigma z in metres to avoid numerical problem in calculating time or distance

Stability Class	Parameter			
	SVMIN		SWMIN	
	Minimum turbulence (σ_v) (m/s)		Minimum turbulence (σ_v) (m/s)	
	Land	Water	Land	Water
A	0.5	0.37	0.2	0.2
B	0.5	0.37	0.12	0.12
C	0.5	0.37	0.08	0.08
D	0.5	0.37	0.06	0.06
E	0.5	0.37	0.03	0.03
F	0.5	0.37	0.016	0.016

Table 3C-17 CALPUFF Model Option Group 12

Input Group 12: Diffusion/Computational Parameters

<table>
<tr><th>Parameters</th><th>Default</th><th>Project</th><th colspan="2">Comments</th></tr>
<tr><td>CDIV</td><td>0.0, 0.0</td><td>0.0, 0.0</td><td colspan="2">Divergence criteria for dw/dz in met cells</td></tr>
<tr><td>NLUTBIL</td><td>4</td><td>4</td><td colspan="2">Search radius for nearest land and water cells used in the subgrid TIBL module</td></tr>
<tr><td>WSCALM</td><td>0.5</td><td>0.5</td><td colspan="2">Minimum wind speed allowed for non-calm conditions (m/s)</td></tr>
<tr><td>XMAXZI</td><td>3000</td><td>3000</td><td colspan="2">Maximum mixing height in metres</td></tr>
<tr><td>XMINZI</td><td>50</td><td>50</td><td colspan="2">Minimum mixing height in metres</td></tr>
<tr><td rowspan="11">TKCAT</td><td>265</td><td>265</td><td>Temperature class 1</td><td rowspan="11">Temperatures (K) used for defining upper bound of categories for emissions scale-factors; 11 upper bounds (K) are entered; the 12th class has no upper</td></tr>
<tr><td>270</td><td>270</td><td>Temperature class 2</td></tr>
<tr><td>275</td><td>275</td><td>Temperature class 3</td></tr>
<tr><td>280</td><td>280</td><td>Temperature class 4</td></tr>
<tr><td>285</td><td>285</td><td>Temperature class 5</td></tr>
<tr><td>290</td><td>290</td><td>Temperature class 6</td></tr>
<tr><td>295</td><td>295</td><td>Temperature class 7</td></tr>
<tr><td>300</td><td>300</td><td>Temperature class 8</td></tr>
<tr><td>305</td><td>305</td><td>Temperature class 9</td></tr>
<tr><td>310</td><td>310</td><td>Temperature class 10</td></tr>
<tr><td>315</td><td>315</td><td>Temperature class 11</td></tr>
<tr><td rowspan="5">WSCAT</td><td>1.54</td><td>1.54</td><td colspan="2">wind speed category 1 [m/s]</td></tr>
<tr><td>3.09</td><td>3.09</td><td colspan="2">wind speed category 2 [m/s]</td></tr>
<tr><td>5.14</td><td>5.14</td><td colspan="2">wind speed category 3 [m/s]</td></tr>
<tr><td>8.23</td><td>8.23</td><td colspan="2">wind speed category 4 [m/s]</td></tr>
<tr><td>10.80</td><td>10.80</td><td colspan="2">wind speed category 5 [m/s]</td></tr>
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<table>
<tr><th rowspan="3">Stability Class</th><th colspan="2">Parameter</th></tr>
<tr><th>PLX0</th><th>PPC (see text)</th></tr>
<tr><th>Wind speed profile exponent</th><th>Plume path coefficient</th></tr>
<tr><td>A</td><td>0.07</td><td>0.5</td></tr>
<tr><td>B</td><td>0.07</td><td>0.5</td></tr>
<tr><td>C</td><td>0.10</td><td>0.5</td></tr>
<tr><td>D</td><td>0.15</td><td>0.5</td></tr>
<tr><td>E</td><td>0.35</td><td>0.35</td></tr>
<tr><td>F</td><td>0.55</td><td>0.35</td></tr>
</table>

Table 3C-17 CALPUFF Model Option Group 12

Input Group 12: Diffusion/Computational Parameters (cont'd)

Parameters	Default	Project	Comments
PTG0	0.020	0.020	Potential temperature gradient for E stability [K/m]
	0.035	0.035	Potential temperature gradient for F stability [K/m]
SL2PF	10	10	Slug-to-puff transition criterion factor equal to sigma y/length of slug
FCLIP	0.0	0.0	No extrapolation of receptor-specific puff/slug properties
NSPLIT	3	Not used	Number of puffs that result every time a puff is split
IRESPLIT	0,0,0,0,0,0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0	0,0,0,0,0,0,0,0,0,0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0	Time(s) of day when split puffs are eligible to be split once again
ZISPLIT	100	100	Minimum allowable last hour's mixing height for puff splitting
ROLDMAX	0.25	0.25	Maximum allowable ratio of last hour's mixing height and maximum mixing height experienced by the puff for puff splitting
NSPLITH	5	5	Number of puffs that result every time a puff is horizontally split
SYSPLITH	1	1	Minimum sigma-y of puff before it may be horizontally split
SHSPLITH	2	2	Minimum puff elongation rate due to wind shear before it may be horizontally split
CNSPLITH	1.0E-7	1.0E-7	Minimum concentration of each species in puff before it may be horizontally split
EPSSLUG	1.00E-04	1.00E-04	Fractional convergence criterion for numerical SLUG sampling iteration
EPSAREA	1.00E-06	1.00E-06	Fractional convergence criterion for numerical AREA sampling iteration
DRISE	1.0	1.0	Trajectory step length for numerical rise
HTMINBC	500	500	Minimum height (m) to which boundary condition puffs are mixed as they are emitted (MBCON=2 ONLY)
RSAMPBC	10	10	Search radius (km) about a receptor for sampling nearest boundary condition puff.
MDEPBC	1	Not used	Concentration is NOT adjusted for depletion

Table 3C-18 CALPUFF Model Option Groups 13, 14, and 15

Input Group 13: Point Source Parameters

Parameters	Default	Project	Comments
NPT1	-	Varies by scenario	Number of point sources with constant stack parameters or variable emission rate scale factors
IPTU	1	1	Units for point source emission rates are g/s
NSPT1	0	0	Number of source-species combinations with variable emissions scaling factors
NPT2	-	0	Number of point sources with variable emission parameters provided in external file
NOTES: Point source parameters are given in Attachment 3A.			

Input Group 14: Area Source Parameters

Parameters	Default	Project	Comments
NAR1	-	Varies by scenario	Number of polygon area sources
IARU	1	1	Units for area source emission rates are g/m^2/s
NSAR1	0	Varies by scenario	Number of source species combinations with variable emissions scaling factors
NAR2	-	0	Number of buoyant polygon area sources with variable location and emission parameters
NOTES: Area source parameters are given in Attachment 3A.			

Table 3C-18 CALPUFF Model Option Groups 13, 14, and 15

Input Group 15: Line Source Parameters

Parameters	Default	Project	Comments
NLN2	-	0	No line sources modelled
NLINES	-	0	Number of buoyant line sources
ILNU	1	1	Units for line source emission rates is g/s
NSLN1	0	0	Number of source-species combinations with variable emissions scaling factors
MXNSEG	7	7	Maximum number of segments used to model each line
NLRISE	6	6	Number of distance at which transitional rise is computed
XL	-	0.1	Average line source length (m)
HBL	-	0.1	Average height of line source height (m)
WBL	-	0.1	Average building width (m)
WML	-	25	Average line source width (m)
DXL	-	0.1	Average separation between buildings (m)
FPRIMEL	-	50	Average buoyancy parameter (m^4/s^3)

Table 3C-19 CALPUFF Model Option Groups 16, 17, 18, 19 and 20

Input Group 16: Volume Source Parameters

Parameter	Default	Project	Comments
NVL1	-	Varies by scenario	Number of volume sources
IVLU	1	1	Units for volume source emission rates is grams per second
NSVL1	0	Varies by scenario	Number of source-species combinations with variable emissions scaling factors
NVL2	0	0	No volume source with variable location and emissions
NOTE: Volume source parameters are given in Attachment 3A.			

Input Group 17: Flare Source Parameters

Parameter	Default	Project	Comments
NFL2	-	0	Number of flare sources defined in FLEMARB.DAT

Input Group 18: Road Source Parameters

Parameter	Default	Project	Comments
NRD1	-	0	Number of road sources
NRD2	-	0	Number of road-links with arbitrarily time-varying emission parameters
NSFRDS	0	Varies by scenario	Number of road links and species combinations with variable emission-rate scale-factors

Input Group 19: Emission Rate Scale-factor Tables

Parameter	Default	Project	Comments
NSFTAB	-	Varies by scenario	Number of emission scale-factors

Input Group 20: Discrete Receptor Information

Parameter	Default	Project	Comments
NREC	-	-	See Section 3C.3.2.
NOTE: Receptors are shown on Figures 3C-1 and 3C-2			

3C.6 REFERENCES

3C.6.1 Literature Cited

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3C.6.2 Personal Communications

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Attachment 3D BACKGROUND AMBIENT AIR QUALITY

Table of Contents

LIST OF PHOTOS

Abbreviations

AAAQG	Alberta Ambient Air Quality Guideline
AAAQO	Alberta Ambient Air Quality Objective
ADRP	Acid Deposition Research Project
AESRD	Alberta Environment and Sustainable Resource Development
AQMG	Alberta Air Quality Model Guideline
CAAQS	Canada Ambient Air Quality Standard
CAC	criteria air contaminants
CCME	Canadian Council for Ministers of the Environment
CDI	Cobalt Development Institute
CEAA	Canadian Environmental Assessment Agency
CO	carbon monoxide
COP	Canada Olympic Park
DIW	deionized water
EBAM	Environmental Beta Attenuation Monitor
LAA	local assessment area
MDL	minimum detection limits
NAPS	National Air Pollution Surveillance
NO_2	nitrogen dioxide
PAH	polycyclic aromatic hydrocarbons

PDA	project development area
PM	particulate matter
$PM_{2.5}$	particulate matter with an aerodynamic diameter of less than 2.5 micrometres
SO_2	sulphur dioxide
the Project	Springbank Off-stream Reservoir Project
TSP	total suspended particulate
VOC	volatile organic compounds
WISSA	Western Interprovincial Scientific Studies Association

3D.1 INTRODUCTION

This attachment provides background ambient air quality values to support the environmental assessment for the Springbank Off-stream Reservoir Project (the Project). Specifically, the attachment:

- identifies desktop and field methods used to determine the background ambient air quality
- compares the background ambient air quality values to their respective ambient air quality criteria

Background ambient air quality is defined for the substances of interest that are listed in the February 2015 Alberta Environment and Sustainable Resource Development (AESRD) Terms of Reference (AESRD 2015) and the August 2016 Canadian Environmental Assessment Agency (CEAA) Final Guidelines (CEAA 2016).

3D.2 METHODS

Background air quality represents contributions from natural sources and from nearby and distant anthropogenic (industry and non-industry) sources. For the project assessment, nearby industry and the main non-industry sources are explicitly included in the Base Case CALPUFF simulation model (see Attachment 3A). Natural and distant anthropogenic sources are grouped together because it is often difficult to distinguish between their respective contributions. The Alberta Air Quality Model Guideline (AESRD 2013) provides guidance for determining background levels:

- Nearby industry background contributions can be determined by including these sources explicitly in the simulation models. While the model guideline indicates a need to include sources within 5 km of the Project, this assessment considers emission sources in the larger 20 by 20 km local assessment area (LAA).
- Background 1-hour concentration contributions can be determined from representative ambient monitoring by using the 90th percentile for refined assessments. The 90th percentile value is obtained from hourly continuous monitoring data that excludes blank values. At least one year of representative monitoring data are required. The air quality assessment is considered a refined assessment.
- Background 24-hour and annual concentrations contributions can be determined from representative ambient monitoring by extracting maximum values for the respective averaging periods using a reduced dataset. The reduced dataset is obtained by excluding blank values and values greater than the 90th percentile. At least one year of representative monitoring data are required.

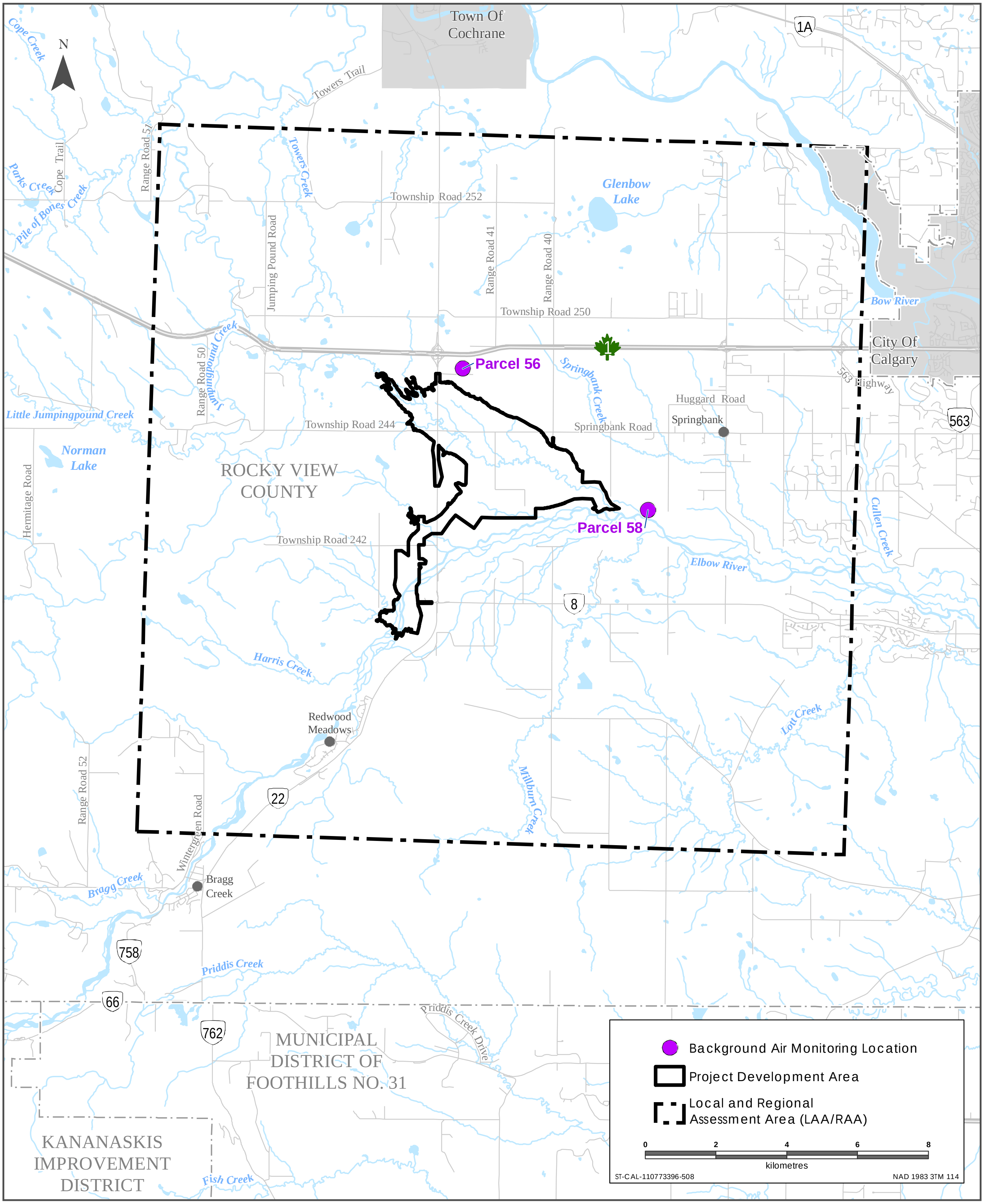
Background concentrations are calculated according to Alberta Air Quality Model Guideline (AQMG) guidance and represent the contributions from emissions not included in the modelling (i.e., emissions from sources located outside the LAA, smaller sources inside the LAA, and natural sources).

The methods to determine of background ambient air quality values using local measurements and other measurements are presented below.

3D.2.1 Local Measurements

Due to the proximity of farms and/or ranch yards to the Project, a background air quality monitoring program was conducted for particulate matter with an aerodynamic diameter of less than 2.5 micrometres ($PM_{2.5}$), total suspended particulate (TSP) and dustfall. The program was conducted from August 2, 2016 to October 13, 2016 at two monitoring stations. The summer period was selected to coincide with expected worst-case conditions for the generation of particulate matter (PM) emissions in rural farm areas due to the exposed surfaces and dry meteorological conditions. Figure 3D-1 shows the location of the two monitoring stations (Parcel 56 and Parcel 58). The following field activities were completed:

- continuous monitoring for background $PM_{2.5}$.
- continuous monitoring for background TSP which includes particles up to 30 µm in aerodynamic diameter.
- passive (monthly) monitoring for background dustfall (including total metals).



Sources: Base Data - ESRI, Government of Alberta, Government of Canada
Thematic Data - ERBC, Government of Alberta, Stantec Ltd

Background Ambient Air Quality Monitoring Locations

Stantec

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Figure 3D-1

3D.2.1.1 Site Selection

The transport and dispersion of TSP and $PM_{2.5}$ depends on the prevailing wind direction and wind speed. The background TSP and $PM_{2.5}$ monitoring locations are based on the measured wind speed and direction data from the nearest meteorological monitoring station, the Springbank Airport. The Springbank Airport is located approximately 5.2 km northeast of the project development area (PDA). The predominant summer (e.g., August and September) wind direction is from the northwest.

Parcel 56 is upwind of the Project PDA, and Parcel 58 is downwind of the Project PDA. These locations considered the siting guidelines given in the Alberta Air Monitoring Directive (AEP 2016a), and the rural siting guidelines in the Ambient Air Quality Monitoring Protocol for $PM_{2.5}$ and Ozone Canada-wide Standards for Particulate Matter and Ozone from the Canadian Council for Ministers of the Environment (CCME) (CCME 2011). Along with addressing overall monitoring objectives, the rural site selection process also considered the following practical factors: reliable electric power source, accessibility, security from unauthorized access and vandalism, specifications for the sampling shelters, and possible interference from local sources of air emissions.

The weight and dimensions of ambient air quality monitoring equipment necessitated monitoring sites that were accessible by vehicle, and suitable locations were found on open and on dry ground. The Parcel 56 monitoring station was located approximately 380 m south of Highway 1 (i.e., the TransCanada Highway). There was a hay field between the Parcel 56 monitoring station and Highway 1. The unpaved road leading to Parcel 56 (from paved Highway 22) terminates in a dead end and is only used by three farm properties. Hence, the unpaved road is not used frequently and likely not a large source of PM emissions. The TSP emissions from infrequent activity at the hay field and traffic along Highway 1, both located north of the monitoring station, are included in the background concentrations.

There are no continuous sources of PM emissions near the Parcel 58 monitoring station. The properties north, south, east, and west of Parcel 58 are grass fields used for cattle grazing. There were no cattle grazing on these lands during the August to October monitoring period. The background air quality monitoring equipment was placed:

- a suitable distance from the surrounding trees (i.e., greater than 20 m)
- a suitable distance from air flow obstacles such as buildings (i.e., greater than 2 x height of obstacle above the sampler)
- unrestricted air flow in three of the four wind quadrants
- no nearby furnace or incinerator flues, and a minimum of 25 m from roads

3D.2.1.2 TSP and $PM_{2.5}$ Instrumentation

Ambient TSP and $PM_{2.5}$ concentrations were measured using EBAM beta-attenuation monitors. One EBAM monitor was installed at Parcel 56 on August 2, 2016, with a size selective inlet for TSP. The other EBAM monitor was installed at Parcel 58 on August 3, 2016 with a size selective inlet for $PM_{2.5}$ (Photo 3D-1 and Photo 3D-2). The size selective inlets were swapped on September 16, 2016.

The EBAM monitor draws ambient air through a glass fiber filter tape; PM present in the ambient air is deposited onto the filter tape. The design of the "size selective" inlet allows PM of the appropriate size range (TSP or $PM_{2.5}$) to pass through the unit, while removing larger particles. The loaded filter tape is then passed between a beta radiation source and detector. Beta particles (electrons) pass through the tape, but some are impeded (attenuated) by the accumulated PM. With proper calibration, the difference between a measured beta count value and the previous value is used to calculate the mass of PM accumulated on the tape during the sampling interval. The mass of collected PM and the flow rate are used to calculate the PM concentration in the sampled ambient air.

The EBAMs were installed on tripod mounts in secure, all-weather enclosures. The units require a continuous power supply, which was provided by extension cords running from the nearest farm building. The EBAMs sample inlet was at least 2 m above ground. The EBAMs were calibrated (Photo 3D-3) following the manufacturer's recommendations. The EBAM calibration records are presented in Section 3D.5. The EBAMs were calibrated using a StreamLine Pro™ MultiCal™ System and its certificate of calibration is presented in Section 3D.6. The EBAM site documentation forms are presented in Section 3D.7.

EBAM data were collected automatically at ten-minute intervals, with hourly and daily averages calculated. The EBAM monitors also recorded other supporting data such as ambient air temperature, along with diagnostic data that includes battery voltages and flow rates, which help determine the quality of the data. Photo 3D-4 shows a TSP deposit on the EBAM filter tape. The EBAMs automatically advance the filter tape once every 24-hours. Photo 3D-5 shows the EBAM monitor data being downloaded to a laptop computer.

During the background monitoring program, technical issues with the power and operation of the EBAM monitors were encountered. The EBAM monitor that was installed at Parcel 58 on August 3, 2016 to record ambient $PM_{2.5}$ concentrations encountered a mother board failure. A repaired EBAM monitor was installed at Parcel 58 on August 15, 2016 and the first complete day of $PM_{2.5}$ monitoring was August 16, 2016. The EBAM monitor that was installed at Parcel 56 to monitor background ambient TSP concentrations experienced a pump failure on August 16, 2016. A new pump was installed in the EBAM on September 16, 2016 and the size selective inlet was changed from TSP to $PM_{2.5}$. The first complete day of $PM_{2.5}$ monitoring at Parcel 56 was September 17, 2016.

3D.2.1.3 Dustfall Monitoring

Dustfall monitoring is a passive method for sampling particulate deposition, using a sample container to collect airborne particles settling from the air column over a 30-day period. The dustfall sample containers supplied by the analytical laboratory contained deionized water (DIW) with a small amount of algaecide. The DIW ensures that the dustfall collected in the container does not get lost due to wind erosion and the algaecide prevented the buildup of algae that could potentially bias the data. The method for background dustfall monitoring followed the “Standard Test Method for Collection and Measurement of Dustfall – Settleable Particulate Matter” (ASTM 2010). The dustfall containers were sent to an analytical laboratory for analysis of total dustfall. At each monitoring station (Parcel 56 and Parcel 58), a second set of dustfall containers was installed, collected, and analyzed for total metals, to provide information on the chemical composition of the dustfall PM. The dustfall analytical reports are provided in Section 3D.8.

Each dustfall site consisted of two anchored wooden poles, topped with a plastic wind screen where the dustfall containers were placed. Bird-deterrent spikes were attached to the wind screen to deter birds from landing near the collection jar and fouling the samples. Photo 3D-6 shows the dustfall collector wind screen, bird spikes and sample container. Approximately every thirty days, Stantec staff visited the sites to collect the dustfall containers and install new ones. The collected containers were sealed and packaged, a chain-of-custody form was completed and the samples were shipped to ALS Environmental Laboratory in Edmonton, AB, where the total dustfall and metal analyses were conducted.

The background deposition for metals was calculated from the total dustfall samples that were collected from Parcel 56 and Parcel 58 on September 16 and October 13, 2016. The background metal deposition values are added to the predicted model values for metals deposition in the air quality environmental assessment (Volume 3A Section 3).

Photo 3D-1 EBAM Monitor (Centre) and Dustfall Collectors (Left and Right) at Parcel 56 on August 2, 2016 (Looking North). A Temporary Security Fence Was Used to Prevent Tampering or Vandalism.

Photo 3D-2 EBAM Monitor (Centre) and Dustfall Collectors (Left and Right) at Parcel 58 on October 13, 2016 (Looking North).

Photo 3D-3 Calibration of EBAM Monitor Prior to Background TSP Monitoring at Parcel 56. August 2, 2016 (Looking Northeast).

Photo 3D-4 Particulate Matter (PM) Deposited on EBAM Filter Tape (Grey Circles). October 13, 2016

Photo 3D-5 Downloading $PM_{2.5}$ Data from EBAM Monitor to a Laptop Computer. October 13, 2016 (Looking North).

Photo 3D-6 Top View of Dustfall Collector Showing Wind Screen (Black), Bird Spikes and Sample Container (White). October 13, 2016.

3D.2.2 Other Measurements

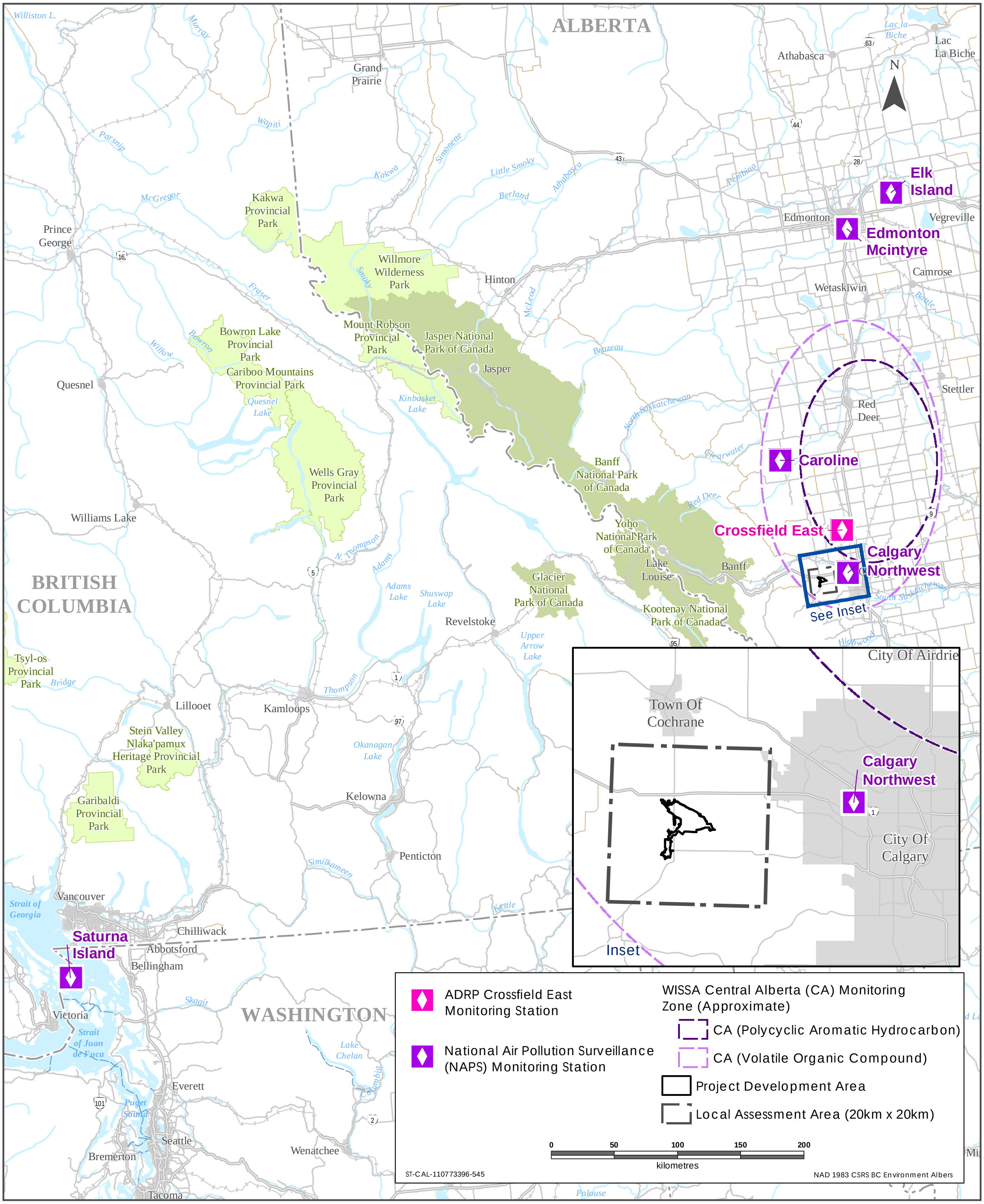
Because the local ambient air quality monitoring program did not measure all substances of interest identified for this Project, ambient air quality monitoring data from other monitoring programs were obtained to represent conditions in the LAA. Multiple information sources were used because there is no single nearby rural station that measures all substances of interest identified for this Project.

The Alberta Air Quality Model Guideline (AESRD 2013) provides explicit guidance for determining background concentrations from continuous hourly monitoring data but does not provide explicit guidance for determining background levels from integrated ambient air quality monitoring data. Continuous hourly monitoring is used to measure nitrogen dioxide (NO_2), sulphur dioxide (SO_2), carbon monoxide (CO) and $PM_{2.5}$ concentrations, and 24-hour integrated monitoring is used to measure hydrocarbon (e.g., volatile organic compounds (VOC) and polycyclic aromatic hydrocarbons (PAH)) compounds and metals. For this assessment, ambient air quality data were obtained from the National Air Pollution Surveillance (NAPS) ambient air quality monitoring stations.

Data from five NAPS monitoring stations are used because no single rural NAPS station monitors all the air quality substances of interest. The data from the following stations were obtained:

- The closest rural NAPS monitoring station to the Project is Caroline, AB. The background values for NO_2, SO_2, TSP and $PM_{2.5}$ are based on monitoring results from the Caroline monitoring station.
- Although NAPS data from urban locations are generally not representative of the rural location (18 km west of Calgary), the background values for CO are based on the Calgary Northwest NAPS station.
- Background concentrations for five of the 11 VOCs were determined from the Edmonton Mcintyre AB, Elk Island AB, and Saturna, BC NAPS stations.

Figure 3D-2 shows the locations of these NAPS air quality monitoring stations. In addition to the NAPS data, data from published reports and journal articles are also used to determine background PAH concentrations because this information is not available at the listed NAPS monitoring stations.



Sources: Base Data - ESRI, Government of Alberta, Government of Canada
Thematic Data - ERBC, Government of Alberta, Stantec Ltd

Regional Ambient Air Quality Monitoring Locations

Stantec

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Figure 3D-2

3D.3 RESULTS

The results from the local and regional background ambient air quality measurements are provided below.

3D.3.1 Local Measurements

3D.3.1.1 $PM_{2.5}$ Concentrations

The 24-hour average $PM_{2.5}$ concentrations at Parcels 56 and 58 are provided in Table 3D-1, and in Figure 3D-3 and Figure 3D-4. Based on both stations, there were 57 days with 18 or more hours of valid data between August 2 and October 13, 2016. The 18 or more hours of hourly data criteria is a completeness requirement specified by the Canadian Council of the Ministers of the Environment (CCME 2011).

The median 24-hour $PM_{2.5}$ concentration based on 57 days was 2.7 µg/m^3 and the mean 24-hour $PM_{2.5}$ concentration was 3.2 µg/m^3. The maximum 24-hour average $PM_{2.5}$ concentration was 11.2 µg/m^3. The mean, median, and maximum $PM_{2.5}$ concentrations are less than the Canadian Ambient Air Quality Standard (CAAQS) set by the CCME for 24-hour average $PM_{2.5}$ concentrations (28 µg/m^3).

Table 3D-1 24-hour $PM_{2.5}$ Concentrations at Parcels 56 and 58

	$PM_{2.5}$ 24-hour average concentration	
Location	**Parcel 56**	**Parcel 58**
Date	**(µg/m³)**	**(µg/m³)**
2-Aug-16	-	a
3-Aug-16	-	a
4-Aug-16	-	a
5-Aug-16	-	a
6-Aug-16	-	a
7-Aug-16	-	a
8-Aug-16	-	a
9-Aug-16	-	a
10-Aug-16	-	a
11-Aug-16	-	a
12-Aug-16	-	a
13-Aug-16	-	a
14-Aug-16	-	a
15-Aug-16	-	b
16-Aug-16	-	8.3
17-Aug-16	-	8.0
18-Aug-16	-	6.2
19-Aug-16	-	4.6
20-Aug-16	-	5.9
21-Aug-16	-	9.3
22-Aug-16	-	5.2
23-Aug-16	-	2.8
24-Aug-16	-	4.0
25-Aug-16	-	4.9
26-Aug-16	-	3.1
27-Aug-16	-	4.5
28-Aug-16	-	1.7
29-Aug-16	-	5.0
30-Aug-16	-	7.0

Table 3D-1 24-hour $PM_{2.5}$ Concentrations at Parcels 56 and 58

	$PM_{2.5}$ 24-hour average concentration	
Location	**Parcel 56**	**Parcel 58**
Date	**(µg/m³)**	**(µg/m³)**
31-Aug-16	-	11.2
1-Sep-16	-	8.3
2-Sep-16	-	4.1
3-Sep-16	-	2.3
4-Sep-16	-	4.0
5-Sep-16	-	4.7
6-Sep-16	-	2.7
7-Sep-16	-	1.6
8-Sep-16	-	1.6
9-Sep-16	-	0.9
10-Sep-16	-	2.5
11-Sep-16	-	1.8
12-Sep-16	-	3.5
13-Sep-16	-	3.7
14-Sep-16	-	3.3
15-Sep-16	-	6.5
16-Sep-16	b	b
17-Sep-16	2.4	-
18-Sep-16	1.0	-
19-Sep-16	1.1	-
20-Sep-16	0.7	-
21-Sep-16	1.9	-
22-Sep-16	2.0	-
23-Sep-16	0.3	-
24-Sep-16	0.5	-
25-Sep-16	1.1	-
26-Sep-16	0.2	-
27-Sep-16	0.5	-
28-Sep-16	1.2	-

Table 3D-1 24-hour $PM_{2.5}$ Concentrations at Parcels 56 and 58

	$PM_{2.5}$ 24-hour average concentration	
Location	**Parcel 56**	**Parcel 58**
Date	**(µg/m³)**	**(µg/m³)**
29-Sep-16	2.7	-
30-Sep-16	3.6	-
1-Oct-16	2.7	-
2-Oct-16	0.3	-
3-Oct-16	1.7	-
4-Oct-16	3.0	-
5-Oct-16	2.4	-
6-Oct-16	3.2	-
7-Oct-16	1.0	-
8-Oct-16	1.0	-
9-Oct-16	0.8	-
10-Oct-16	1.1	-
11-Oct-16	2.4	-
12-Oct-16	0.7	-
13-Oct-16	b	-
Count	**57**	
Maximum	**11.2**	
90th Percentile	**6.7**	
Average	**3.2**	
Median	**2.7**	
Minimum	**0.2**	

NOTES:
No $PM_{2.5}$ sampling was conducted
a no data available due to EBAM mother board failure
b Less than 18 hours of recorded data available

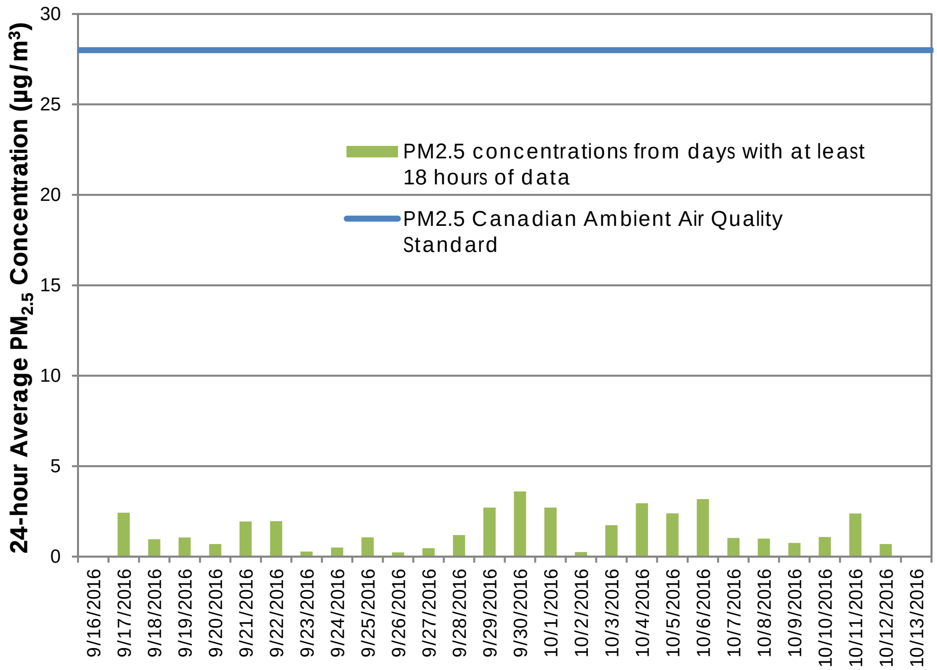


Figure 3D-3 24-hour $PM_{2.5}$ Concentrations at the Parcel 56 Monitoring Station

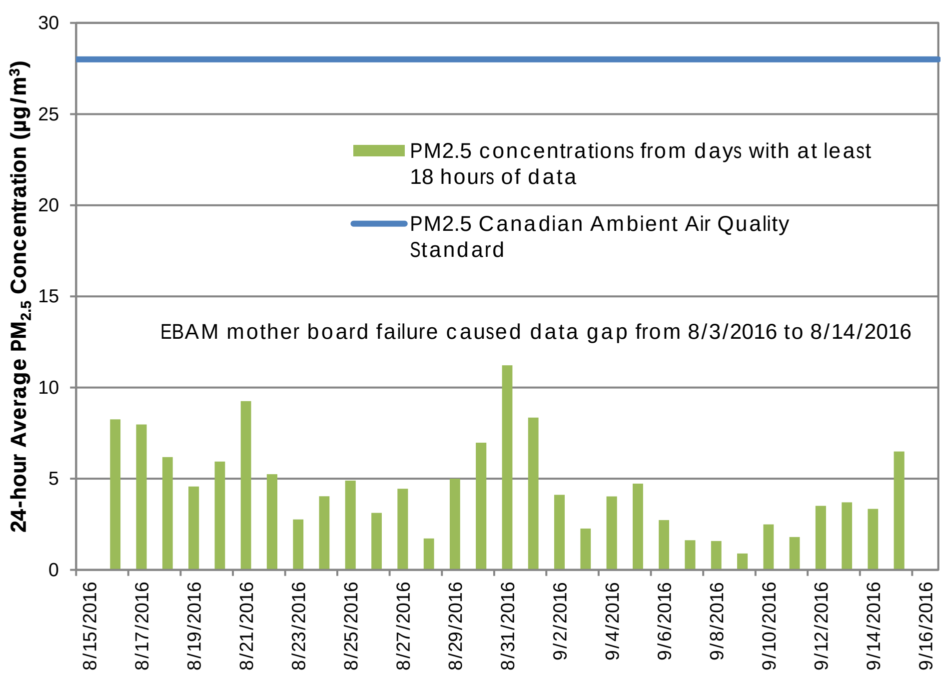


Figure 3D-4 24-hour $PM_{2.5}$ Concentrations at the Parcel 58 Monitoring Station

3D.3.1.2 TSP Concentrations

The 24-hour average TSP concentrations at Parcels 56 and 58 are shown in Table 3D-2, and in Figure 3D-5 and Figure 3D-6. Based on both stations, there were 39 days with 18 or more hours of valid data between August 2 and October 13, 2016. The 18 or more hours of hourly data criteria is a completeness requirement specified by the Canadian Council of the Ministers of the Environment (CCME 2011).

The median 24-hour TSP concentration based on 39 days is 6.9 µg/m^3, and the mean 24-hour TSP concentration is 9.2 µg/m^3. The maximum 24-hour TSP concentration was 48.5 µg/m^3. The mean, median and maximum concentrations are less than the Alberta Ambient Air Quality Guideline (AAAQG) for 24-hour average TSP concentrations (100 µg/m^3).

Table 3D-2 24-hour TSP Concentrations at Parcels 56 and 58

Date	Parcel 56 TSP 24-hour average concentration ($\mu g/m^3$)	Parcel 58 TSP 24-hour average concentration ($\mu g/m^3$)
2-Aug-16	-	-
3-Aug-16	2.5	-
4-Aug-16	5.8	-
5-Aug-16	7.4	-
6-Aug-16	6.9	-
7-Aug-16	5.0	-
8-Aug-16	5.0	-
9-Aug-16	9.0	-
10-Aug-16	6.9	-
11-Aug-16	1.9	-
12-Aug-16	2.6	-
13-Aug-16	6.0	-
14-Aug-16	5.7	-
15-Aug-16	7.8	-
16-Aug-16	a	-
17-Aug-16	a	-
18-Aug-16	a	-
19-Aug-16	a	-
20-Aug-16	a	-
21-Aug-16	a	-
22-Aug-16	a	-
23-Aug-16	a	-
24-Aug-16	a	-
25-Aug-16	a	-
26-Aug-16	a	-
27-Aug-16	a	-
28-Aug-16	a	-
29-Aug-16	a	-
30-Aug-16	a	-
31-Aug-16	a	-

Table 3D-2 24-hour TSP Concentrations at Parcels 56 and 58

Date	Parcel 56 TSP 24-hour average concentration (µg/m³)	Parcel 58 TSP 24-hour average concentration (µg/m³)
1-Sep-16	a	-
2-Sep-16	a	-
3-Sep-16	a	-
4-Sep-16	a	-
5-Sep-16	a	-
6-Sep-16	a	-
7-Sep-16	a	-
8-Sep-16	a	-
9-Sep-16	a	-
10-Sep-16	a	-
11-Sep-16	a	-
12-Sep-16	a	-
13-Sep-16	a	-
14-Sep-16	a	-
15-Sep-16	a	-
16-Sep-16	-	b
17-Sep-16	-	6.6
18-Sep-16	-	4.2
19-Sep-16	-	10.1
20-Sep-16	-	5.4
21-Sep-16	-	7.3
22-Sep-16	-	13.0
23-Sep-16	-	3.4
24-Sep-16	-	3.6
25-Sep-16	-	3.7
26-Sep-16	-	4.2
27-Sep-16	-	8.9
28-Sep-16	-	13.6
29-Sep-16	-	17.9
30-Sep-16	-	20.9

Table 3D-2 24-hour TSP Concentrations at Parcels 56 and 58

Date	Parcel 56 TSP 24-hour average concentration (µg/m³)	Parcel 58 TSP 24-hour average concentration (µg/m³)
1-Oct-16	-	15.0
2-Oct-16	-	3.6
3-Oct-16	-	6.2
4-Oct-16	-	9.3
5-Oct-16	-	8.2
6-Oct-16	-	10.6
7-Oct-16	-	48.5
8-Oct-16	-	6.7
9-Oct-16	-	22.5
10-Oct-16	-	15.7
11-Oct-16	-	8.4
12-Oct-16	-	7.8
13-Oct-16	-	b
Count	**39**	
Maximum	**48.5**	
90th Percentile	**16.1**	
Average	**9.2**	
Median	**6.9**	
Minimum	**1.9**	

NOTES:
No TSP sampling was occurring at this monitoring site on this date
a no data available due to EBAM pump failure
b Less than 18 hours of data was available

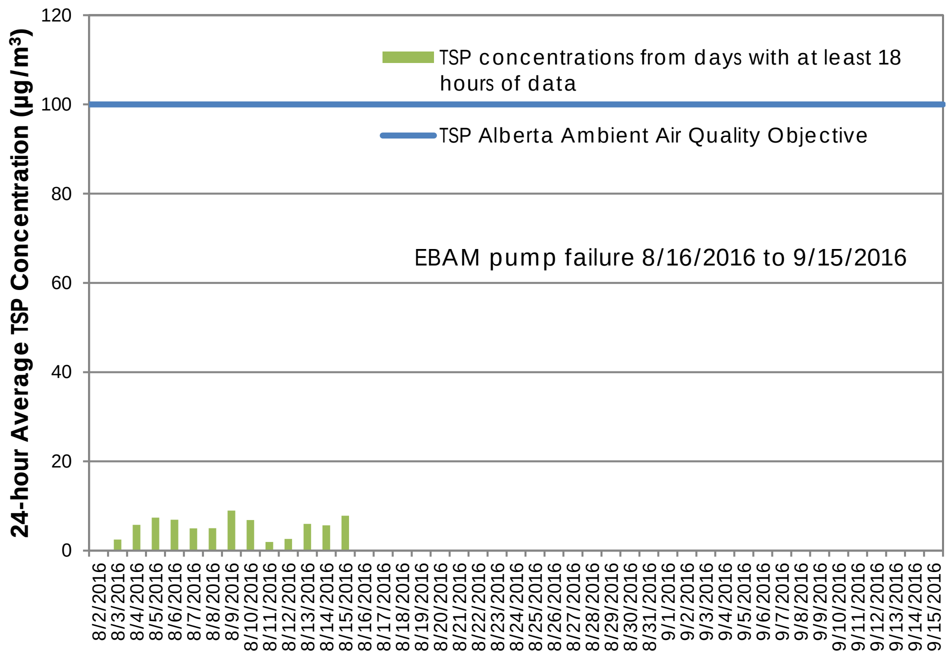


Figure 3D-5 24-hour Average TSP Concentrations at the Parcel 56 Monitoring Station

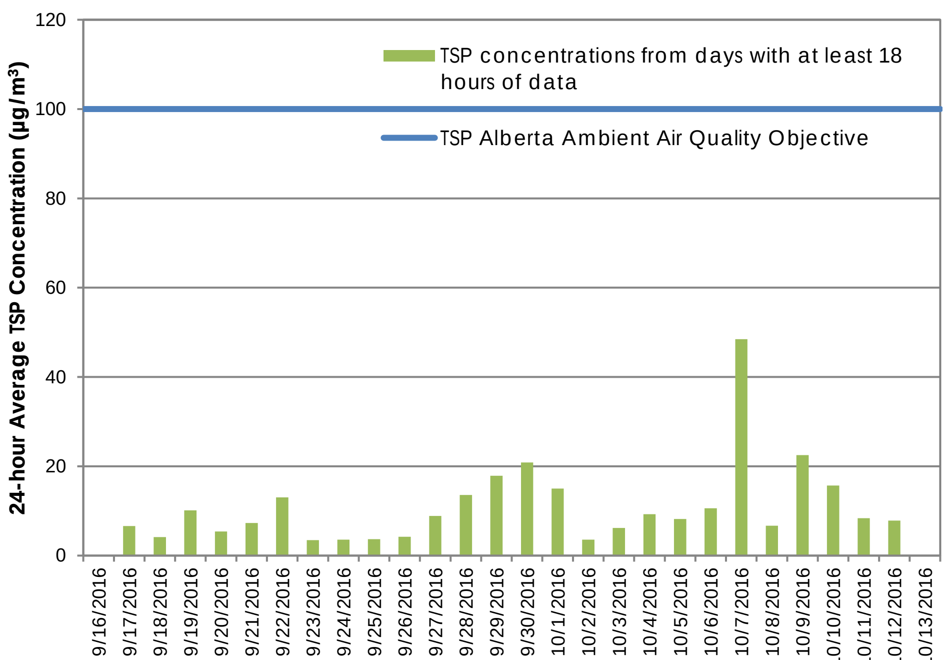


Figure 3D-6 24-hour Average TSP Concentrations at the Parcel 58 Monitoring Station

3D.3.1.3 Dustfall Deposition

The 30-day total dustfall deposition values for Parcels 56 and 58 are summarized in Table 3D-3. There were two 30-day periods during the study period.

The mean 30-day total dustfall at Parcel 56 is 22.6 mg/100 cm^2 for the August 2 to October 13, 2016 monitoring period. The mean 30-day total dustfall at Parcel 58 was 12.8 mg/100 cm^2 for the August 2 to October 13, 2016 monitoring period. The overall mean 30-day total dustfall value for two samples collected at both parcels is 17.7 mg/100 cm^2.

These values are less than the 30-day AAAQG for total dustfall (58 mg/100 cm^2) that is applicable to residential and recreational areas. They are also less than the 30-day AAAQG for total dustfall (158 mg/100 cm^2) that is applicable to commercial and industrial areas.

Table 3D-3 Background Total Dustfall

2016 Monitoring Period	Parcel 56 (mg/100 cm^2/30-day)	Parcel 58 (mg/100 cm^2/30-day)	Average (mg/100 cm^2/30-day)
August 2 to August 26	22.6	13.6	18.1
August 26 to October 13	22.6	12.0	17.3
Average	**22.6**	**12.8**	**17.7**

NOTE:
The AAAQG for total dustfall for residential and recreational areas is 58 mg/100 cm^2/30-days (AEP 2016b).

3D.3.1.4 Metal Deposition

The metal deposition in the dustfall for Parcels 56 and 58 during the 10.5-week monitoring period (August 2 to October 13, 2016) are provided in Table 3D-4. Since there are currently no significant industrial sources of air emissions in the study area, metal deposition levels result from rural traffic and/or agricultural activities. Most of the results were less than the minimum detection limits (MDL). The maximum metal deposition rates at each dustfall station are presented in Table 3D-4. Of the 15 metals analyzed, eight metals had at least one reading during a one-month period that were greater than the MDL.

The are no regulatory criteria for metal deposition in dustfall. To assess potential residual effects, the average background metals values in the right-hand column were added to the model predictions in the air quality assessment (Volume 3A, Section 3).

3D.3.1.5 Meteorological Conditions

Ambient background concentrations of TSP and $PM_{2.5}$ (and total dustfall) are influenced by meteorological conditions. Dry conditions tend to enhance ambient TSP and $PM_{2.5}$ concentrations (and total dustfall) because higher PM emissions are generated by fugitive dust sources during dry conditions. Wet conditions tend to decrease ambient TSP and $PM_{2.5}$ concentrations (and total dustfall) because PM emissions are suppressed during wet conditions.

The total precipitation records from the nearest automated meteorological station were reviewed to determine if the conditions during the background monitoring program (e.g. August 3 to October 12, 2016) were wetter or drier than normal. The Springbank Airport meteorological monitoring station does not record total precipitation so data from next closest meteorological station were obtained. The Canada Olympic Park (COP) Upper meteorological station is located approximately 12.6 km east of the PDA. Data from the COP Upper meteorological station is available online from Alberta Agriculture and Forestry (http://www.agriculture.alberta.ca/acis/alberta-weather-data-viewer.jsp).

Precipitation recorded at the COP Upper station during the study period was 111.5 mm. The normal precipitation associated with the study period is 105.1 mm. Hence, the background monitoring program study period was approximately 6% wetter than normal. This is not a significant departure from normal conditions, therefore, the measured TSP and $PM_{2.5}$ concentrations, and total dustfall are viewed as being representative.

Table 3D-4 Metal Deposition

Location	Parcel 56		Parcel 58		
Period	August 2 to August 26, 2016	August 26 to October 13, 2016	August 2 to August 26, 2016	August 26 to October 13, 2016	Background Average
Metal	(mg/100 cm²/day)				
Arsenic (As)	0.0000037	0.0000021	0.0000027	0.0000032	0.0000029
Barium (Ba)	0.000158	0.0000981	0.0000700	0.0000604	0.0000966
Beryllium (Be)	<0.000013	<0.0000092	<0.000012	<0.0000066	<0.0000102
Cadmium (Cd)	<0.0000013	<0.00000092	<0.0000012	<0.00000066	<0.0000010
Chromium (Cr)	<0.000013	<0.0000092	<0.000012	0.0000073	0.0000104
Cobalt (Co)	<0.0000026	<0.0000018	<0.0000024	<0.0000013	<0.0000020
Copper (Cu)	<0.000039	0.0000443	<0.000024	<0.000033	0.0000351
Lead (Pb)	<0.0000065	0.00000397	<0.0000036	0.00000314	0.0000043
Manganese (Mn)	0.000215	0.000174	0.000101	0.000113	0.0001508
Mercury (Hg)	<0.0000013	<0.00000092	<0.0000012	<0.00000066	<0.0000010
Molybdenum (Mo)	0.0000016	<0.00000092	<0.0000012	<0.00000066	0.0000011
Nickel (Ni)	<0.000013	<0.0000092	<0.000012	<0.0000066	<0.0000102
Uranium (U)	<0.00000026	<0.00000018	<0.00000024	<0.00000013	<0.00000020
Vanadium (V)	<0.000026	<0.000018	<0.000024	<0.000013	<0.0000203
Zinc (Zn)	0.000251	0.000186	0.000090	<0.000080	0.0001518

NOTES:
To calculate the average, values less than the MDL were assumed to be at the MDL.
Grey shading indicates values less than the MDL.

3D.3.2 Other Measurements

The local 10-week monitoring program focused on PM measurements (i.e., $PM_{2.5}$, TSP and dustfall) since PM emissions due to construction activities are viewed as the substances of primary interest. The local measurements provide a snapshot of existing conditions. One primary focus on reviewing ambient air monitoring data is to determine background concentrations that represent contributions from sources not explicitly included in the modelling. The model predictions for the Base Case emission scenario plus the background represents the Base Case ambient concentrations.

To provide a more robust definition of background ambient air quality conditions, the local monitoring results are combined with ambient air quality data from more distant air quality monitoring stations with longer data records. Ambient air quality data from these monitoring stations have longer data records that incorporate all seasons. The selected background values adopted for the air quality assessment are listed in: Table 3D-5 for Criteria Air Contaminants (CAC) compounds, Table 3D-6 for PAH and VOC compounds, and Table 3D-7 for metals. The following are noted relative to the background values identified in these tables:

- Background NO_2, SO_2, and $PM_{2.5}$ concentrations are based on the NAPS Caroline hourly data from 2015. The approach outlined in the AQMG was adopted to select the values. The 24-hour background $PM_{2.5}$ value of 11.0 µg/m³ is similar to the maximum value of 11.3 µg/m³ obtained from the local monitoring program. Similarly, the annual background $PM_{2.5}$ value of 3.5 µg/m³ is similar to the average value of 3.2 µg/m³ obtained from the local monitoring program.
- Background CO concentrations are based on the NAPS Calgary NW station. The approach outlined in the AQMG was adopted to select the values.
- Background TSP concentrations are based on $PM_{2.5}$ concentrations from the NAPS Caroline hourly data from 2015. The Brook et al (1997) generalized relationships $PM_{2.5}/PM_{10} = 0.49$ and $PM_{10}/TSP = 0.44$ indicate TSP is typically 4.6 times $PM_{2.5}$. The 24-hour background TSP value of 51 µg/m³ is similar to the maximum value of 48.5 µg/m³ obtained from the local monitoring program. The annual background TSP value of 16.2 µg/m³ is greater than the average value of 11.0 µg/m³ obtained from the local monitoring program.
- Fifteen of the 16 PAH values are based on data from the Western Interprovincial Scientific Studies Association (WISSA) monitoring program. The values are based on Central Alberta data collected over the 2001-2002 period.

- Fifteen out of the 16 VOC values are based on data from the WISSA monitoring program. The values are based on Central Alberta data collected over the 2001-2002 period.
- Twelve out of the 15 metal concentration values are based on data from the Alberta Acid Deposition Research Program (ADRP) and the data are from the Crossfield East monitoring station (1986 to 1987).

Representative background concentrations derived from NAPS 24-hour sampling data were based on the maximum 24-hour measurements. Background concentrations for 1-hour and annual averaging periods were derived from the 24-hour values using the formula recommended by AESRD (AESRD 2013).

Tables 3D-5 to 3D-7 identifies the background air quality values and compares them to regulatory criteria. The selected background concentrations range from 0.005 to 51 percent of the regulatory criteria. Of the 35 substance/averaging period combinations, ten background values are greater than 10% of the criteria, and five are greater than 25% of the criteria. The occurrence of these latter values is likely associated with selecting an overly conservative value rather than suggesting existing air quality is compromised in the Springbank region.

The high percent values are associated with particles, specifically with ambient $PM_{2.5}$ and TSP concentrations, and with dustfall. The background 24-hour $PM_{2.5}$ value of 11 µg/m^3 is similar to the largest value measured locally (i.e., 11.2 µg/m^3). The background 24-hour TSP value of 51 µg/m^3 is similar to the largest value measured locally (i.e., 48.5 µg/m^3).

Determining representative background rural air quality is challenging because most ambient air quality monitoring stations with complete, robust, and quality assured data are located in urban areas. Although some of the background air quality values selected for this assessment are conservative, they are suitable for the determination of potential residual effects in the air quality environmental assessment (Volume 3A, Section 3).

Table 3D-5 Background CAC Concentrations

Substance	Averaging Period	Ambient Background Concentrations (µg/m³)	AAAQO/AAAQG (µg/m³)	Comparison of Background to AAAQO/AAAQG (%)
NO_2 [a]	1-hour	9.59	300	3.2
	Annual	3.77	45	8.4
SO_2 [a]	1-hour	5.24	450	1.2
	24 hour	4.95	125	4.0
	30 day	3.08	30	10.3
	Annual	2.49	20	12.5
CO [b]	1-hour	344	15,000	2.3
	8-hour	344	6,000	5.7
TSP [c]	24-hour	51.0	100	51.0
	Annual	16.2	60	27.0
$PM_{2.5}$ [a]	1-hour	11.0	80	13.8
	24-hour	11.0	28 [g]	39.3
	Annual	3.50	10 [g]	35.0
Dustfall [d]	30-day	17.7	53	33.4

NOTES:

[a] NO_2, SO_2 and $PM_{2.5}$ background values ae derived from 2015 data measured at NAPS Caroline Station

[b] CO background values ae derived from 2015 data measured at NAPS Calgary NW Station

[c] TSP data was extrapolated from 2015 Caroline $PM_{2.5}$ data using the correlation proposed by Brook et al (1997). $PM_{2.5}/PM_{10}$ ratio of 0.49 and PM_{10}/TSP ratio of 0.44.

[d] Background dustfall data based on the 2016 summer monitoring program at the project site.

Table 3D-6 Background PAH and VOC Concentrations

Compound	Background Concentrations (µg/m³)			Information Source
	1-hour	24-hour	Annual	
PAH				
Naphthalene	0.120	0.120	0.052	WISSA (2006)
Dibenzo(a,h)anthracene	0.00022	0.00022	0.000068	WISSA (2006)
Fluoranthene	0.00054	0.00054	0.00017	WISSA (2006)
Acenaphthene	0.003	0.003	0.00098	WISSA (2006)
Acenaphthylene	0.000477	0.000477	0.0001587	WISSA (2006)
Anthracene	0.000268	0.000268	0.0000936	WISSA (2006)
Benz(a)anthracene	0.000154	0.000154	0.000051	WISSA (2006)
Benzo(a)pyrene	0.00039	0.000080	0.000022	NAPS Edmonton Mcintyre, AB (ECCC 2016)
Benzo(b)fluoranthene	0.00018	0.00018	0.000036	WISSA (2006)
Benzo(g,h,i)perylene	0.000164	0.000164	0.0000506	WISSA (2006)
Benzo(k)fluoranthene	0.00021	0.00021	0.000041	WISSA (2006)
Chrysene	0.000141	0.000141	0.000042	WISSA (2006)
Fluorene	0.0033	0.0033	0.0013	WISSA (2006)
Indeno(1,2,3,c,d)pyrene	0.0002	0.0002	0.000047	WISSA (2006)
Phenanthrene	0.0032	0.0032	0.0015	WISSA (2006)
Pyrene	0.0012	0.0012	0.00025	WISSA (2006)
VOC				
Benzene	0.81	0.81	0.32	WISSA (2006)
1,3-Butadiene	0.725	0.148	0.018	NAPS Elk Island, AB (ECCC 2016)
Formaldehyde	9.90	6.37	2.60	NAPS Saturna, BC and HC 2001 (ECCC 2016)
Acetaldehyde	3.38	1.35	0.270	Millet et al (2010)
Acrolein	0.29	0.048	0.025	NAPS Saturna, BC (ECCC 2016)
2,2,4-Trimethylpentane	18.71	3.82	0.166	NAPS Elk Island, AB (ECCC 2016)
Ethylbenzene	0.19	0.19	0.073	WISSA (2006)
Propionaldehyde	0.405	0.405	0.224	NAPS Saturna, BC (ECCC 2016)
Styrene	0.011	0.011	0.0022	WISSA (2006)
Toluene	1.00	1.00	0.45	WISSA (2006)
Xylene	0.22	0.22	0.083	WISSA (2006)

NOTES:
WISSA (2006) refers to the Western Interprovincial Scientific Studies Association monitoring program and the values are based on Central Alberta data collected over the 2001-2002 period.
Millet et al (2010) refers to a research paper related to the Global Atmospheric Budget for Acetaldehyde.

Table 3D-7 Background Metal Concentrations

Metal	Background Concentrations (µg/m³)			Information Source
	1-hour	24-hour	Annual	
Arsenic	0.00050	0.0005	0.00016	Legge and Krupa (1990)
Barium	0.0116	0.0116	0.0031	Legge and Krupa (1990)
Beryllium	0.0125	0.0050	0.001	Armiento et al (2012)
Cadmium	0.0015	0.0015	0.00053	Legge and Krupa (1990)
Chromium	0.00060	0.0006	0.00032	Legge and Krupa (1990)
Cobalt	0.0125	0.0050	0.001	CDI (2006)
Copper	0.0012	0.0012	0.00053	Legge and Krupa (1990)
Lead	0.0384	0.0384	0.0169	Legge and Krupa (1990)
Mercury	0.00017	0.00017	0.00006	Legge and Krupa (1990)
Molybdenum	0.0008	0.0008	0.00023	Legge and Krupa (1990)
Manganese	0.0045	0.0045	0.002	Legge and Krupa (1990)
Nickel	0.00036	0.00036	0.00017	Legge and Krupa (1990)
Uranium	0.00125	0.00050	0.0001	CCME (2007)
Vanadium	0.00074	0.00074	0.00033	Legge and Krupa (1990)
Zinc	0.0057	0.0057	0.0032	Legge and Krupa (1990)

NOTES:

Legge and Krupa (1990) refers to the Alberta ADRP and the data are from the Crossfield East monitoring station (1986 to 1987).

Armiento et al (2012) refers to a research paper related to Beryllium Natural Background Concentration and Mobility.

CDI (2006) refers to a publication from the Cobalt Development Institute (CDI) related to Cobalt in the Atmosphere.

CCME (2007) refers to the Canadian Soil Guideline for Uranium.

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3D.5 EBAM CALIBRATION RECORDS

13 E-BAM AUDIT SHEET

* installed at parcel 56
Laurie and Chris Maruszewski

Model:	E-BAM	**Serial Number:**	K1524
Audit Date:	Aug 2, 2016	**Audited By:**	Don Jarratt, Kamran Rahnama

Streamline Pro Calibration Kit s/N M14019

Flow Audits			
Flow Reference Standard Used:	Model:	Serial No:	Calibration Date: 17 JAN 2014
Temperature Standard Used:	Model: as above	Serial No: as above	Calibration Date: "
Barometric Pressure Standard Used:	Model:	Serial No:	Calibration Date: "

Leak Check Value: as found: 0.5 lpm as left: 0.5 lpm

		E-BAM	Ref. Std.		E-BAM	Ref. Std.
Ambient Temperature:	as found:	25.4 C	22.1 C	as left:	22.1 C	22.1 C
Barometric Pressure:	as found:	656.7 mmHg	656.3 mmHg	as left:	656.3 mmHg	656.3 mmHg
17.5 ~~**16.7**~~ **lpm Flow Rate (Actual):**	as found:	17.5 lpm	16.26 lpm	as left:	17.6 lpm	17.6 lpm
14.0 ~~**16.7**~~ **lpm Flow Rate (~~Standard~~) Actual:**	as found:	14.0 ~~s~~lpm	13.1 ~~s~~lpm	as left:	14.0 ~~s~~lpm	14.0 ~~s~~lpm
16.7 lpm		16.7 lpm	16.7 lpm		16.7 lpm	16.7 lpm

Mechanical Audits

Sample nozzle clean:	as found ☐	as left ☐	PM10 particle trap clean:	as found ☐	as left ☐
Tape support vane clean:	as found ☐	as left ☐	PM10 drip jar empty:	as found ☐	as left ☐
Tape spool covers tight:	as found ☐	as left ☐	PM10 bug screen clear:	as found ☐	as left ☐
	as found ☐	as left ☐	PM2.5 particle trap clean:	as found ☐	as left ☐

Analog Voltage Output Audit	N/A ☐
DAC Test Screen	**E-BAM Volt Output**
0.010 Volts	Volts
0.500 Volts	Volts
0.990 Volts	Volts

Manual Span Membrane Test	
Expected Span Mass (mg/cm2):	
Measured Span Mass (mg/cm2):	
Difference (mg/cm2):	
% Difference:	

Pump Test	
Flow Setpoint	**E-BAM Flow**
14.0 lpm	see
16.7 lpm	above
17.5 lpm	

REF DAC FS: 8.0V

Setup and Calibration Values

Parameter	Expected	Found	Parameter	Expected	Found	Parameter	Expected	Found
Clock	OK	OK	Analog Mode	real time		Flow Type	actual	
Location	01	01	Baud Rate	19,200		Restart Voltage	12.5V	
Tape Advance	24/hr	24/hr	RH Setpoint	45%		Std Cond Temp	25°C	
Realtime Avg	10min	10min	Delta-T Setpoint	15°C				
Machine Type	EB4M	PM10	RH Control	ON				
Analog FS	1.0V	1.0V	Flow Setpoint	16.7 lpm				

→ TSP inlet installed

RH CONNECTED: NO
PUMP PROTECT: OFF

Last 6 Errors in E-BAM Error Log

Error	Date	Time	Error	Date	Time
1			4		
2			5		
3			6		

Audit Notes: Initial setup of instrument

Memory ~~99~~ 100 % remaining

~~79.2~~ 70.3 days remaining

BAM Calibrate

ZERO: 0.350 mg/cm^2

SPAN: 0.533 mg/cm^2

13 E-BAM AUDIT SHEET

Model: E-BAM **Serial Number:** U13987

Audit Date: Aug 15, 2016 **Audited By:** KAMRAN RAHNAMA

Streamline Pro Calibration Kit SN: 140101

Flow Audits			
Flow Reference Standard Used:	Model:	Serial No:	Calibration Date: 05/11/2016
Temperature Standard Used:	Model:	Serial No:	Calibration Date: 05/11/2016
Barometric Pressure Standard Used:	Model:	Serial No:	Calibration Date: 05/11/2016

Leak Check Value: as found: 0.3 lpm as left: 0.3 lpm

		E-BAM (as found)	Ref. Std. (as found)		E-BAM (as left)	Ref. Std. (as left)
Ambient Temperature: (HIGH)	as found:	22.7 C	23.8 C	as left:	23.8 C	23.8 C
Barometric Pressure:	as found:	663.9 mmHg	663.7 mmHg	as left:	663.7 mmHg	663.7 mmHg 663.7
17.5 ~~16.7~~ **lpm Flow Rate (Actual):**	as found:	17.5 lpm	17.7 lpm	as left:	17.5 lpm	17.5 lpm
14.0 **16.7 lpm Flow Rate (Standard):**	as found:	14.0 slpm	14.27 slpm	as left:	14.0 slpm	14.0 slpm
16.7		16.7	16.7		no calibration option	

Mechanical Audits

Sample nozzle clean:	as found ☐	as left ☐		PM10 particle trap clean:	as found ☐	as left ☐
Tape support vane clean:	as found ☐	as left ☐		PM10 drip jar empty:	as found ☐	as left ☐
Tape spool covers tight:	as found ☐	as left ☐		PM10 bug screen clear:	as found ☐	as left ☐
	as found ☐	as left ☐		PM2.5 particle trap clean:	as found ☐	as left ☐

Analog Voltage Output Audit N/A ☐

DAC Test Screen	E-BAM Volt Output
0.010 Volts	Volts
0.500 Volts	Volts
0.990 Volts	Volts

Manual Span Membrane Test	
Expected Span Mass (mg/cm2):	
Measured Span Mass (mg/cm2):	
Difference (mg/cm2):	
% Difference:	

Pump Test	
Flow Setpoint	**E-BAM Flow**
14.0 lpm	
16.7 lpm	16.7
17.5 lpm	

Setup and Calibration Values

Parameter	Expected	Found	Parameter	Expected	Found	Parameter	Expected	Found
Clock	14:29	14:29	Analog Mode	real time		Flow Type	Actual	
Location	2	2	Baud Rate	19200		Restart Voltage	12.5V	
Tape Advance	24 hr	24 hr	RH Setpoint	45%		Std Cond Temp	25 °C	
Realtime Avg	10 min	10 min	Delta-T Setpoint	15 C				
Machine Type	PM 2.5	PM 2.5	RH Control	ON				
Analog FS	1.0 V	1.0 V	Flow Setpoint	16.7	LPM			

REF DAC FS: 8.0 V

RH Connected : NO
Pump Protect : OFF

Last 6 Errors in E-BAM Error Log

	Error	Date	Time
1			
2			
3			
4			
5			
6			

Audit Notes: Memory : BAM Calibrate:
100% Remaining ZERO : 0.350 mg/cm²
30.3 Days Remaining SPAN : 0.763 mg/cm²

13 E-BAM AUDIT SHEET

Model: E-BAM **Serial Number:** K1524

Audit Date: 16Sep2016 **Audited By:** Kamran Rahmama

Streamline Pro Calibration Kit SN. C140101

Flow Audits			
Flow Reference Standard Used:	Model:	Serial No:	Calibration Date:
Temperature Standard Used:	Model:	Serial No:	Calibration Date:
Barometric Pressure Standard Used:	Model:	Serial No:	Calibration Date:

Leak Check Value: as found: 0.5 lpm @ 224.2mmHg as left: 0.5 lpm @ 224.2mmHg

		E-BAM	Ref. Std.		E-BAM	Ref. Std.
Ambient Temperature:	as found:	22.5 C	23.8 C	as left:	23.8 C	23.8 C
Barometric Pressure:	as found:	653.4 mmHg	656.3 mmHg	as left:	653.4 mmHg	653.4 mmHg
14.0 ~~16.7~~ **lpm Flow Rate (Actual):**	as found:	14.0 lpm	13.1 lpm	as left:	14.0 lpm	13.93 lpm
16.7 lpm Flow Rate (~~Standard~~):	as found:	16.7 slpm	Ø slpm	as left:	16.7 slpm	Ø slpm
17.5 lpm Flow Rate (Actual)		18.3	17.8		17.5	17.5

Mechanical Audits

Sample nozzle clean:	as found ☐	as left ☐	PM10 particle trap clean:	as found ☐	as left ☐
Tape support vane clean:	as found ☐	as left ☐	PM10 drip jar empty:	as found ☐	as left ☐
Tape spool covers tight:	as found ☐	as left ☐	PM10 bug screen clear:	as found ☐	as left ☐
________	as found ☐	as left ☐	PM2.5 particle trap clean:	as found ☐	as left ☐

Analog Voltage Output Audit	N/A ☐
DAC Test Screen	**E-BAM Volt Output**
0.010 Volts	Volts
0.500 Volts	Volts
0.990 Volts	Volts

Manual Span Membrane Test	
Expected Span Mass (mg/cm2:	
Measured Span Mass (mg/cm2):	
Difference (mg/cm2):	
% Difference:	

Pump Test	
Flow Setpoint	**E-BAM Flow**
14.0 lpm	
16.7 lpm	
17.5 lpm	

Setup and Calibration Values

Parameter	Expected	Found	Parameter	Expected	Found	Parameter	Expected	Found
Clock	16:11	[illegible]	Analog Mode	Real Time		Flow Type	Actual	
Location	01		Baud Rate	19 200		Restart Voltage	12.5V	
Tape Advance	24hrs.		RH Setpoint	45%		Std Cond Temp	25°C	
Realtime Avg	10 mins		Delta-T Setpoint	15°C		Pump Protect	OFF	
Machine Type	PM2.5		RH Control	ON				
Analog FS	1.0V		Flow Setpoint	16.7				

REFDAC FS : 8.0V RH connected? NO.

Last 6 Errors in E-BAM Error Log

	Error	Date	Time
1			
2			
3			
4			
5			
6			

Audit Notes: BAM Calibrate : MEMORY: 100% remaining
ZERO: 0.350 mg/cm² 30.3 days
SPAN: 0.533 mg/cm²

3D.6 STREAMLINE PRO CALIBRATION CERTIFICATE

Certificate of Calibration

This Streamline Pro™ MultiCal™ System, serial number: **M140101**
was calibrated against the following NIST-traceable Reference Standards:
Flow: Critical Flow Venturi S/Ns 10962, 10963 on date: 05/19/16
Barometric Pressure: Precision Barometer S/N 913930-M1 on date: 05/13/16
Temperature: NIST Traceable Hg-in-glass thermometers, S/Ns 2J3106, 2Y6027, 3L9452. on date: 05/13/16

Quality Assurance:

Flow:

Reference Std. Q_{ref} (l/min)	Streamline Pro Q_{SLPro} (l/min)	Absolute difference (l/min)	% Diff. F.S.
0.90	0.89	-0.01	-0.07%
3.01	3.03	0.02	0.13%
6.67	6.66	-0.01	-0.05%
10.00	9.99	-0.01	-0.05%
13.66	13.67	0.00	0.01%
16.67	16.68	0.01	0.06%
19.00	19.00	-0.01	-0.03%

BP:

Reference Std. BP_{ref} (atm)	Streamline Pro BP_{SLPro} (atm)	Absolute difference (atm)	% Diff. F.S.
0.750	0.750	0.000	0.00%
0.900	0.900	0.000	0.02%
1.050	1.050	0.000	-0.01%

Temp.:

Reference Std. T_{ref} (°C)	Streamline Pro T_{SLPro} (°C)	Absolute difference (°C)	% Diff. F.S.*
0.0	0.0	0.0	0.00%
23.5	23.5	0.0	0.00%
44.3	44.3	0.0	0.01%

* based on absolute temp. scale (K)

Lab temp: 23.3 °C Lab pressure: 0.857 atm

Certified By: Roger Sanders Date: May 19, 2016

Chinook Engineering
555 Absaraka Street
Sheridan, Wyoming USA 82801
(307) 674-7506
www.chinookengineering.net

Certificate of Accuracy

Transfer Standard Type: Streamline Pro™ External Temperature Probe

This Streamline Pro™ MultiCal™ System External Temperature Probe,

Model No. SLPRT203, SERIAL NUMBER: T140101

Was compared to:
NIST Traceable Hg-in-glass thermometers, serial numbers 2J3106, 2Y6027, 3L9452, and ice point. Miller & Weber Hg-in-glass thermometer S/Ns 2J3106 and 2Y6027 are traceable to NIST Test No. 209621, Test Method ASTME E-77. 2J3106 is traceable through Standard No. 1S1262. 2Y6027 is traceable through Standard No. 9C8072. Miller & Weber Hg-in-glass themometer S/N 3L9452 is traceable to NIST thermometer 40350, through Transfer Standards 3C4465 & 1Y9716.

Date: **May 11, 2016**

Lab temperature: 23.9 ºC
Barometric Pressure: 664.4 mmHg

Reference Standard (ºC)	Transfer Standard (ºC)	Difference from Reference (ºC)	Transfer Standard Correction* (ºC)
0.0	0.0	0.0	0.0
22.5	22.5	0.0	0.0
41.9	41.9	0.0	0.0

Note: If no sign is given on the correction, the true temperature is higher than the indicated temperature. If the sign is negative, the true temperature is lower than the indicated temperature.

Certified By: [signature] Date: May 11, 2016

Chinook Engineering
a division of Inter-Mountain Laboratories, Inc.
555 Absaraka Street
Sheridan, Wyoming 82801 USA
(307) 674-7506
chinook@imlinc.com

3D.7 SITE DOCUMENTATION FORMS

Stantec

Site Documentation Form

Site Name:	Parcel 56		
Location:		**Circle One**	
UTMX	678128 E	Measured	Calculated
UTMY	5662124 N		
UTMZone	11 U		
Latitude	51°4'58.54" N	Measured	Calculated
Longitude	114°27'24.33" W		
Elevation	1,246 m	Measured	Calculated
Datum	NAD 83		
Height of monitor (a.g.s.)	2.0 m		
Description			
Type of Station	Dustfall, Continuous Particulate (TSP and PM2.5)		
Installed Equipment	Two dustfall collectors with wooden bases. One E-BAM Particulate Sampler rented from Pine Environmental Services. 10 minute sampling interval. E-BAM was powered (115 VAC, 60 Hz) using an extension cord leading to an electrical outlet inside the nearest farm building. Plastic fence surrounded the monitoring station to prevent tampering.		
Terrain	agricultural farmland, hay field to the north, farm buildings to the west, unattended pasture to the east and south.		
Tree Canopy	Poplar trees (10 m high) located approximately 50 m east of the monitoring station. No trees in the north, south and east directions.		
Nearby Sources	no nearby incinerator or furnace flues. Highway 1 (TransCanada) located approximately 380 m north. Gravel road (only local traffic for three farm residences) located 150 m south.		
Pictures			
Direction Looking	**Picture ID**		
North	img_20160802_Parcel_56_north.jpg		
East	img_20160802_Parcel_56_east.jpg		
South	img_20160802_Parcel_56_south.jpg		
West	img_20160802_Parcel_56_west.jpg		
Access	via Parcel 56 landowner's yard		
Other Pictures of Interest			
Access			
Describe the Access to the site and any signs or markers used to identify the site			
The station is on the east side of the Parcel 56 farm property. Drive west on Highway 1 (TransCanada), head south on Highway 22 (Cowboy Trail). Turn left onto the first gravel road heading east. Turn left into the Parcel 56 farm driveway.			
Date and Time of Deployment	August 2, 2016 15:20		
Field Crew Leader	Daniel Jarratt, EP, P.Eng.		

Parcel 56 – View North Toward E-BAM Particulate Monitor and dustfall collectors (August 2, 2016)

Parcel 56 – View East Toward E-BAM Particulate Monitor and dustfall collectors (August 2, 2016)

Parcel 56 – View South Toward E-BAM Particulate Monitors and dustfall collectors (August 2, 2016)

Parcel 56 – View West Toward E-BAM Particulate Monitor and dustfall collectors (August 2, 2016)

Site Documentation Form

Site Name:	Parcel 58

Location:		Circle One	
UTMX	683151 E	Measured	Calculated
UTMY	5658336 N		
UTMZone	11 U		
Latitude	51°2'49.94" N	Measured	Calculated
Longitude	114°22'54.65" W		
Elevation	1,175 m	Measured	Calculated
Datum	NAD83		
Height of monitor (a.g.s.)	2.0 m		

Description	
Type of Station	Dustfall, Continuous Particulate (TSP and PM2.5)
Installed Equipment	Two dustfall collectors with wooden bases. One E-BAM Particulate Sampler rented from Pine Environmental Services. 10 minute sampling interval. E-BAM was powered (115 VAC, 60 Hz) using an extension cord leading to an electrical outlet inside the nearest farm building.
Terrain	agricultural farmland, farm buildings and trees to the south, unattended cattle pasture to the north, east and west.
Tree Canopy	Spruce and pine trees (6 m high) located approximately 25 m south of the monitoring station and (14 m high) poplar trees located approximately 45 m west. No nearby trees in the north and east
Nearby Sources	no nearby incinerator or furnace flues. Gravel road (driveway for the Parcel 58 farm residence) located 125 m south. Unpaved Range Road 34 located approximately 575 m east.

Pictures	
Direction Looking	**Picture ID**
North	img_20160803_Parcel_58_north.jpg
East	img_20160803_Parcel_58_east.jpg
South	img_20160803_Parcel_58_south.jpg
West	img_20160803_Parcel_58_west.jpg
Access	via Parcel 58 landowner's yard
Other Pictures of Interest	

Access

Describe the Access to the site and any signs or markers used to identify the site

Drive west on Springbank Road, turn left (south) onto Range Road 34. Drive approximately 2.3 km south towards the Elbow River. Turn right into driveway for Parcel 58 property. Drive west approximately 620 m to arrive at the residence for the Parcel 56 landowner. The monitoring station is approximately 140 m north of the residence.

Date and Time of Deployment	August 15, 2016 15:00 (the first E-BAM was installed August 3, 2016 but it experienced a mother board failure)
Field Crew Leader	Daniel Jarratt, EP, P.Eng.

Parcel 58 – View North Toward E-BAM Particulate Monitor and dustfall collectors (August 3, 2016)

Parcel 58 – View East Toward E-BAM Particulate Monitor and dustfall collectors (August 3, 2016)

Parcel 58 – View South Toward E-BAM Particulate Monitors and dustfall collectors (August 3, 2016)

Parcel 58 – View West Toward E-BAM Particulate Monitor and dustfall collectors (August 3, 2016)

3D.8 DUSTFALL LABORATORY REPORTS

Stantec Consulting Ltd.
ATTN: Daniel Jarratt
Suite 200 - 325 25 Street SE
Calgary AB T2A 7H8

Date Received: 26-AUG-16
Report Date: 06-SEP-16 15:59 (MT)
Version: FINAL

Client Phone: 403-441-5064

Certificate of Analysis

Lab Work Order #: L1819937

Project P.O. #: NOT SUBMITTED
Job Reference: 110773396 301.600.206.3
C of C Numbers: 14-480362
Legal Site Desc:

Jessica Spira, Env. Tech. DIPL
Senior Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L1819937-1 PARCEL 56 02AUG-26AUG2016							
Sampled By: KAMRAN RAHNAMA on 26-AUG-16 @ 11:45							
Matrix: DUSTFALL							
Miscellaneous Parameters							
Total Dustfall (mg/100cm2/30days)	22.6		8.0	mg		02-SEP-16	R3539924
Total Fixed Dustfall (mg/100cm2/30days)	6.5		5.0	mg		02-SEP-16	R3539924
Interval			1	days		02-SEP-16	R3540239
Mercury (Hg)-Total	<0.0000013		0.0000013	mg/dm2.day	02-SEP-16	03-SEP-16	R3541033
Total Metals in Dustfalls by ICPMS							
Aluminum (Al)-Total	0.00426		0.000079	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Interval			1	days		02-SEP-16	R3540239
Antimony (Sb)-Total	<0.0000026		0.0000026	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Arsenic (As)-Total	0.0000037		0.0000026	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Barium (Ba)-Total	0.000158		0.0000013	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Beryllium (Be)-Total	<0.000013		0.000013	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Bismuth (Bi)-Total	<0.000013		0.000013	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Boron (B)-Total	<0.00026		0.00026	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Cadmium (Cd)-Total	<0.0000013		0.0000013	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Calcium (Ca)-Total	0.0377		0.00052	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Chromium (Cr)-Total	<0.000013		0.000013	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Cobalt (Co)-Total	<0.0000026		0.0000026	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Copper (Cu)-Total	<0.000039	DLB	0.000039	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Lead (Pb)-Total	<0.0000065	DLB	0.0000065	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Iron (Fe)-Total	0.00548		0.00079	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Lithium (Li)-Total	<0.00013		0.00013	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Magnesium (Mg)-Total	0.00879		0.00013	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Manganese (Mn)-Total	0.000215		0.0000013	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Molybdenum (Mo)-Total	0.0000016		0.0000013	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Nickel (Ni)-Total	<0.000013		0.000013	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Phosphorus (P)-Total	0.0033		0.0013	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Potassium (K)-Total	0.0068		0.0013	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Selenium (Se)-Total	<0.000026		0.000026	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Silicon (Si)-Total	0.0080		0.0013	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Silver (Ag)-Total	<0.00000026		0.00000026	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Sodium (Na)-Total	0.0020		0.0013	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Strontium (Sr)-Total	0.0000585		0.0000026	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Thallium (Tl)-Total	<0.0000026		0.0000026	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Tin (Sn)-Total	<0.0000026		0.0000026	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Titanium (Ti)-Total	<0.00026		0.00026	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Uranium (U)-Total	<0.00000026		0.00000026	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Vanadium (V)-Total	<0.000026		0.000026	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Zinc (Zn)-Total	0.000251		0.000079	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
L1819937-2 PARCEL 58 03AUG-26AUG2016							
Sampled By: KAMRAN RAHNAMA on 26-AUG-16 @ 10:40							
Matrix: DUSTFALL							
Miscellaneous Parameters							
Total Dustfall (mg/100cm2/30days)	13.6		8.0	mg		02-SEP-16	R3539924
Total Fixed Dustfall (mg/100cm2/30days)	<5.0		5.0	mg		02-SEP-16	R3539924
Interval			1	days		02-SEP-16	R3540239
Mercury (Hg)-Total	<0.0000012		0.0000012	mg/dm2.day	02-SEP-16	03-SEP-16	R3541033
Total Metals in Dustfalls by ICPMS							
Aluminum (Al)-Total	0.00185		0.000073	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Interval			1	days		02-SEP-16	R3540239

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L1819937-2 PARCEL 58 03AUG-26AUG2016							
Sampled By: KAMRAN RAHNAMA on 26-AUG-16 @ 10:40							
Matrix: DUSTFALL							
Total Metals in Dustfalls by ICPMS							
Antimony (Sb)-Total	<0.0000024		0.0000024	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Arsenic (As)-Total	0.0000027		0.0000024	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Barium (Ba)-Total	0.0000700		0.0000012	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Beryllium (Be)-Total	<0.000012		0.000012	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Bismuth (Bi)-Total	<0.000012		0.000012	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Boron (B)-Total	<0.00024		0.00024	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Cadmium (Cd)-Total	<0.0000012		0.0000012	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Calcium (Ca)-Total	0.0178		0.00049	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Chromium (Cr)-Total	<0.000012		0.000012	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Cobalt (Co)-Total	<0.0000024		0.0000024	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Copper (Cu)-Total	<0.000024	DLB	0.000024	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Lead (Pb)-Total	<0.0000036	DLB	0.0000036	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Iron (Fe)-Total	0.00213		0.00073	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Lithium (Li)-Total	<0.00012		0.00012	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Magnesium (Mg)-Total	0.00421		0.00012	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Manganese (Mn)-Total	0.000101		0.0000012	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Molybdenum (Mo)-Total	<0.0000012		0.0000012	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Nickel (Ni)-Total	<0.000012		0.000012	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Phosphorus (P)-Total	0.0019		0.0012	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Potassium (K)-Total	0.0047		0.0012	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Selenium (Se)-Total	<0.000024		0.000024	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Silicon (Si)-Total	0.0045		0.0012	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Silver (Ag)-Total	<0.00000024		0.0000002 4	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Sodium (Na)-Total	<0.0012		0.0012	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Strontium (Sr)-Total	0.0000275		0.0000024	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Thallium (Tl)-Total	<0.0000024		0.0000024	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Tin (Sn)-Total	<0.0000024		0.0000024	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Titanium (Ti)-Total	<0.00024		0.00024	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Uranium (U)-Total	<0.00000024		0.0000002 4	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Vanadium (V)-Total	<0.000024		0.000024	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313
Zinc (Zn)-Total	0.000090		0.000073	mg/dm2.day	02-SEP-16	03-SEP-16	R3541313

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

Reference Information

Sample Parameter Qualifier Key:

Qualifier	Description
DLB	Detection Limit Raised. Analyte detected at comparable level in Method Blank.
MB-LOR	Method Blank exceeds ALS DQO. Limits of Reporting have been adjusted for samples with positive hits below 5x blank level.

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
DUSTFALL-TOT-ED	Air	Dustfall, Total	AB Env 32020

Dustfall analysis is carried out in accordance with procedures published in AB 32020.

ALS Test Code	Matrix	Test Description	Method Reference**
DUSTFALL-TOTFIX-ED	Air	Dustfall, Total Fixed	AB Env 32020

Dustfall analysis is carried out in accordance with procedures published in AB 32020.

ALS Test Code	Matrix	Test Description	Method Reference**
HG-DUST(DM2-CVAFS-VA	Dustfall	Total Mercury in Dustfalls by CVAFS	EPA 245.7

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). Instrumental analysis is by cold vapour atomic fluorescence spectrophotometry or atomic absorption spectrophotometry (EPA Method 245.7).

ALS Test Code	Matrix	Test Description	Method Reference**
MET-DUST(DM2)-MS-VA	Dustfall	Total Metals in Dustfalls by ICPMS	EPA 6020A

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). Instrumental analysis is by inductively coupled plasma - mass spectrometry (EPA Method 6020A).

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
ED	ALS ENVIRONMENTAL - EDMONTON, ALBERTA, CANADA
VA	ALS ENVIRONMENTAL - VANCOUVER, BRITISH COLUMBIA, CANADA

Chain of Custody Numbers:

14-480362

GLOSSARY OF REPORT TERMS

Surrogates are compounds that are similar in behaviour to target analyte(s), but that do not normally occur in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery. In reports that display the D.L. column, laboratory objectives for surrogates are listed there.
mg/kg - milligrams per kilogram based on dry weight of sample
mg/kg wwt - milligrams per kilogram based on wet weight of sample
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight
mg/L - unit of concentration based on volume, parts per million.
< - Less than.
D.L. - The reporting limit.
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

Quality Control Report

Client: Stantec Consulting Ltd.
Suite 200 - 325 25 Street SE
Calgary AB T2A 7H8

Contact: Daniel Jarratt

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
DUSTFALL-TOT-ED	**Air**							
Batch R3539924								
WG2378533-3 DUP		**L1819937-1**						
Total Dustfall (mg/100cm2/30days)		22.6	23.8		mg	5.3	20	02-SEP-16
WG2378533-2 LCS								
Total Dustfall (mg/100cm2/30days)			102.1		%		80-120	02-SEP-16
WG2378533-1 MB								
Total Dustfall (mg/100cm2/30days)			<8.0		mg		8	02-SEP-16
DUSTFALL-TOTFIX-ED	**Air**							
Batch R3539924								
WG2378533-3 DUP		**L1819937-1**						
Total Fixed Dustfall (mg/100cm2/30days)		6.5	6.7		mg	3.7	20	02-SEP-16
WG2378533-2 LCS								
Total Fixed Dustfall (mg/100cm2/30days)			99.1		%		80-120	02-SEP-16
WG2378533-1 MB								
Total Fixed Dustfall (mg/100cm2/30days)			<5.0		mg		5	02-SEP-16
HG-DUST(DM2-CVAFS-VA	**Dustfall**							
Batch R3541033								
WG2381649-2 DUP		**L1819937-1**						
Mercury (Hg)-Total		<0.0000013	<0.0000013	RPD-NA	mg/dm2.day	N/A	20	03-SEP-16
WG2381649-1 MB								
Mercury (Hg)-Total			<0.0000013		mg/dm2.day		0.0000013	03-SEP-16
MET-DUST(DM2)-MS-VA	**Dustfall**							
Batch R3541313								
WG2381649-2 DUP		**L1819937-1**						
Aluminum (Al)-Total		0.00426	0.00443		mg/dm2.day	3.9	20	03-SEP-16
Antimony (Sb)-Total		<0.0000026	<0.0000026	RPD-NA	mg/dm2.day	N/A	20	03-SEP-16
Arsenic (As)-Total		0.0000037	0.0000036		mg/dm2.day	3.7	20	03-SEP-16
Barium (Ba)-Total		0.000158	0.000163		mg/dm2.day	3.1	20	03-SEP-16
Beryllium (Be)-Total		<0.000013	<0.000013	RPD-NA	mg/dm2.day	N/A	20	03-SEP-16
Bismuth (Bi)-Total		<0.000013	<0.000013	RPD-NA	mg/dm2.day	N/A	20	03-SEP-16
Boron (B)-Total		<0.00026	<0.00026	RPD-NA	mg/dm2.day	N/A	20	03-SEP-16
Cadmium (Cd)-Total		<0.0000013	<0.0000013	RPD-NA	mg/dm2.day	N/A	20	03-SEP-16
Calcium (Ca)-Total		0.0377	0.0385		mg/dm2.day	2.2	20	03-SEP-16
Chromium (Cr)-Total		<0.000013	<0.000013	RPD-NA	mg/dm2.day	N/A	20	03-SEP-16
Cobalt (Co)-Total		<0.0000026	<0.0000026	RPD-NA	mg/dm2.day	N/A	20	03-SEP-16
Copper (Cu)-Total		<0.000039	<0.000039	RPD-NA	mg/dm2.day	N/A	20	03-SEP-16
Lead (Pb)-Total		<0.0000065	<0.0000065	RPD-NA	mg/dm2.day	N/A	20	03-SEP-16

ALS Environmental

Quality Control Report

Workorder: L1819937 Report Date: 06-SEP-16

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-DUST(DM2)-MS-VA	**Dustfall**							
Batch R3541313								
WG2381649-2 DUP		**L1819937-1**						
Iron (Fe)-Total		0.00548	0.00566		mg/dm2.day	3.2	20	03-SEP-16
Lithium (Li)-Total		<0.00013	<0.00013	RPD-NA	mg/dm2.day	N/A	20	03-SEP-16
Magnesium (Mg)-Total		0.00879	0.00872		mg/dm2.day	0.8	20	03-SEP-16
Manganese (Mn)-Total		0.000215	0.000213		mg/dm2.day	0.9	20	03-SEP-16
Molybdenum (Mo)-Total		0.0000016	0.0000015		mg/dm2.day	3.8	20	03-SEP-16
Nickel (Ni)-Total		<0.000013	<0.000013	RPD-NA	mg/dm2.day	N/A	20	03-SEP-16
Phosphorus (P)-Total		0.0033	0.0032		mg/dm2.day	3.5	20	03-SEP-16
Potassium (K)-Total		0.0068	0.0069		mg/dm2.day	1.5	20	03-SEP-16
Selenium (Se)-Total		<0.000026	<0.000026	RPD-NA	mg/dm2.day	N/A	20	03-SEP-16
Silicon (Si)-Total		0.0080	0.0084		mg/dm2.day	4.6	20	03-SEP-16
Silver (Ag)-Total		<0.00000026	<0.0000002	RPD-NA	mg/dm2.day	N/A	20	03-SEP-16
Sodium (Na)-Total		0.0020	0.0020		mg/dm2.day	2.2	20	03-SEP-16
Strontium (Sr)-Total		0.0000585	0.0000604		mg/dm2.day	3.2	20	03-SEP-16
Thallium (Tl)-Total		<0.0000026	<0.0000026	RPD-NA	mg/dm2.day	N/A	20	03-SEP-16
Tin (Sn)-Total		<0.0000026	<0.0000026	RPD-NA	mg/dm2.day	N/A	20	03-SEP-16
Titanium (Ti)-Total		<0.00026	<0.00026	RPD-NA	mg/dm2.day	N/A	20	03-SEP-16
Uranium (U)-Total		<0.00000026	<0.0000002	RPD-NA	mg/dm2.day	N/A	20	03-SEP-16
Vanadium (V)-Total		<0.000026	<0.000026	RPD-NA	mg/dm2.day	N/A	20	03-SEP-16
Zinc (Zn)-Total		0.000251	0.000257		mg/dm2.day	2.6	20	03-SEP-16
WG2381649-1 MB								
Aluminum (Al)-Total			<0.000079		mg/dm2.day		0.000079	03-SEP-16
Antimony (Sb)-Total			<0.0000026		mg/dm2.day		0.0000026	03-SEP-16
Arsenic (As)-Total			<0.0000026		mg/dm2.day		0.0000026	03-SEP-16
Barium (Ba)-Total			<0.0000013		mg/dm2.day		0.0000013	03-SEP-16
Beryllium (Be)-Total			<0.000013		mg/dm2.day		0.000013	03-SEP-16
Bismuth (Bi)-Total			<0.000013		mg/dm2.day		0.000013	03-SEP-16
Boron (B)-Total			<0.00026		mg/dm2.day		0.00026	03-SEP-16
Cadmium (Cd)-Total			<0.0000013		mg/dm2.day		0.0000013	03-SEP-16
Calcium (Ca)-Total			<0.00052		mg/dm2.day		0.00052	03-SEP-16
Chromium (Cr)-Total			<0.000013		mg/dm2.day		0.000013	03-SEP-16
Cobalt (Co)-Total			<0.0000026		mg/dm2.day		0.0000026	03-SEP-16
Copper (Cu)-Total			0.000061	MB-LOR	mg/dm2.day		0.000013	03-SEP-16
Lead (Pb)-Total			0.0000015	MB-LOR	mg/dm2.day		0.0000013	03-SEP-16
Iron (Fe)-Total			<0.00079		mg/dm2.day		0.00079	03-SEP-16

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-DUST(DM2)-MS-VA	**Dustfall**							
Batch R3541313								
WG2381649-1 MB								
Lithium (Li)-Total			<0.00013		mg/dm2.day		0.00013	03-SEP-16
Magnesium (Mg)-Total			<0.00013		mg/dm2.day		0.00013	03-SEP-16
Manganese (Mn)-Total			0.0000038	MB-LOR	mg/dm2.day		0.0000013	03-SEP-16
Molybdenum (Mo)-Total			<0.000001З		mg/dm2.day		0.0000013	03-SEP-16
Nickel (Ni)-Total			<0.000013		mg/dm2.day		0.000013	03-SEP-16
Phosphorus (P)-Total			<0.0013		mg/dm2.day		0.0013	03-SEP-16
Potassium (K)-Total			<0.0013		mg/dm2.day		0.0013	03-SEP-16
Selenium (Se)-Total			<0.000026		mg/dm2.day		0.000026	03-SEP-16
Silicon (Si)-Total			<0.0013		mg/dm2.day		0.0013	03-SEP-16
Silver (Ag)-Total			<0.0000002		mg/dm2.day		0.00000026	03-SEP-16
Sodium (Na)-Total			<0.0013		mg/dm2.day		0.0013	03-SEP-16
Strontium (Sr)-Total			<0.0000026		mg/dm2.day		0.0000026	03-SEP-16
Thallium (Tl)-Total			<0.0000026		mg/dm2.day		0.0000026	03-SEP-16
Tin (Sn)-Total			<0.0000026		mg/dm2.day		0.0000026	03-SEP-16
Titanium (Ti)-Total			<0.00026		mg/dm2.day		0.00026	03-SEP-16
Uranium (U)-Total			<0.0000002		mg/dm2.day		0.00000026	03-SEP-16
Vanadium (V)-Total			<0.000026		mg/dm2.day		0.000026	03-SEP-16
Zinc (Zn)-Total			<0.000079		mg/dm2.day		0.000079	03-SEP-16

Quality Control Report

Legend:

Limit	ALS Control Limit (Data Quality Objectives)
DUP	Duplicate
RPD	Relative Percent Difference
N/A	Not Available
LCS	Laboratory Control Sample
SRM	Standard Reference Material
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ADE	Average Desorption Efficiency
MB	Method Blank
IRM	Internal Reference Material
CRM	Certified Reference Material
CCV	Continuing Calibration Verification
CVS	Calibration Verification Standard
LCSD	Laboratory Control Sample Duplicate

Sample Parameter Qualifier Definitions:

Qualifier	Description
MB-LOR	Method Blank exceeds ALS DQO. Limits of Reporting have been adjusted for samples with positive hits below 5x blank level.
RPD-NA	Relative Percent Difference Not Available due to result(s) being less than detection limit.

Hold Time Exceedances:

All test results reported with this submission were conducted within ALS recommended hold times.

ALS recommended hold times may vary by province. They are assigned to meet known provincial and/or federal government requirements. In the absence of regulatory hold times, ALS establishes recommendations based on guidelines published by the US EPA, APHA Standard Methods, or Environment Canada (where available). For more information, please contact ALS.

The ALS Quality Control Report is provided to ALS clients upon request. ALS includes comprehensive QC checks with every analysis to ensure our high standards of quality are met. Each QC result has a known or expected target value, which is compared against pre-determined data quality objectives to provide confidence in the accuracy of associated test results.

Please note that this report may contain QC results from anonymous Sample Duplicates and Matrix Spikes that do not originate from this Work Order.

ALS Environmental
www.alsglobal.com

Chain of Custody (COC) / Analytical Request Form

Canada Toll Free: 1 800 668 9878

L1819937-COFC

COC Number: 14 - 480362

Page ____ of ____

Report To	
Company:	STANTEC CONSULTING LTD.
Contact:	DANIEL JARRATT
Address:	200-325 25th St SE, Calgary, AB T2A7H8
Phone:	403 441 5064

Report Format / Distribution

Select Report Format: ☑ PDF ☑ EXCEL ☐ EDD (DIGITAL)
Quality Control (QC) Report with Report ☑ Yes ☐ No
☐ Criteria on Report - provide details below if box checked
Select Distribution: ☑ EMAIL ☐ MAIL ☐ FAX
Email 1 or Fax DANIEL.JARRATT@stantec.com
Email 2

Select Service Level Below (Rush Turnaround Time (TAT) is not available for all tests)

R ☑ Regular (Standard TAT if received by 3pm)
P ☐ Priority (2-4 business days if received by 3pm)
E ☐ Emergency (1-2 business days if received by 3pm)
E2 ☐ Same day or weekend emergency if received by 10am – contact ALS for surcharge.
Specify Date Required for E2,E or P:

Invoice To — Same as Report To ☐ Yes ☐ No
Copy of Invoice with Report ☐ Yes ☐ No
Company:
Contact:

Invoice Distribution

Select Invoice Distribution: ☑ EMAIL ☐ MAIL ☐ FAX
Email 1 or Fax
Email 2

Project Information

ALS Quote #:
Job #: 111440336 500.200
PO / AFE:
LSD:

Oil and Gas Required Fields (client use)

Approver ID: | Cost Center:
GL Account: | Routing Code:
Activity Code:
Location:

ALS Lab Work Order # (lab use only)

ALS Contact: Jessica Spira | Sampler: Kamran Rahnama

Analysis Request — Indicate Filtered (F), Preserved (P) or Filtered and Preserved (F/P) below

ALS Sample # (lab use only)	Sample Identification and/or Coordinates (This description will appear on the report)	Date (dd-mmm-yy)	Time (hh:mm)	Sample Type	Total Particulate	Soluble Particulate	Insoluble Particulate	Number of Containers
	Parcel 56 02Aug-26Aug 2016	26-Aug-16	11:45	Dustfall	✓	✓	✓	1
	Parcel 56	"	"	Dustfall	✓	✓	✓	1
	Parcel 58 03Aug-26Aug 2016	26-Aug-16	10:40	Dustfall	✓	✓	✓	1
	Parcel 58	"	"	Dustfall	✓	✓	✓	1

Drinking Water (DW) Samples[1] (client use)

Are samples taken from a Regulated DW System? ☐ Yes ☐ No
Are samples for human drinking water use? ☐ Yes ☐ No

Special Instructions / Specify Criteria to add on report (client Use)

SAMPLE CONDITION AS RECEIVED (lab use only)

Frozen ☐ | SIF Observations Yes ☐ No ☐
Ice packs Yes ☐ No ☑ | Custody seal intact Yes ☐ No ☐
Cooling Initiated ☐

INITIAL COOLER TEMPERATURES °C: 21.2 °C
FINAL COOLER TEMPERATURES °C:

SHIPMENT RELEASE (client use)			INITIAL SHIPMENT RECEPTION (lab use only)			FINAL SHIPMENT RECEPTION (lab use only)		
Released by: K Rahnama Kamran Rahnama	Date: 26 Aug 2016	Time: 15:15	Received by: JK	Date: 08/26	Time: 3:20 pm	Received by:	Date:	Time:

REFER TO BACK PAGE FOR ALS LOCATIONS AND SAMPLING INFORMATION

WHITE - LABORATORY COPY YELLOW - CLIENT COPY

NA FM-0326a v09 Front/04 January 2014

Failure to complete all portions of this form may delay analysis. Please fill in this form LEGIBLY. By the use of this form the user acknowledges and agrees with the Terms and Conditions as specified on the back page of the white - report copy.

1. If any water samples are taken from a Regulated Drinking Water (DW) System, please submit using an Authorized DW COC form.

Stantec Consulting Ltd.
ATTN: Daniel Jarratt
Suite 200 - 325 25 Street SE
Calgary AB T2A 7H8

Date Received: 14-OCT-16
Report Date: 27-OCT-16 08:32 (MT)
Version: FINAL

Client Phone: 403-441-5064

Certificate of Analysis

Lab Work Order #: L1843583

Project P.O. #: NOT SUBMITTED

Job Reference: 110773396

C of C Numbers: 15-583215

Legal Site Desc:

Jessica Spira, Env. Tech. DIPL
Senior Account Manager

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L1843583-1 PARCEL 56 26 AUG - 13 OCTOBER							
Sampled By: DANIEL JARRATT on 13-OCT-16 @ 14:00							
Matrix: DUSTFALL							
Miscellaneous Parameters							
Total Dustfall (mg/100cm2/30days)	22.6		8.0	mg		24-OCT-16	R3578408
Total Fixed Dustfall (mg/100cm2/30days)	8.1		5.0	mg		24-OCT-16	R3578408
Interval			1	days		21-OCT-16	R3577050
Mercury (Hg)-Total	<0.00000092		0.00000092	mg/dm2.day	21-OCT-16	21-OCT-16	R3576852
Total Metals in Dustfalls by ICPMS							
Aluminum (Al)-Total	0.00255		0.000055	mg/dm2.day	21-OCT-16	24-OCT-16	R3579330
Interval			1	days		21-OCT-16	R3577050
Antimony (Sb)-Total	<0.0000018		0.0000018	mg/dm2.day	21-OCT-16	24-OCT-16	R3579330
Arsenic (As)-Total	0.0000021		0.0000018	mg/dm2.day	21-OCT-16	24-OCT-16	R3579330
Barium (Ba)-Total	0.0000981		0.00000092	mg/dm2.day	21-OCT-16	24-OCT-16	R3579330
Beryllium (Be)-Total	<0.0000092		0.0000092	mg/dm2.day	21-OCT-16	24-OCT-16	R3579330
Bismuth (Bi)-Total	<0.0000092		0.0000092	mg/dm2.day	21-OCT-16	24-OCT-16	R3579330
Boron (B)-Total	<0.00018		0.00018	mg/dm2.day	21-OCT-16	24-OCT-16	R3579330
Cadmium (Cd)-Total	<0.00000092		0.00000092	mg/dm2.day	21-OCT-16	24-OCT-16	R3579330
Calcium (Ca)-Total	0.0257		0.00037	mg/dm2.day	21-OCT-16	24-OCT-16	R3579330
Chromium (Cr)-Total	<0.0000092		0.0000092	mg/dm2.day	21-OCT-16	24-OCT-16	R3579330
Cobalt (Co)-Total	<0.0000018		0.0000018	mg/dm2.day	21-OCT-16	24-OCT-16	R3579330
Copper (Cu)-Total	0.0000443		0.0000092	mg/dm2.day	21-OCT-16	26-OCT-16	R3580543
Lead (Pb)-Total	0.00000397		0.00000092	mg/dm2.day	21-OCT-16	24-OCT-16	R3579330
Iron (Fe)-Total	0.00361		0.00055	mg/dm2.day	21-OCT-16	24-OCT-16	R3579330
Lithium (Li)-Total	<0.000092		0.000092	mg/dm2.day	21-OCT-16	24-OCT-16	R3579330
Magnesium (Mg)-Total	0.00571		0.000092	mg/dm2.day	21-OCT-16	24-OCT-16	R3579330
Manganese (Mn)-Total	0.000174		0.00000092	mg/dm2.day	21-OCT-16	24-OCT-16	R3579330
Molybdenum (Mo)-Total	<0.00000092		0.00000092	mg/dm2.day	21-OCT-16	24-OCT-16	R3579330
Nickel (Ni)-Total	<0.0000092		0.0000092	mg/dm2.day	21-OCT-16	24-OCT-16	R3579330
Phosphorus (P)-Total	0.00147		0.00092	mg/dm2.day	21-OCT-16	24-OCT-16	R3579330
Potassium (K)-Total	0.00373		0.00092	mg/dm2.day	21-OCT-16	24-OCT-16	R3579330
Selenium (Se)-Total	<0.000018		0.000018	mg/dm2.day	21-OCT-16	24-OCT-16	R3579330
Silicon (Si)-Total	0.00486		0.00092	mg/dm2.day	21-OCT-16	24-OCT-16	R3579330
Silver (Ag)-Total	<0.00000018		0.00000018	mg/dm2.day	21-OCT-16	24-OCT-16	R3579330
Sodium (Na)-Total	0.00269		0.00092	mg/dm2.day	21-OCT-16	24-OCT-16	R3579330
Strontium (Sr)-Total	0.0000376		0.0000018	mg/dm2.day	21-OCT-16	24-OCT-16	R3579330
Thallium (Tl)-Total	<0.0000018		0.0000018	mg/dm2.day	21-OCT-16	24-OCT-16	R3579330
Tin (Sn)-Total	<0.0000018		0.0000018	mg/dm2.day	21-OCT-16	26-OCT-16	R3580543
Titanium (Ti)-Total	<0.00018		0.00018	mg/dm2.day	21-OCT-16	24-OCT-16	R3579330
Uranium (U)-Total	<0.00000018		0.00000018	mg/dm2.day	21-OCT-16	24-OCT-16	R3579330
Vanadium (V)-Total	<0.000018		0.000018	mg/dm2.day	21-OCT-16	24-OCT-16	R3579330
Zinc (Zn)-Total	0.000186		0.000055	mg/dm2.day	21-OCT-16	24-OCT-16	R3579330
L1843583-2 PARCEL 58 26 AUG - 13 OCTOBER							
Sampled By: DANIEL JARRATT on 13-OCT-16 @ 09:50							
Matrix: DUSTFALL							
Miscellaneous Parameters							
Total Dustfall (mg/100cm2/30days)	12.0		8.0	mg		24-OCT-16	R3578408
Total Fixed Dustfall (mg/100cm2/30days)	<5.0		5.0	mg		24-OCT-16	R3578408
Interval			1	days		21-OCT-16	R3577050

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

ALS ENVIRONMENTAL ANALYTICAL REPORT

Sample Details/Parameters	Result	Qualifier*	D.L.	Units	Extracted	Analyzed	Batch
L1843583-2 PARCEL 58 26 AUG - 13 OCTOBER							
Sampled By: DANIEL JARRATT on 13-OCT-16 @ 09:50							
Matrix: DUSTFALL							
Mercury (Hg)-Total	<0.00000066		0.00000066	mg/dm2.day	21-OCT-16	21-OCT-16	R3576852
Total Metals in Dustfalls by ICPMS							
Aluminum (Al)-Total	0.00223		0.000040	mg/dm2.day	21-OCT-16	21-OCT-16	R3579330
Interval			1	days		21-OCT-16	R3577050
Antimony (Sb)-Total	<0.0000013		0.0000013	mg/dm2.day	21-OCT-16	21-OCT-16	R3579330
Arsenic (As)-Total	0.0000032		0.0000013	mg/dm2.day	21-OCT-16	21-OCT-16	R3579330
Barium (Ba)-Total	0.0000604		0.00000066	mg/dm2.day	21-OCT-16	21-OCT-16	R3579330
Beryllium (Be)-Total	<0.0000066		0.0000066	mg/dm2.day	21-OCT-16	21-OCT-16	R3579330
Bismuth (Bi)-Total	<0.0000066		0.0000066	mg/dm2.day	21-OCT-16	21-OCT-16	R3579330
Boron (B)-Total	<0.00013		0.00013	mg/dm2.day	21-OCT-16	21-OCT-16	R3579330
Cadmium (Cd)-Total	<0.00000066		0.00000066	mg/dm2.day	21-OCT-16	21-OCT-16	R3579330
Calcium (Ca)-Total	0.0146		0.00027	mg/dm2.day	21-OCT-16	21-OCT-16	R3579330
Chromium (Cr)-Total	0.0000073		0.0000066	mg/dm2.day	21-OCT-16	21-OCT-16	R3579330
Cobalt (Co)-Total	<0.0000013		0.0000013	mg/dm2.day	21-OCT-16	21-OCT-16	R3579330
Copper (Cu)-Total	<0.000033	DLB	0.000033	mg/dm2.day	21-OCT-16	21-OCT-16	R3579330
Lead (Pb)-Total	0.00000314		0.00000066	mg/dm2.day	21-OCT-16	21-OCT-16	R3579330
Iron (Fe)-Total	0.00247		0.00040	mg/dm2.day	21-OCT-16	21-OCT-16	R3579330
Lithium (Li)-Total	<0.000066		0.000066	mg/dm2.day	21-OCT-16	21-OCT-16	R3579330
Magnesium (Mg)-Total	0.00296		0.000066	mg/dm2.day	21-OCT-16	21-OCT-16	R3579330
Manganese (Mn)-Total	0.000113		0.00000066	mg/dm2.day	21-OCT-16	21-OCT-16	R3579330
Molybdenum (Mo)-Total	<0.00000066		0.00000066	mg/dm2.day	21-OCT-16	21-OCT-16	R3579330
Nickel (Ni)-Total	<0.0000066		0.0000066	mg/dm2.day	21-OCT-16	21-OCT-16	R3579330
Phosphorus (P)-Total	0.00086		0.00066	mg/dm2.day	21-OCT-16	21-OCT-16	R3579330
Potassium (K)-Total	0.00271		0.00066	mg/dm2.day	21-OCT-16	21-OCT-16	R3579330
Selenium (Se)-Total	<0.000013		0.000013	mg/dm2.day	21-OCT-16	21-OCT-16	R3579330
Silicon (Si)-Total	0.00426		0.00066	mg/dm2.day	21-OCT-16	21-OCT-16	R3579330
Silver (Ag)-Total	<0.00000013		0.00000013	mg/dm2.day	21-OCT-16	21-OCT-16	R3579330
Sodium (Na)-Total	0.00170		0.00066	mg/dm2.day	21-OCT-16	21-OCT-16	R3579330
Strontium (Sr)-Total	0.0000229		0.0000013	mg/dm2.day	21-OCT-16	21-OCT-16	R3579330
Thallium (Tl)-Total	<0.0000013		0.0000013	mg/dm2.day	21-OCT-16	21-OCT-16	R3579330
Tin (Sn)-Total	0.0000036		0.0000013	mg/dm2.day	21-OCT-16	21-OCT-16	R3579330
Titanium (Ti)-Total	<0.00013		0.00013	mg/dm2.day	21-OCT-16	21-OCT-16	R3579330
Uranium (U)-Total	<0.00000013		0.00000013	mg/dm2.day	21-OCT-16	21-OCT-16	R3579330
Vanadium (V)-Total	<0.000013		0.000013	mg/dm2.day	21-OCT-16	21-OCT-16	R3579330
Zinc (Zn)-Total	<0.000080	DLB	0.000080	mg/dm2.day	21-OCT-16	21-OCT-16	R3579330

* Refer to Referenced Information for Qualifiers (if any) and Methodology.

Reference Information

Sample Parameter Qualifier Key:

Qualifier	Description
DLB	Detection Limit Raised. Analyte detected at comparable level in Method Blank.
MB-LOR	Method Blank exceeds ALS DQO. Limits of Reporting have been adjusted for samples with positive hits below 5x blank level.

Test Method References:

ALS Test Code	Matrix	Test Description	Method Reference**
DUSTFALL-TOT-ED	Air	Dustfall, Total	AB Env 32020

Dustfall analysis is carried out in accordance with procedures published in AB 32020.

ALS Test Code	Matrix	Test Description	Method Reference**
DUSTFALL-TOTFIX-ED	Air	Dustfall, Total Fixed	AB Env 32020

Dustfall analysis is carried out in accordance with procedures published in AB 32020.

ALS Test Code	Matrix	Test Description	Method Reference**
HG-DUST(DM2-CVAFS-VA	Dustfall	Total Mercury in Dustfalls by CVAFS	EPA 245.7

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). Instrumental analysis is by cold vapour atomic fluorescence spectrophotometry or atomic absorption spectrophotometry (EPA Method 245.7).

ALS Test Code	Matrix	Test Description	Method Reference**
MET-DUST(DM2)-MS-VA	Dustfall	Total Metals in Dustfalls by ICPMS	EPA 6020A

This analysis is carried out using procedures adapted from "Standard Methods for the Examination of Water and Wastewater" published by the American Public Health Association, and with procedures adapted from "Test Methods for Evaluating Solid Waste" SW-846 published by the United States Environmental Protection Agency (EPA). Instrumental analysis is by inductively coupled plasma - mass spectrometry (EPA Method 6020A).

** ALS test methods may incorporate modifications from specified reference methods to improve performance.

The last two letters of the above test code(s) indicate the laboratory that performed analytical analysis for that test. Refer to the list below:

Laboratory Definition Code	Laboratory Location
ED	ALS ENVIRONMENTAL - EDMONTON, ALBERTA, CANADA
VA	ALS ENVIRONMENTAL - VANCOUVER, BRITISH COLUMBIA, CANADA

Chain of Custody Numbers:

15-583215

GLOSSARY OF REPORT TERMS

Surrogates are compounds that are similar in behaviour to target analyte(s), but that do not normally occur in environmental samples. For applicable tests, surrogates are added to samples prior to analysis as a check on recovery. In reports that display the D.L. column, laboratory objectives for surrogates are listed there.
mg/kg - milligrams per kilogram based on dry weight of sample
mg/kg wwt - milligrams per kilogram based on wet weight of sample
mg/kg lwt - milligrams per kilogram based on lipid-adjusted weight
mg/L - unit of concentration based on volume, parts per million.
< - Less than.
D.L. - The reporting limit.
N/A - Result not available. Refer to qualifier code and definition for explanation.

Test results reported relate only to the samples as received by the laboratory.
UNLESS OTHERWISE STATED, ALL SAMPLES WERE RECEIVED IN ACCEPTABLE CONDITION.
Analytical results in unsigned test reports with the DRAFT watermark are subject to change, pending final QC review.

Quality Control Report

Workorder: L1843583 Report Date: 27-OCT-16

Client: Stantec Consulting Ltd.
Suite 200 - 325 25 Street SE
Calgary AB T2A 7H8

Contact: Daniel Jarratt

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
DUSTFALL-TOT-ED	**Air**							
Batch R3578408								
WG2412859-2 LCS								
Total Dustfall (mg/100cm2/30days)			101.6		%		80-120	24-OCT-16
WG2412859-1 MB								
Total Dustfall (mg/100cm2/30days)			<8.0		mg		8	24-OCT-16
DUSTFALL-TOTFIX-ED	**Air**							
Batch R3578408								
WG2412859-2 LCS								
Total Fixed Dustfall (mg/100cm2/30days)			97.5		%		80-120	24-OCT-16
WG2412859-1 MB								
Total Fixed Dustfall (mg/100cm2/30days)			<5.0		mg		5	24-OCT-16
HG-DUST(DM2-CVAFS-VA	**Dustfall**							
Batch R3576852								
WG2415436-2 DUP		**L1843583-1**						
Mercury (Hg)-Total		<0.00000092	<0.0000009	RPD-NA	mg/dm2.day	N/A	20	21-OCT-16
WG2415436-1 MB								
Mercury (Hg)-Total			<0.0000013		mg/dm2.day		0.0000013	21-OCT-16
WG2415436-3 MS		**L1843583-2**						
Mercury (Hg)-Total			101.1		%		70-130	21-OCT-16
MET-DUST(DM2)-MS-VA	**Dustfall**							
Batch R3579330								
WG2415436-2 DUP		**L1843583-1**						
Aluminum (Al)-Total		0.00255	0.00257		mg/dm2.day	1.0	20	24-OCT-16
Antimony (Sb)-Total		<0.0000018	<0.0000018	RPD-NA	mg/dm2.day	N/A	20	24-OCT-16
Arsenic (As)-Total		0.0000021	<0.0000018	RPD-NA	mg/dm2.day	N/A	20	24-OCT-16
Barium (Ba)-Total		0.0000981	0.000100		mg/dm2.day	2.2	20	24-OCT-16
Beryllium (Be)-Total		<0.0000092	<0.0000092	RPD-NA	mg/dm2.day	N/A	20	24-OCT-16
Bismuth (Bi)-Total		<0.0000092	<0.0000092	RPD-NA	mg/dm2.day	N/A	20	24-OCT-16
Boron (B)-Total		<0.00018	<0.00018	RPD-NA	mg/dm2.day	N/A	20	24-OCT-16
Cadmium (Cd)-Total		<0.00000092	<0.0000009	RPD-NA	mg/dm2.day	N/A	20	24-OCT-16
Calcium (Ca)-Total		0.0257	0.0253		mg/dm2.day	1.6	20	24-OCT-16
Chromium (Cr)-Total		<0.0000092	<0.0000092	RPD-NA	mg/dm2.day	N/A	20	24-OCT-16
Cobalt (Co)-Total		<0.0000018	<0.0000018	RPD-NA	mg/dm2.day	N/A	20	24-OCT-16
Lead (Pb)-Total		0.00000397	0.00000345		mg/dm2.day	14	20	24-OCT-16
Iron (Fe)-Total		0.00361	0.00348		mg/dm2.day	3.8	20	24-OCT-16
Lithium (Li)-Total		<0.000092	<0.000092	RPD-NA	mg/dm2.day	N/A	20	24-OCT-16
Magnesium (Mg)-Total		0.00571	0.00558		mg/dm2.day	2.3	20	24-OCT-16

ALS Environmental

Quality Control Report

Workorder: L1843583 Report Date: 27-OCT-16

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-DUST(DM2)-MS-VA	**Dustfall**							
Batch R3579330								
WG2415436-2 DUP		**L1843583-1**						
Manganese (Mn)-Total		0.000174	0.000160		mg/dm2.day	8.7	20	24-OCT-16
Molybdenum (Mo)-Total		<0.00000092	<0.0000009	RPD-NA	mg/dm2.day	N/A	20	24-OCT-16
Nickel (Ni)-Total		<0.0000092	<0.0000092	RPD-NA	mg/dm2.day	N/A	20	24-OCT-16
Phosphorus (P)-Total		0.00147	0.00163		mg/dm2.day	10	20	24-OCT-16
Potassium (K)-Total		0.00373	0.00362		mg/dm2.day	2.9	20	24-OCT-16
Selenium (Se)-Total		<0.000018	<0.000018	RPD-NA	mg/dm2.day	N/A	20	24-OCT-16
Silicon (Si)-Total		0.00486	0.00540		mg/dm2.day	11	20	24-OCT-16
Silver (Ag)-Total		<0.00000018	<0.0000001	RPD-NA	mg/dm2.day	N/A	20	24-OCT-16
Sodium (Na)-Total		0.00269	0.00255		mg/dm2.day	5.2	20	24-OCT-16
Strontium (Sr)-Total		0.0000376	0.0000373		mg/dm2.day	0.7	20	24-OCT-16
Thallium (Tl)-Total		<0.0000018	<0.0000018	RPD-NA	mg/dm2.day	N/A	20	24-OCT-16
Titanium (Ti)-Total		<0.00018	<0.00018	RPD-NA	mg/dm2.day	N/A	20	24-OCT-16
Uranium (U)-Total		<0.00000018	<0.0000001	RPD-NA	mg/dm2.day	N/A	20	24-OCT-16
Vanadium (V)-Total		<0.000018	<0.000018	RPD-NA	mg/dm2.day	N/A	20	24-OCT-16
Zinc (Zn)-Total		0.000186	0.000155		mg/dm2.day	18	20	24-OCT-16
WG2415436-1 MB								
Aluminum (Al)-Total			<0.000079		mg/dm2.day		0.000079	24-OCT-16
Antimony (Sb)-Total			<0.0000026		mg/dm2.day		0.0000026	24-OCT-16
Arsenic (As)-Total			<0.0000026		mg/dm2.day		0.0000026	24-OCT-16
Barium (Ba)-Total			<0.0000013		mg/dm2.day		0.0000013	24-OCT-16
Beryllium (Be)-Total			<0.000013		mg/dm2.day		0.000013	24-OCT-16
Bismuth (Bi)-Total			<0.000013		mg/dm2.day		0.000013	24-OCT-16
Boron (B)-Total			<0.00026		mg/dm2.day		0.00026	24-OCT-16
Cadmium (Cd)-Total			<0.0000013		mg/dm2.day		0.0000013	24-OCT-16
Calcium (Ca)-Total			<0.00052		mg/dm2.day		0.00052	24-OCT-16
Chromium (Cr)-Total			<0.000013		mg/dm2.day		0.000013	24-OCT-16
Cobalt (Co)-Total			<0.0000026		mg/dm2.day		0.0000026	24-OCT-16
Copper (Cu)-Total			0.000030	MB-LOR	mg/dm2.day		0.000013	24-OCT-16
Lead (Pb)-Total			<0.0000013		mg/dm2.day		0.0000013	24-OCT-16
Iron (Fe)-Total			<0.00079		mg/dm2.day		0.00079	24-OCT-16
Lithium (Li)-Total			<0.00013		mg/dm2.day		0.00013	24-OCT-16
Magnesium (Mg)-Total			<0.00013		mg/dm2.day		0.00013	24-OCT-16
Manganese (Mn)-Total			0.0000021	MB-LOR	mg/dm2.day		0.0000013	24-OCT-16
Molybdenum (Mo)-Total			<0.0000013		mg/dm2.day		0.0000013	24-OCT-16

Quality Control Report

Test	Matrix	Reference	Result	Qualifier	Units	RPD	Limit	Analyzed
MET-DUST(DM2)-MS-VA	**Dustfall**							
Batch R3579330								
WG2415436-1 MB								
Nickel (Ni)-Total			<0.000013		mg/dm2.day		0.000013	24-OCT-16
Phosphorus (P)-Total			<0.0013		mg/dm2.day		0.0013	24-OCT-16
Potassium (K)-Total			<0.0013		mg/dm2.day		0.0013	24-OCT-16
Selenium (Se)-Total			<0.000026		mg/dm2.day		0.000026	24-OCT-16
Silicon (Si)-Total			<0.0013		mg/dm2.day		0.0013	24-OCT-16
Silver (Ag)-Total			<0.0000002		mg/dm2.day		0.00000026	24-OCT-16
Sodium (Na)-Total			<0.0013		mg/dm2.day		0.0013	24-OCT-16
Strontium (Sr)-Total			<0.0000026		mg/dm2.day		0.0000026	24-OCT-16
Thallium (Tl)-Total			<0.0000026		mg/dm2.day		0.0000026	24-OCT-16
Tin (Sn)-Total			<0.0000026		mg/dm2.day		0.0000026	24-OCT-16
Titanium (Ti)-Total			<0.00026		mg/dm2.day		0.00026	24-OCT-16
Uranium (U)-Total			<0.0000002		mg/dm2.day		0.00000026	24-OCT-16
Vanadium (V)-Total			<0.000026		mg/dm2.day		0.000026	24-OCT-16
Zinc (Zn)-Total			0.000199	MB-LOR	mg/dm2.day		0.000079	24-OCT-16
Batch R3580543								
WG2415436-2 DUP		**L1843583-1**						
Copper (Cu)-Total		0.0000443	0.0000275	J	mg/dm2.day	0.000016	0.0000184	26-OCT-16
Tin (Sn)-Total		<0.0000018	<0.0000018	RPD-NA	mg/dm2.day	N/A	20	26-OCT-16

Quality Control Report

Legend:

Limit	ALS Control Limit (Data Quality Objectives)
DUP	Duplicate
RPD	Relative Percent Difference
N/A	Not Available
LCS	Laboratory Control Sample
SRM	Standard Reference Material
MS	Matrix Spike
MSD	Matrix Spike Duplicate
ADE	Average Desorption Efficiency
MB	Method Blank
IRM	Internal Reference Material
CRM	Certified Reference Material
CCV	Continuing Calibration Verification
CVS	Calibration Verification Standard
LCSD	Laboratory Control Sample Duplicate

Sample Parameter Qualifier Definitions:

Qualifier	Description
J	Duplicate results and limits are expressed in terms of absolute difference.
MB-LOR	Method Blank exceeds ALS DQO. Limits of Reporting have been adjusted for samples with positive hits below 5x blank level.
RPD-NA	Relative Percent Difference Not Available due to result(s) being less than detection limit.

Hold Time Exceedances:

All test results reported with this submission were conducted within ALS recommended hold times.

ALS recommended hold times may vary by province. They are assigned to meet known provincial and/or federal government requirements. In the absence of regulatory hold times, ALS establishes recommendations based on guidelines published by the US EPA, APHA Standard Methods, or Environment Canada (where available). For more information, please contact ALS.

The ALS Quality Control Report is provided to ALS clients upon request. ALS includes comprehensive QC checks with every analysis to ensure our high standards of quality are met. Each QC result has a known or expected target value, which is compared against pre-determined data quality objectives to provide confidence in the accuracy of associated test results.

Please note that this report may contain QC results from anonymous Sample Duplicates and Matrix Spikes that do not originate from this Work Order.

ALS Environmental
www.alsglobal.com

Chain of Custody (COC) / Analytical Request Form

Canada Toll Free: 1 800 668 9878

L1843583-COFC

COC Number: 15 - 583215

Page of

Report To	Contact and company name below will appear on the final report
Company:	STANTEC CONSULTING LTD.
Contact:	DANIEL JARRATT
Phone:	(403) 441-5064
	Company address below will appear on the final report
Street:	200-325-25 Street SE
City/Province:	Calgary, AB
Postal Code:	T2A 7H8
Invoice To	Same as Report To ☑ YES ☐ NO
	Copy of Invoice with Report ☐ YES ☐ NO
Company:	
Contact:	

Report Format / Distribution

Select Report Format: ☑ PDF ☑ EXCEL ☐ EDD (DIGITAL)

Quality Control (QC) Report with Report ☑ YES ☐ NO

☐ Compare Results to Criteria on Report - provide details below if box checked

Select Distribution: ☐ EMAIL ☐ MAIL ☐ FAX

Email 1 or Fax: daniel.jarratt@stantec.com

Email 2

Email 3

Invoice Distribution

Select Invoice Distribution: ☑ EMAIL ☐ MAIL ☐ FAX

Email 1 or Fax

Email 2

Select Service Level Below - Please confirm all E&P TATs with your AM - surcharges will apply

Regular [R] ☒ Standard TAT if received by 3 pm - business days - no surcharges apply

PRIORITY (Business Days): 4 day [P4] ☐ 3 day [P3] ☐ 2 day [P2] ☐

EMERGENCY: 1 Business day [E1] ☐ Same Day, Weekend or Statutory holiday [E0] ☐

Date and Time Required for all E&P TATs:

For tests that can not be performed according to the service level selected, you will be contacted.

Project Information	
ALS Account # / Quote #:	Q54745 Jessica Spira
Job #:	110773396 tasknumber
PO / AFE:	30.600.206.3 Field
LSD:	Program #1
ALS Lab Work Order # (lab use only)	L1843582

Oil and Gas Required Fields (client use)

AFE/Cost Center: PO#

Major/Minor Code: Routing Code:

Requisitioner:

Location:

ALS Contact: Jessica Spira Sampler: Daniel Jarratt

Analysis Request — Indicate Filtered (F), Preserved (P) or Filtered and Preserved (F/P) below

ALS Sample # (lab use only)	Sample Identification and/or Coordinates (This description will appear on the report)	Date (dd-mmm-yy)	Time (hh:mm)	Sample Type	Dustfall, Total	Dustfall, Total Fixed	Total mercury in dustfall by CVAFS	Total metals in dustfall by ICPMS	Number of Containers
	Parcel 56 26 Aug - 13 October	13-Oct-16	2:00PM	dustfall	X	X			1
	Parcel 56 26 Aug - 13 October	13-Oct-16	2:05PM	dustfall			X	X	1
	Parcel 58 26 Aug - 13 October	13-Oct-16	9:50AM	dustfall	X	X			1
	Parcel 58 26 Aug - 13 October	13-Oct-16	9:50AM	dustfall			X	X	1

Drinking Water (DW) Samples[1] (client use)

Are samples taken from a Regulated DW System? ☐ YES ☒ NO

Are samples for human drinking water use? ☐ YES ☒ NO

Special Instructions / Specify Criteria to add on report by clicking on the drop-down list below (electronic COC only)

SAMPLE CONDITION AS RECEIVED (lab use only)

Frozen ☐ SIF Observations Yes ☐ No ☐

Ice Packs ☐ Ice Cubes ☐ Custody seal intact Yes ☐ No ☐

Cooling Initiated ☐

INITIAL COOLER TEMPERATURES °C: 9

FINAL COOLER TEMPERATURES °C:

SHIPMENT RELEASE (client use)	INITIAL SHIPMENT RECEPTION (lab use only)	FINAL SHIPMENT RECEPTION (lab use only)
Released by: Daniel Jarratt Date: Oct. 13, 2016 Time: 5:00PM	Received by: Don Date: 10/14 Time: 2:40	Received by: Date: Time:

REFER TO BACK PAGE FOR ALS LOCATIONS AND SAMPLING INFORMATION — WHITE - LABORATORY COPY — YELLOW - CLIENT COPY

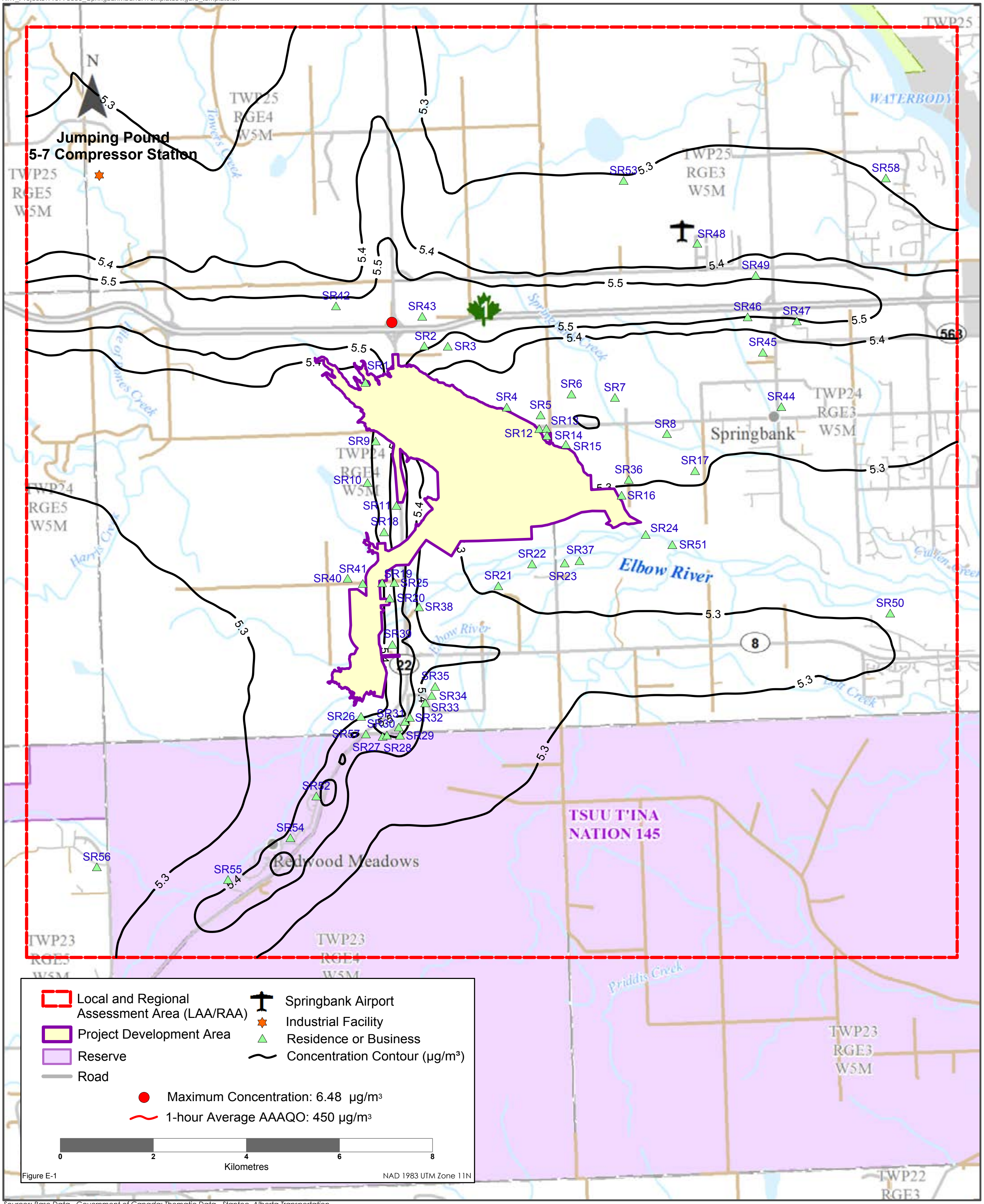
OCTOBER 2015 FRONT

Failure to complete all portions of this form may delay analysis. Please fill in this form LEGIBLY. By the use of this form the user acknowledges and agrees with the Terms and Conditions as specified on the back page of the white - report copy.

1. If any water samples are taken from a Regulated Drinking Water (DW) System, please submit using an Authorized DW COC form.

Attachment 3E ADDITIONAL CONCENTRATION ISOPLETH MAPS FOR CONSTRUCTION

N:\1_Projects\110773396_Springbank\Surfer\Templates\figure_template.srf



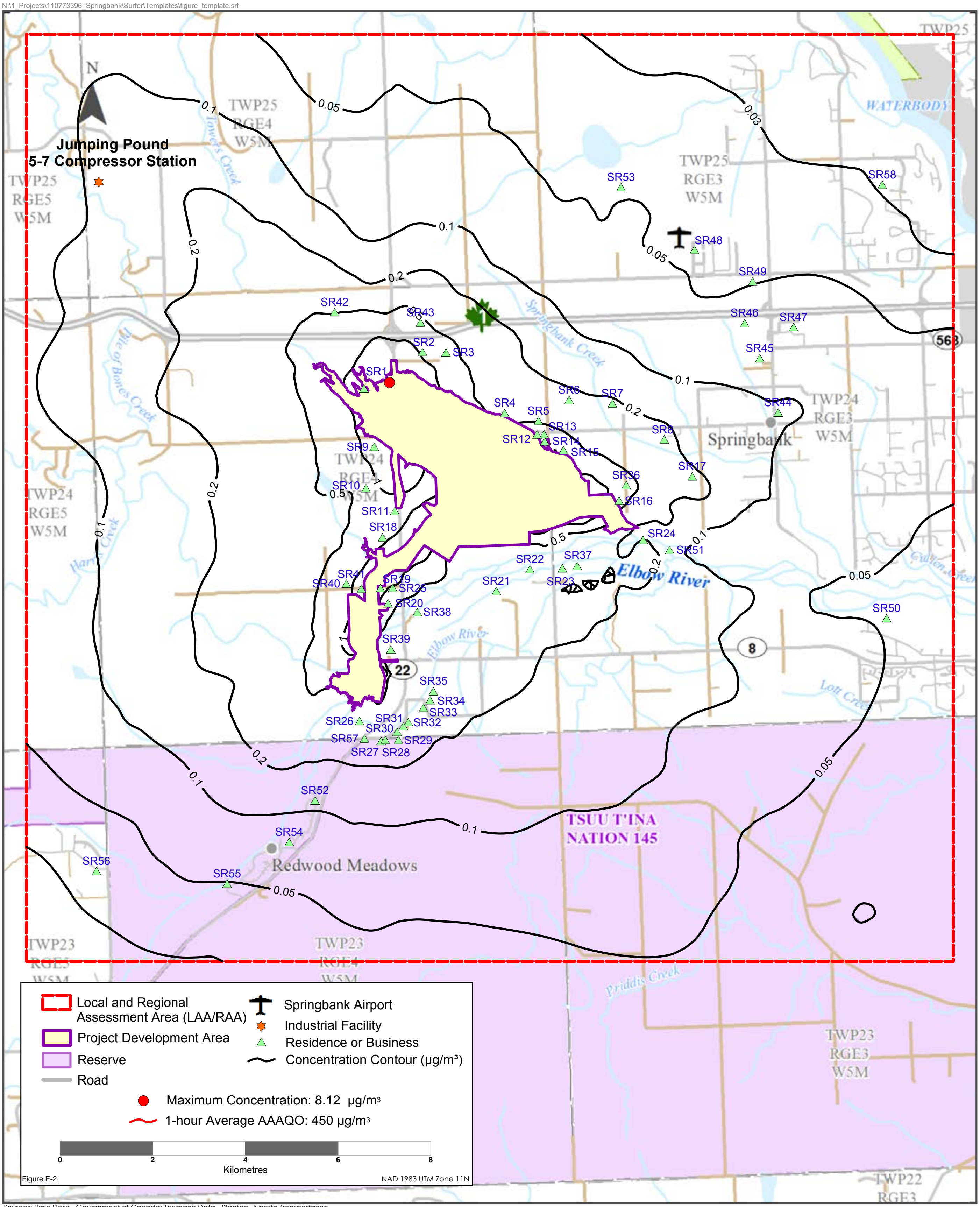
Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Predicted 9th Highest 1-hour Average SO_2 Concentrations (Base Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-1



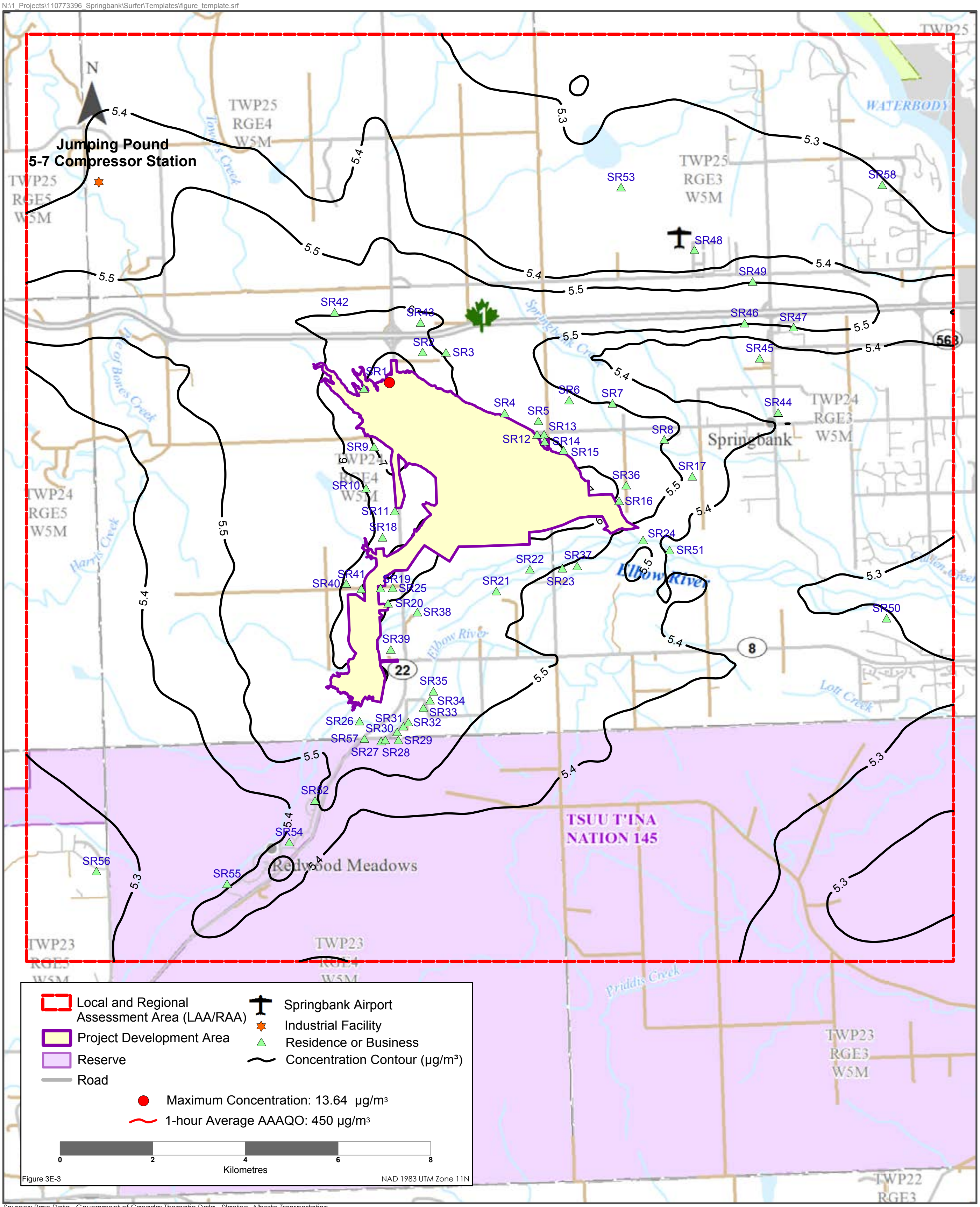
Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Predicted 9th Highest 1-hour Average SO_2 Concentrations (Project Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-2



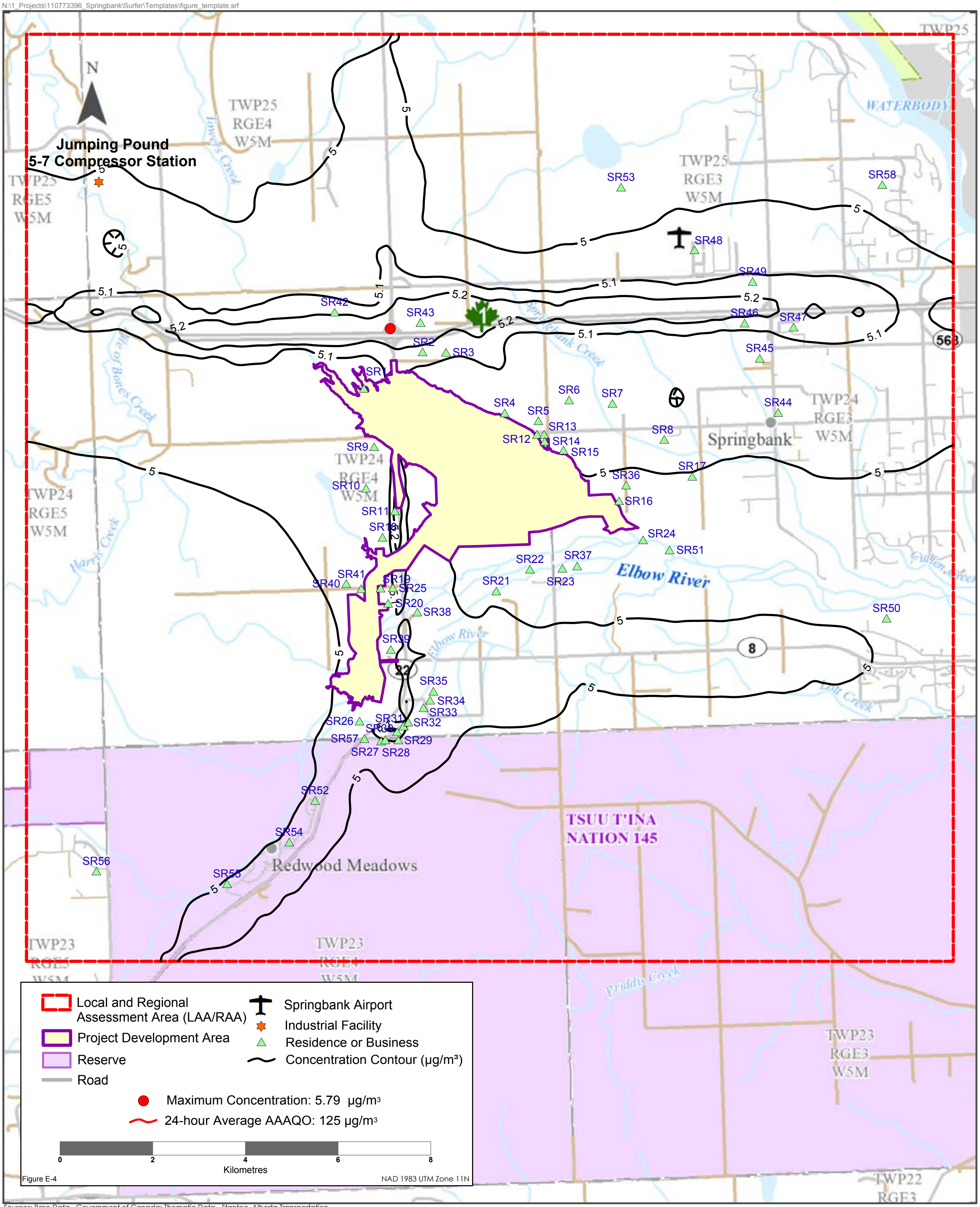
Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Predicted 9th Highest 1-hour Average SO_2 Concentrations (Application Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

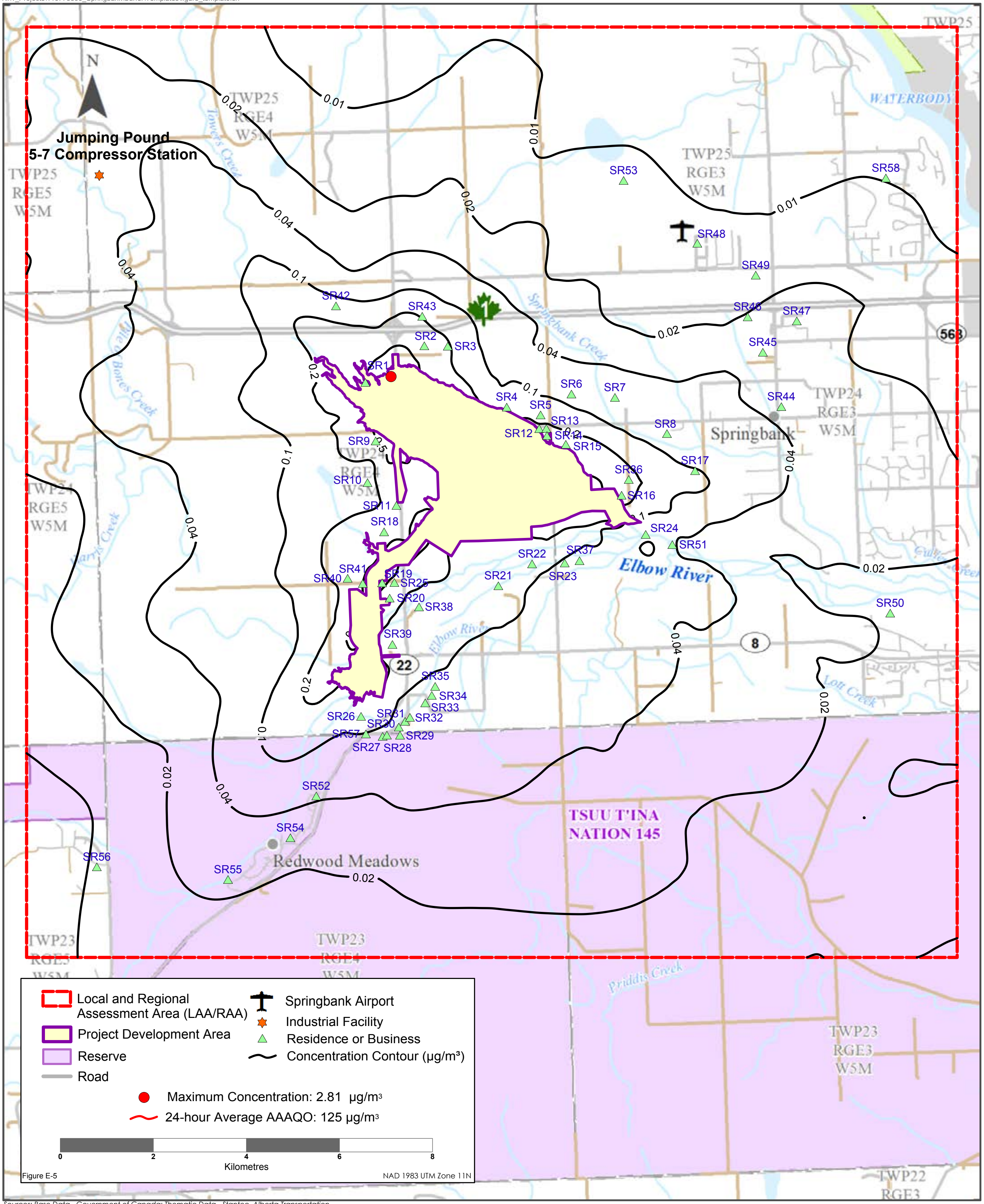
Figure 3E-3



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Maximum Predicted 24-hour Average SO_2 Concentrations (Base Case)

N:\1_Projects\110773396_Springbank\Surfer\Templates\figure_template.srf



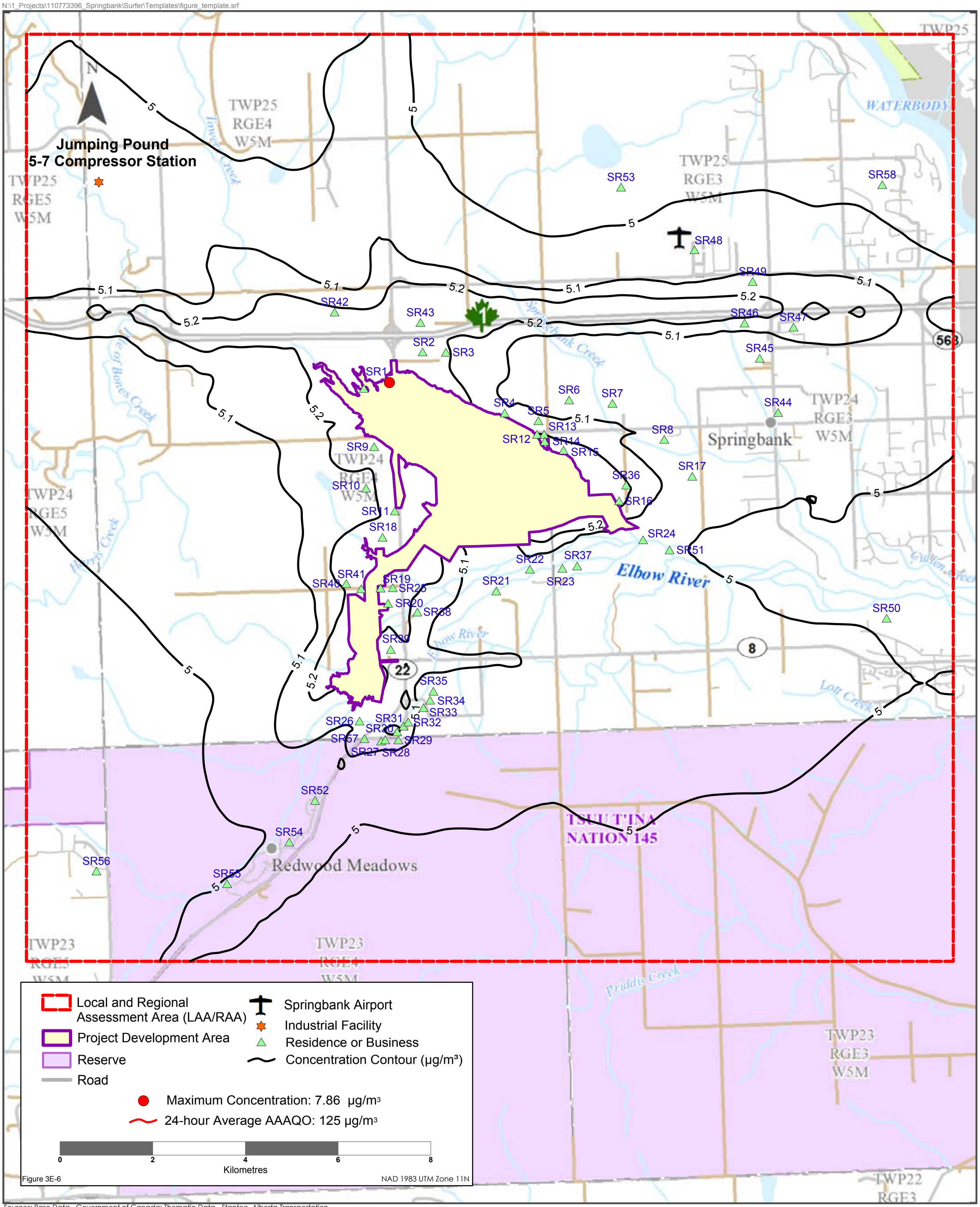
Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Maximum Predicted 24-hour Average SO_2 Concentrations (Project Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-5



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

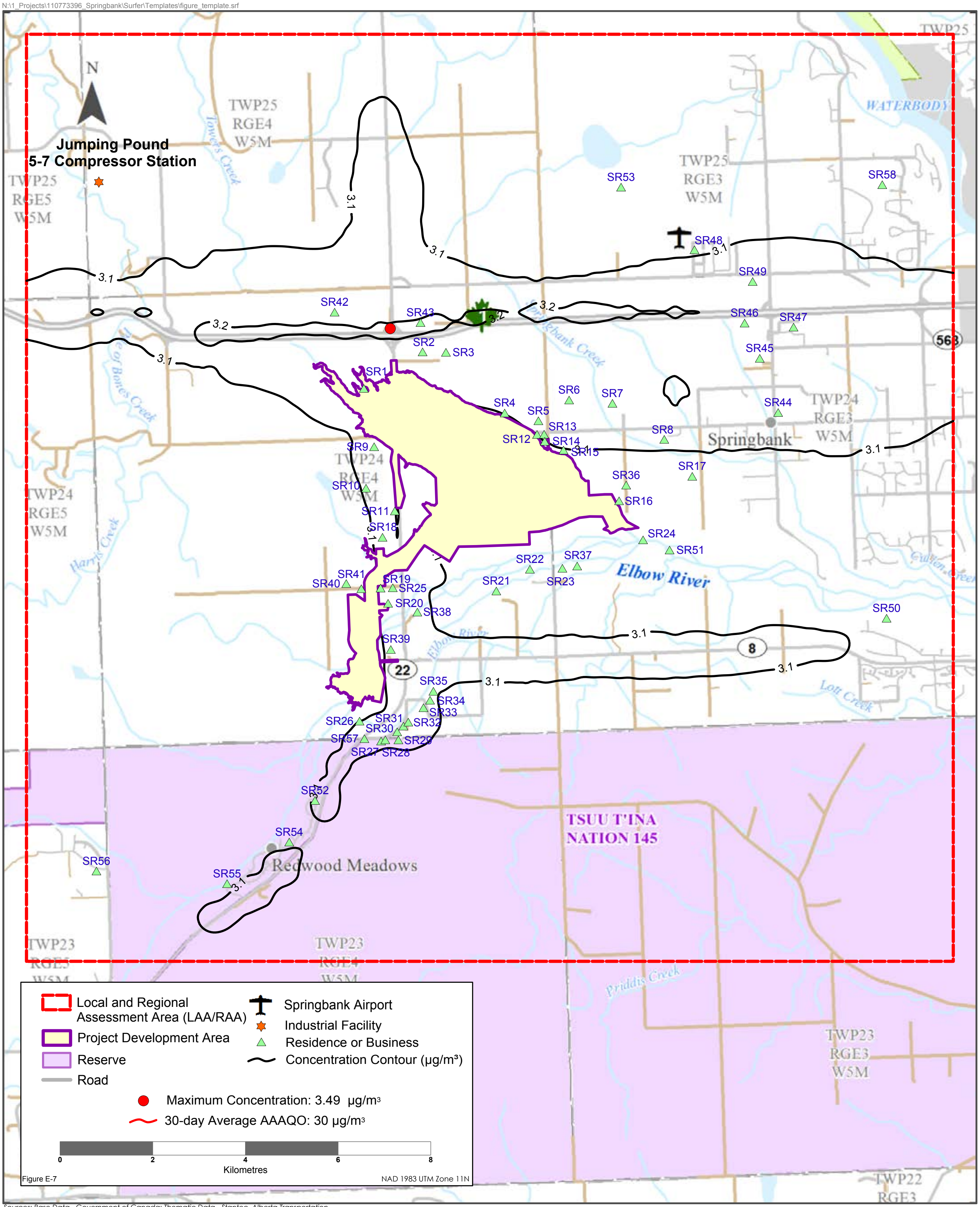
Maximum Predicted 24-hour Average SO_2 Concentrations (Application Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-6

N:\1_Projects\110773396_Springbank\Surfer\Templates\figure_template.srf



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

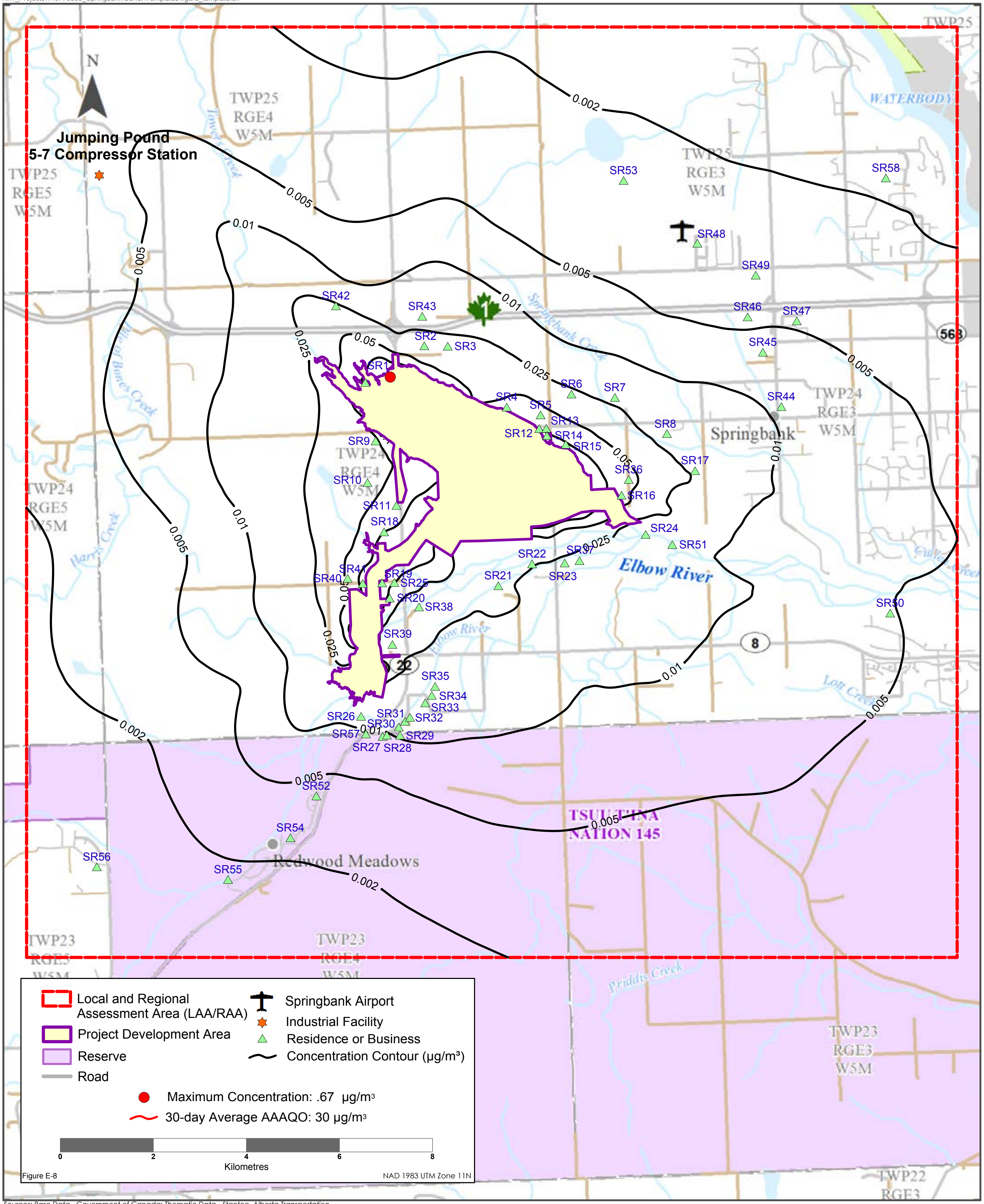
Maximum Predicted 30-day Average SO_2 Concentrations (Base Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-7

N:\1_Projects\110773396_Springbank\Surfer\Templates\figure_template.srf



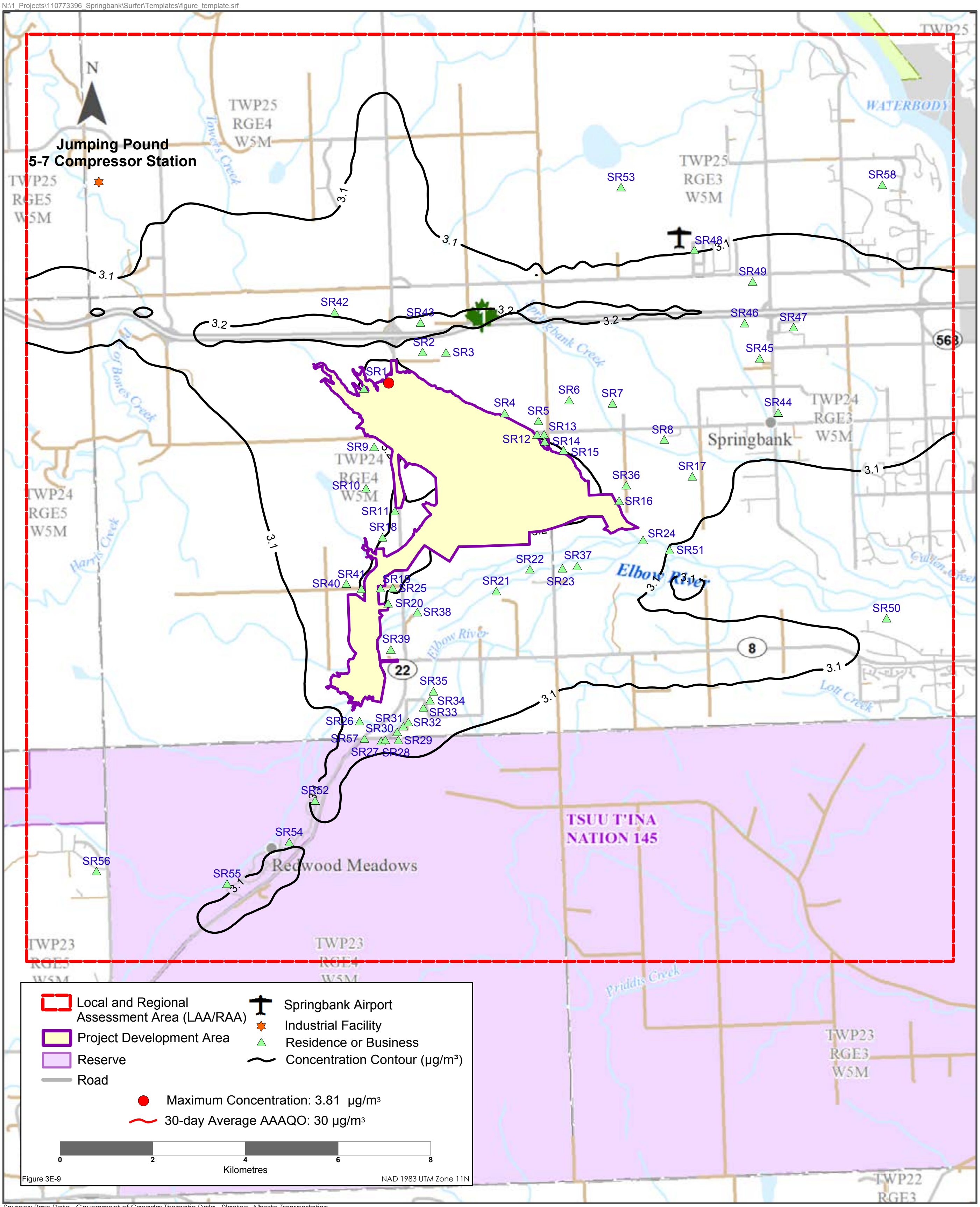
Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Maximum Predicted 30-day Average SO_2 Concentrations (Project Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-8



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

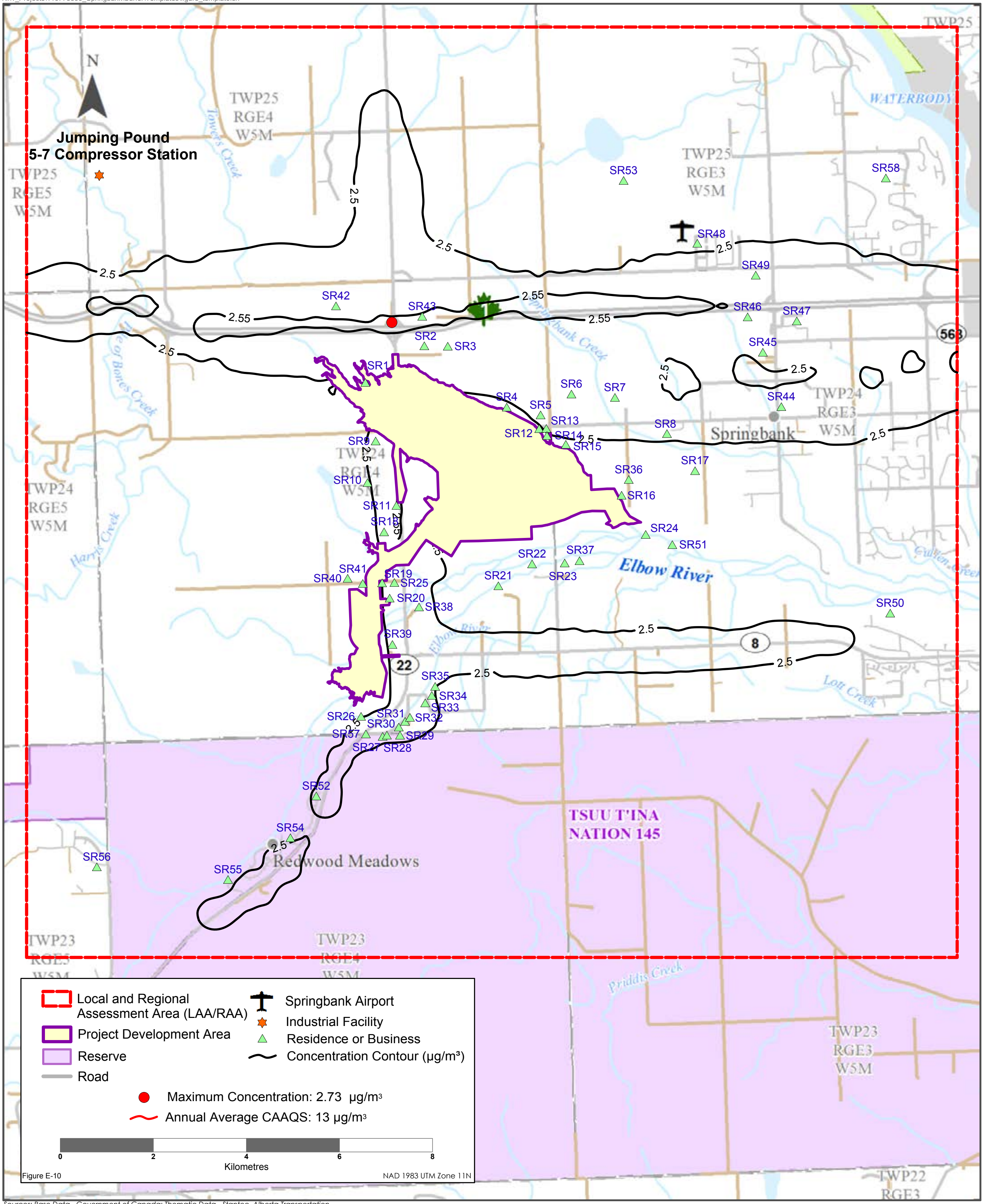
Maximum Predicted 30-day Average SO_2 Concentrations (Application Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

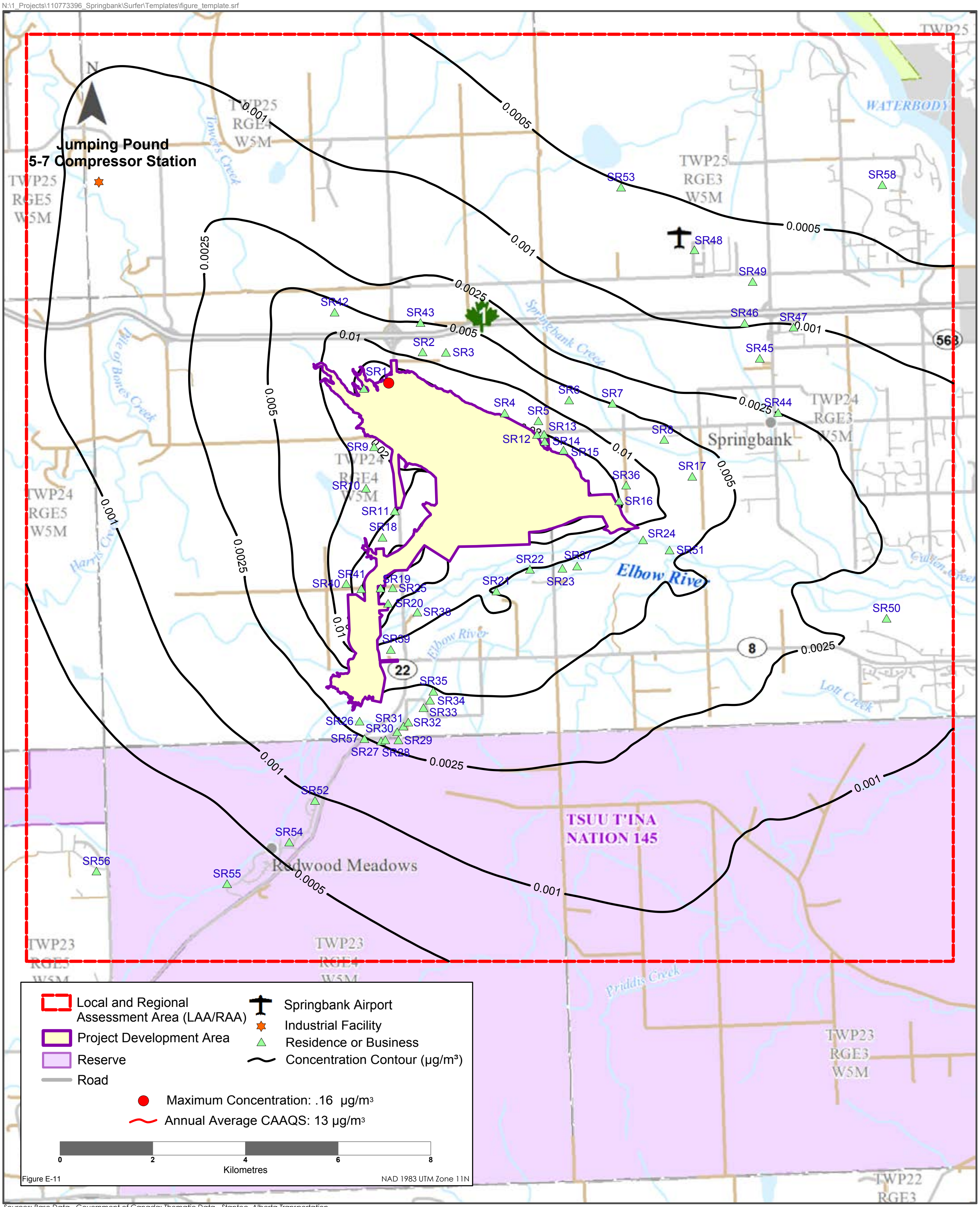
Figure 3E-9

N:\1_Projects\110773396_Springbank\Surfer\Templates\figure_template.srf



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Maximum Predicted Annual Average SO_2 Concentrations (Base Case)



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Maximum Predicted Annual Average SO_2 Concentrations (Project Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-11

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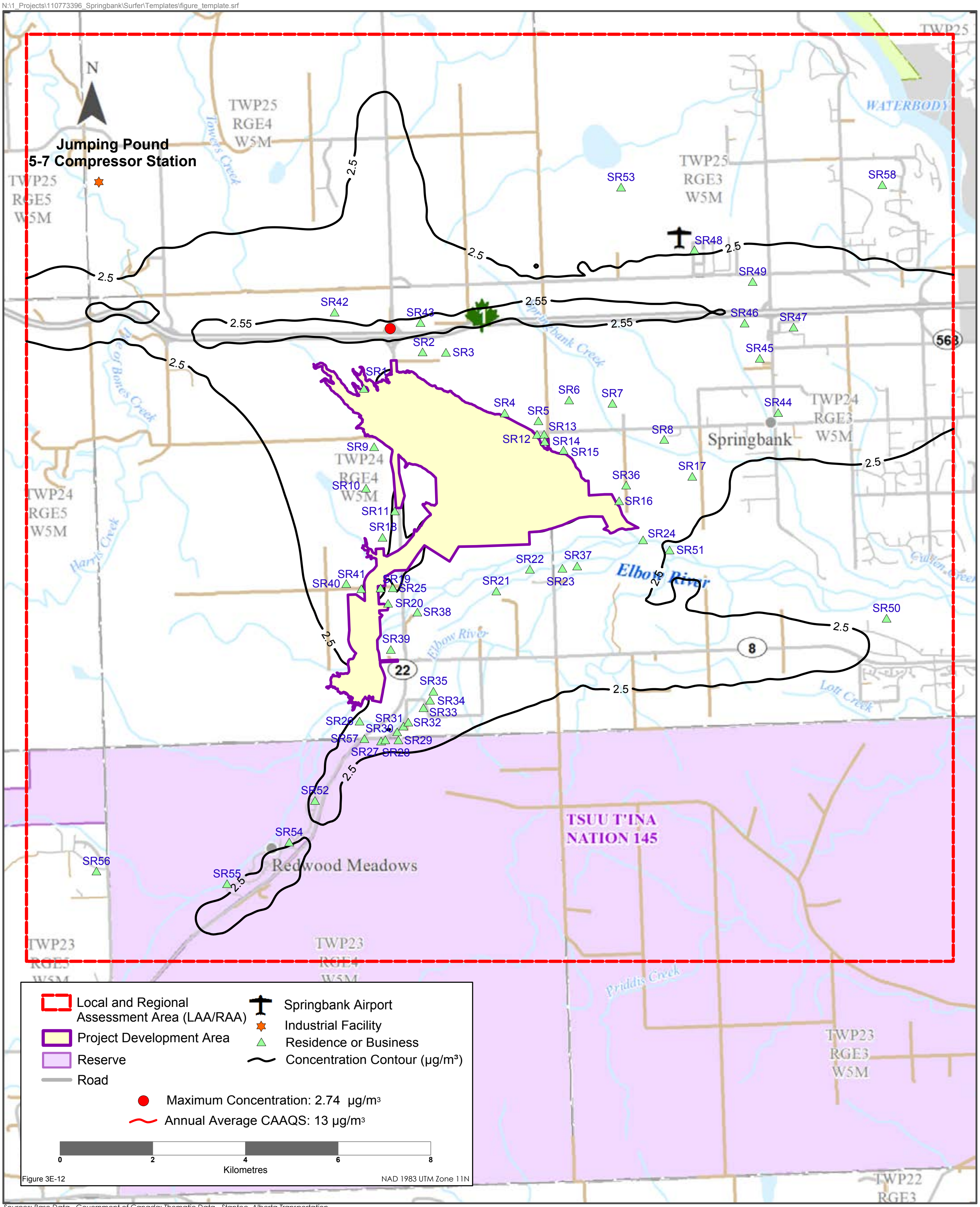


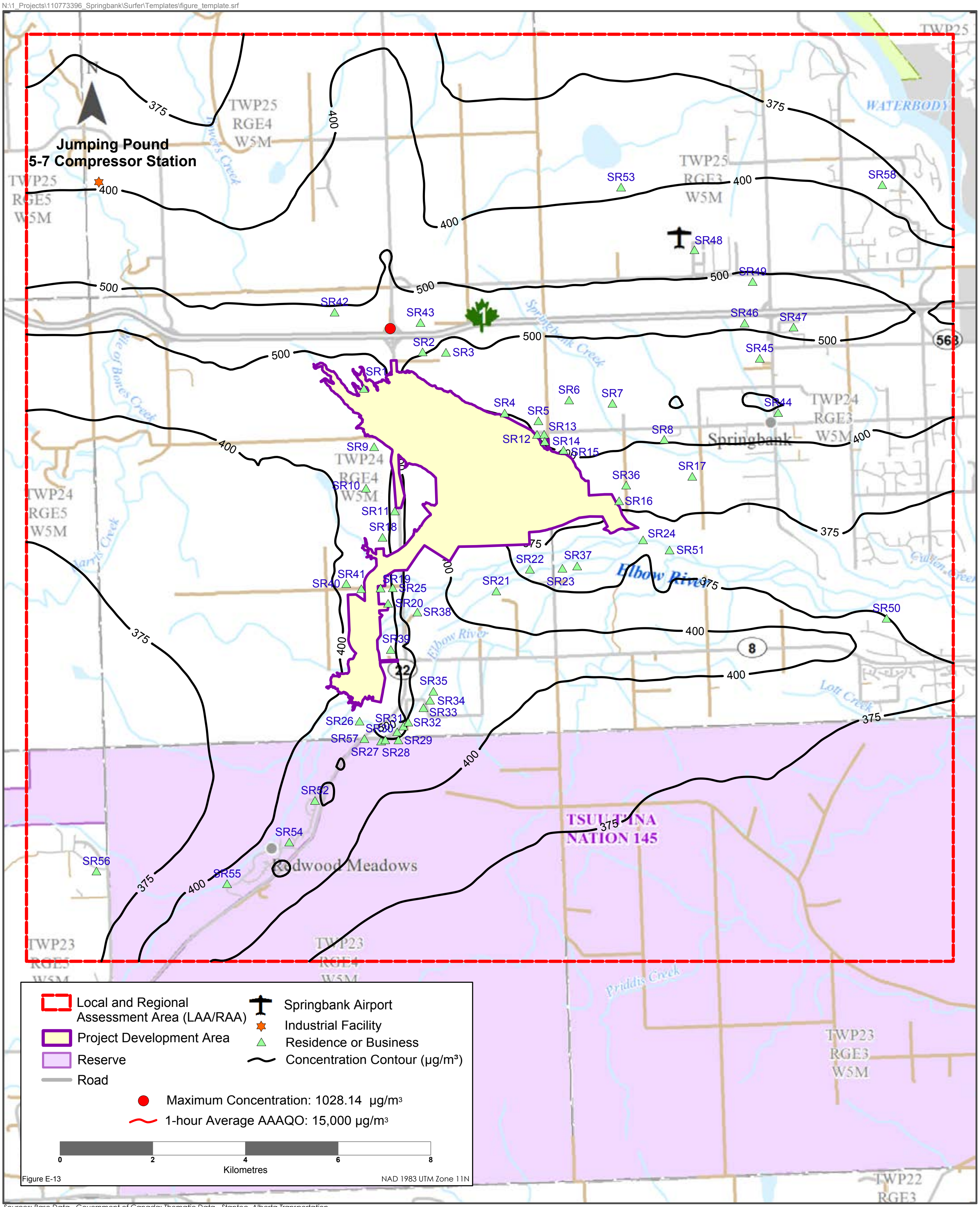
Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Maximum Predicted Annual Average SO_2 Concentrations (Application Case)

Stantec

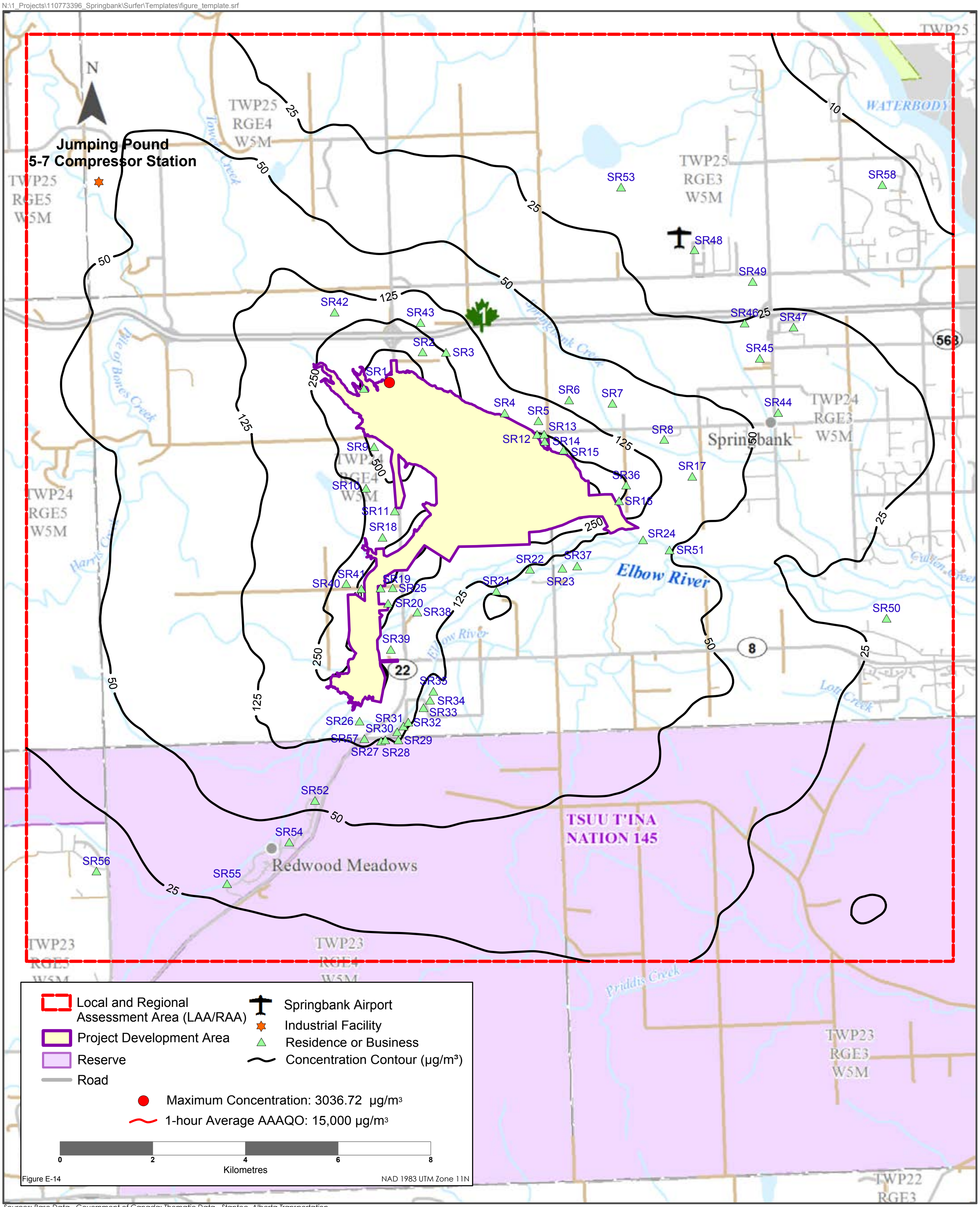
SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-12



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Predicted 9th Highest 1-hour Average CO Concentrations (Base Case)



Predicted 9th Highest 1-hour Average CO Concentrations (Project Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-14

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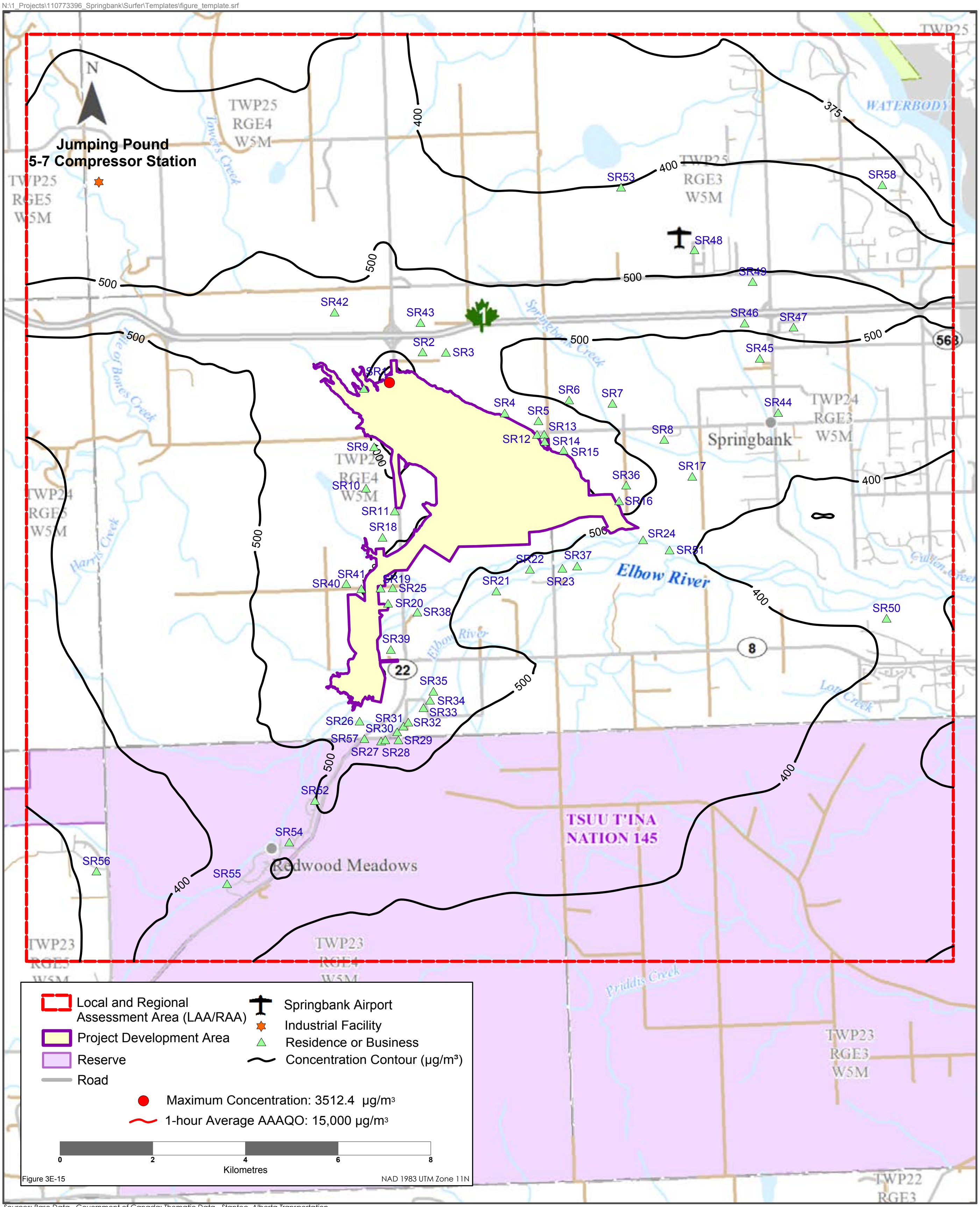

Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Predicted 9th Highest 1-hour Average CO Concentrations (Application Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-15

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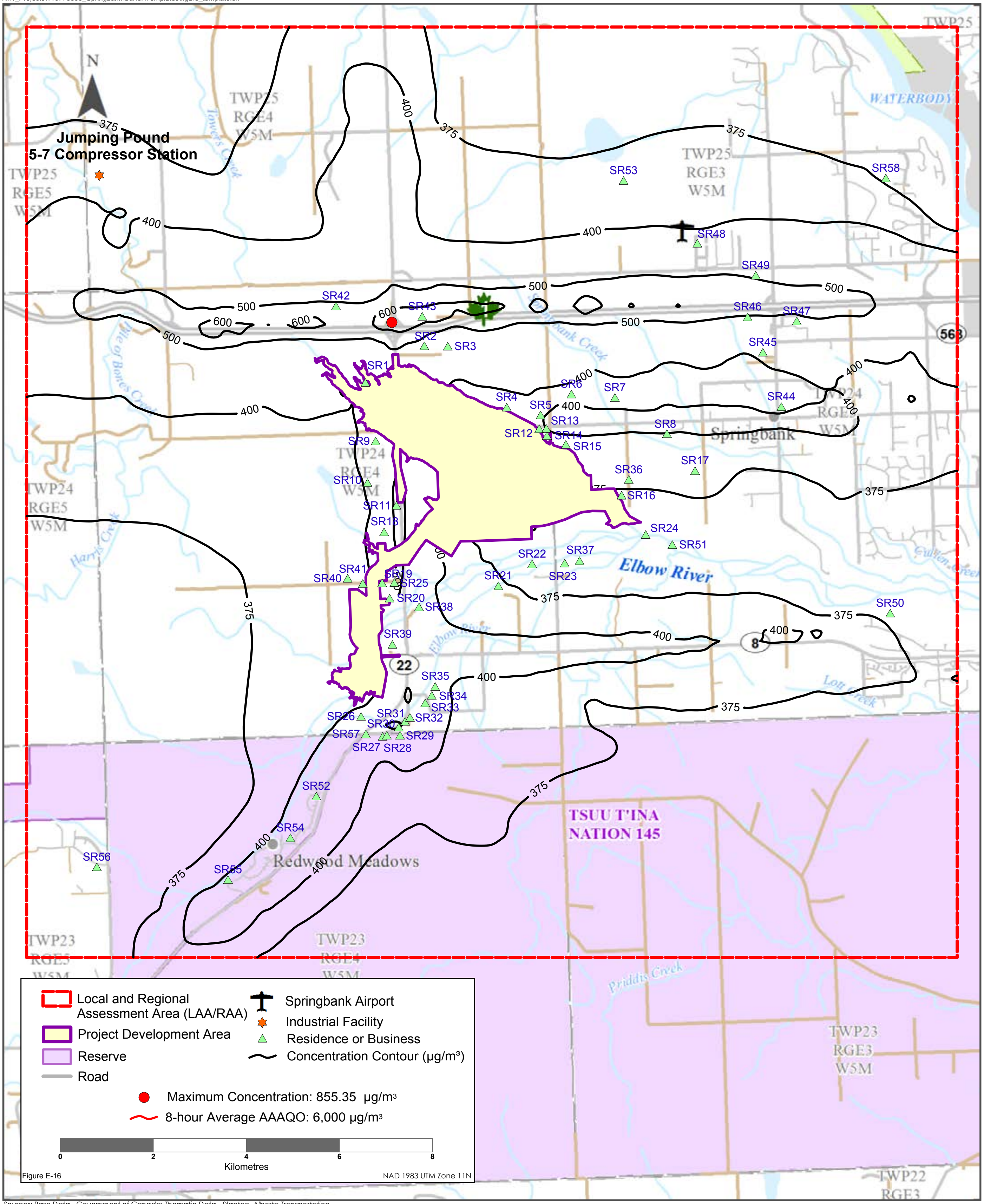


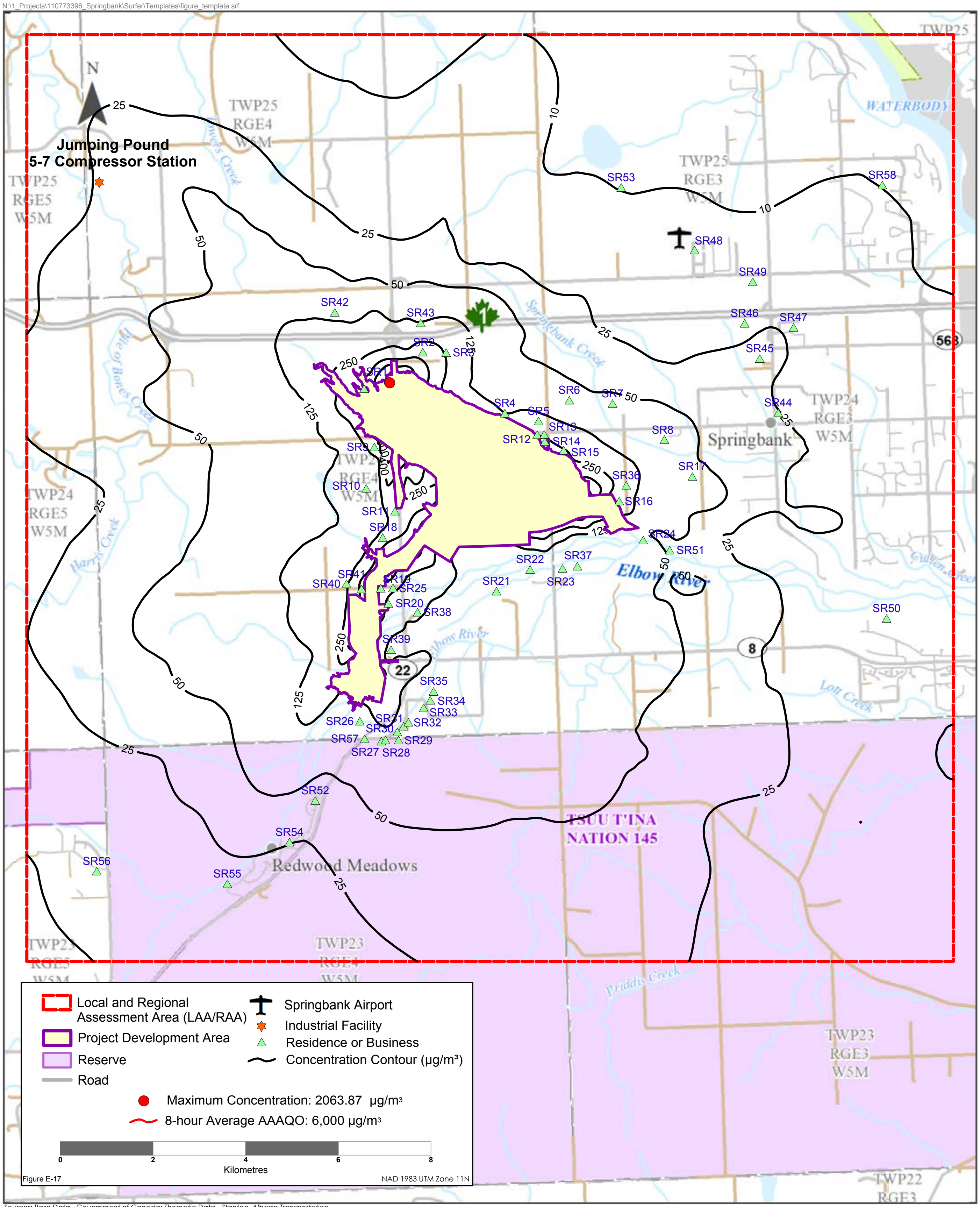
Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Maximum Predicted 8-hour Average CO Concentrations (Base Case)

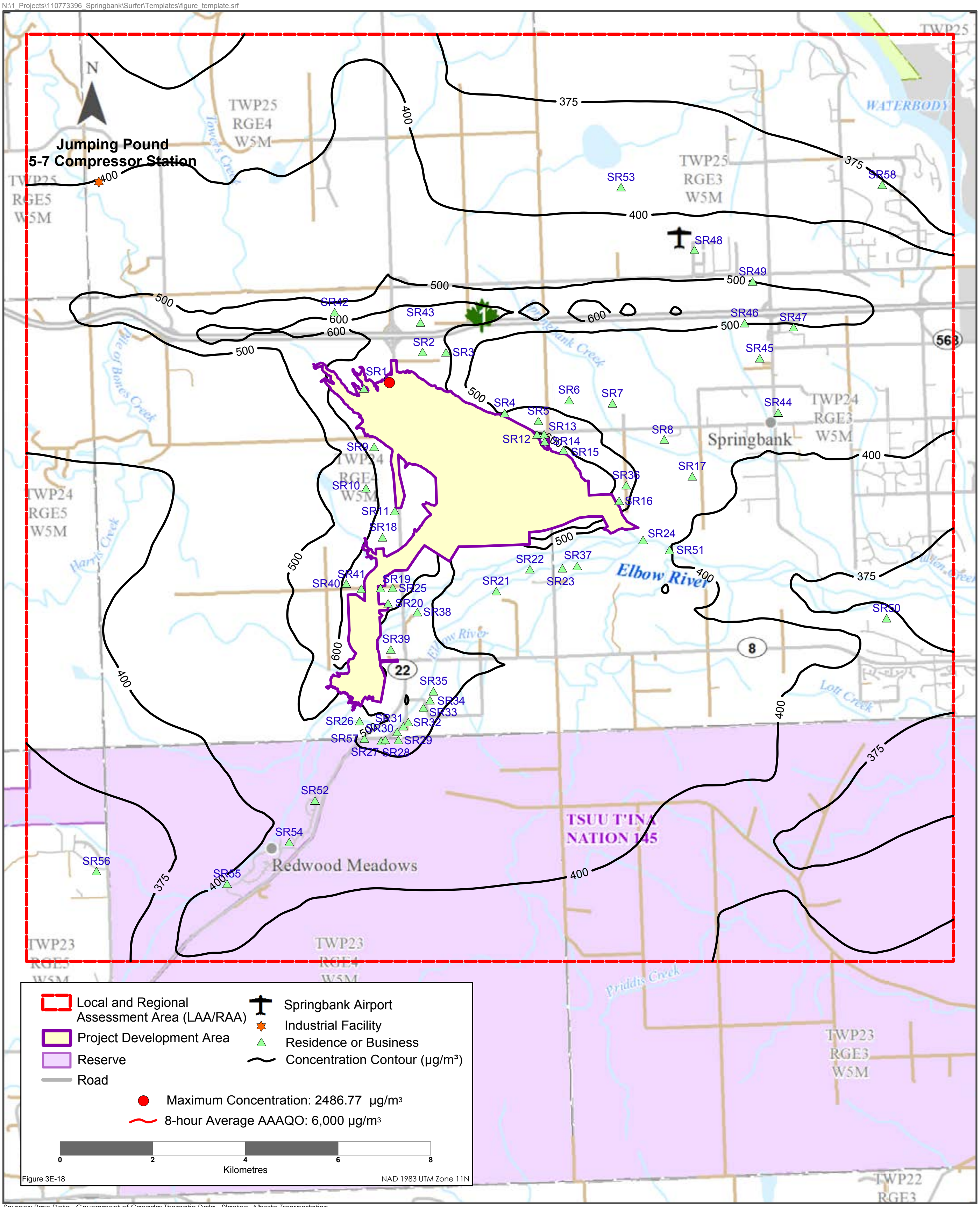
Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-16



Maximum Predicted 8-hour Average CO Concentrations (Project Case)



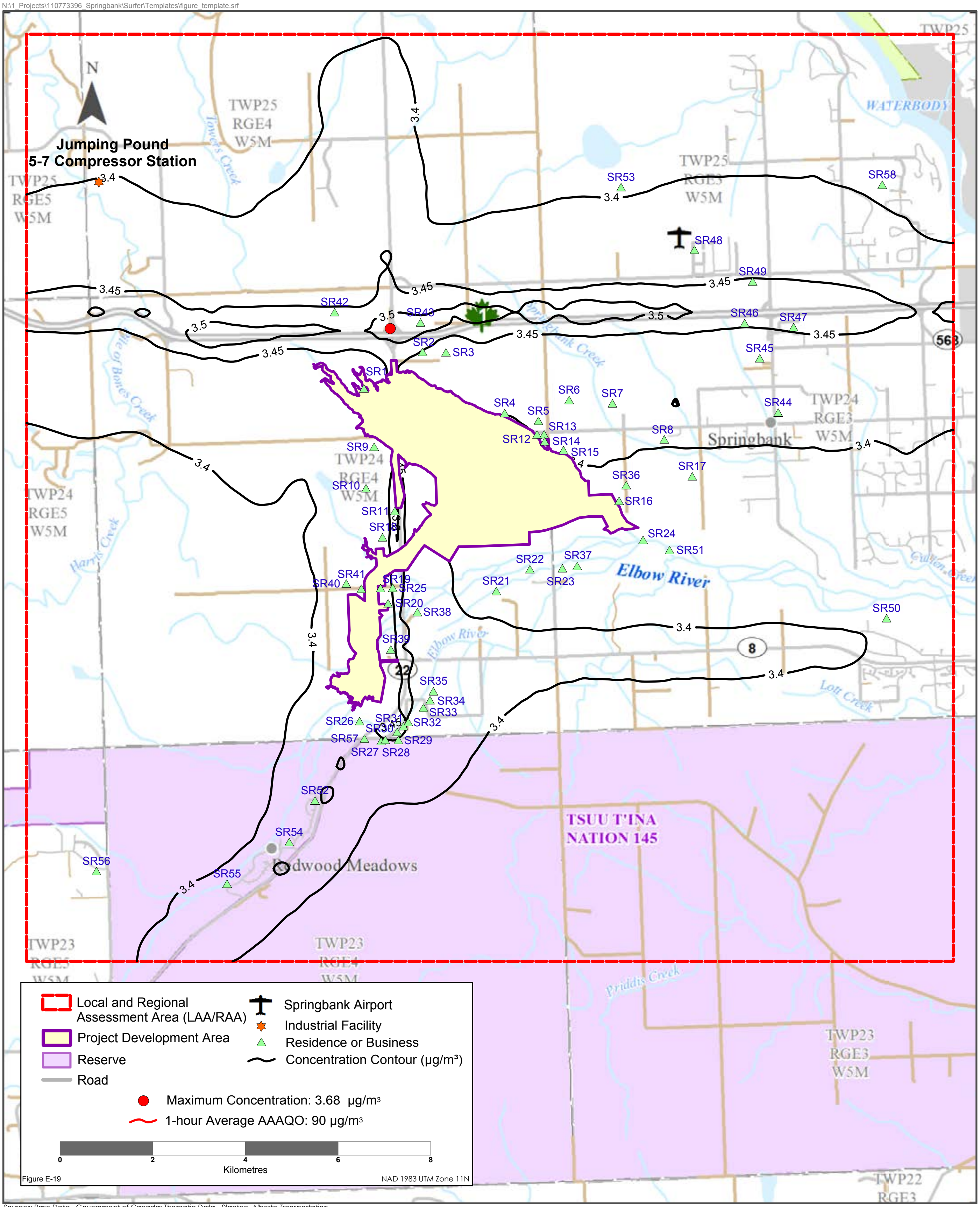
Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Maximum Predicted 8-hour Average CO Concentrations (Application Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-18



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Predicted 9th Highest 1-hour Average Acetaldehyde Concentrations (Base Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-19

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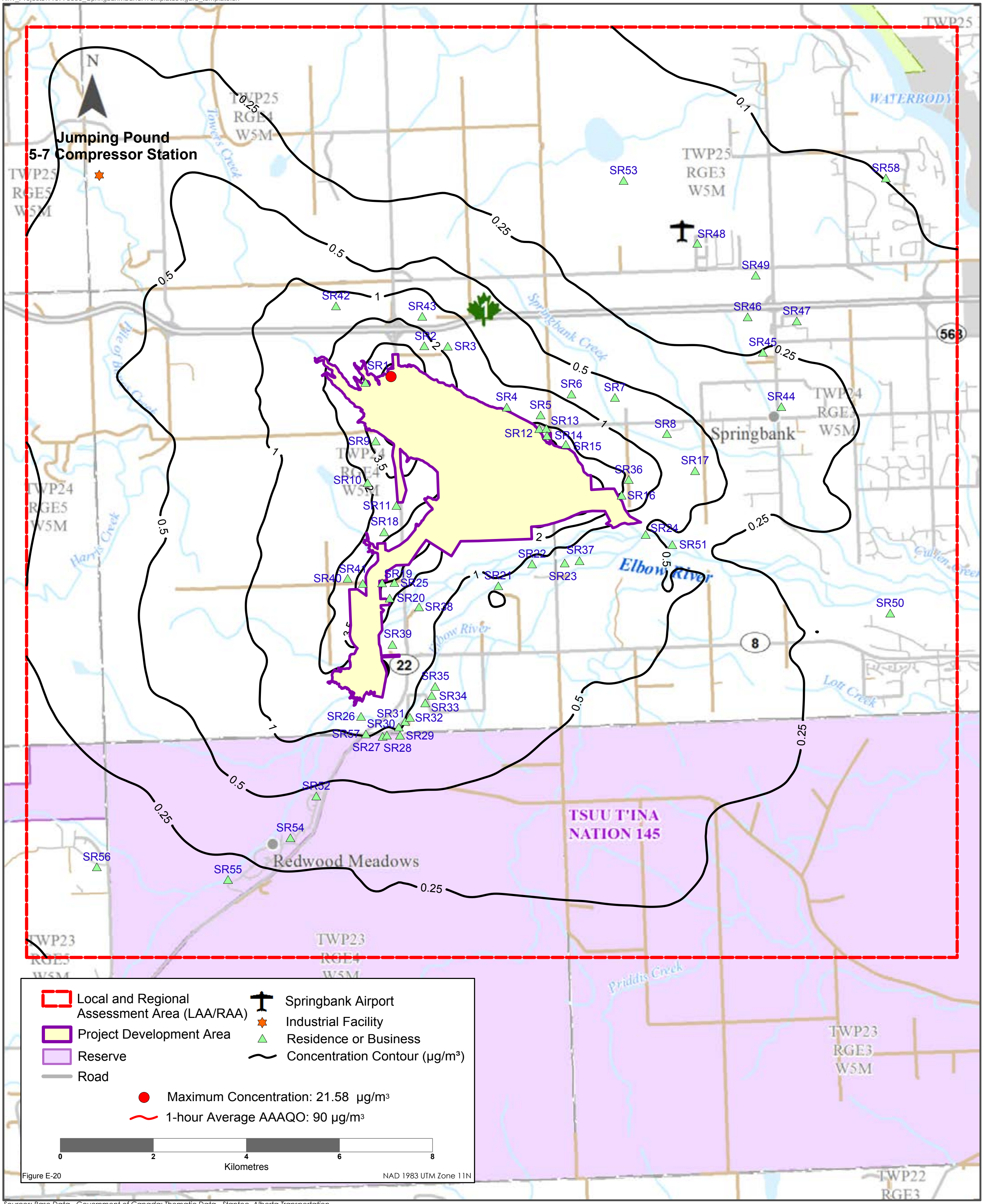


Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

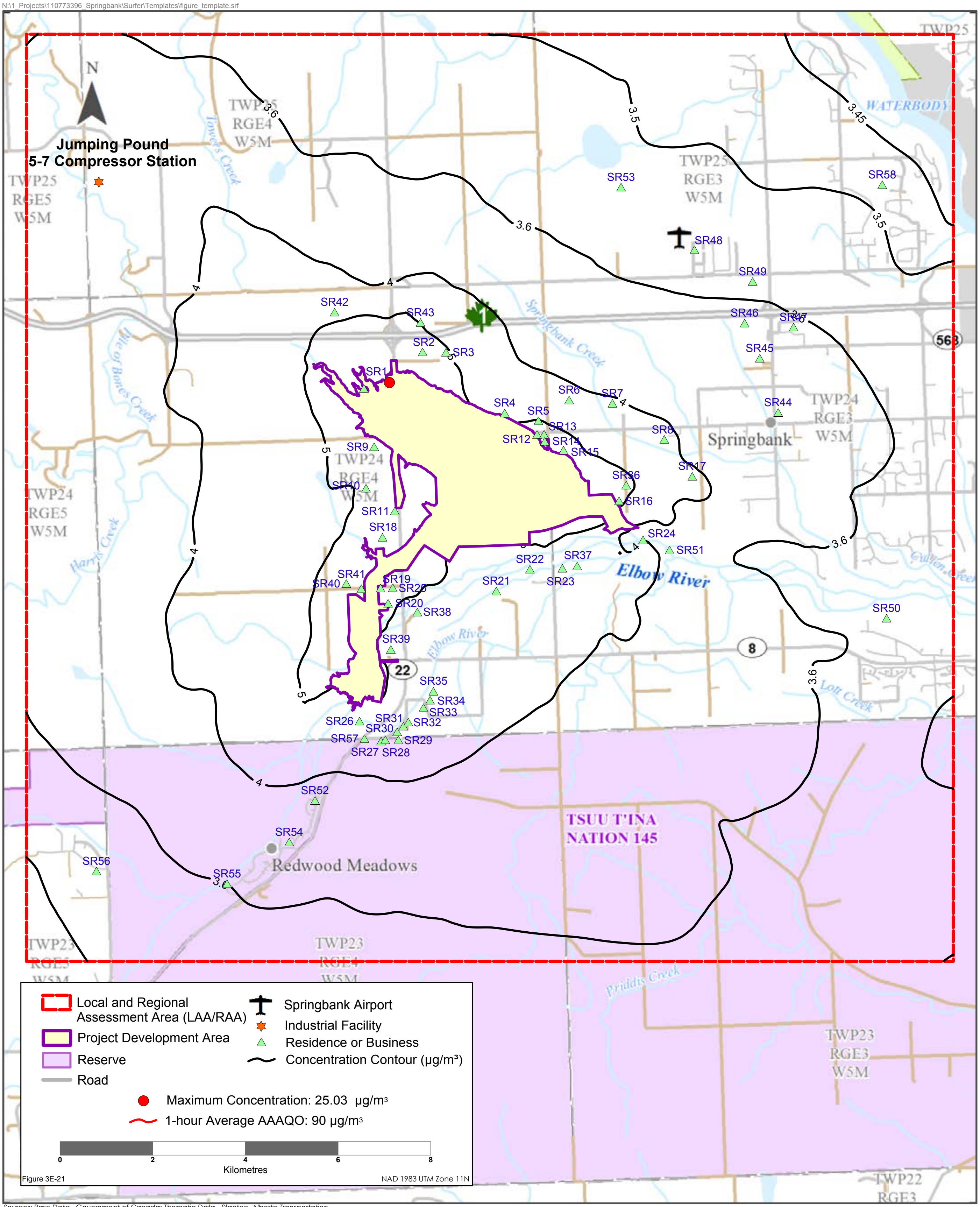
Predicted 9th Highest 1-hour Average Acetaldehyde Concentrations (Project Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-20

N:\1_Projects\110773396_Springbank\Surfer\Templates\figure_template.srf



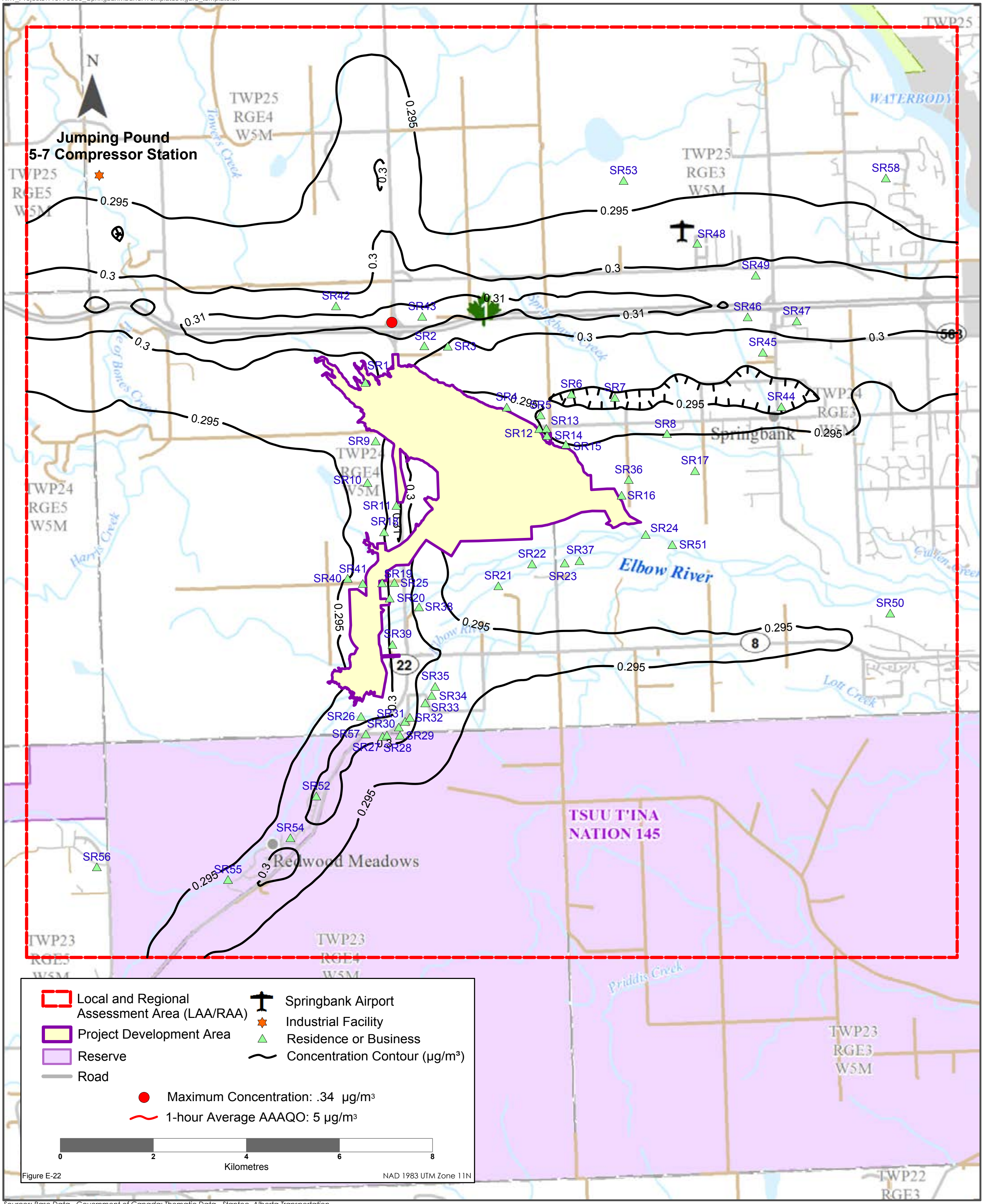
Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Predicted 9th Highest 1-hour Average Acetaldehyde Concentrations (Application Case)

Stantec

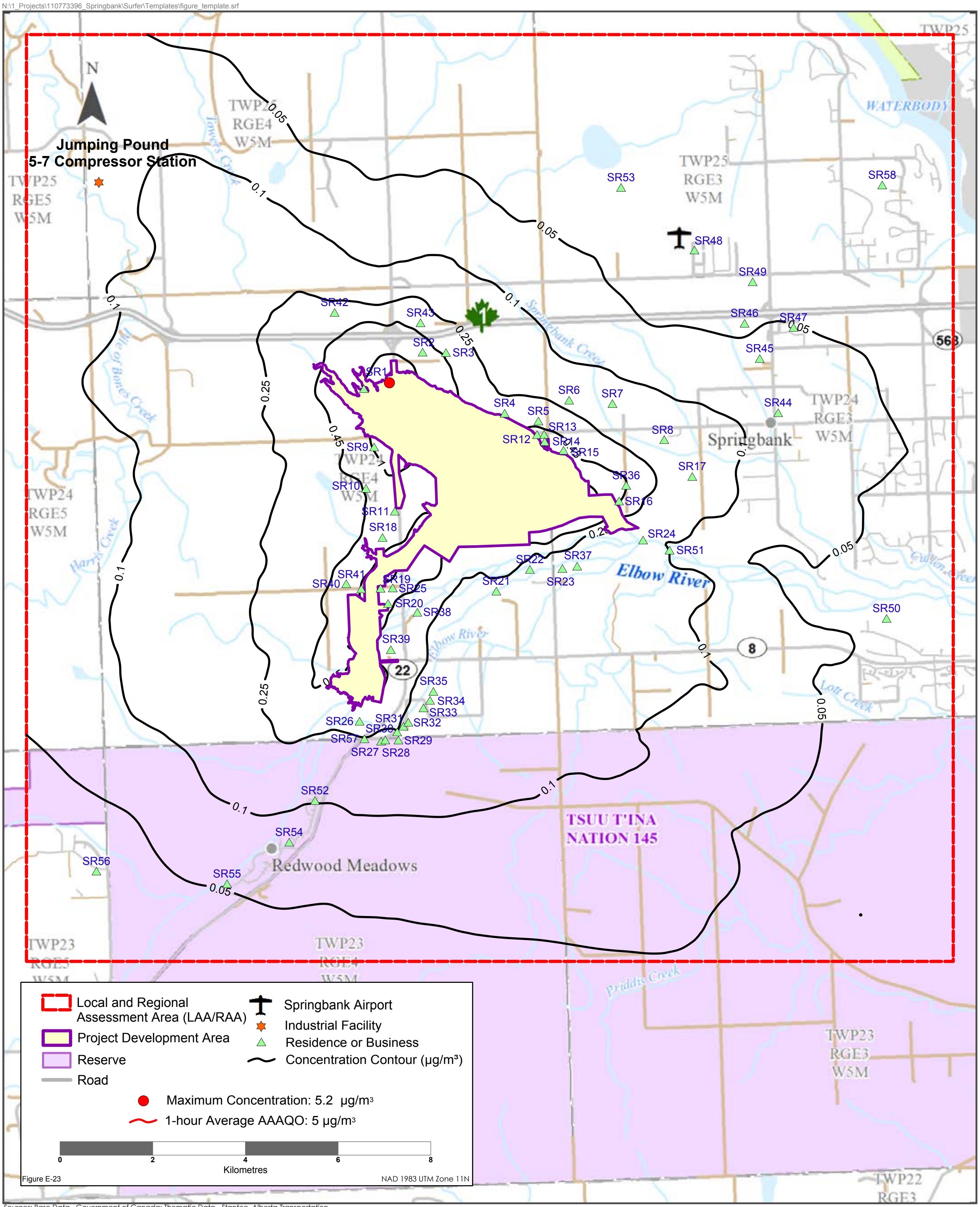
SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-21



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Predicted 9th Highest 1-hour Average Acrolein Concentrations (Base Case)



Predicted 9th Highest 1-hour Average Acrolein Concentrations (Project Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-23

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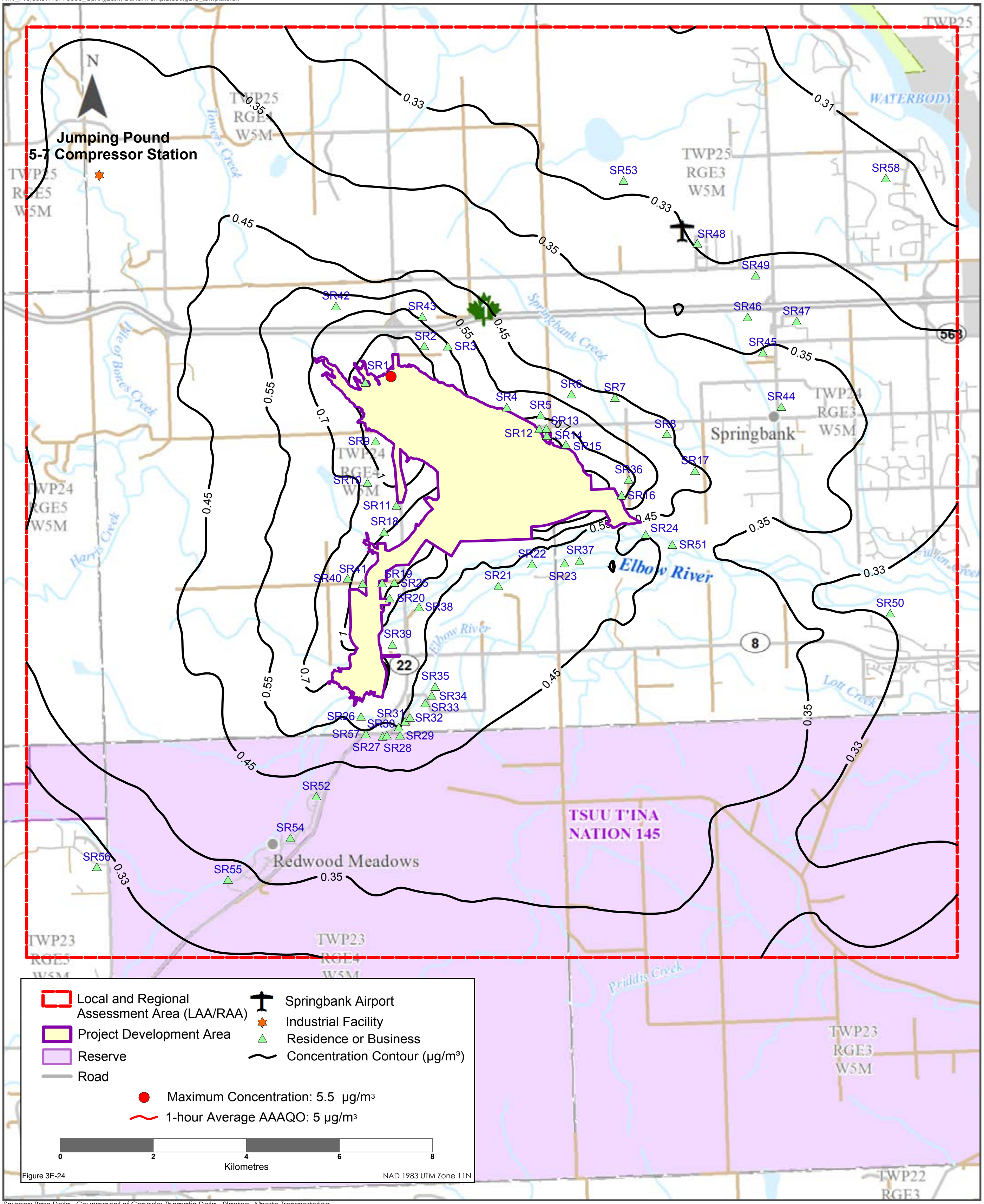


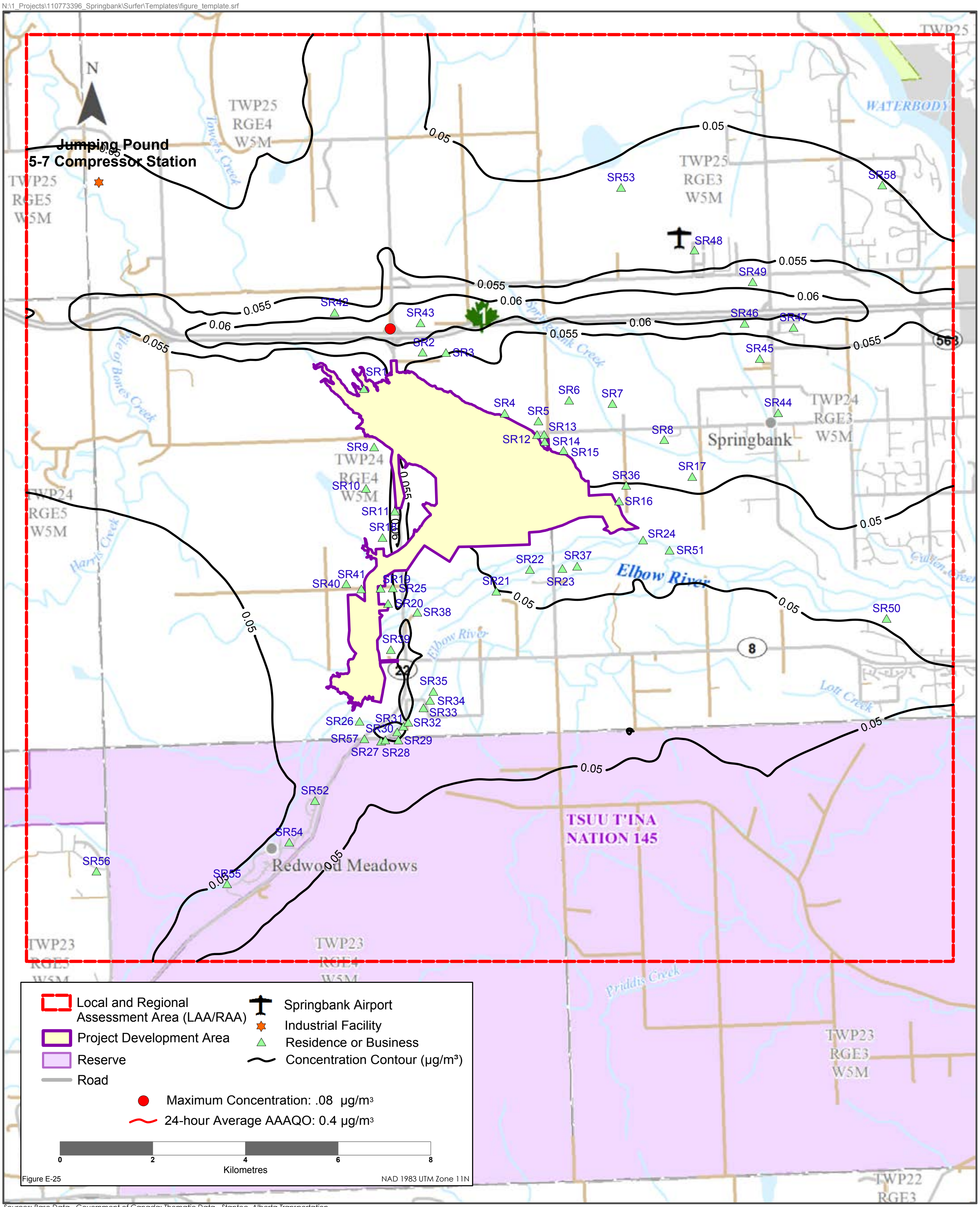
Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Predicted 9th Highest 1-hour Average Acrolein Concentrations (Application Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-24



Maximum Predicted 24-hour Average Acrolein Concentrations (Base Case)

Stantec

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Figure 3E-25

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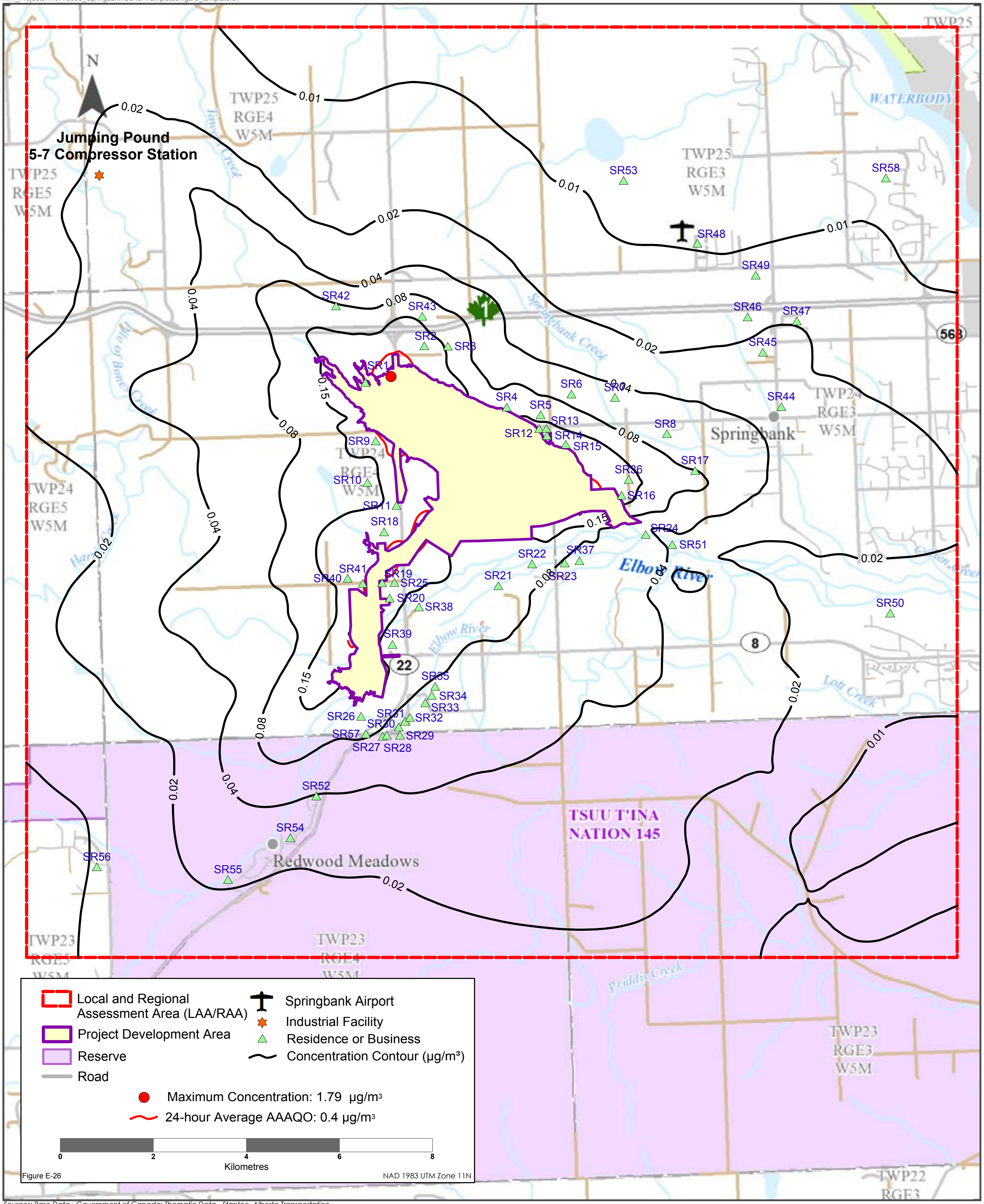

Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Maximum Predicted 24-hour Average Acrolein Concentrations (Project Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-26

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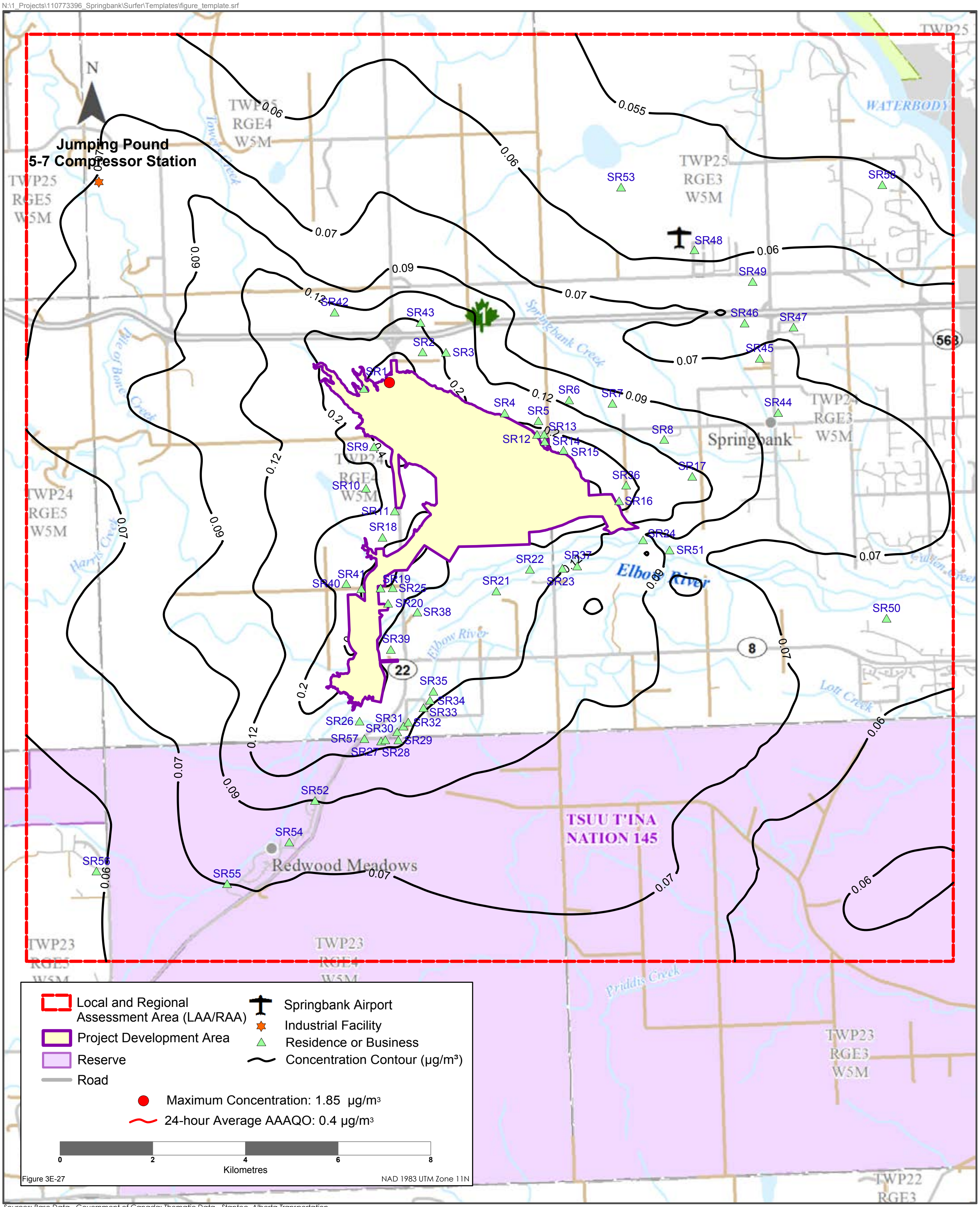
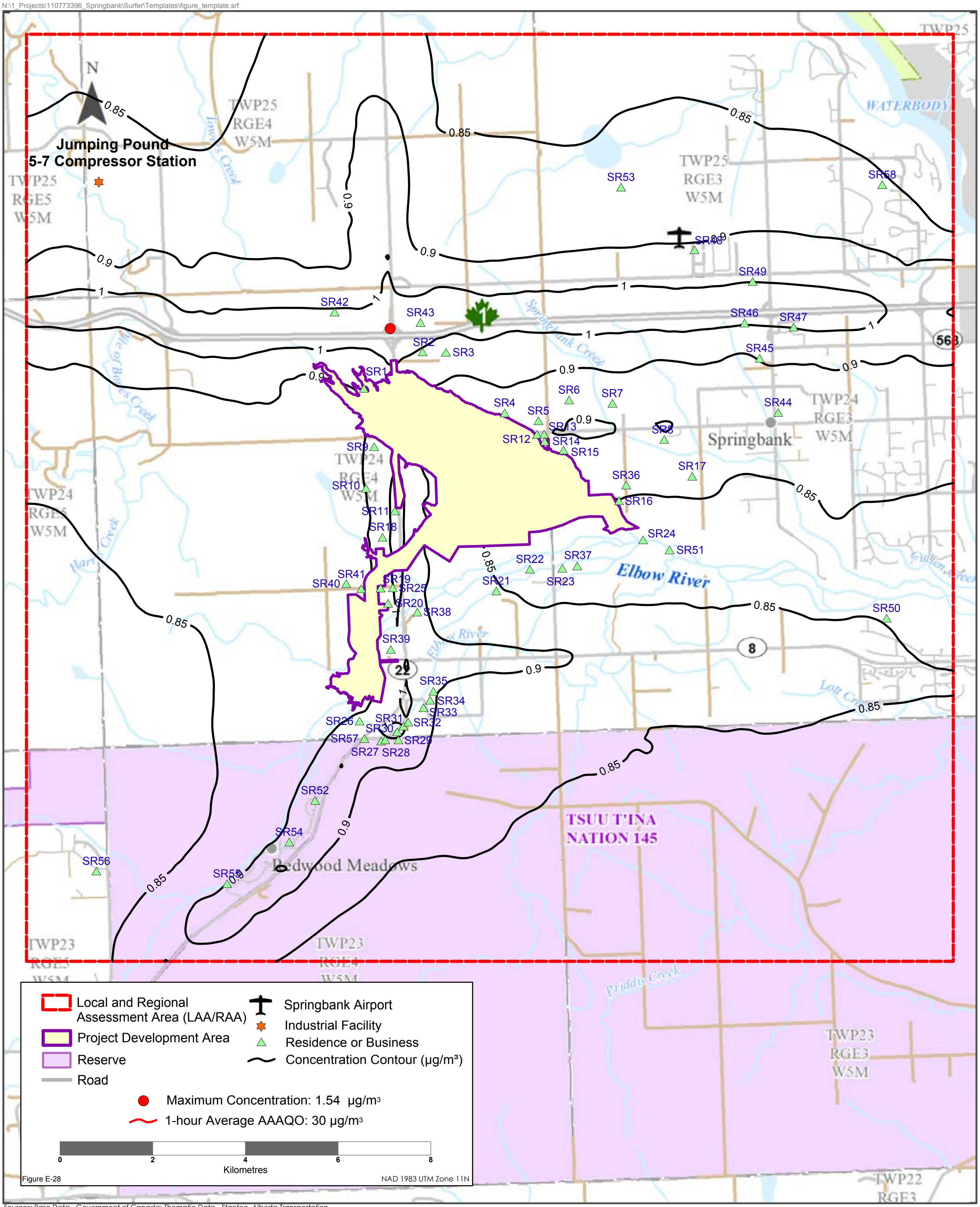


Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Maximum Predicted 24-hour Average Acrolein Concentrations (Application Case)



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

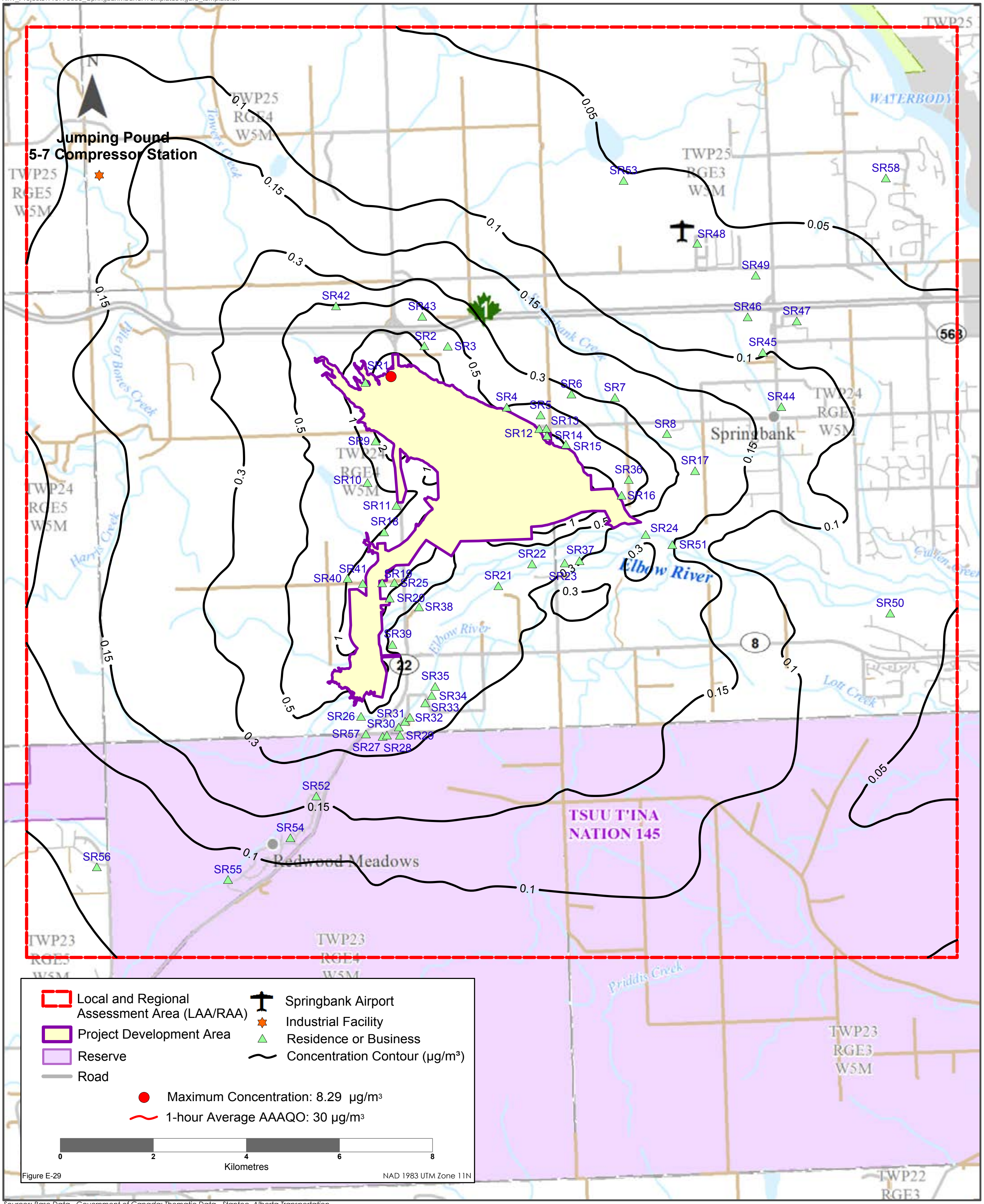
Predicted 9th Highest 1-hour Average Benzene Concentrations (Base Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-28

N:\1_Projects\110773396_Springbank\Surfer\Templates\figure_template.srf



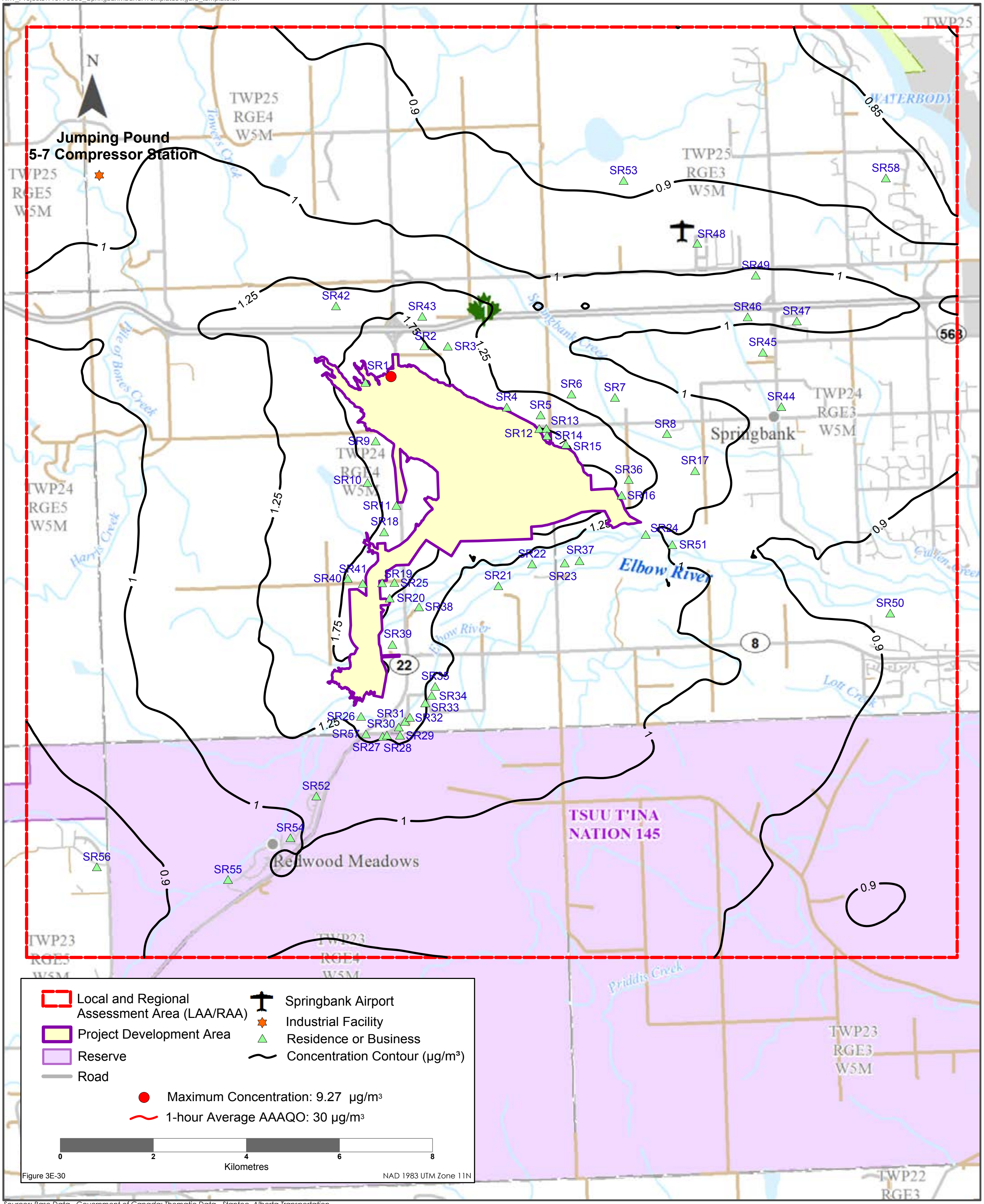
Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Predicted 9th Highest 1-hour Average Benzene Concentrations (Project Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-29



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Predicted 9th Highest 1-hour Average Benzene Concentrations (Application Case)

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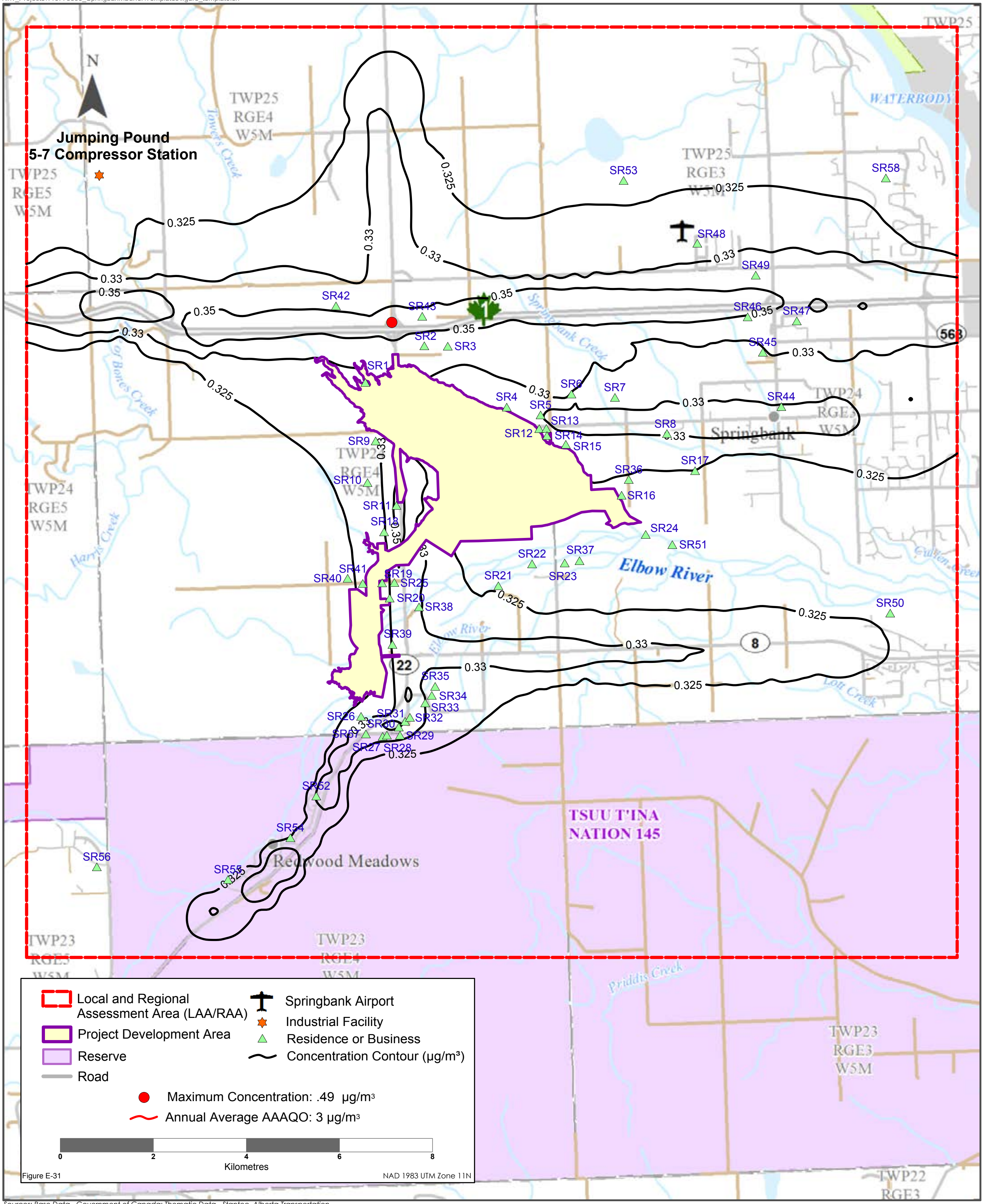


Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

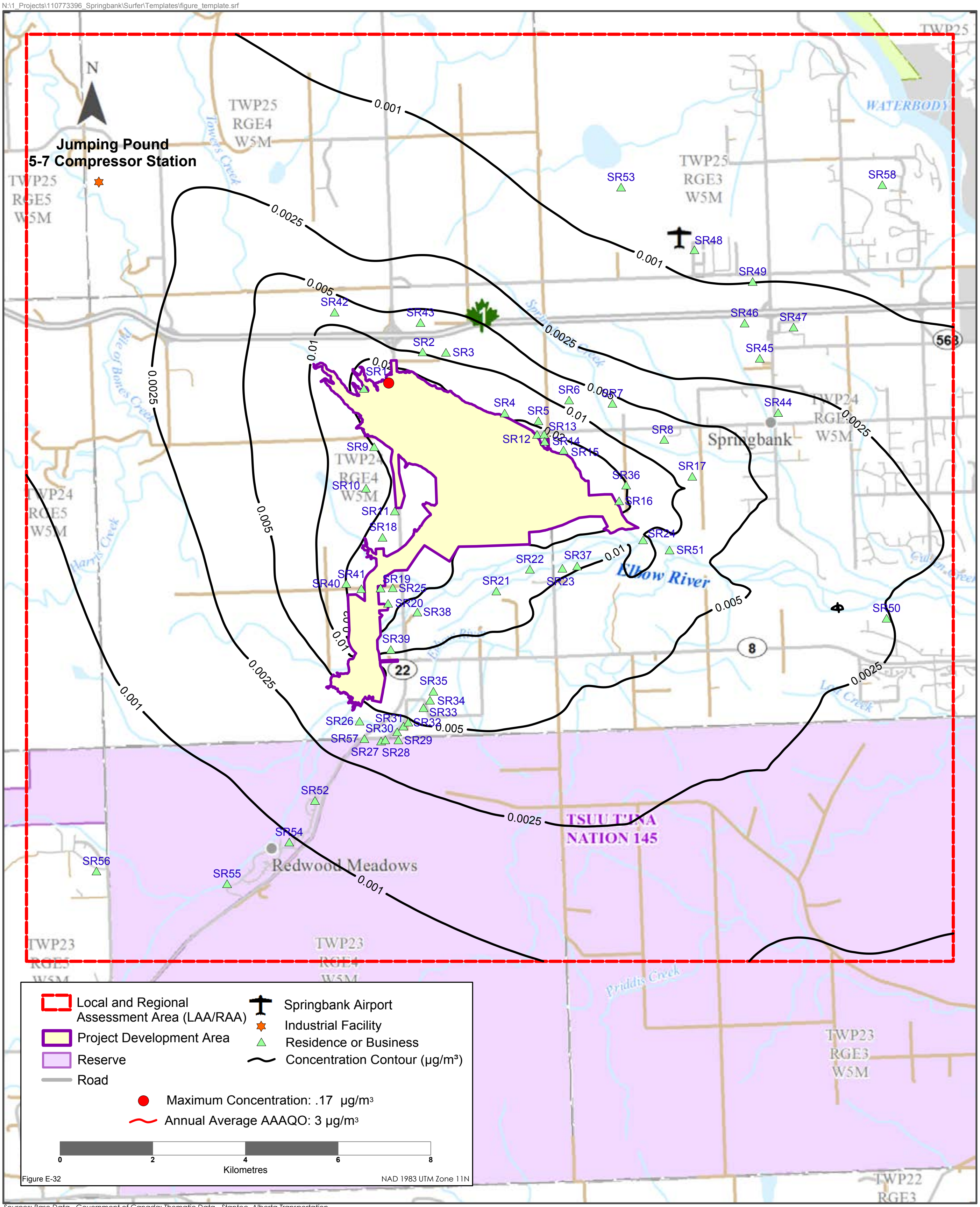
Maximum Predicted Annual Average Benzene Concentrations (Base Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-31

N:\1_Projects\110773396_Springbank\Surfer\Templates\figure_template.srf

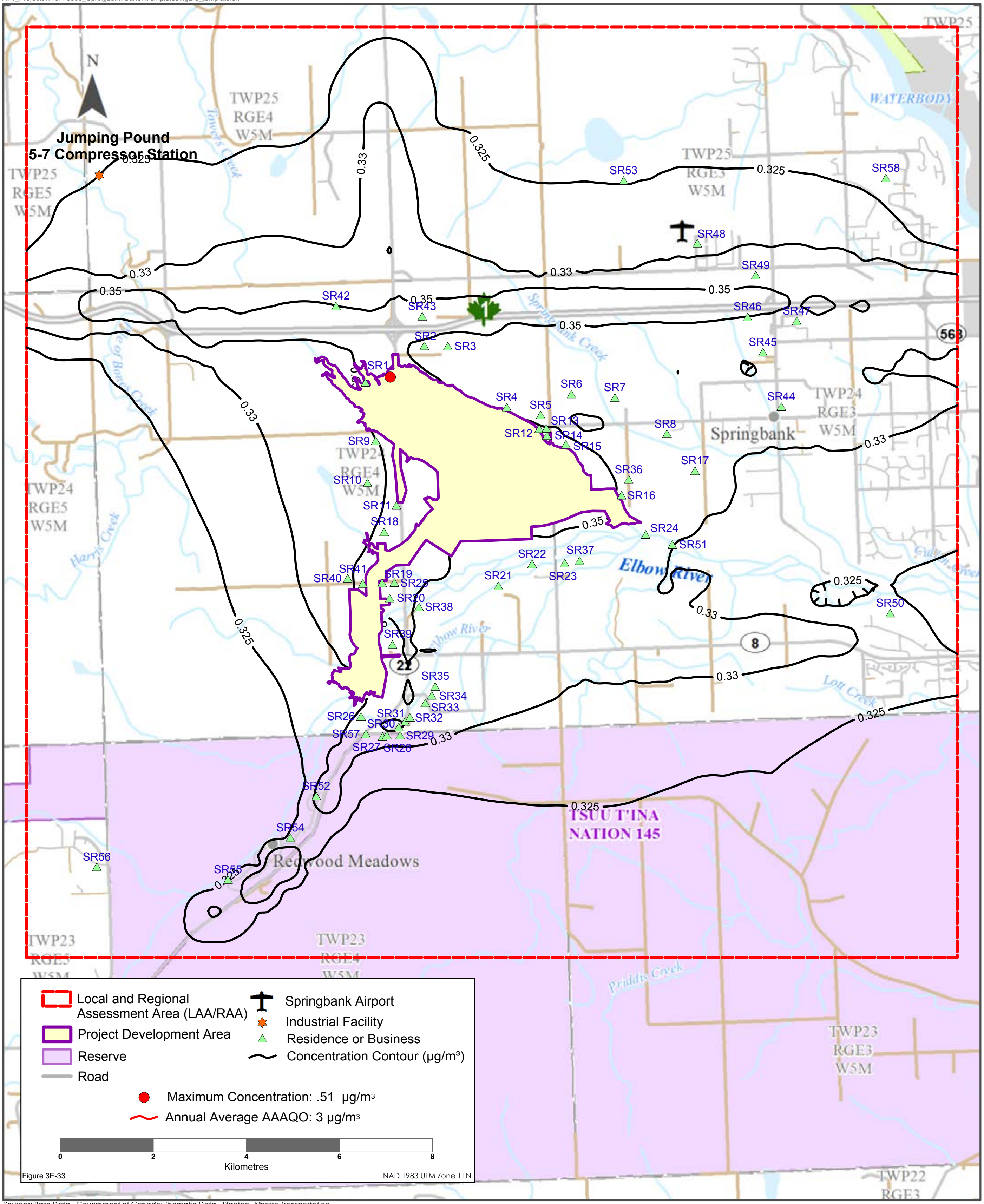


Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Maximum Predicted Annual Average Benzene Concentrations (Project Case)

Figure 3E-32

N:\1_Projects\110773396_Springbank\Surfer\Templates\figure_template.srf

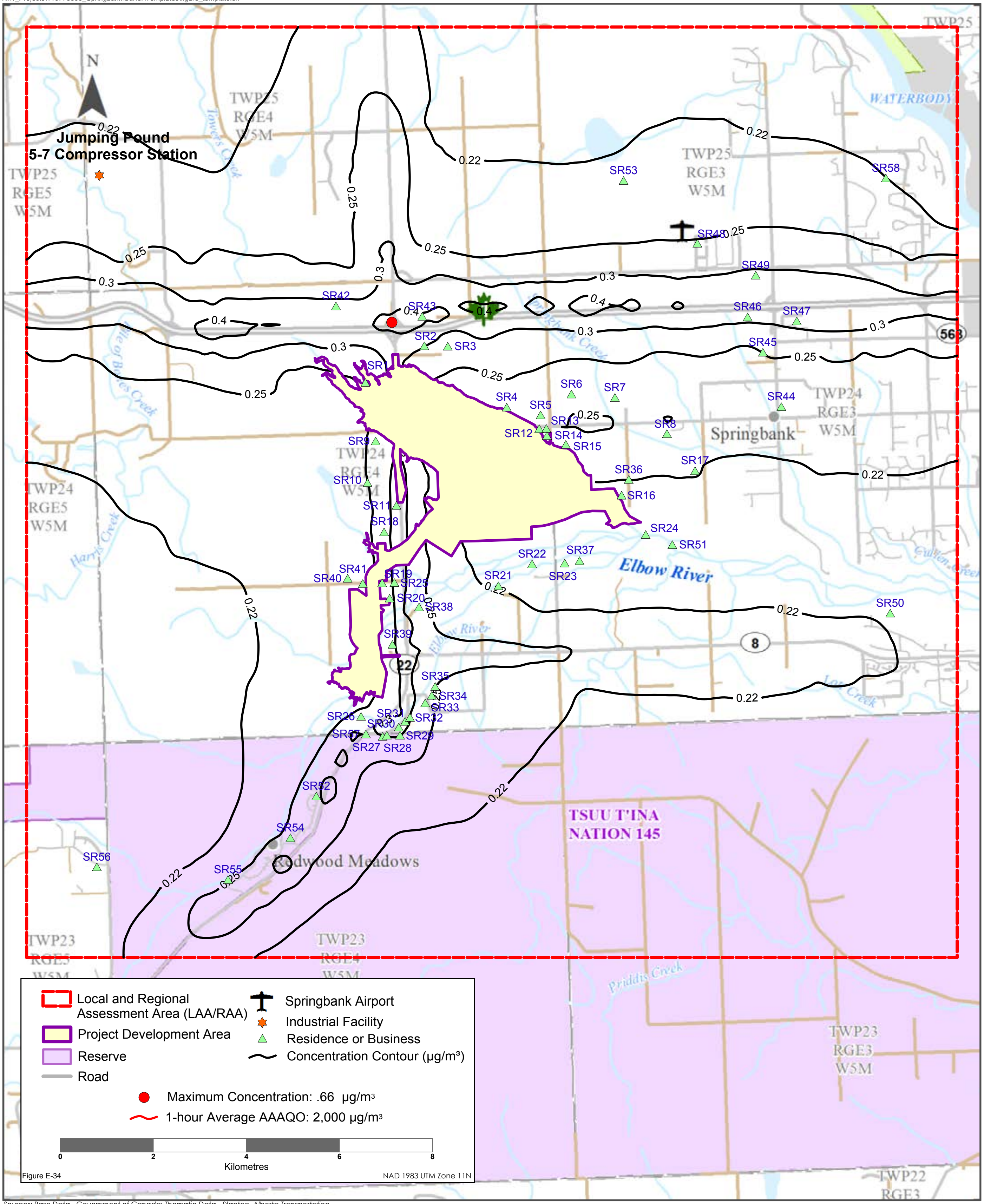


Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Maximum Predicted Annual Average Benzene Concentrations (Application Case)

Figure 3E-33

N:\1_Projects\110773396_Springbank\Surfer\Templates\figure_template.srf



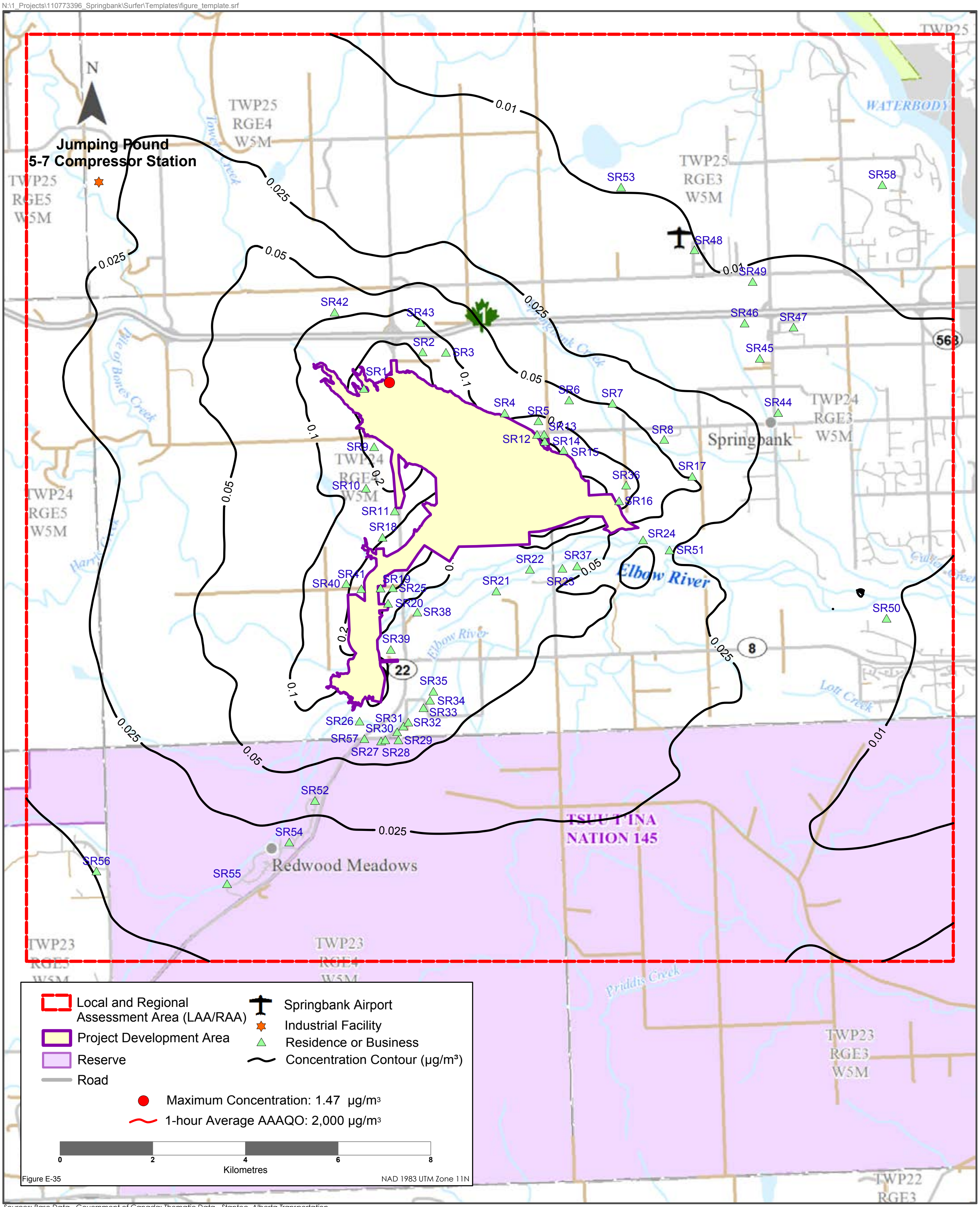
Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Predicted 9th Highest 1-hour Average Ethyl Benzene Concentrations (Base Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-34



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Predicted 9th Highest 1-hour Average Ethyl Benzene Concentrations (Project Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-35

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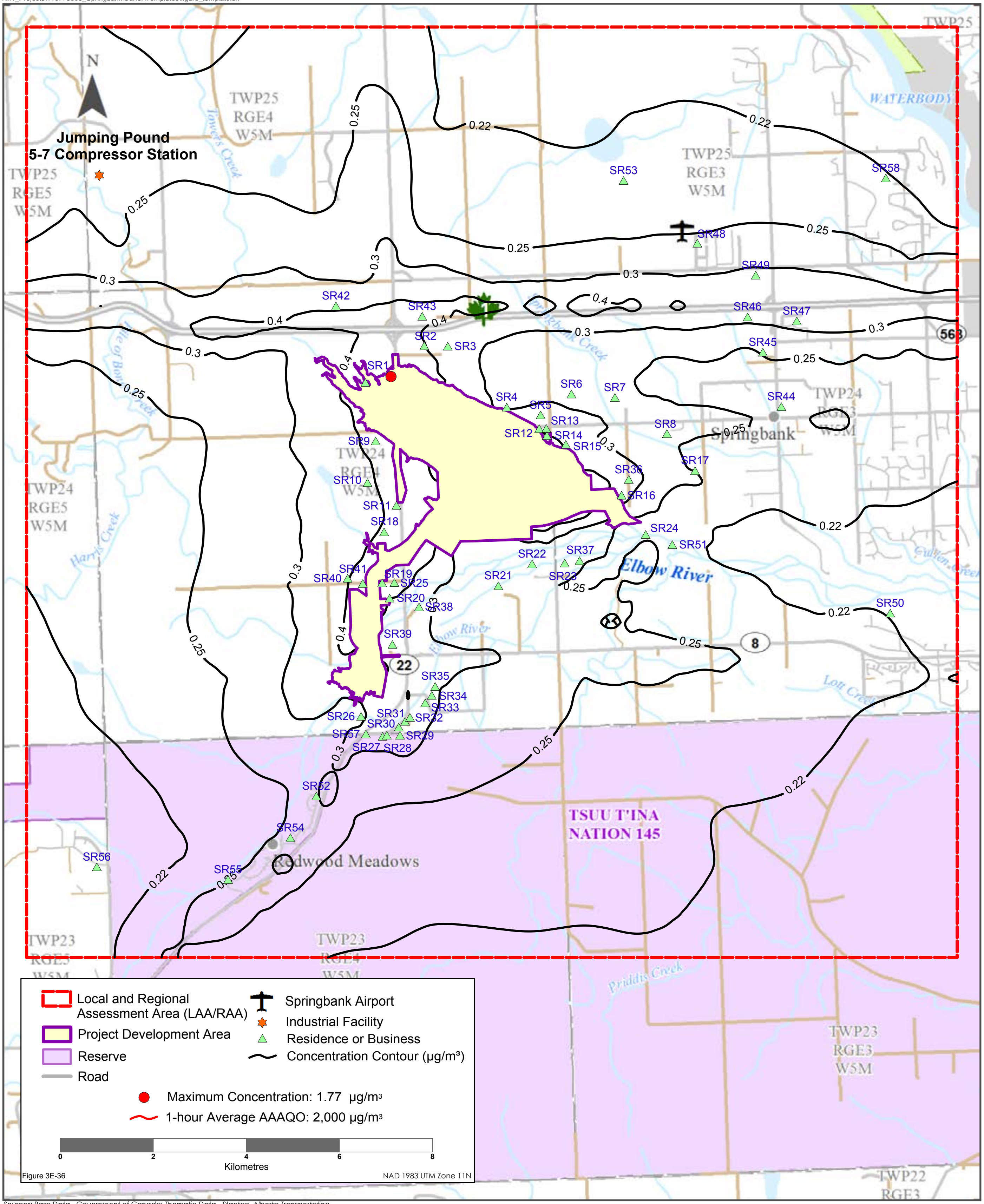


Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

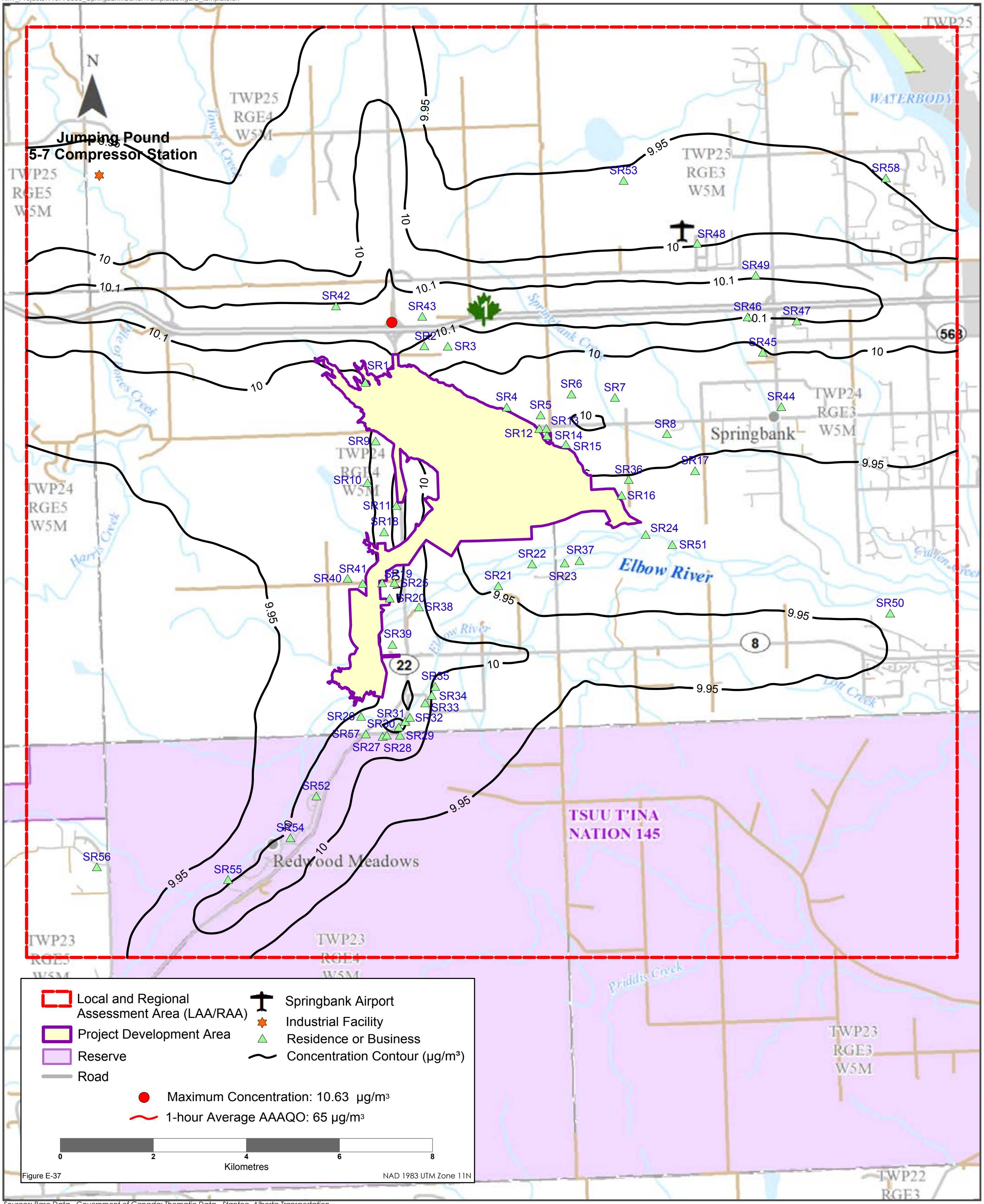
Predicted 9th Highest 1-hour Average Ethyl Benzene Concentrations (Application Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-36

N:\1_Projects\110773396_Springbank\Surfer\Templates\figure_template.srf



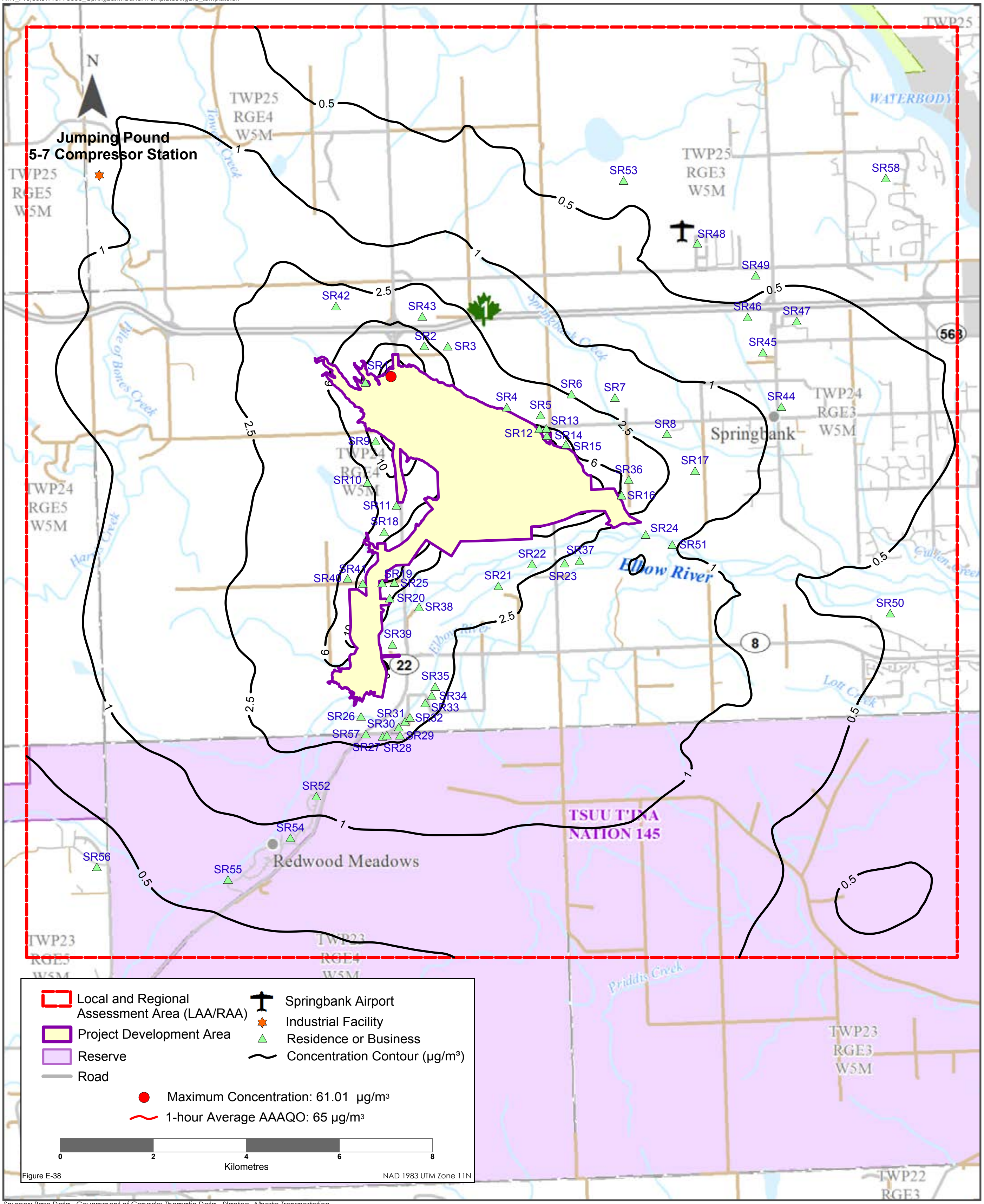
Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Predicted 9th Highest 1-hour Average Formaldehyde Concentrations (Base Case)

Stantec
SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-37

N:\1_Projects\110773396_Springbank\Surfer\Templates\figure_template.srf



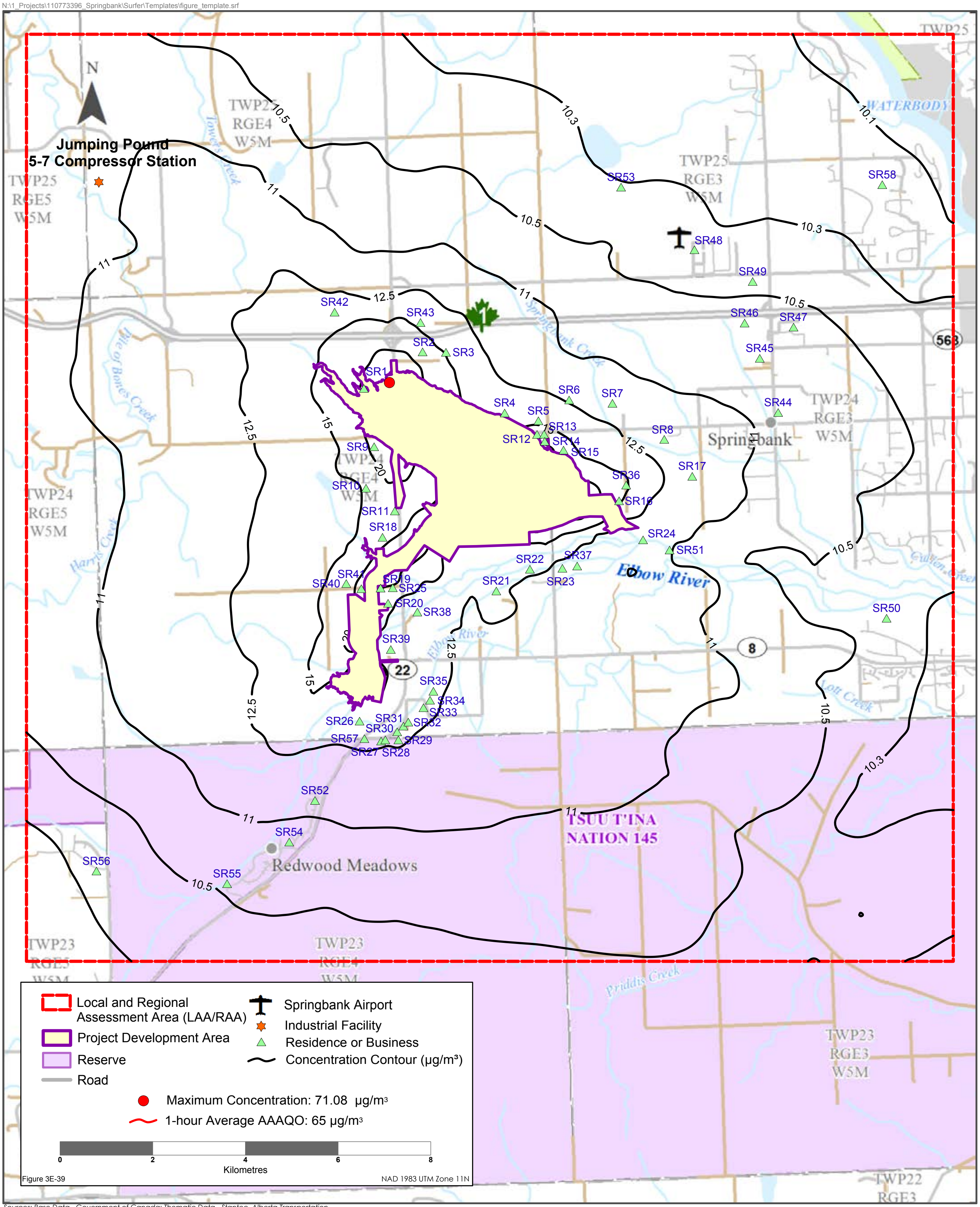
Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Predicted 9th Highest 1-hour Average Formaldehyde Concentrations (Project Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-38



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

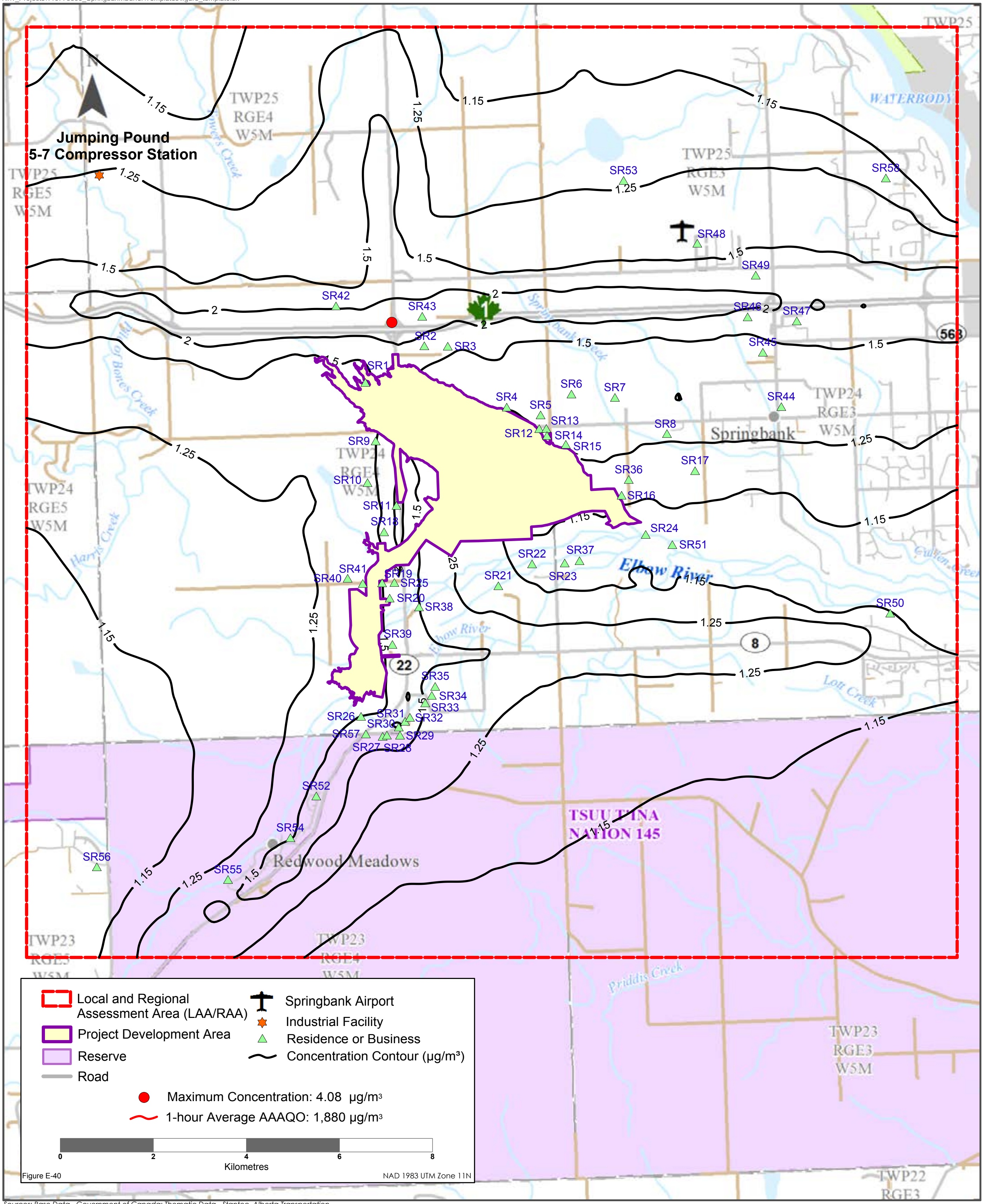
Predicted 9th Highest 1-hour Average Formaldehyde Concentrations (Application Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-39

N:\1_Projects\110773396_Springbank\Surfer\Templates\figure_template.srf



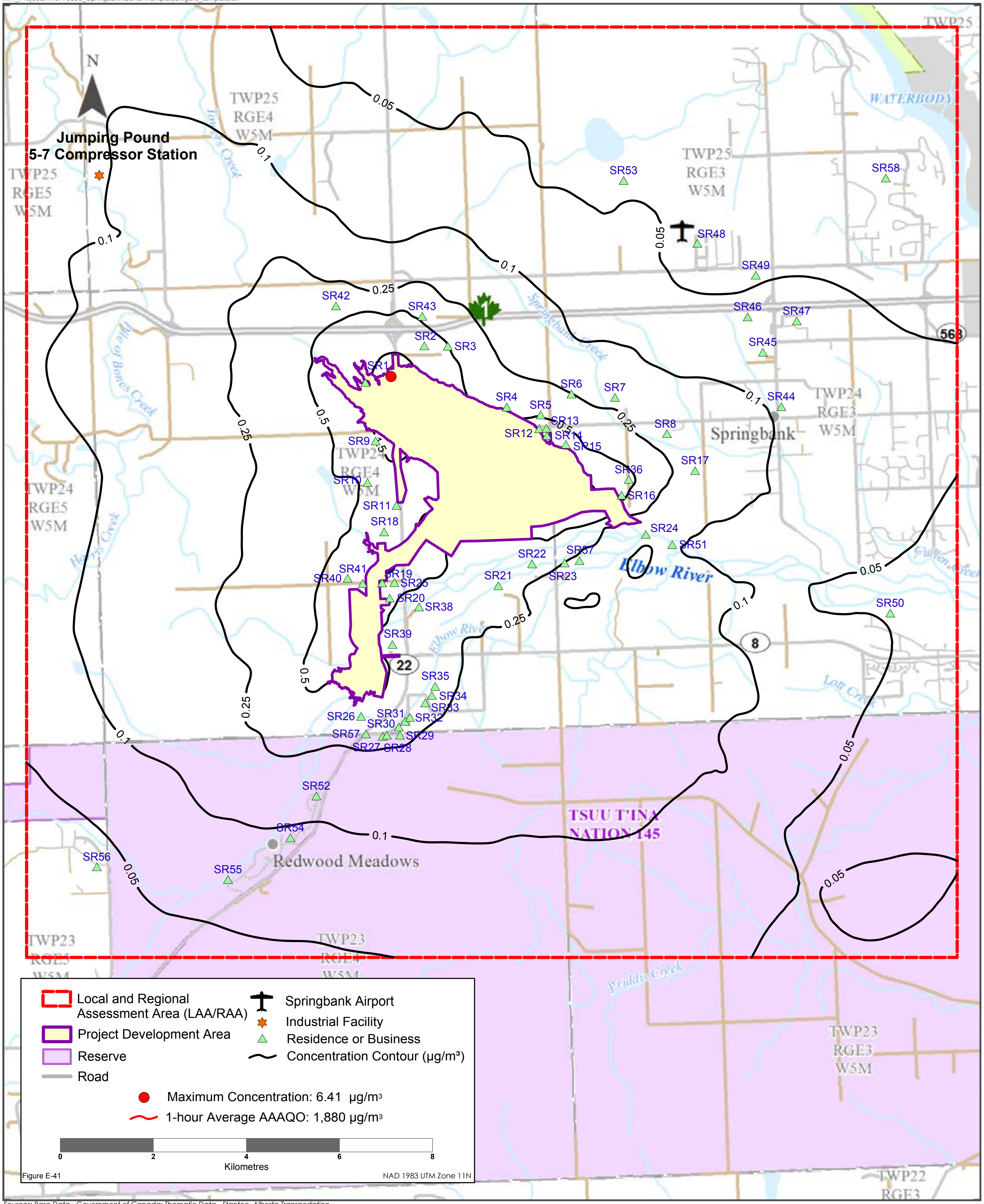
Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Predicted 9th Highest 1-hour Average Toluene Concentrations (Base Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-40



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

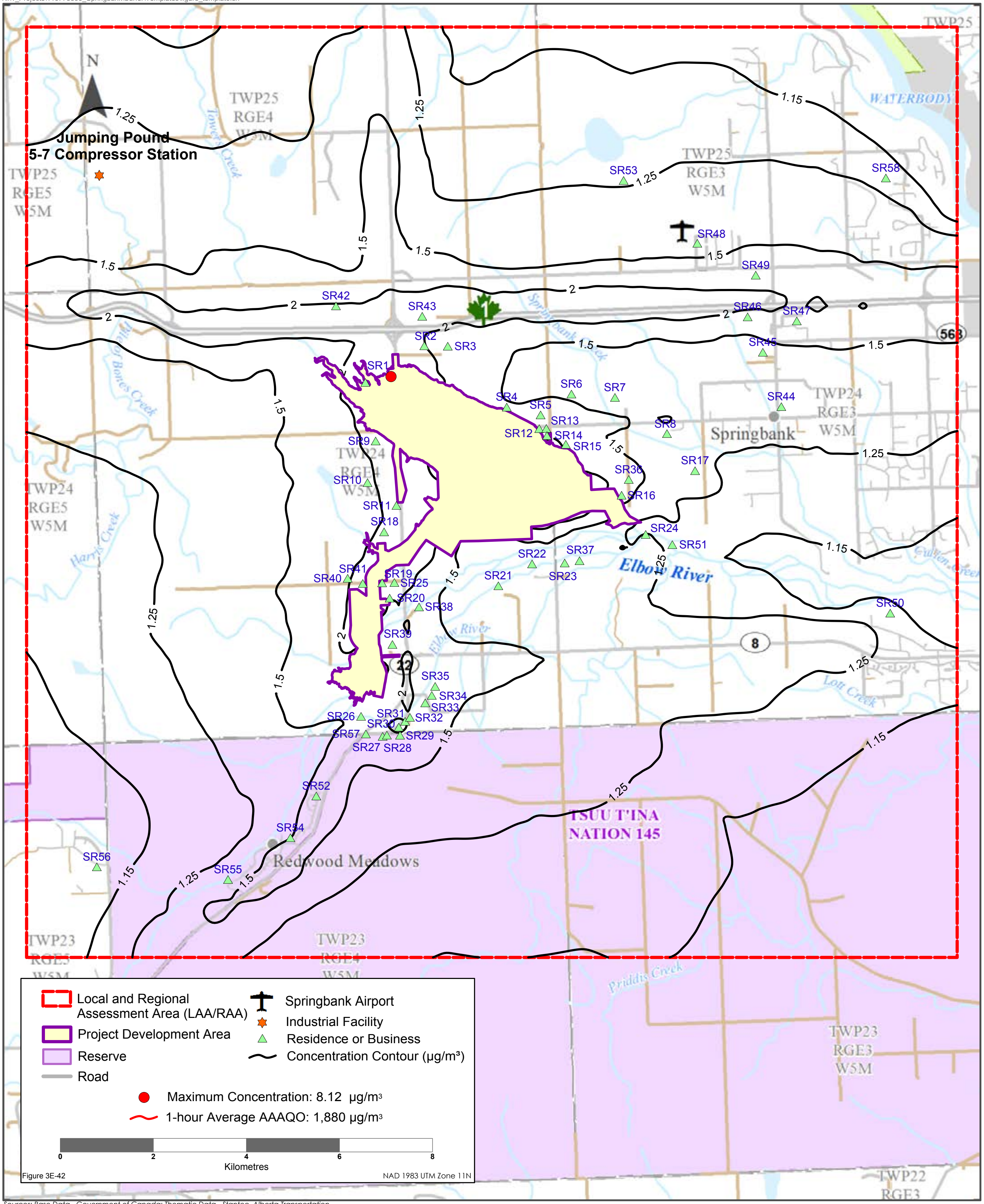
Predicted 9th Highest 1-hour Average Toluene Concentrations (Project Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-41

N:\1_Projects\110773396_Springbank\Surfer\Templates\figure_template.srf



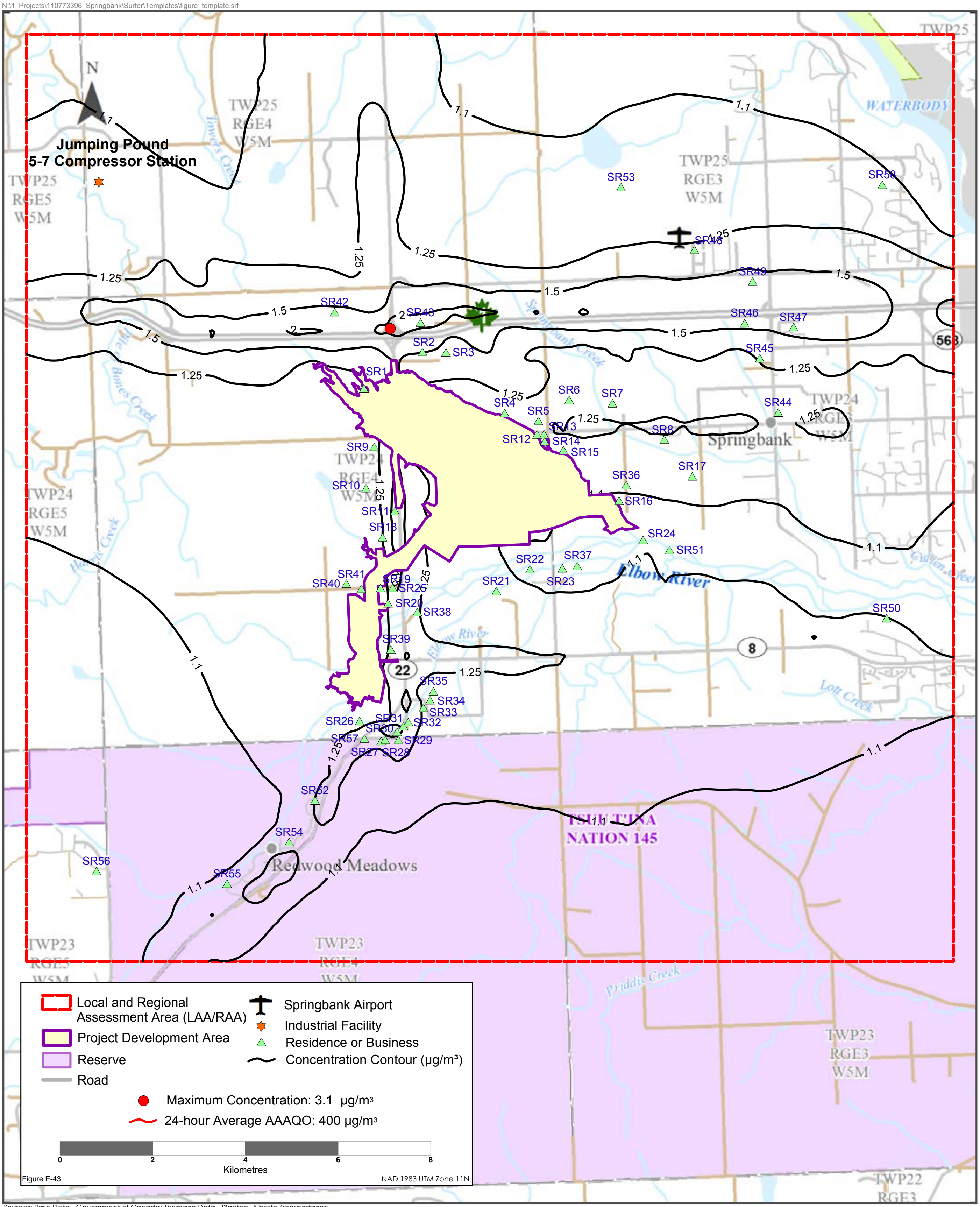
Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Predicted 9th Highest 1-hour Average Toluene Concentrations (Application Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

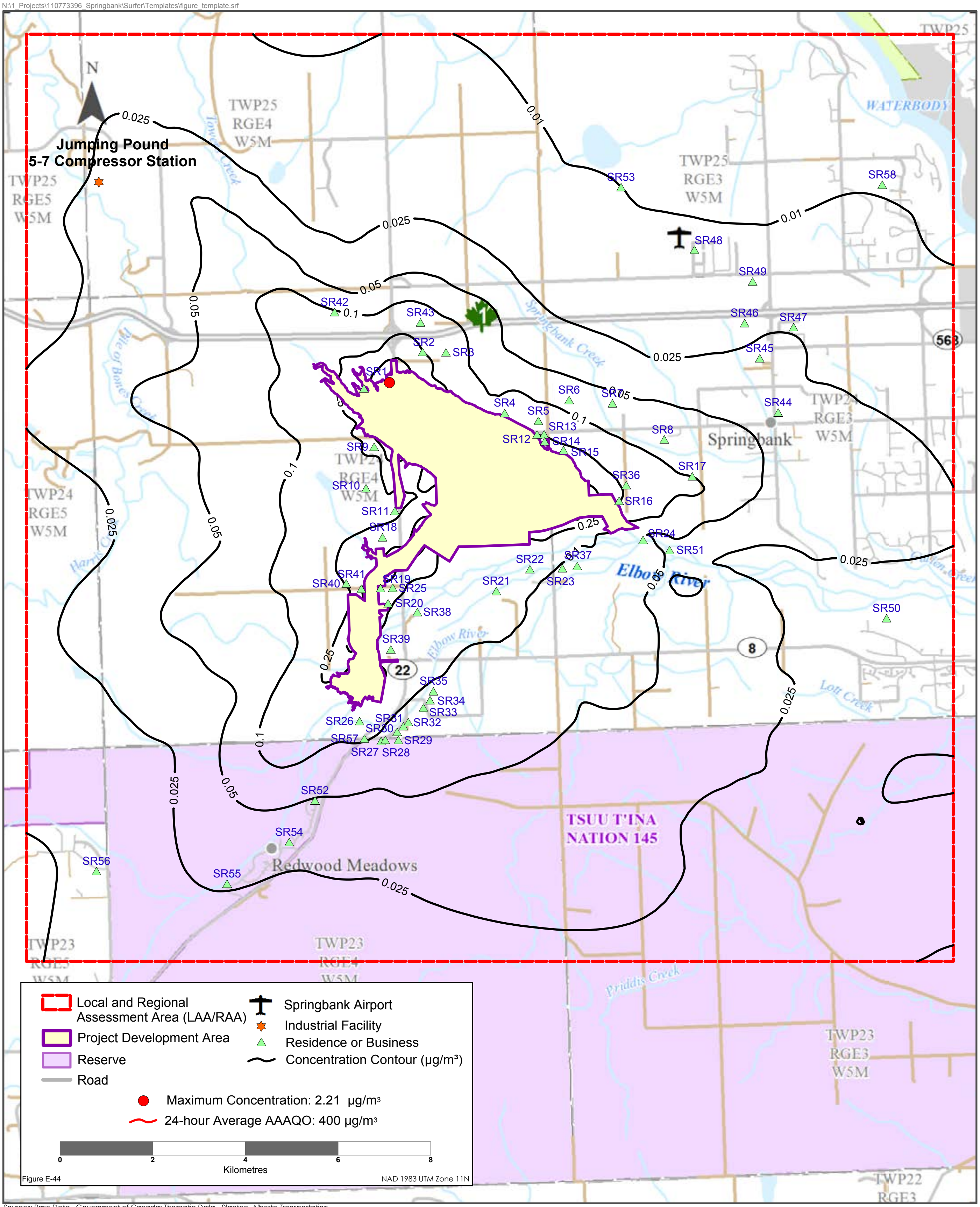
Figure 3E-42



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Maximum Predicted 24-hour Average Toluene Concentrations (Base Case)

N:\1_Projects\110773396_Springbank\Surfer\Templates\figure_template.srf



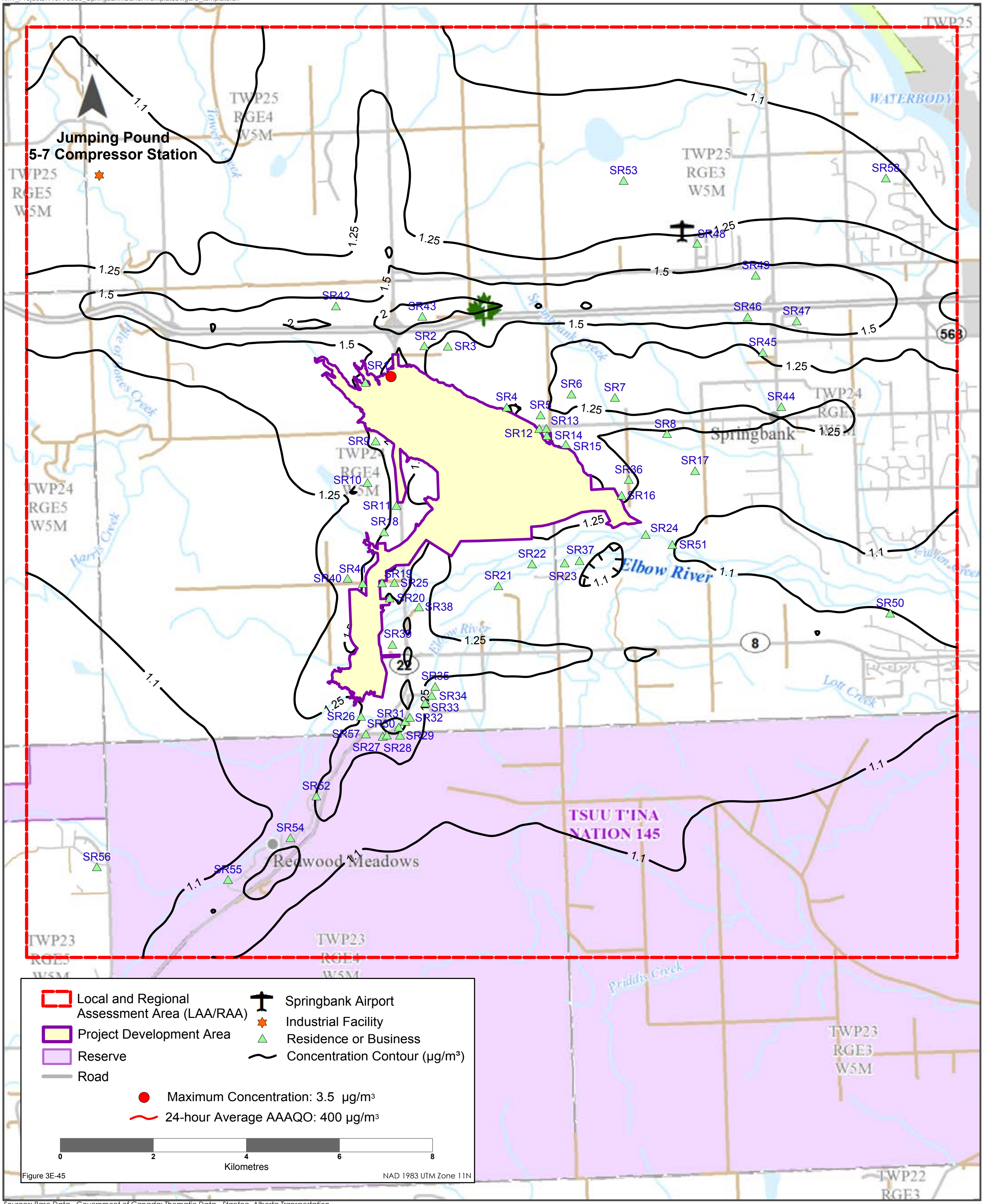
Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Maximum Predicted 24-hour Average Toluene Concentrations (Project Case)

Stantec

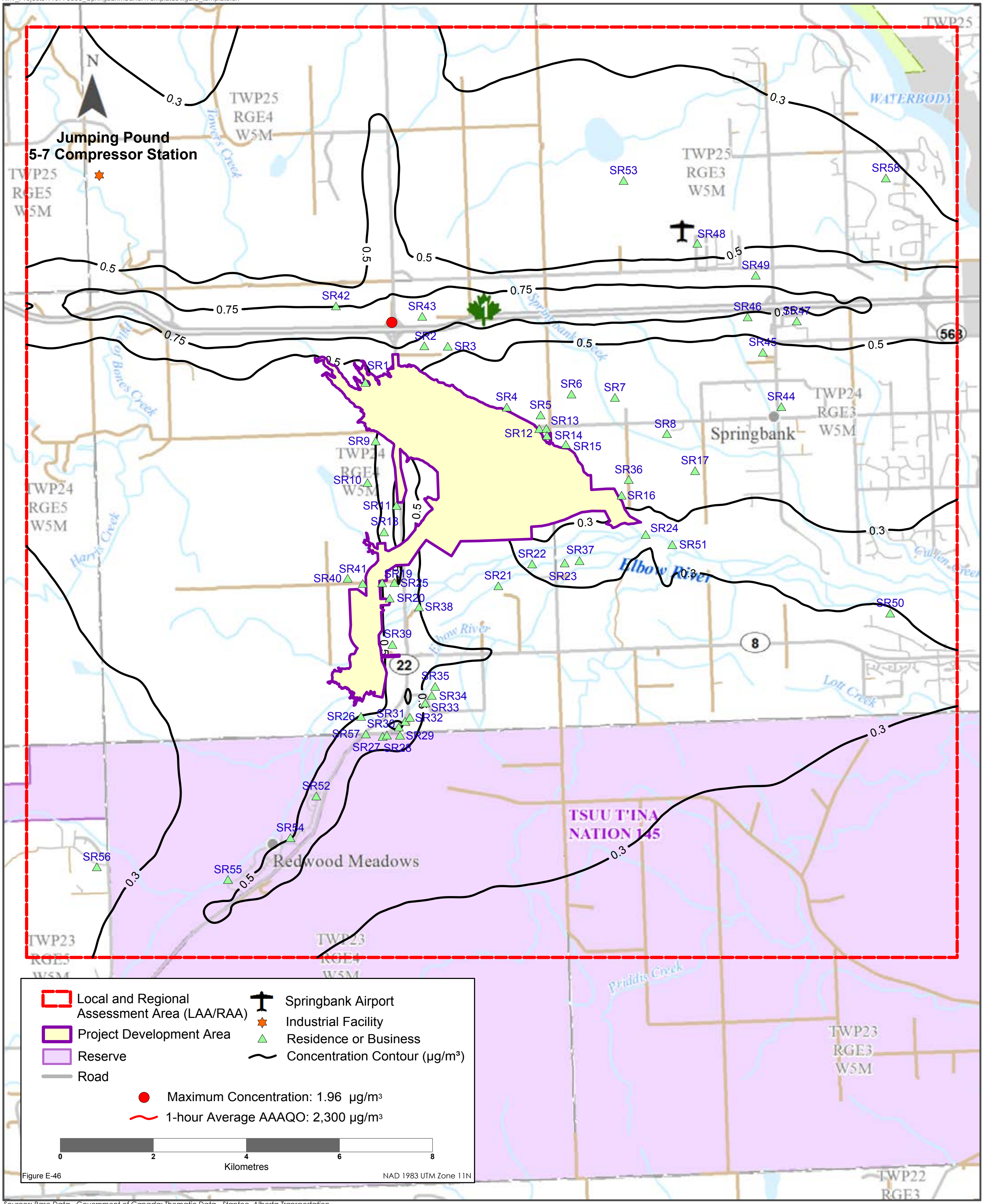
SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-44



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Maximum Predicted 24-hour Average Toluene Concentrations (Application Case)



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

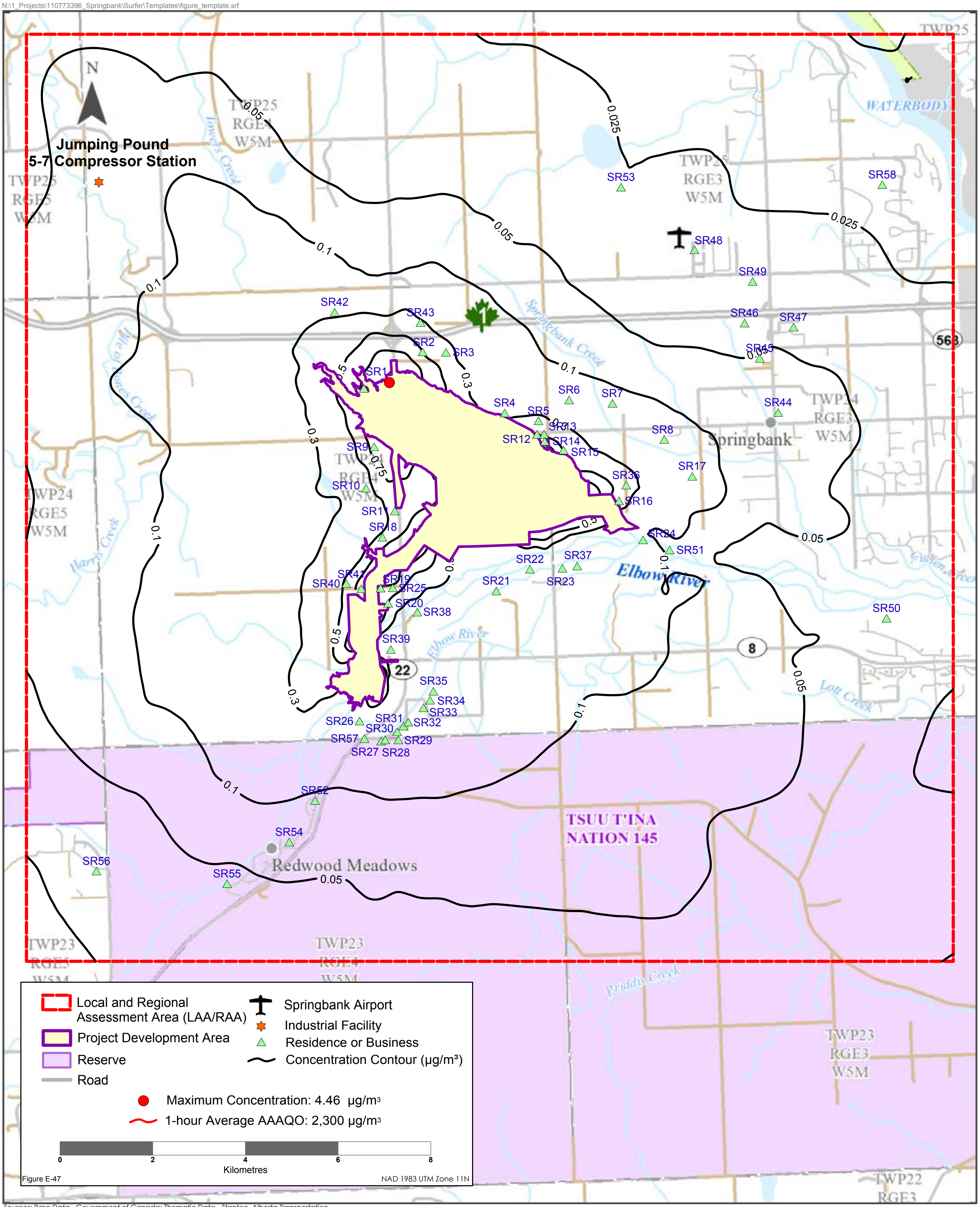
Predicted 9th Highest 1-hour Average Xylene Concentrations (Base Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

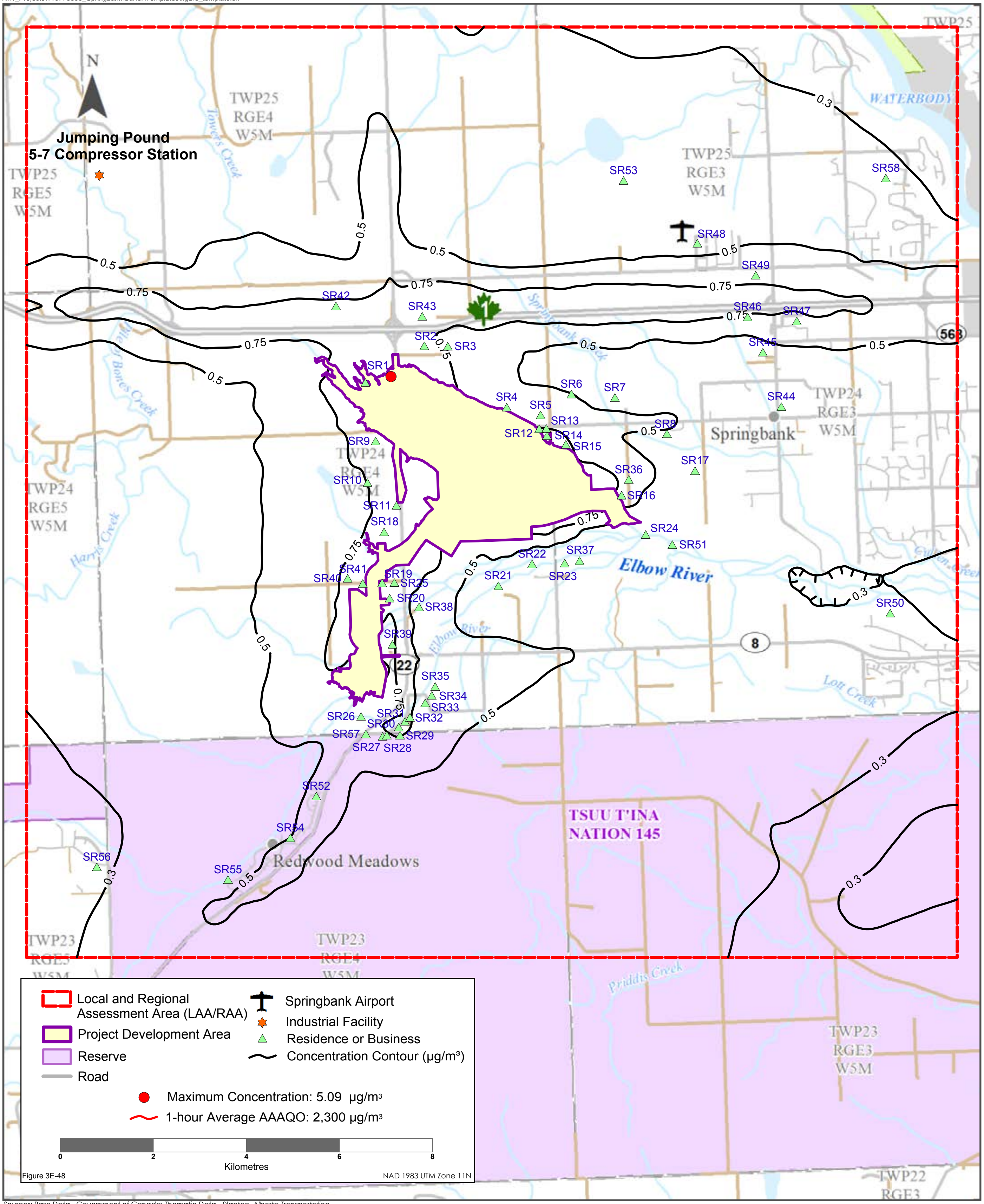
Figure 3E-46

N:\1_Projects\110773396_Springbank\Surfer\Templates\figure_template.srf



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Predicted 9th Highest 1-hour Average Xylene Concentrations (Project Case)



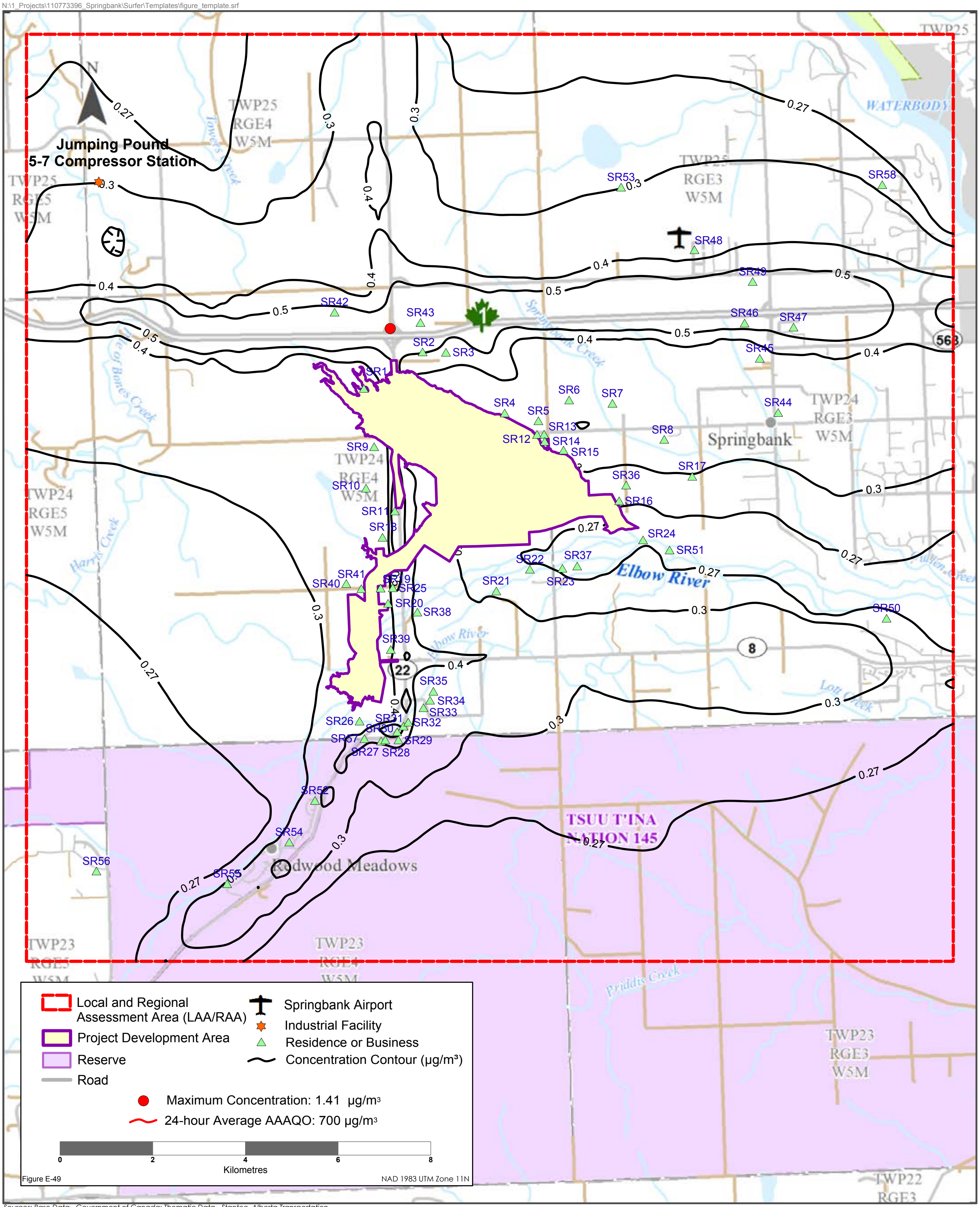
Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Predicted 9th Highest 1-hour Average Xylene Concentrations (Application Case)

Stantec

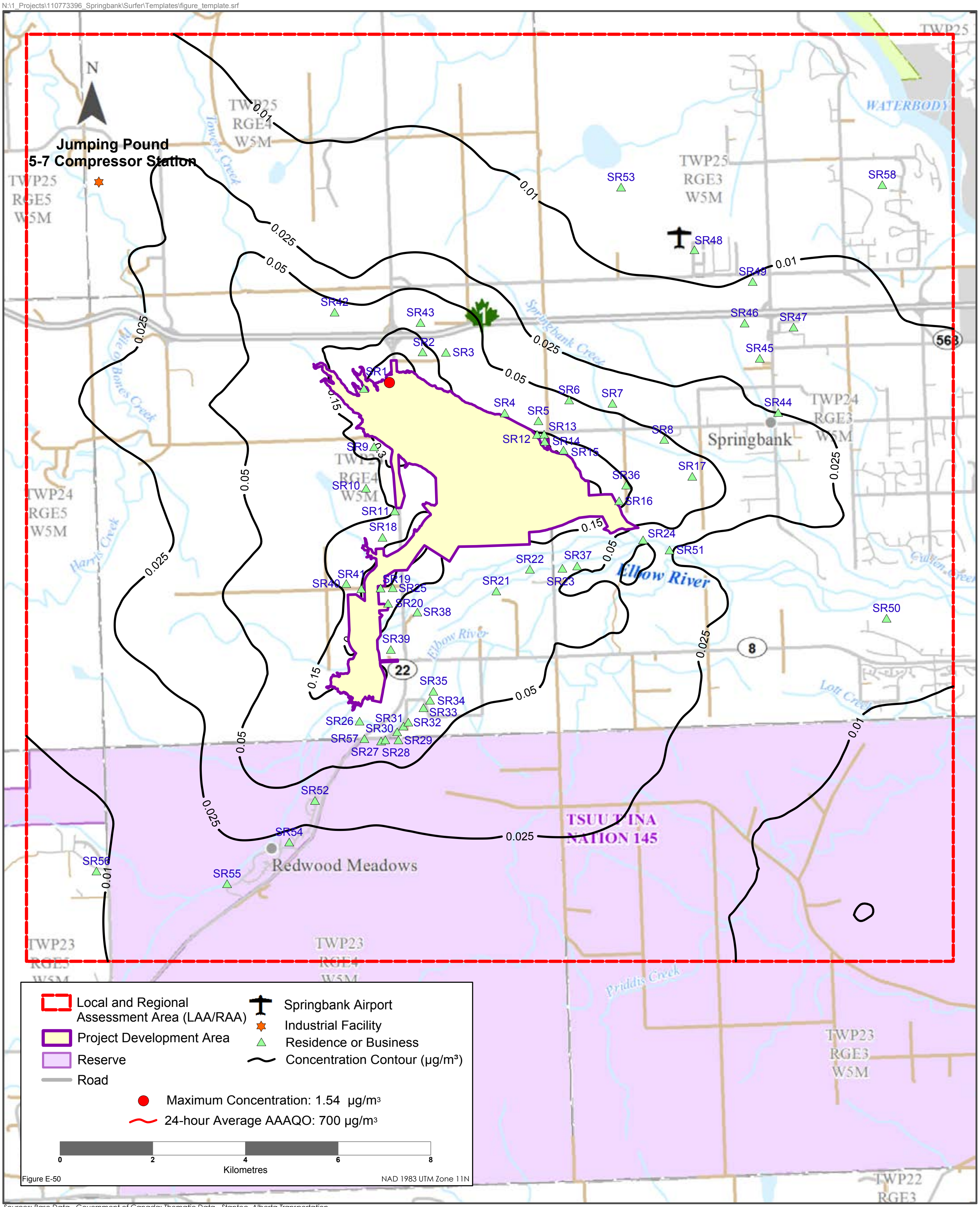
SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-48



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Maximum Predicted 24-hour Average Xylene Concentrations (Base Case)



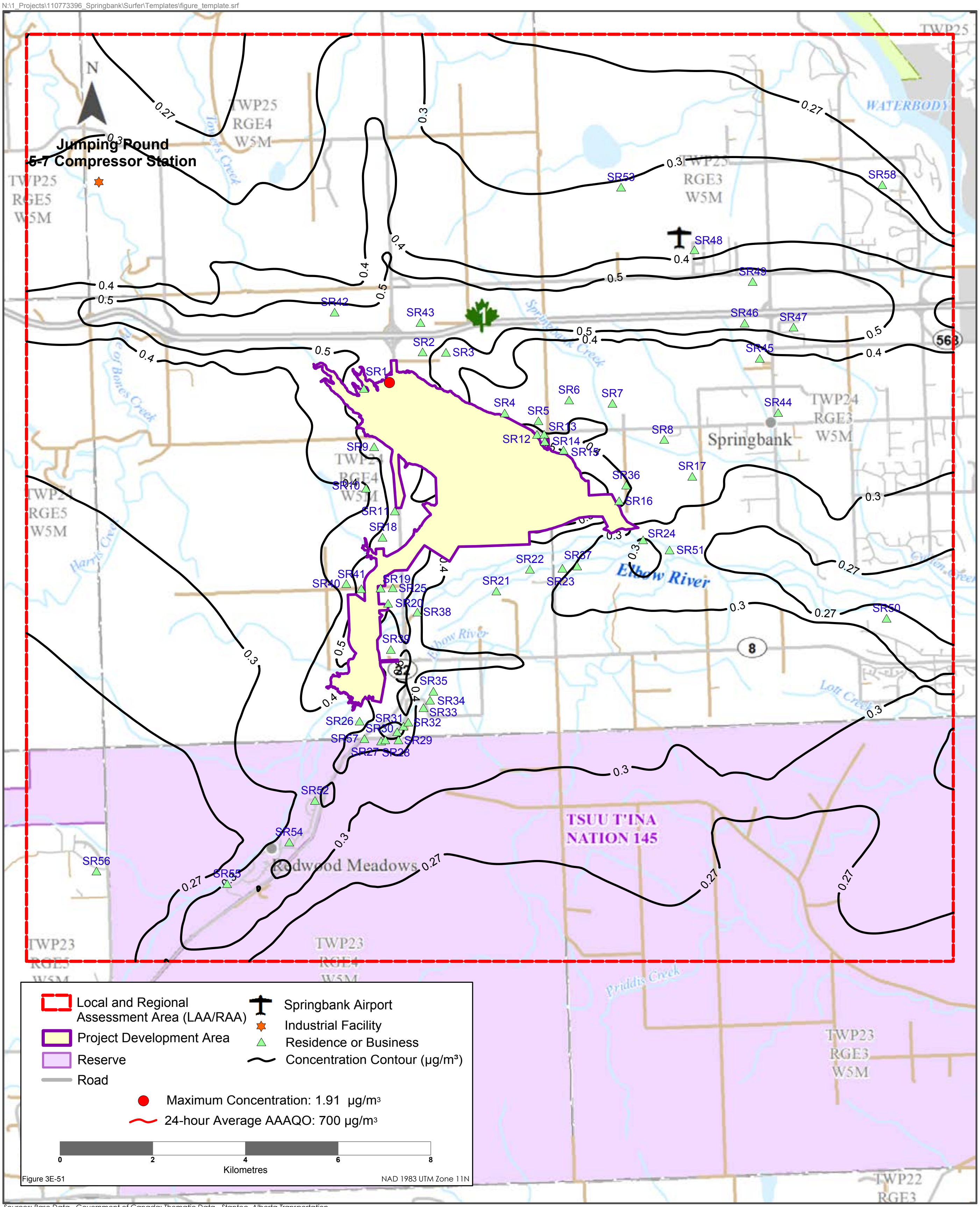
Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Maximum Predicted 24-hour Average Xylene Concentrations (Project Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-50



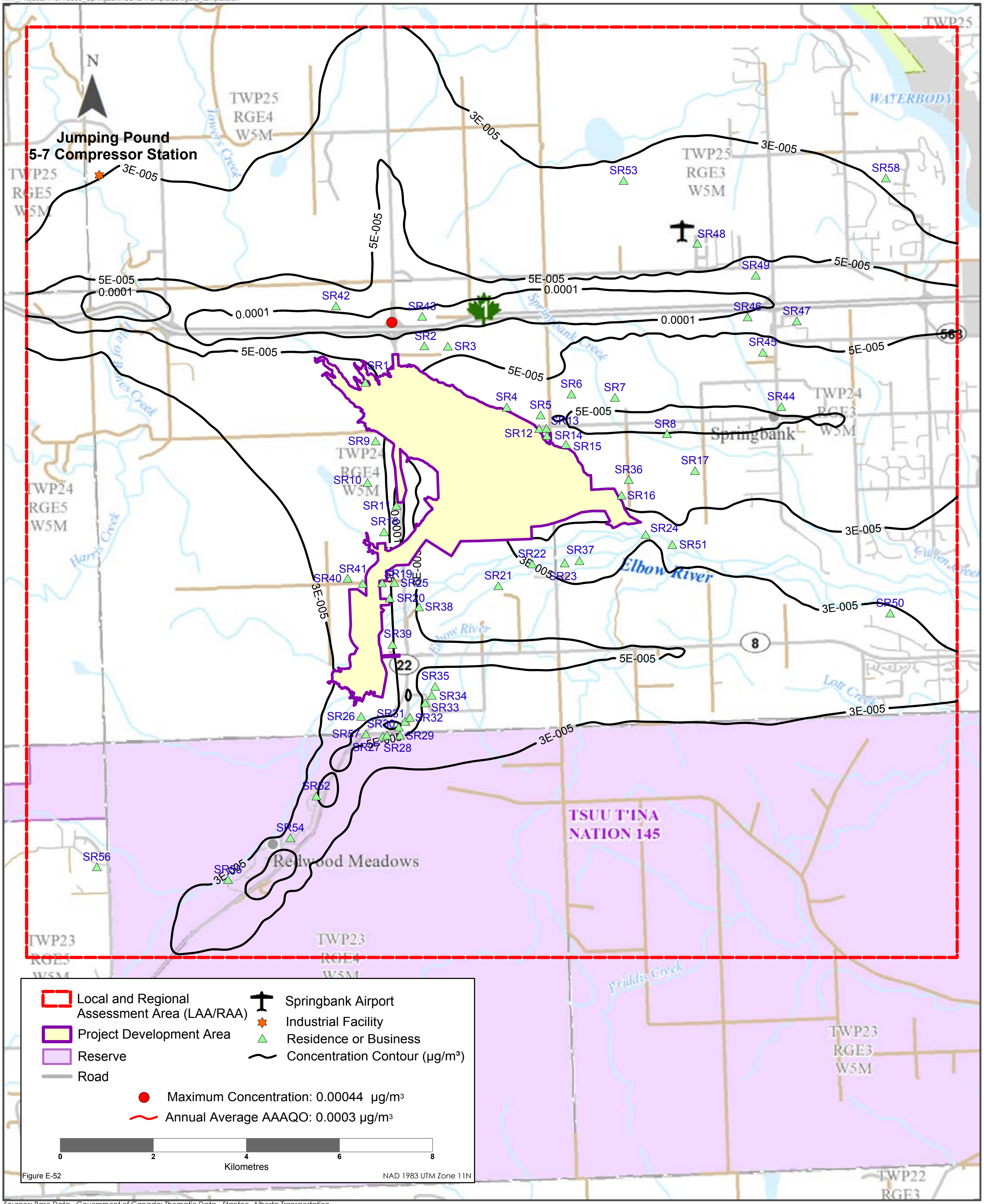
Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Maximum Predicted 24-hour Average Xylene Concentrations (Application Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-51



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

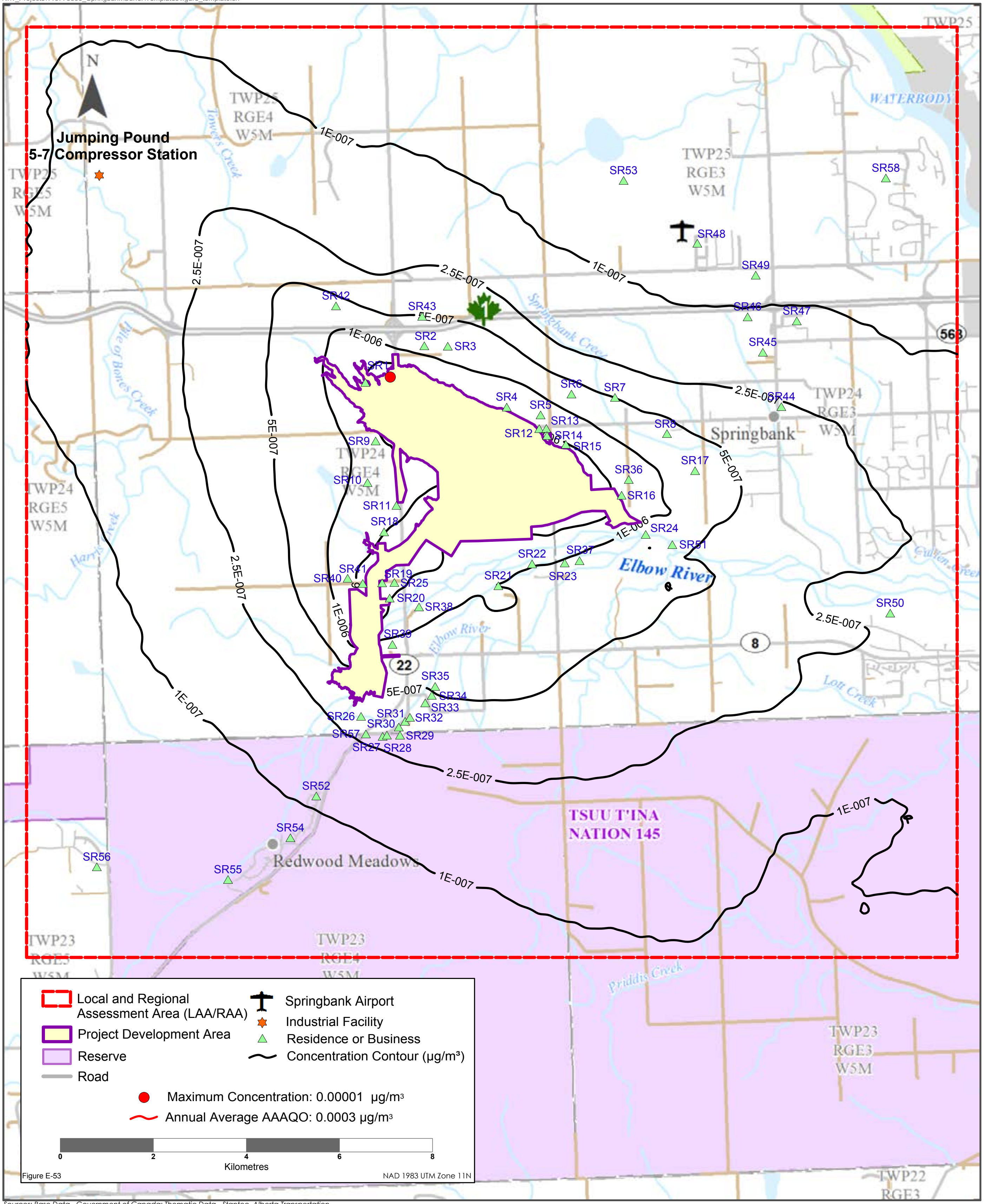
Maximum Predicted Annual Average Benzo(a)pyrene Concentrations (Base Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

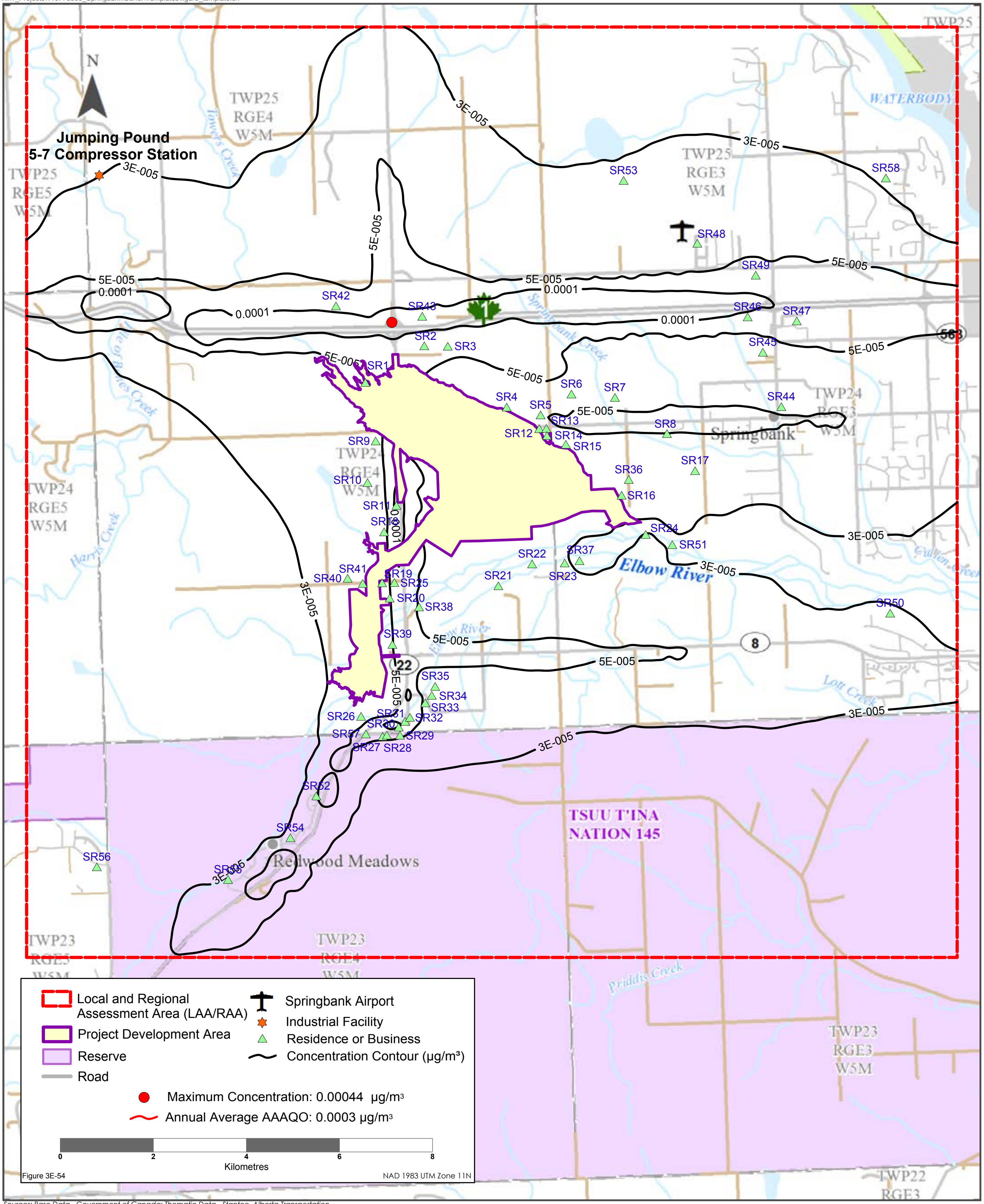
Figure 3E-52

N:\1_Projects\110773396_Springbank\Surfer\Templates\figure_template.srf



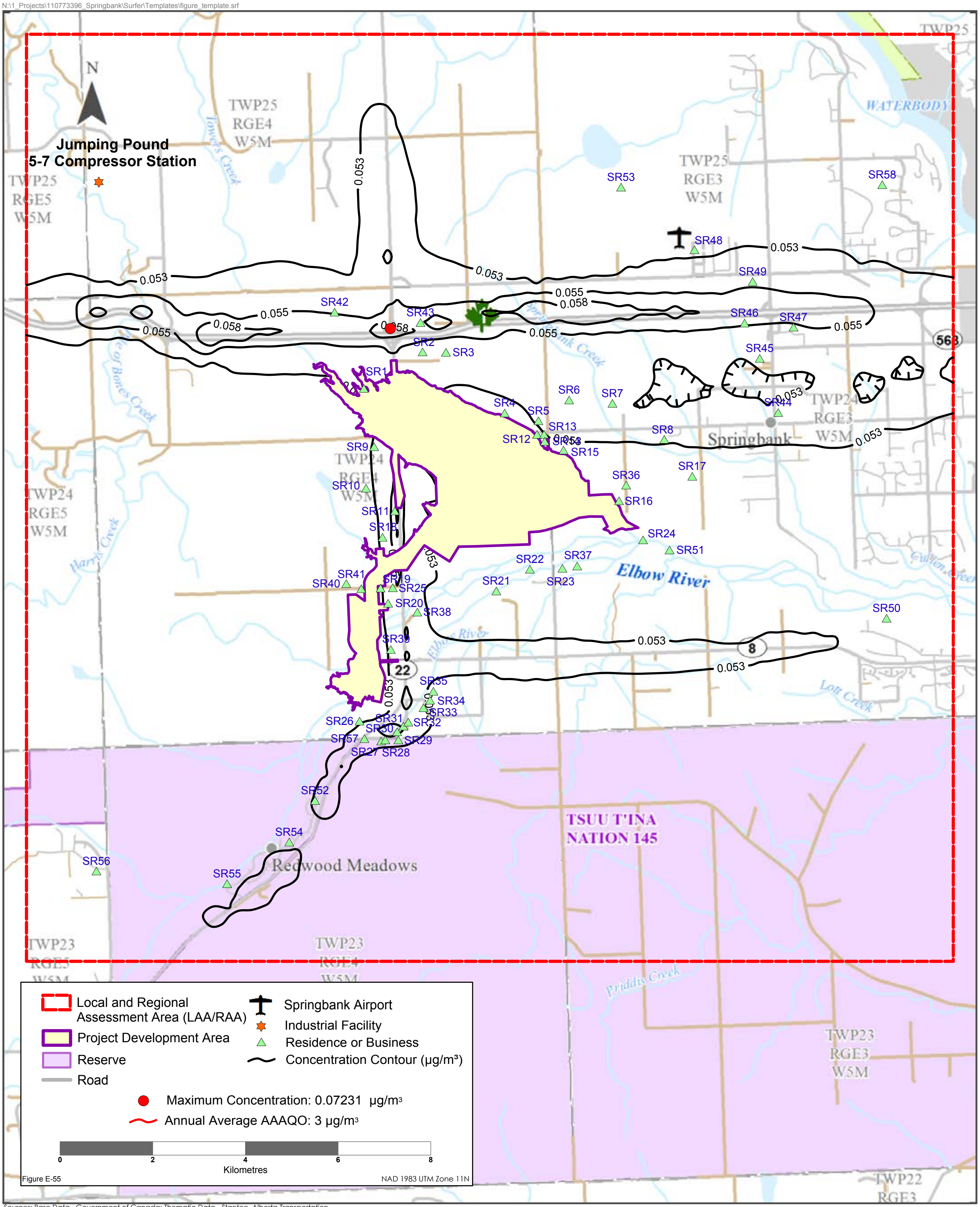
Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Maximum Predicted Annual Average Benzo(a)pyrene Concentrations (Project Case)



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Maximum Predicted Annual Average Benzo(a)pyrene Concentrations (Application Case)



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

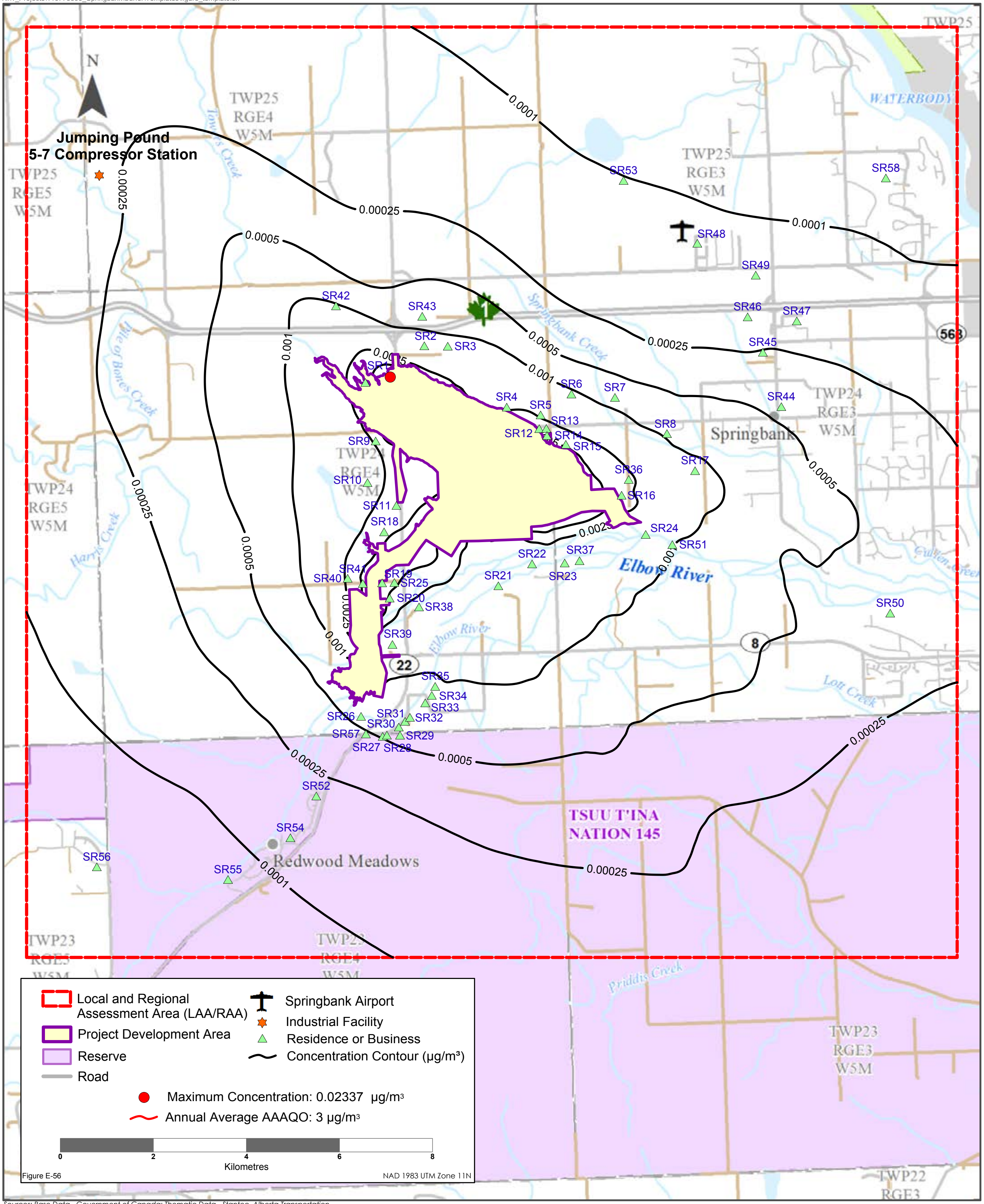
Maximum Predicted Annual Average Naphthalene Concentrations (Base Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-55

N:\1_Projects\110773396_Springbank\Surfer\Templates\figure_template.srf



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

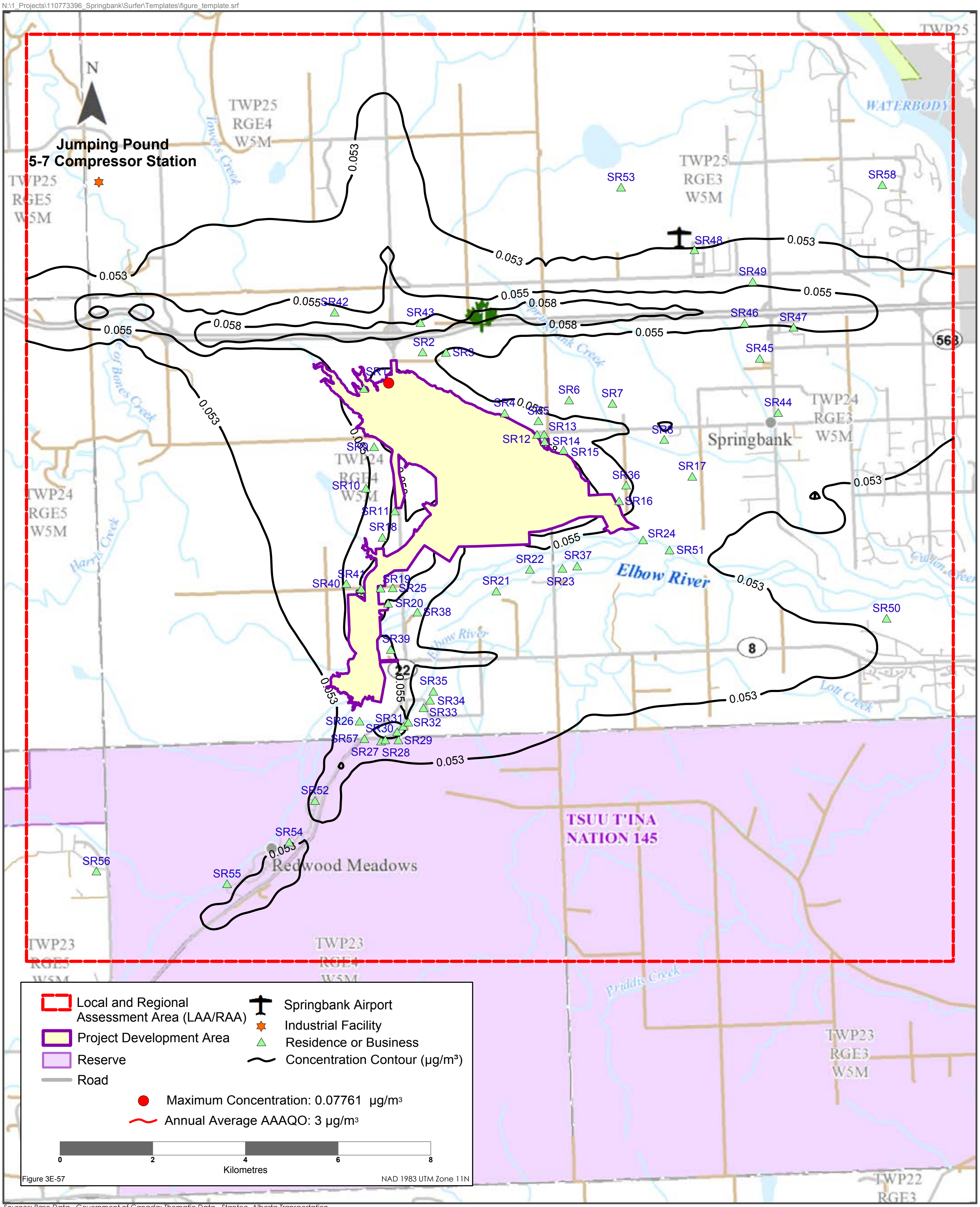
Maximum Predicted Annual Average Naphthalene Concentrations (Project Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-56

N:\1_Projects\110773396_Springbank\Surfer\Templates\figure_template.srf



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

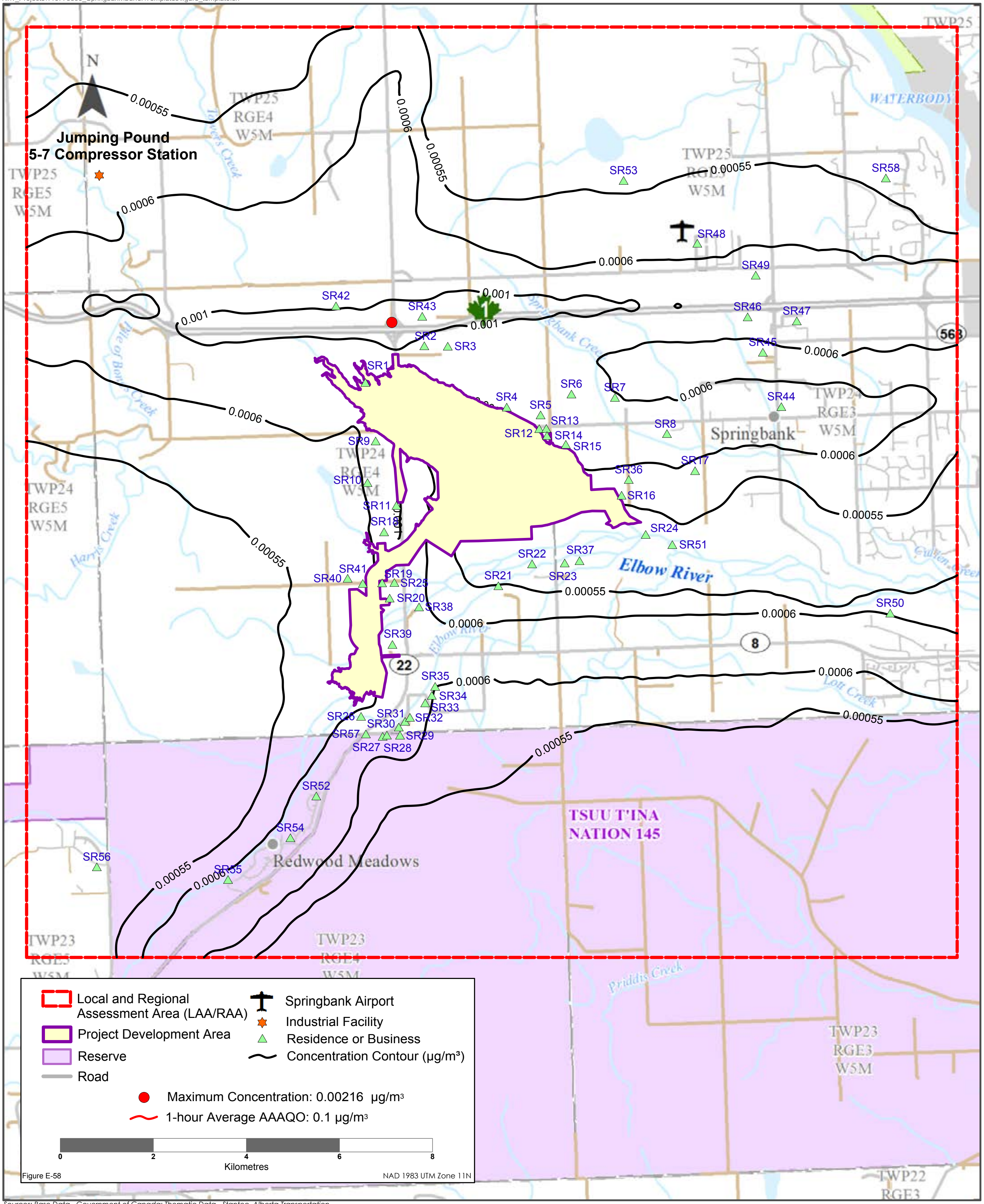
Maximum Predicted Annual Average Naphthalene Concentrations (Application Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-57

N:\1_Projects\110773396_Springbank\Surfer\Templates\figure_template.srf



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

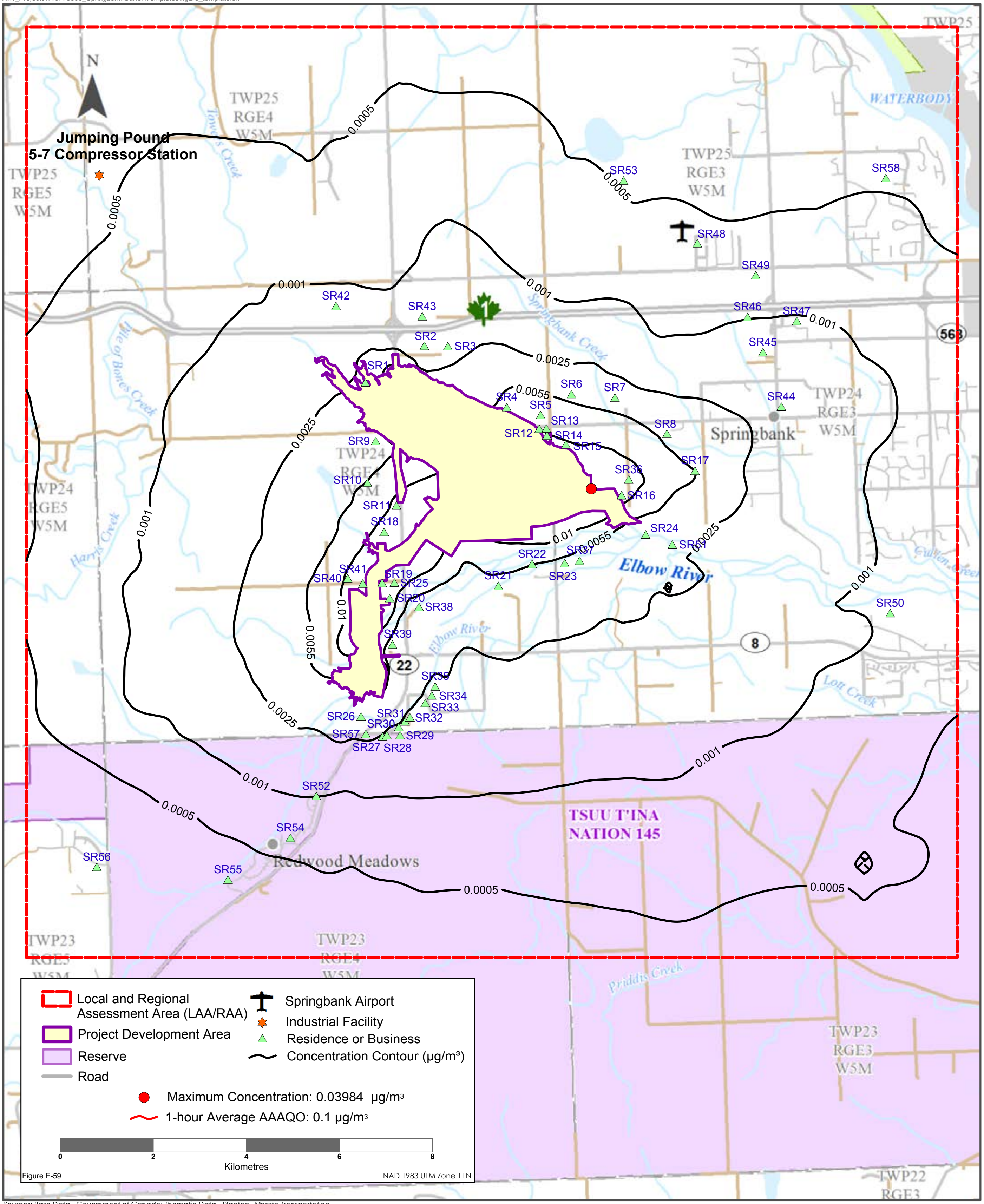
Predicted 9th Highest 1-hour Average Arsenic Concentrations (Base Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-58

N:\1_Projects\110773396_Springbank\Surfer\Templates\figure_template.srf



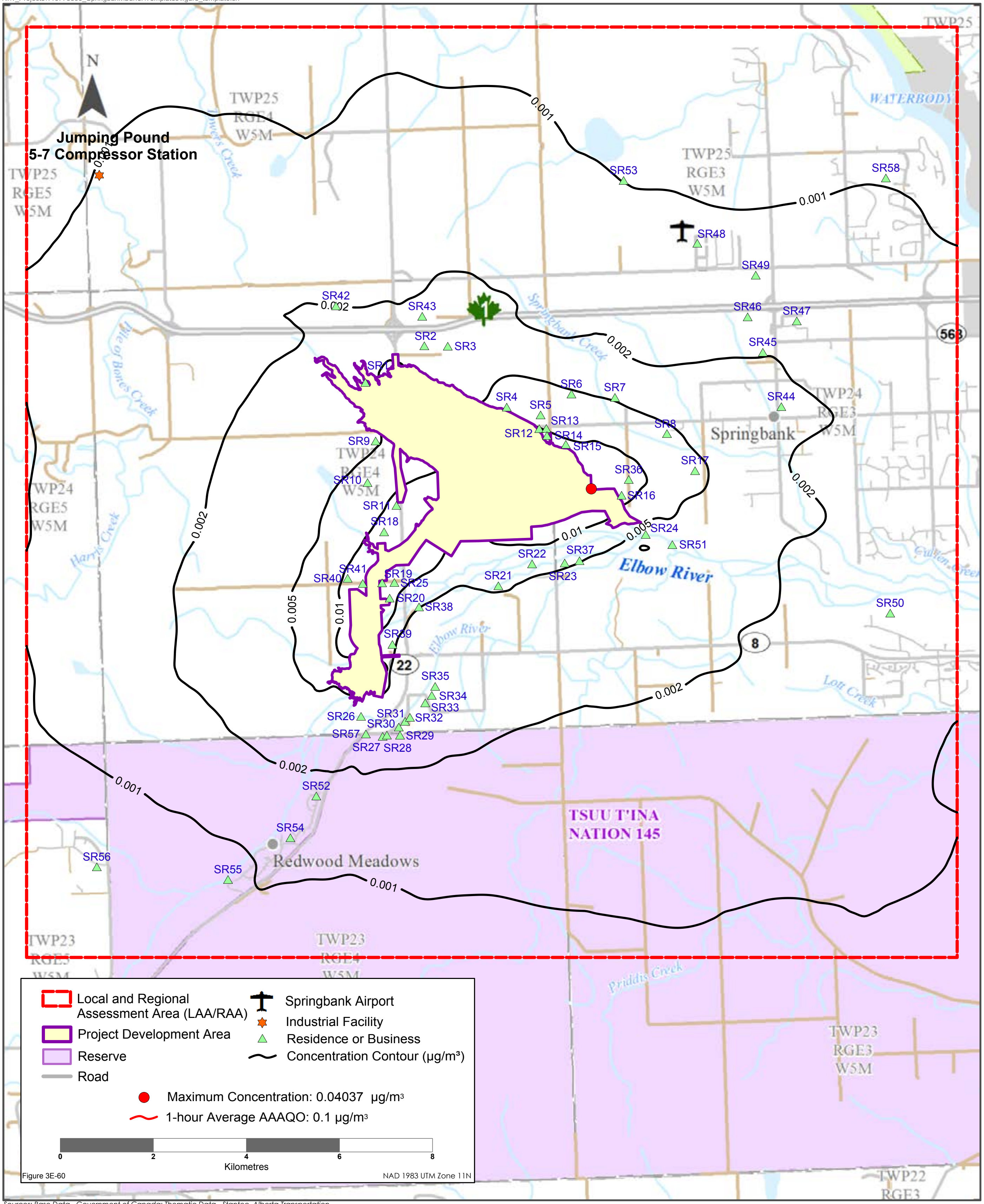
Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Predicted 9th Highest 1-hour Average Arsenic Concentrations (Project Case)

Stantec

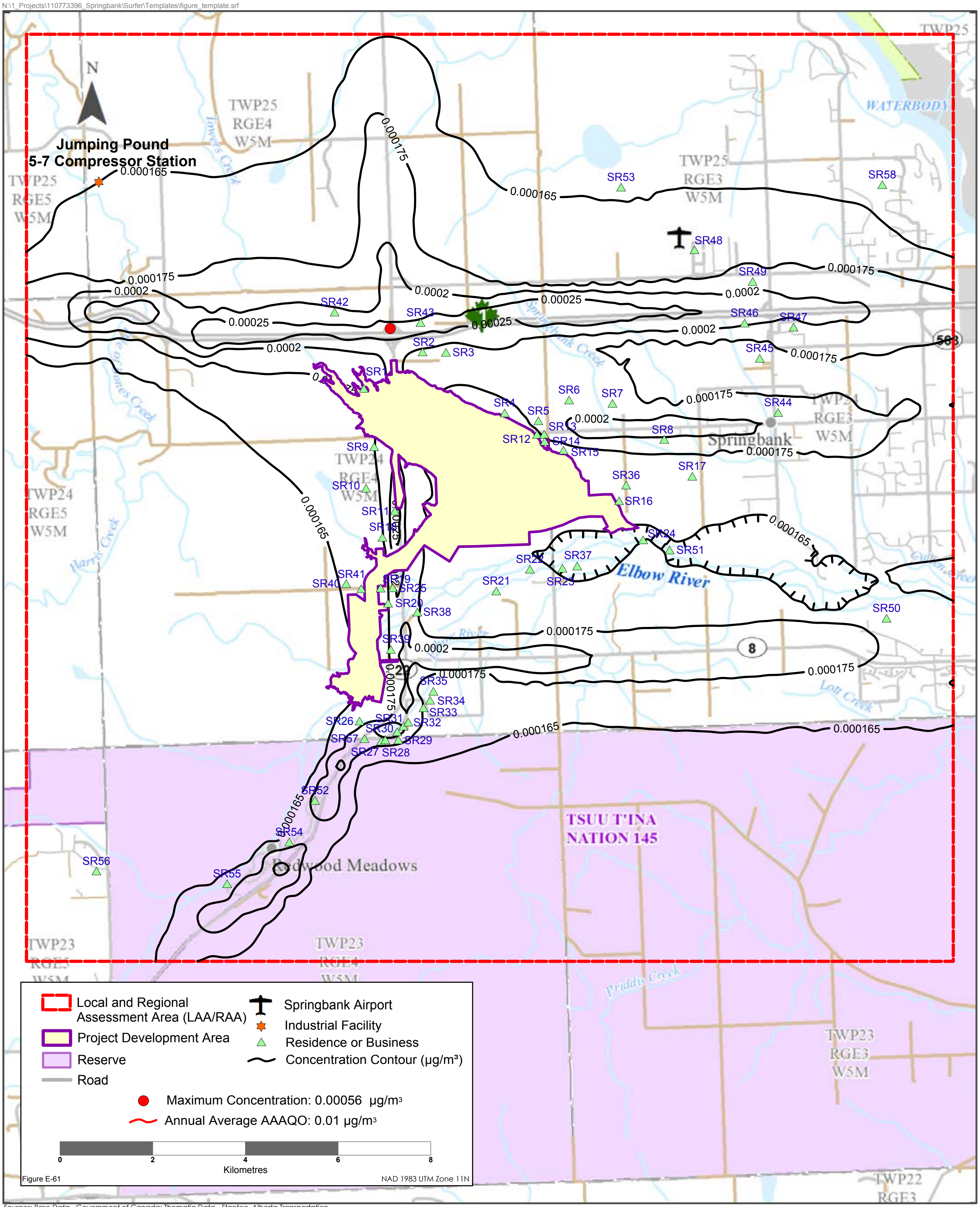
SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-59



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Predicted 9th Highest 1-hour Average Arsenic Concentrations (Application Case)



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Maximum Predicted Annual Average Arsenic Concentrations (Base Case)

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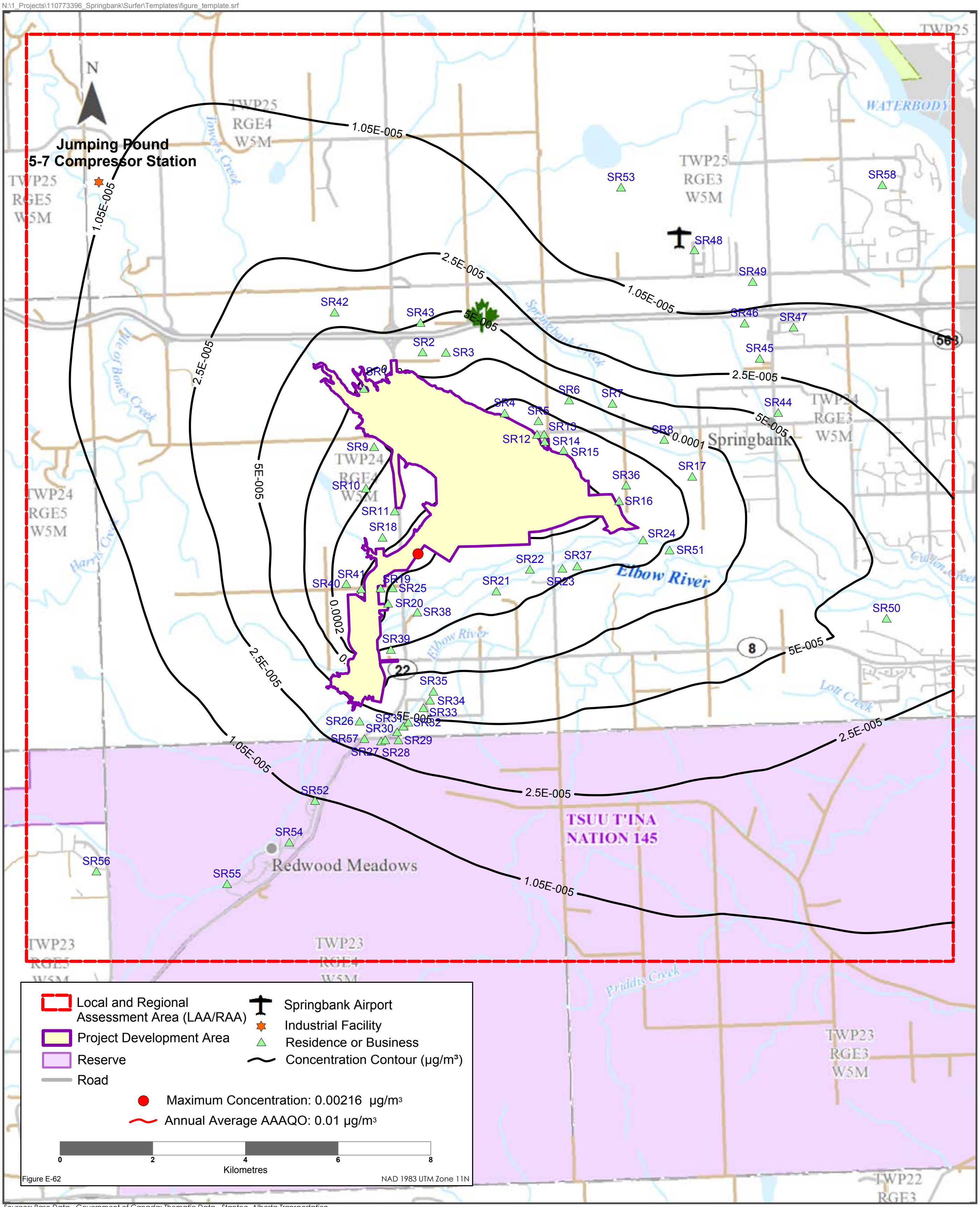


Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

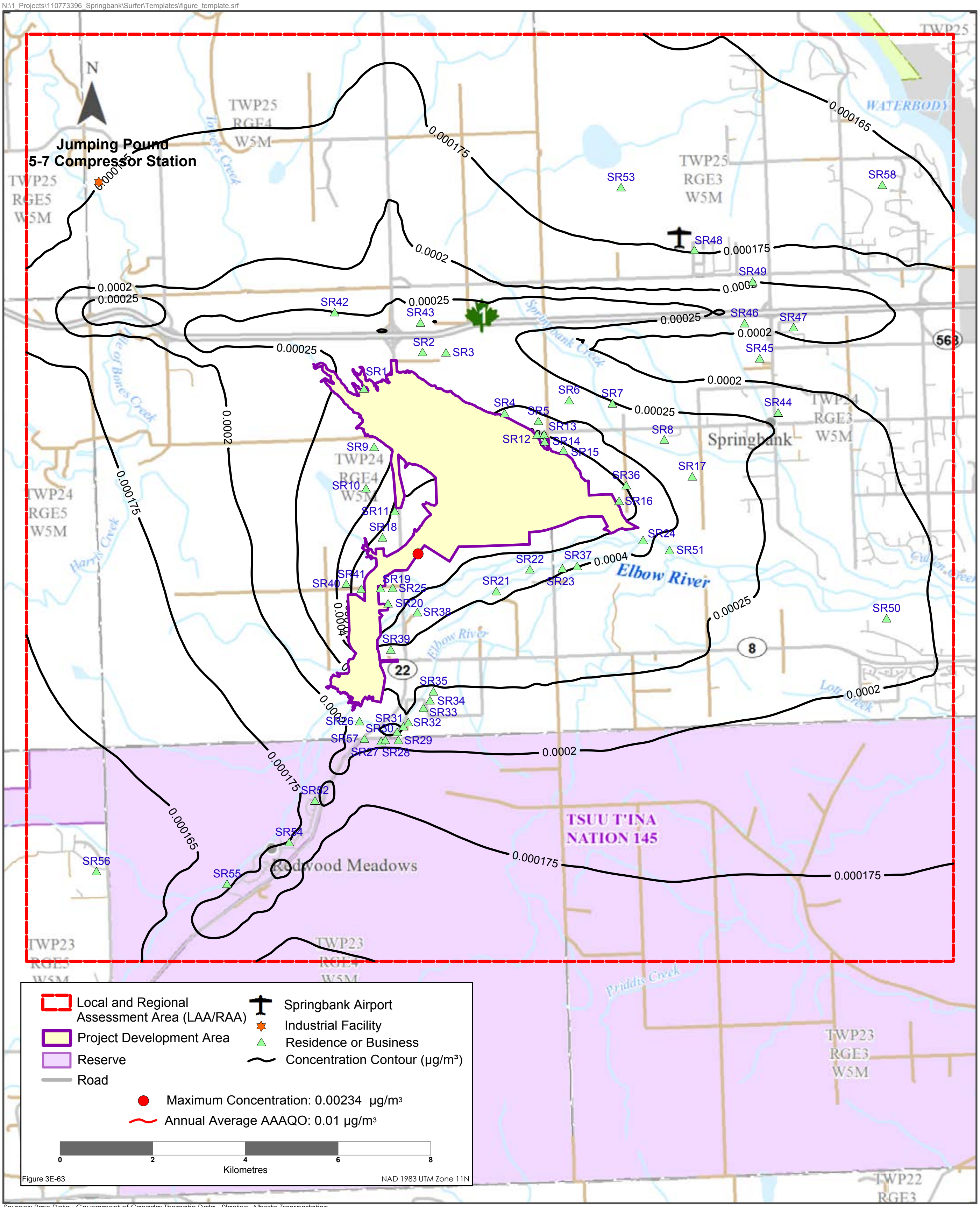
Maximum Predicted Annual Average Arsenic Concentrations (Project Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

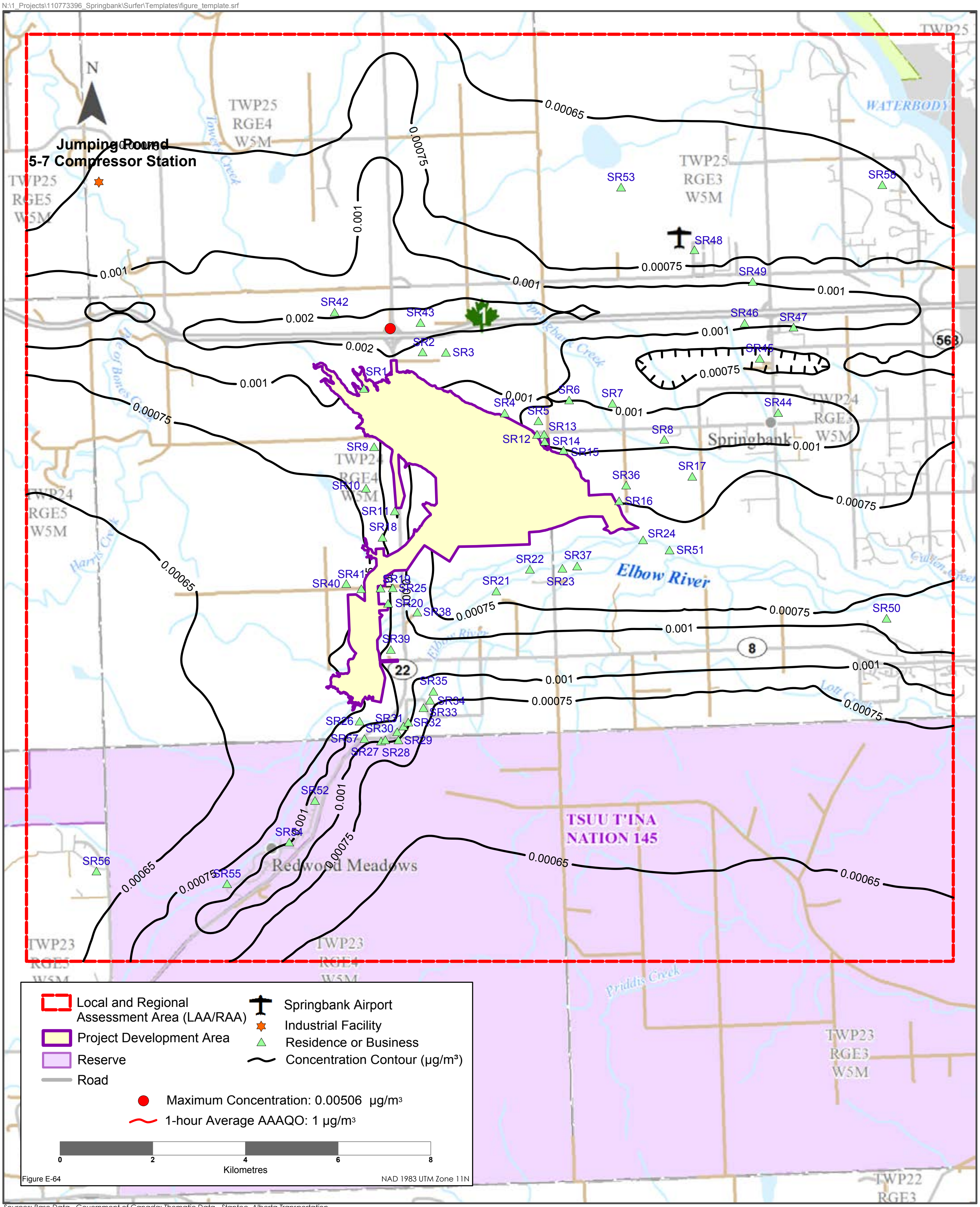
Figure 3E-62

N:\1_Projects\110773396_Springbank\Surfer\Templates\figure_template.srf



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

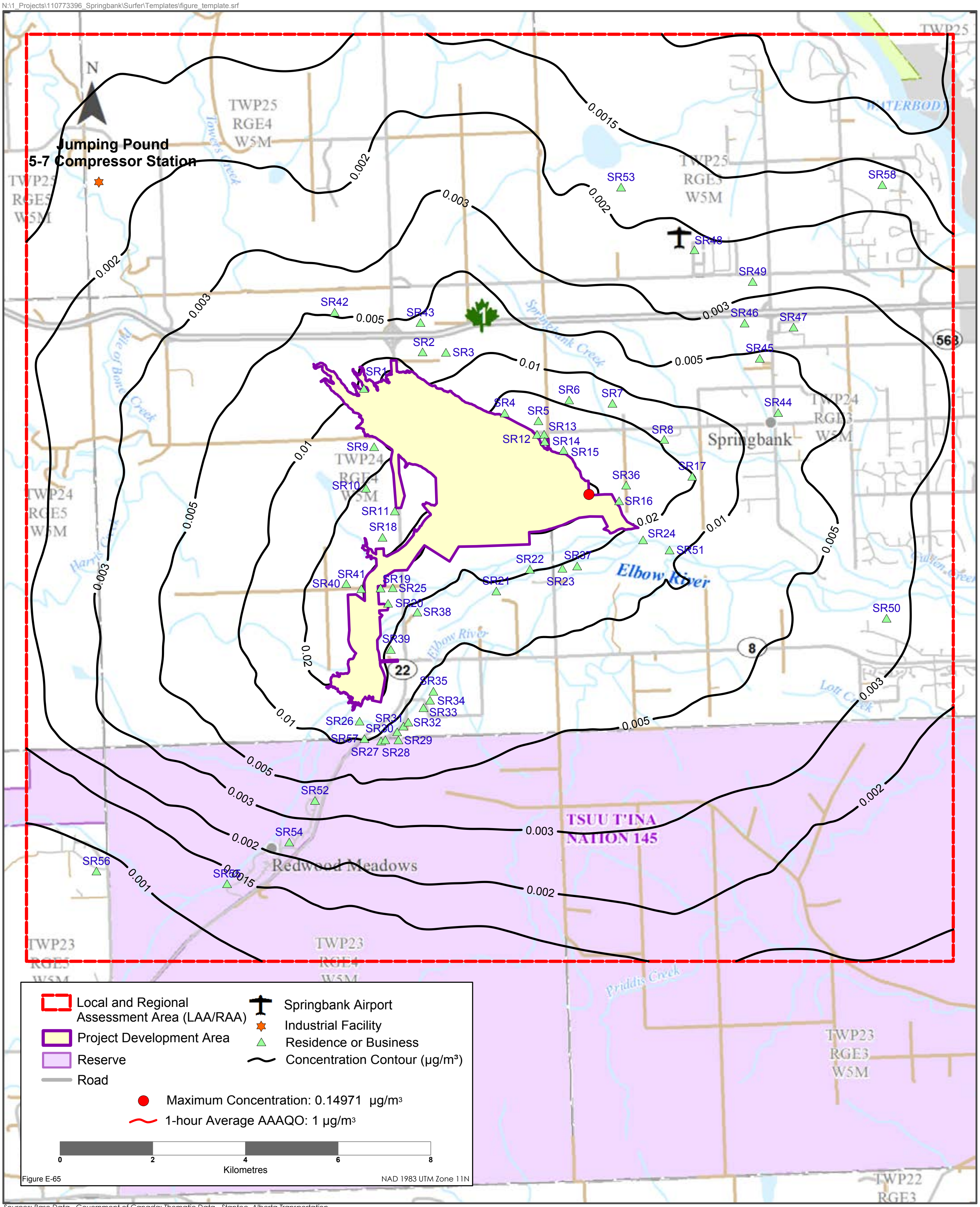
Maximum Predicted Annual Average Arsenic Concentrations (Application Case)



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Predicted 9th Highest 1-hour Average Chromium Concentrations (Base Case)

Figure 3E-64



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Predicted 9th Highest 1-hour Average Chromium Concentrations (Project Case)

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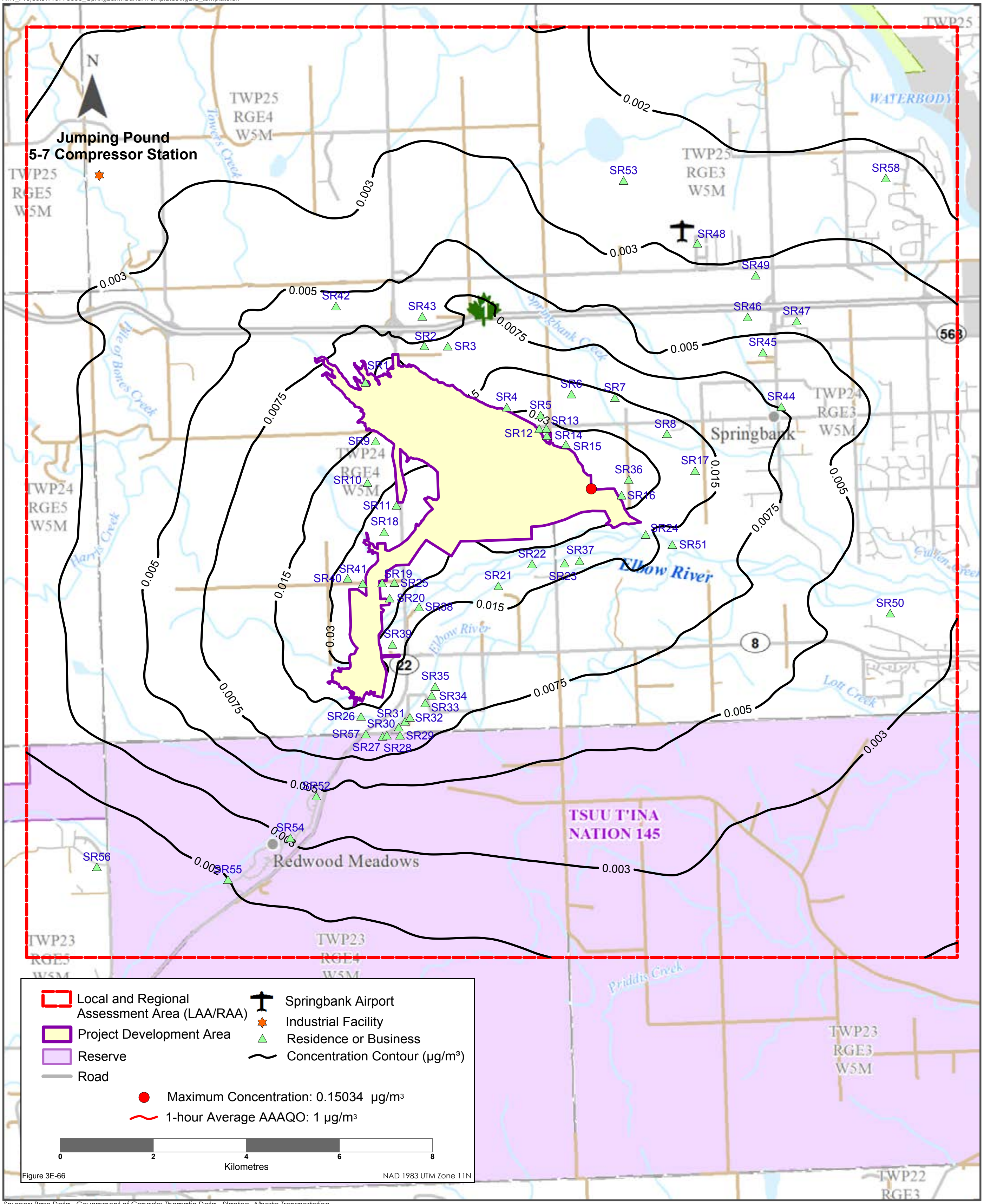


Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

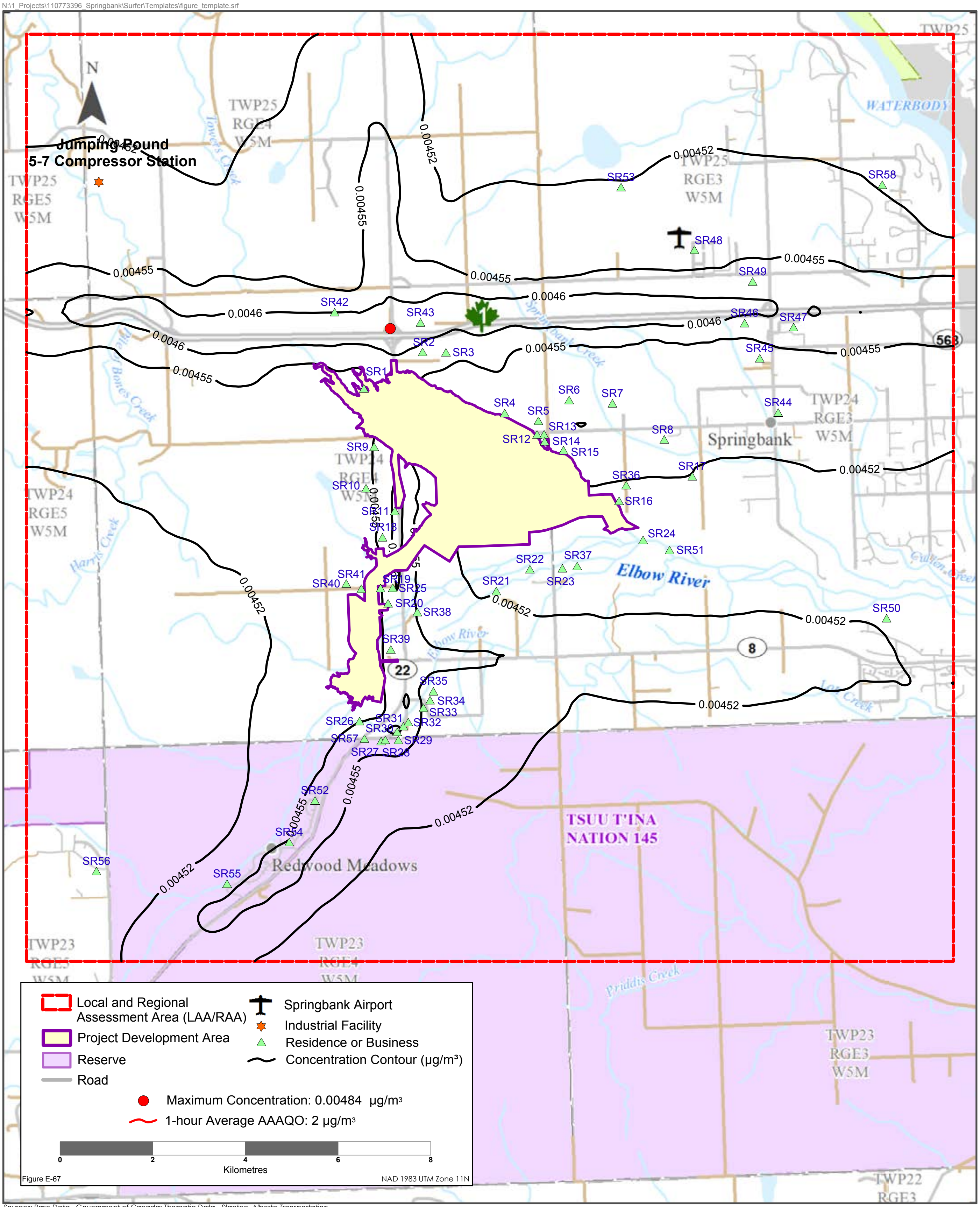
Predicted 9th Highest 1-hour Average Chromium Concentrations (Application Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-66

N:\1_Projects\110773396_Springbank\Surfer\Templates\figure_template.srf



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

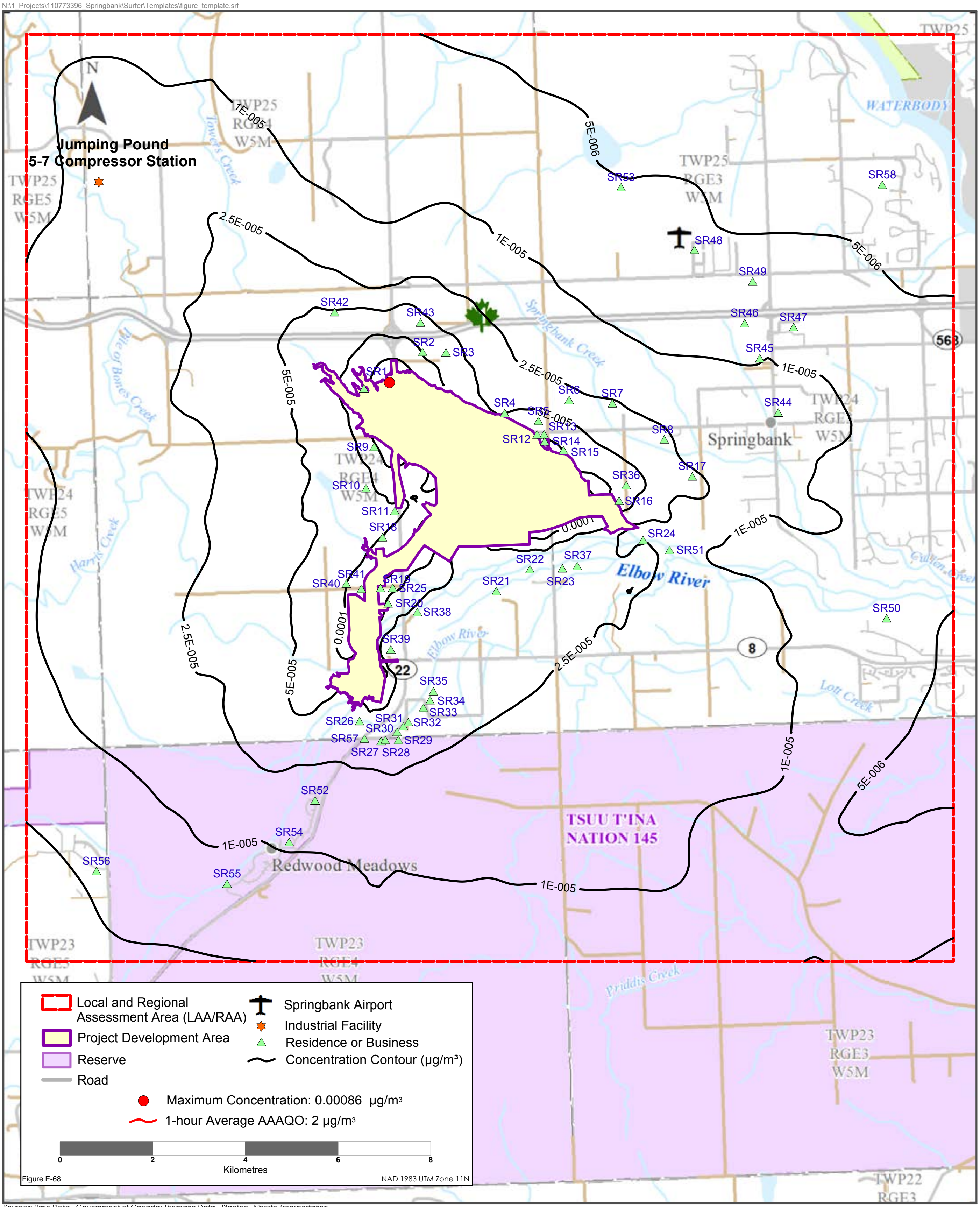
Predicted 9th Highest 1-hour Average Manganese Concentrations (Base Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-67

N:\1_Projects\110773396_Springbank\Surfer\Templates\figure_template.srf



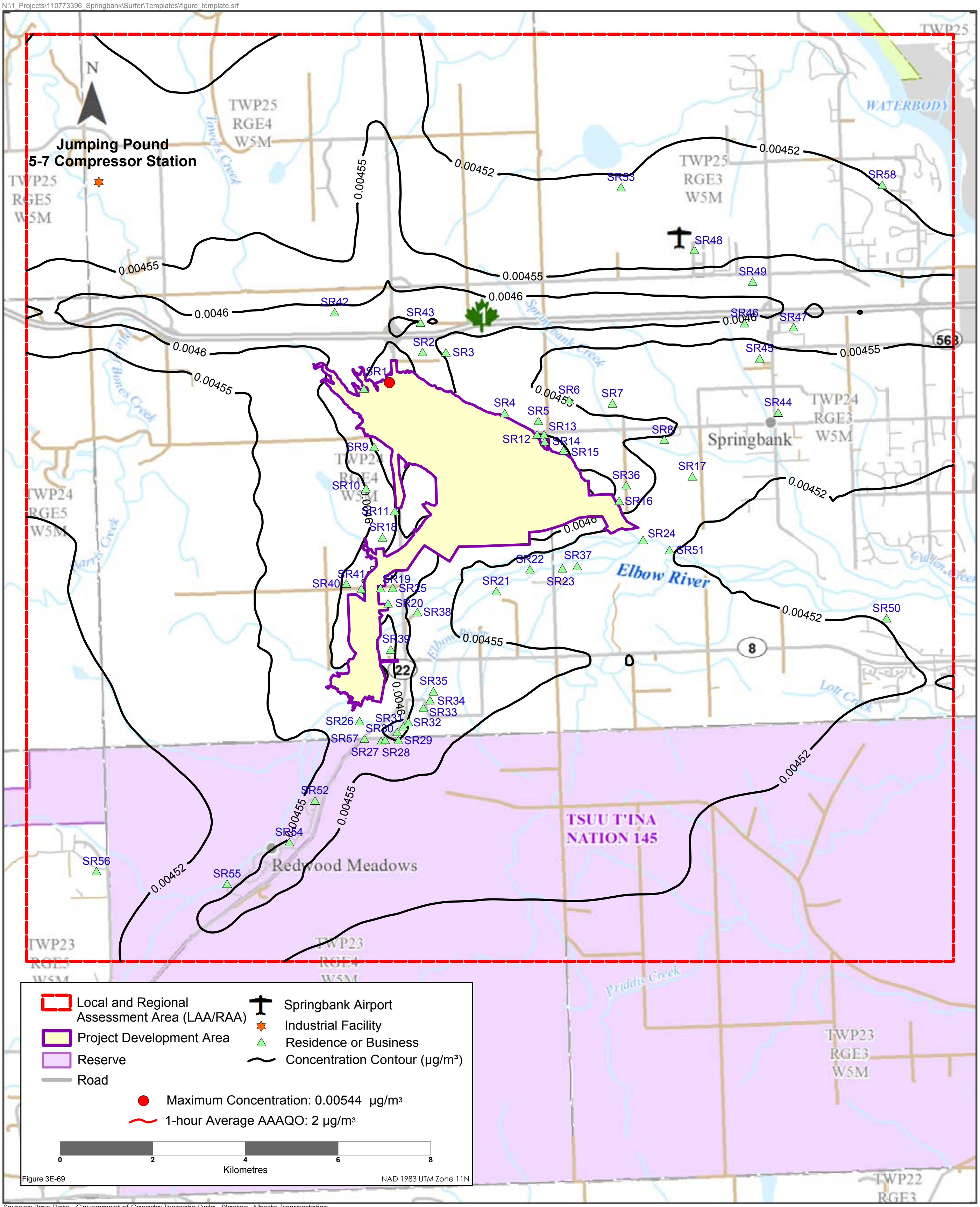
Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Predicted 9th Highest 1-hour Average Manganese Concentrations (Project Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-68



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

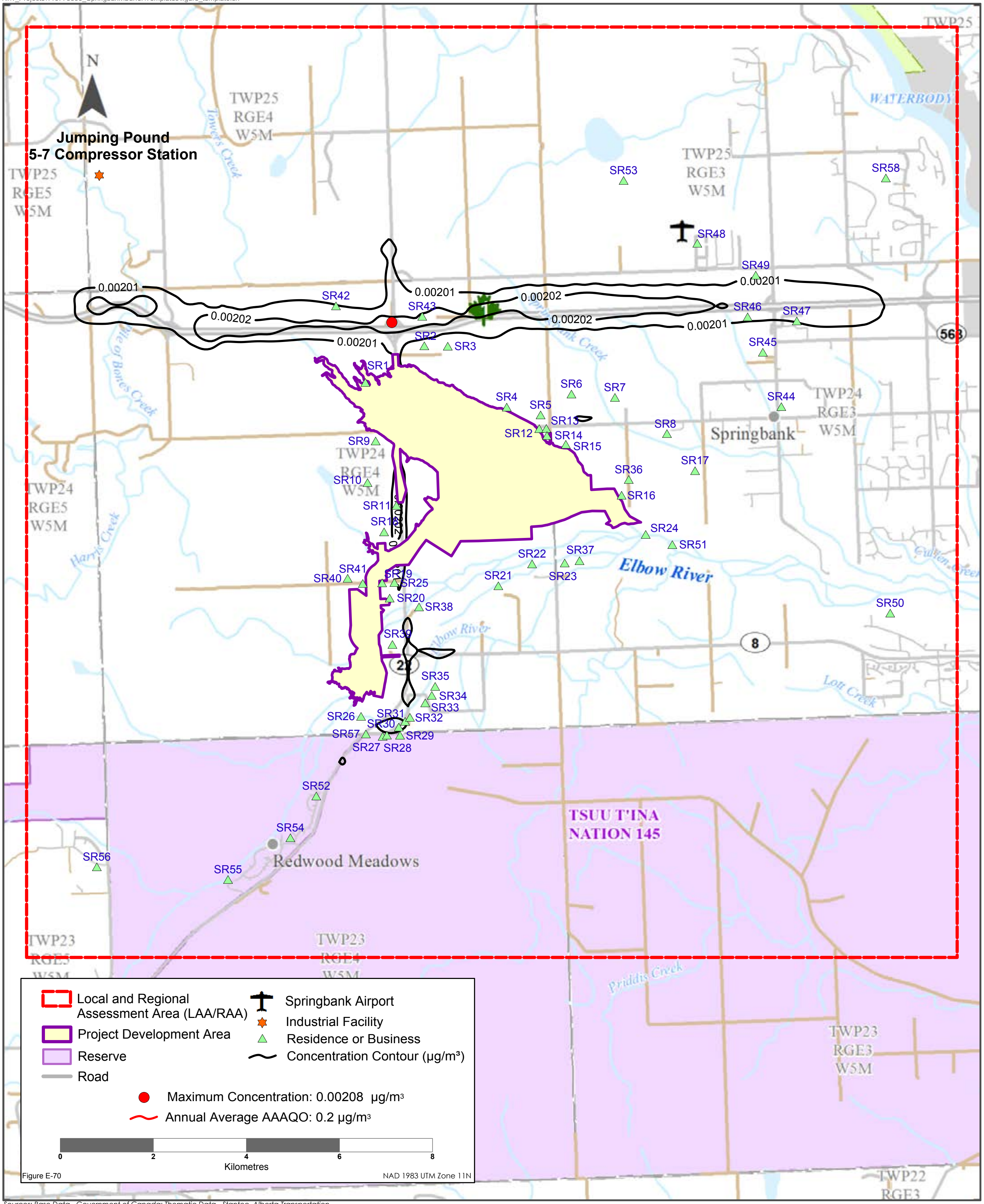
Predicted 9th Highest 1-hour Average Manganese Concentrations (Application Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-69

N:\1_Projects\110773396_Springbank\Surfer\Templates\figure_template.srf



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

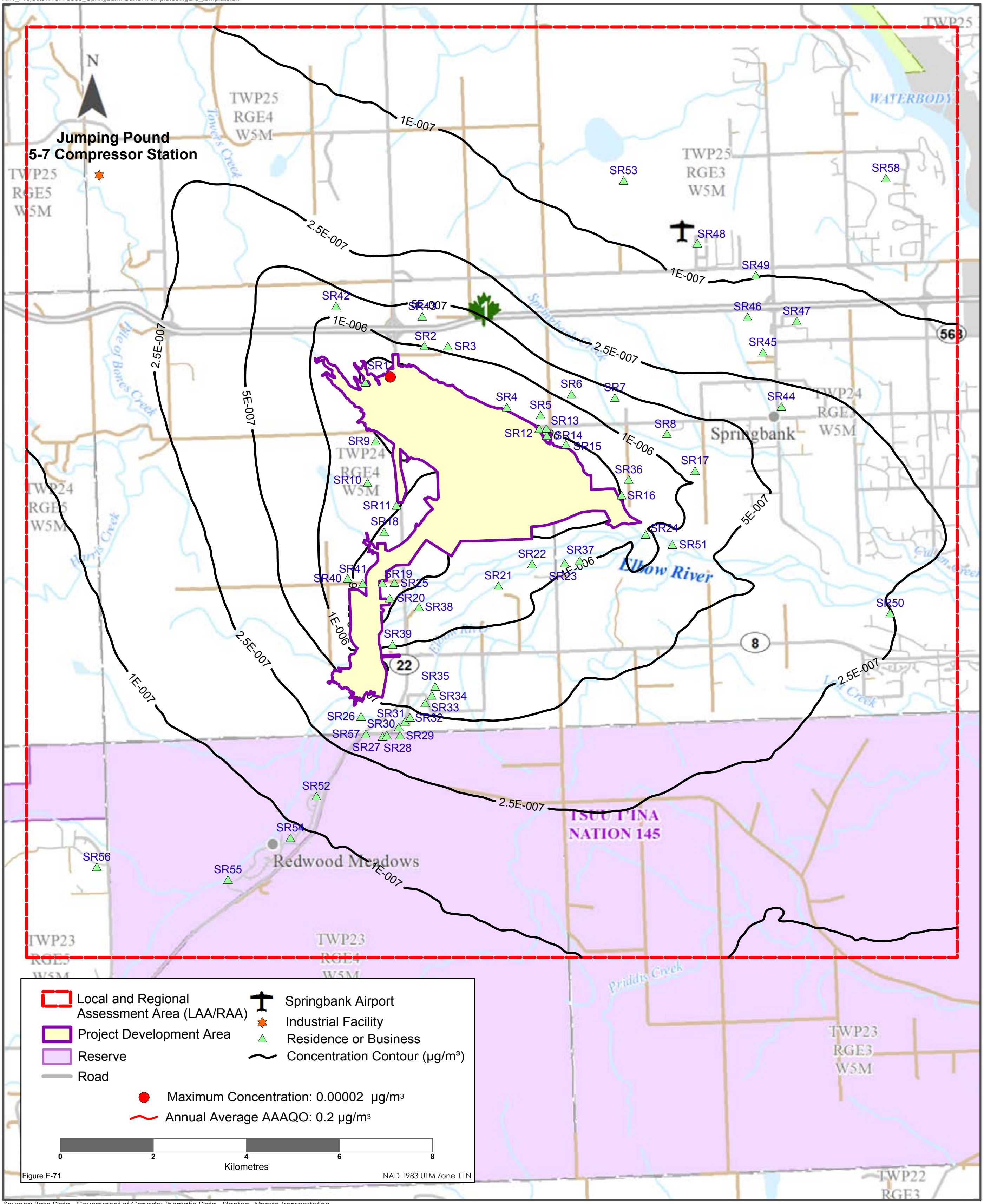
Maximum Predicted Annual Average Manganese Concentrations (Base Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

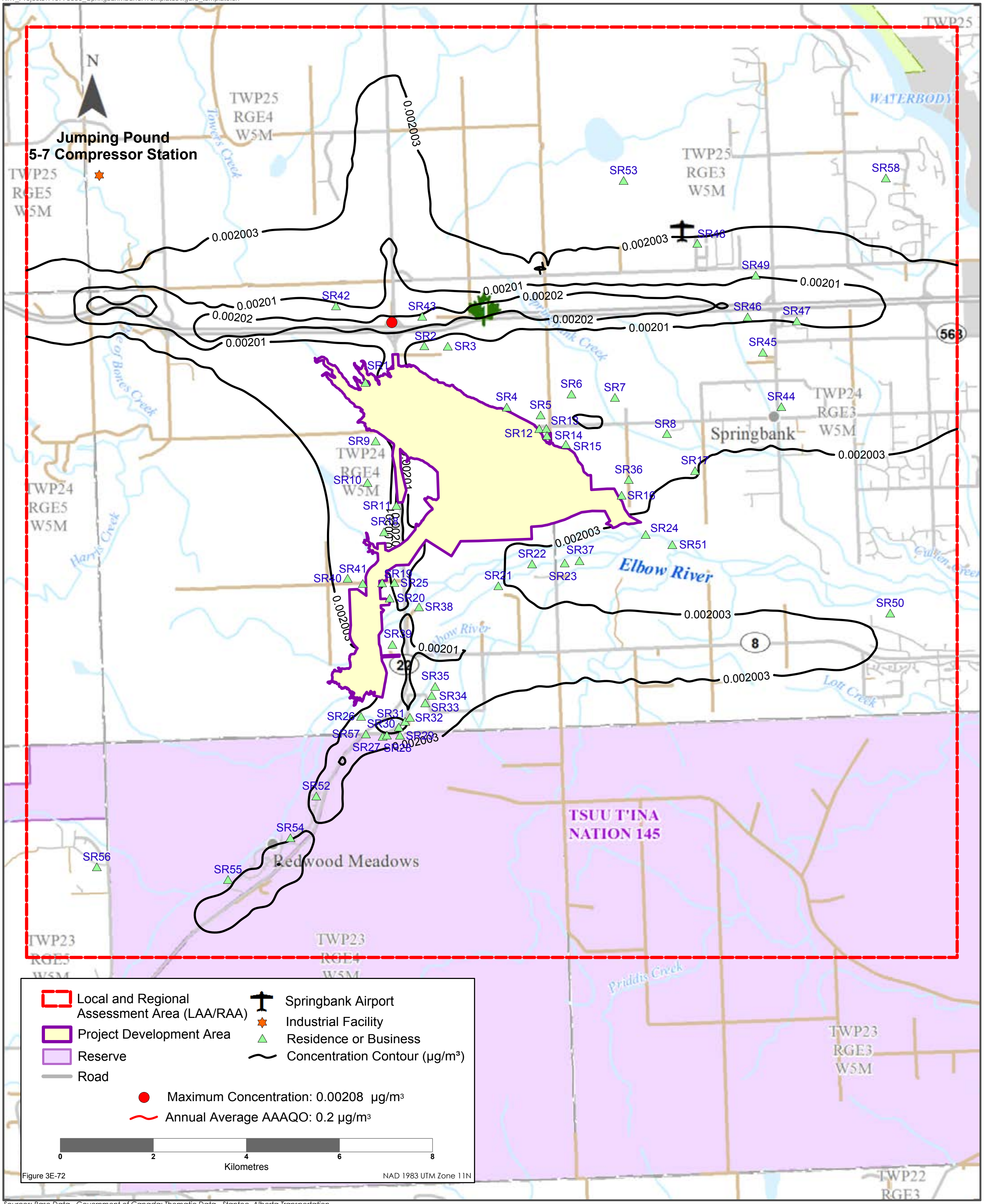
Figure 3E-70

N:\1_Projects\110773396_Springbank\Surfer\Templates\figure_template.srf



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Maximum Predicted Annual Average Manganese Concentrations (Project Case)



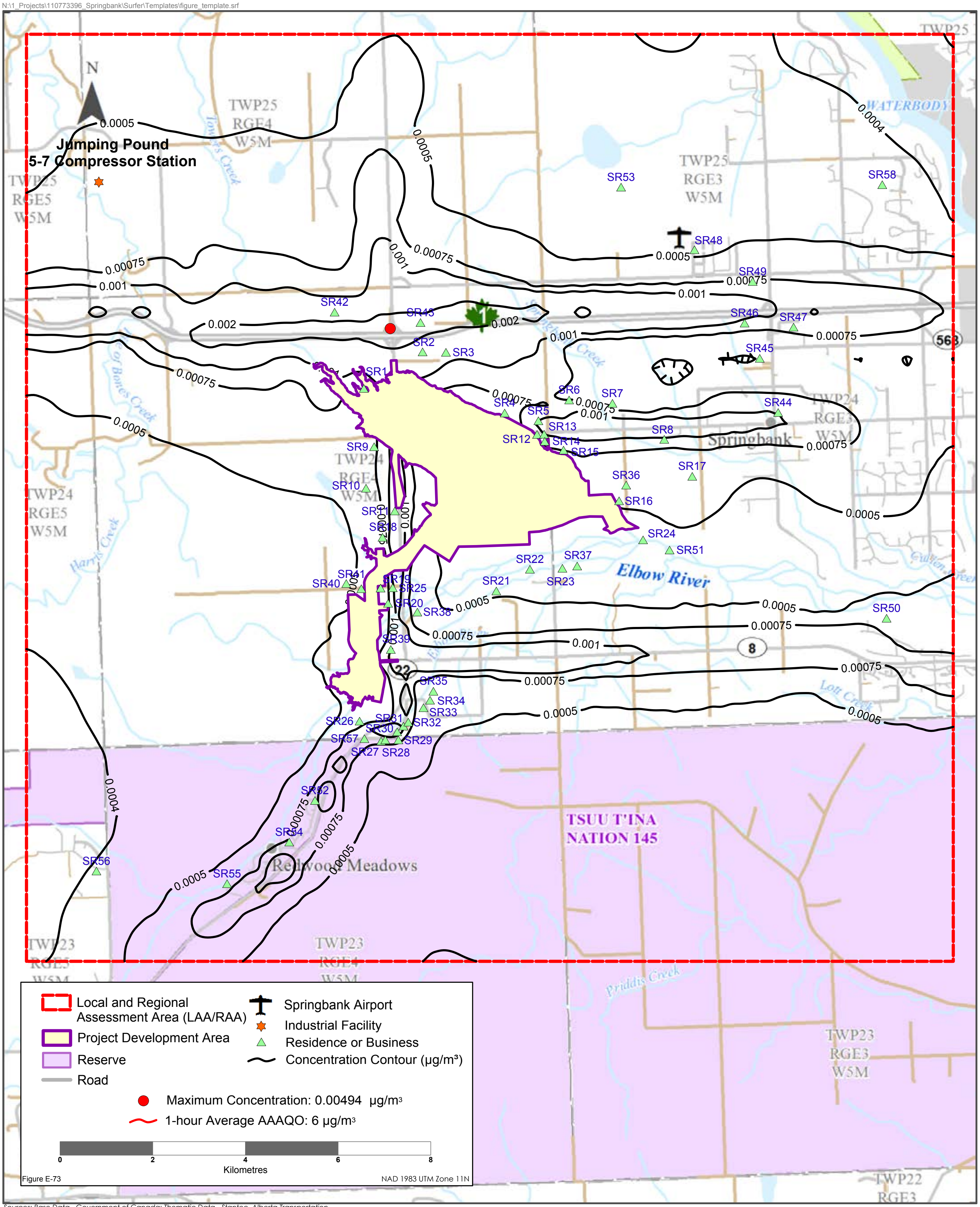
Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Maximum Predicted Annual Average Manganese Concentrations (Application Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-72



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

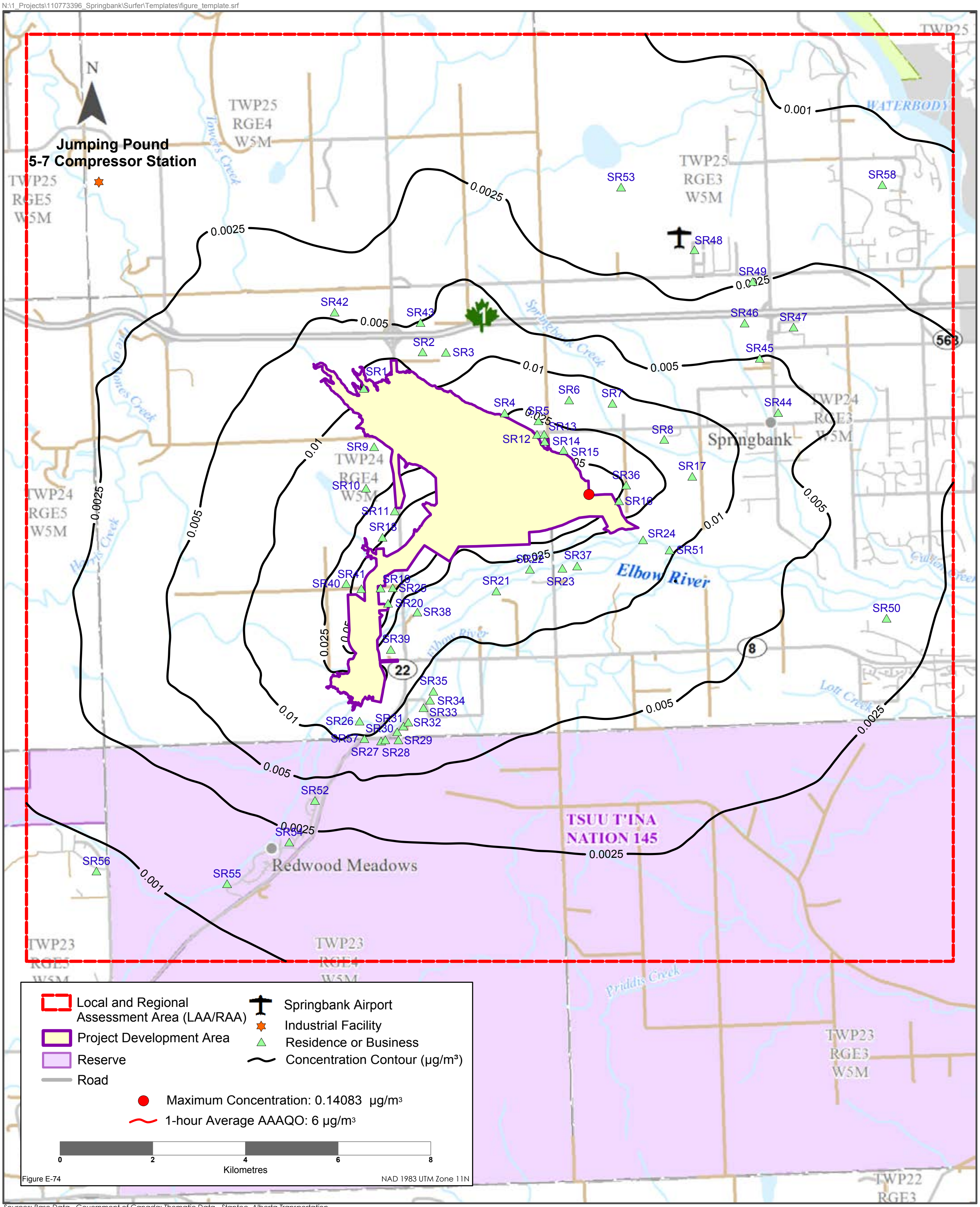
Predicted 9th Highest 1-hour Average Nickel Concentrations (Base Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-73

N:\1_Projects\110773396_Springbank\Surfer\Templates\figure_template.srf



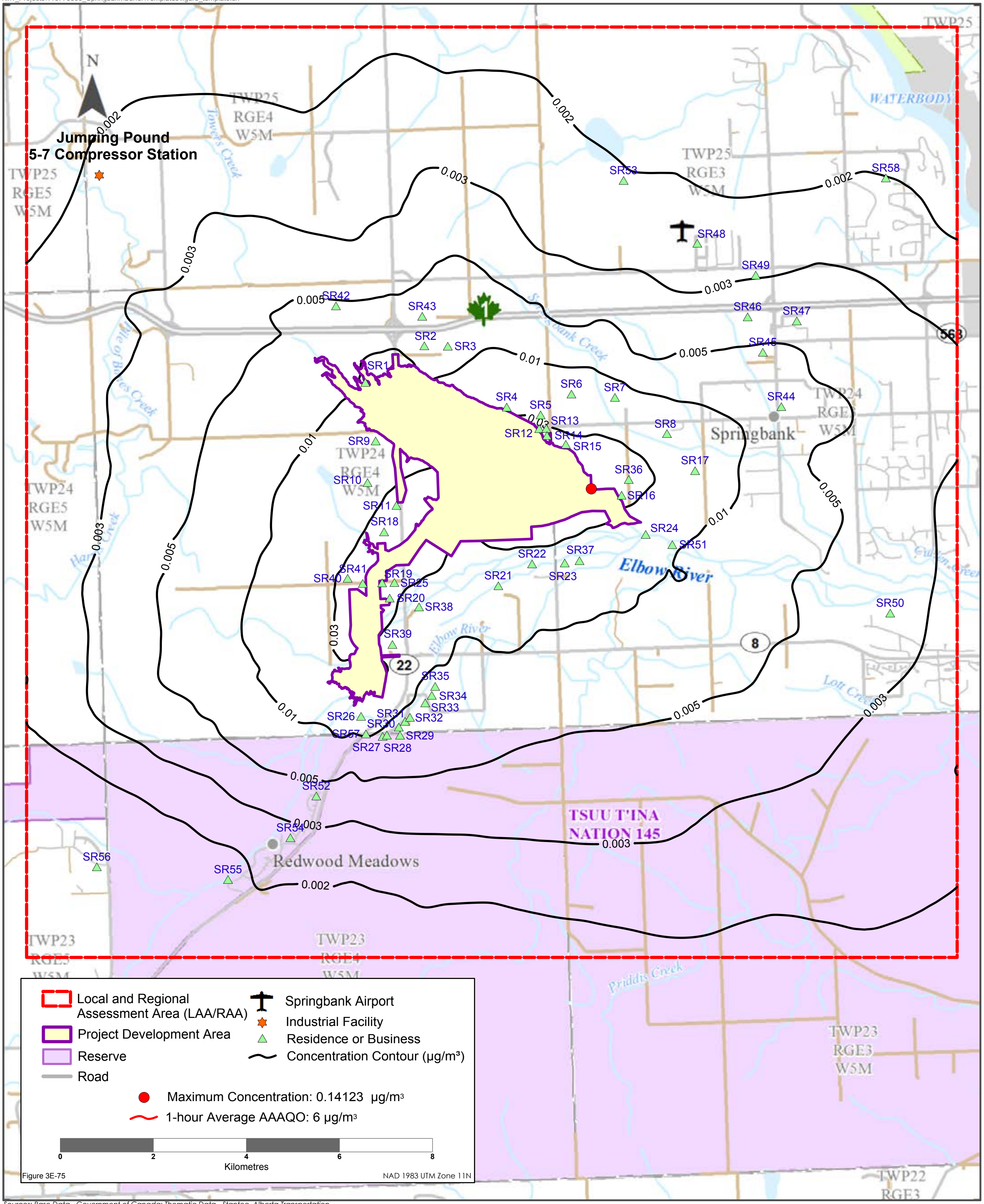
Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Predicted 9th Highest 1-hour Average Nickel Concentrations (Project Case)

Stantec
SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-74

N:\1_Projects\110773396_Springbank\Surfer\Templates\figure_template.srf



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Predicted 9th Highest 1-hour Average Nickel Concentrations (Application Case)

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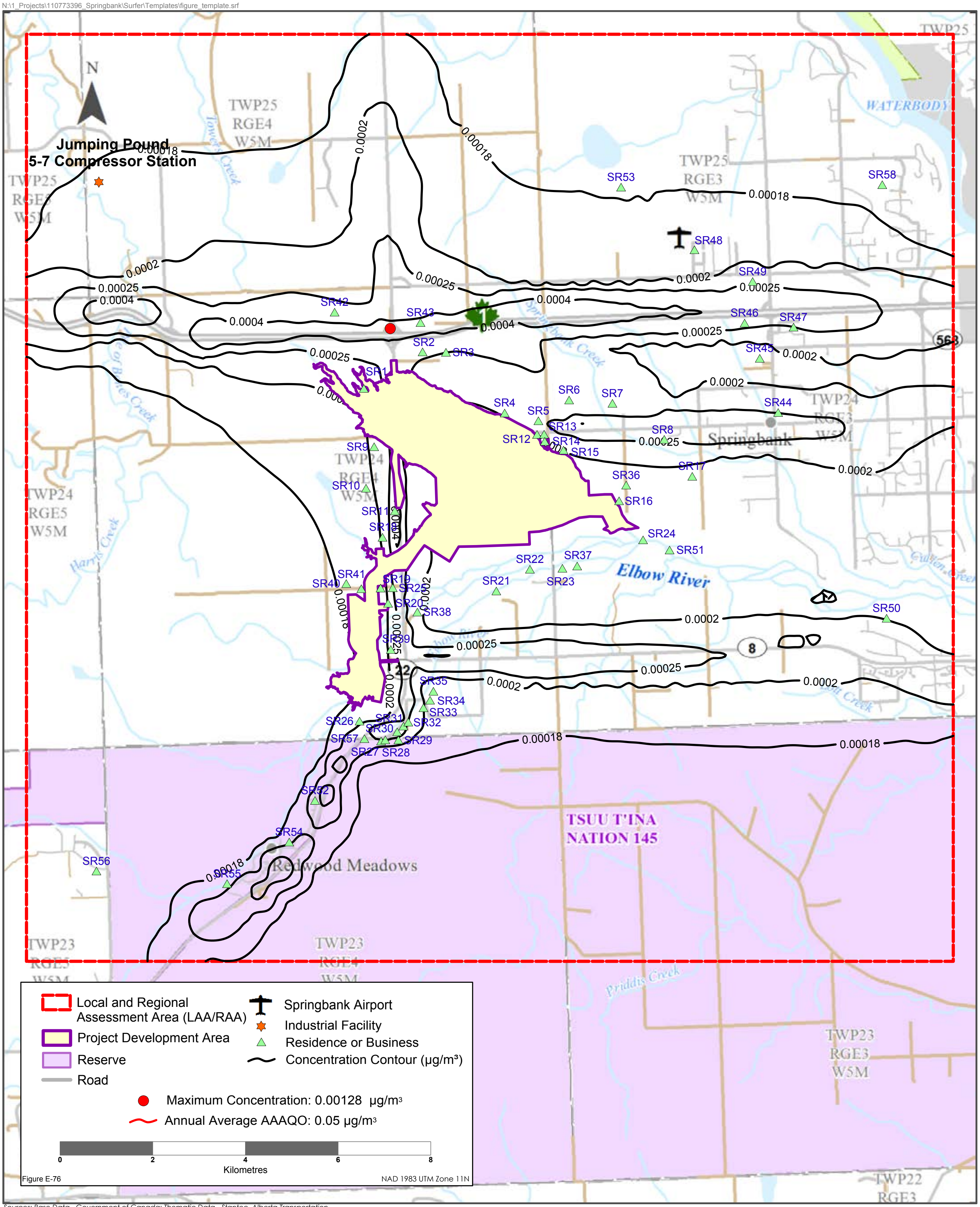


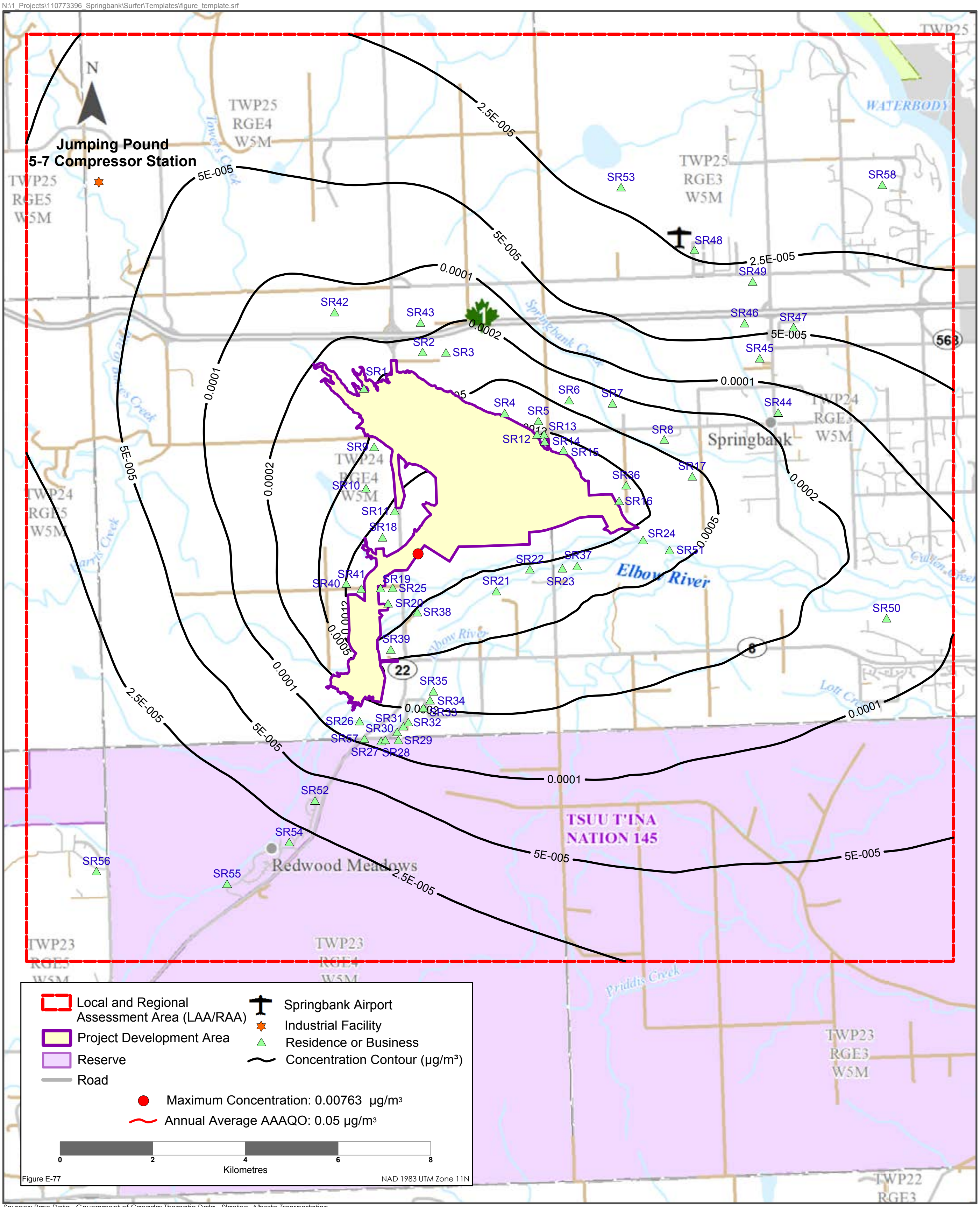
Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Maximum Predicted Annual Average Nickel Concentrations (Base Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-76



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

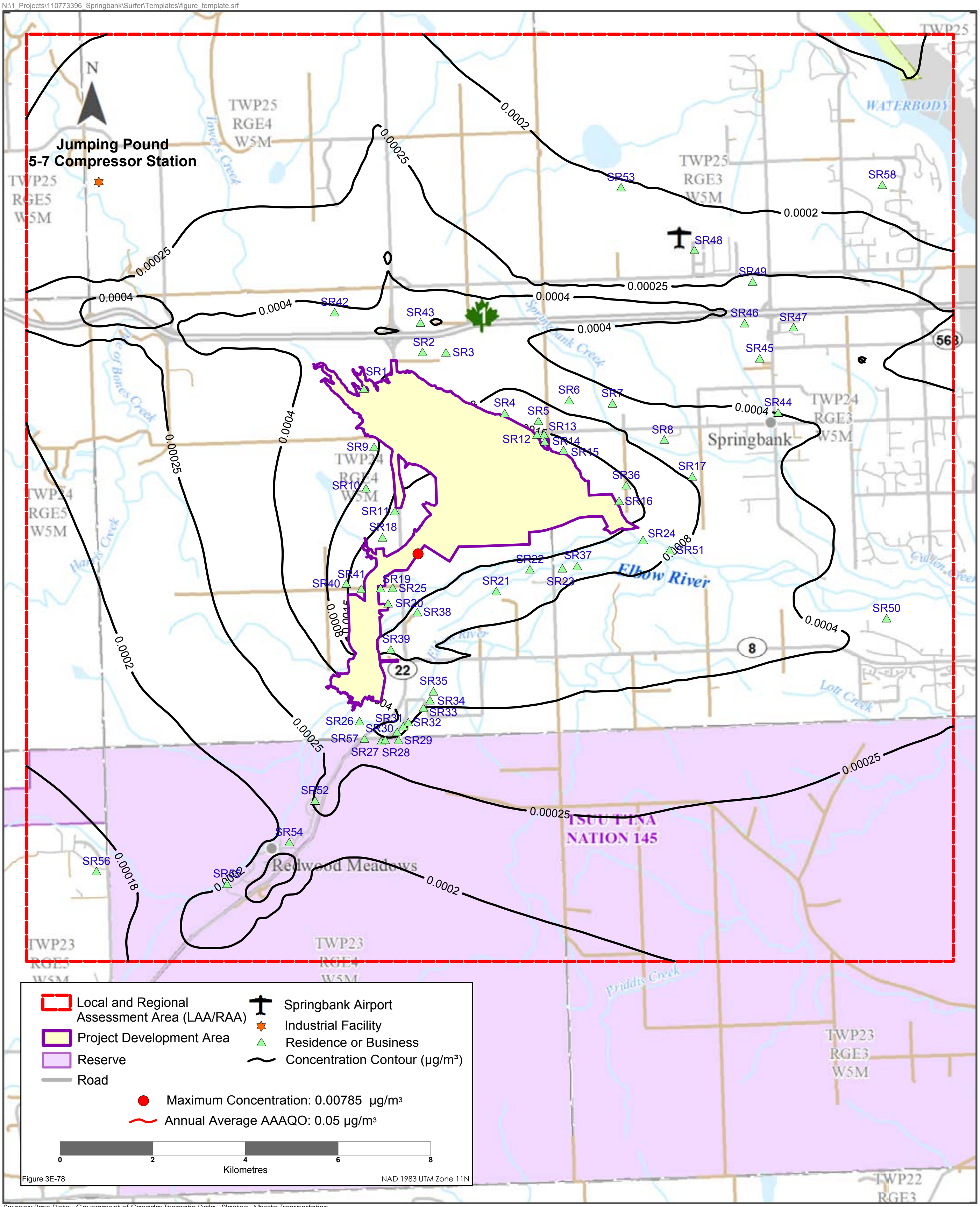
Maximum Predicted Annual Average Nickel Concentrations (Project Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-77

N:\1_Projects\110773396_Springbank\Surfer\Templates\figure_template.srf



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Maximum Predicted Annual Average Nickel Concentrations (Application Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure 3E-78

Attachment 3F GREENHOUSE GAS EMISSIONS FOR CONSTRUCTION

Table of Contents

LIST OF TABLES

Abbreviations

CO_2	carbon dioxide
CH_4	methane
N_2O	nitrous oxide
GHG	greenhouse gas
CO_2e	Carbon dioxide equivalent
Project	Springbank Off-stream Reservoir Project
TDR	technical data report
ECCC	Environment and Climate Change Canada
GWP	Global Warming Potential
kL	Kilolitres

3F.1 INTRODUCTION

This attachment includes information on greenhouse gases (GHGs) that supports the environmental assessment for the Springbank Off-stream Reservoir Project (the Project). Specifically, this attachment contains:

- description of methods used to assess potential effects of the project on GHG emissions
- list of data sources
- explanation of how the data were assessed
- results of these analyses

3F.2 METHODS

The methods used to estimate GHG emissions from the Project are based on accounting and reporting principles of the GHG Protocol developed by the World Resource Institute and the World Business Council for Sustainable Development (WRI 2013). This protocol is an internationally accepted accounting and reporting standard for quantifying and reporting GHG emissions. The guiding principles of the protocol for compiling an inventory of GHG data are relevance, completeness, consistency, transparency, and accuracy. In cases where uncertainty is high, conservative quantification parameters and assumptions were applied, resulting in an over estimate of the GHG emissions.

To calculate GHG emissions, emission factors from the National Inventory Report (Environment and Climate Change Canada 2016) for off-road diesel combustion were used. These factors are presented in Table 3F-1.

Table 3F-1 GHG Emission Factors

Species	Emission Factor (g/L)
Carbon dioxide (CO_2)	2,690
Methane (CH_4)	0.15
Nitrous oxide (N_2O)	1.00

Source: (ECCC 2016, Table A6-12 for off-road diesel)

Emissions in tonnes or each GHG are calculated as:

$$\text{Emissions (t)} = \text{Fuel Volume (L)} * \text{Emission Factor (g/L)} * (1\ \text{t} / 10^6\ \text{g})$$

Emissions of each GHG are multiplied by their 100-year global warming potential (GWP) and are reported as carbon dioxide equivalent (CO_2e). The GWPs for these GHGs are:

- CO_2 = 1.0
- CH_4 = 25
- N_2O = 298

The source of the GWP is International Panel on Climate Change (IPCC) Fourth Assessment Report (IPCC 2007). Carbon dioxide equivalents for the Project are calculated as:

$$CO_2e = (\text{mass } CO_2 \times 1.0) + (\text{mass } CH_4 \times 25) + (\text{mass } N_2O \times 298)$$

3F.3 ESTIMATED CONSTRUCTION GREENHOUSE GAS EMISSIONS

3F.3.1 Heavy Construction Equipment

The construction equipment is assumed to be powered with diesel fuel. The engine type, number of units, power rating, fuel consumption rate, utilization factors and total operating hours of all the equipment are estimated using the US EPA NONROAD model (U.S. EPA 2010). For the GHG assessment, the fuel consumption rate and total operating hours are used to determine the total volume of diesel combusted by each piece of equipment.

The specific equipment, operating hours, fuel consumption rate, and emissions are presented in Table 3F-2.

Table 3F-2 Construction Equipment and GHG Emissions

Equipment	Operating Hours per unit (h)	Fuel Consumption Rate per unit (L/h)	Total Fuel per unit (kL)	CO_2 Emissions (t)	CH_4 Emissions (t)	N_2O Emissions (t)	CO_2e Emissions (t)
Diversion Channel							
2 articulated dump trucks (17 m^3 capacity)	5,136	91.4	469.5	2,526	0.141	0.939	2,809
Dam Structure							
28 articulated dump trucks (17 m^3 capacity)	5,136	91.4	469.5	35,316	1.972	13.145	39,328
4 backhoes	5,136	28.4	145.7	1,568	0.087	0.583	1,744

Table 3F-2 Construction Equipment and GHG Emissions

Equipment	Operating Hours per unit (h)	Fuel Consumption Rate per unit (L/h)	Total Fuel per unit (kL)	CO_2 Emissions (t)	CH_4 Emissions (t)	N_2O Emissions (t)	CO_2e Emissions (t)
5 scrapers (38 m³ capacity)	600	98.5	59.1	795	0.044	0.296	884
5 scrapers (38 m³ capacity)	600	55.8	33.5	450	0.025	0.167	500
2 bulldozers	5,136	33.5	172.0	925	0.052	0.344	1,029
2 vibratory soil compactors	5,136	30.9	158.9	855	0.048	0.318	951
1 water truck	5,136	74.9	384.5	1,034	0.058	0.384	1,150
69 portable light generators	5,136	6.6	33.7	6,264	0.349	2.328	6,966
Floodplain Berm Structure							
4 articulated dump trucks (17 m³ capacity)	720	91.4	65.8	708	0.039	0.263	788
2 bulldozers	720	33.5	24.1	130	0.007	0.048	144
1 concrete truck	120	69.0	8.3	22	0.001	0.008	25
River Reroute at Diversion Channel							
2 CAT 740 articulated dump truck (rock truck) capacity 17 m³	540	91.4	49.4	266	0.015	0.099	295
2 CAT 325 FL excavators	540	31.7	17.1	92	0.005	0.034	102
1 CAT 982 M front end loader	540	85.9	46.4	125	0.007	0.046	139
1 CAT D6 bulldozer	540	33.5	18.1	49	0.003	0.018	54

Table 3F-2 Construction Equipment and GHG Emissions

Equipment	Operating Hours per unit (h)	Fuel Consumption Rate per unit (L/h)	Total Fuel per unit (kL)	CO_2 Emissions (t)	CH_4 Emissions (t)	N_2O Emissions (t)	CO_2e Emissions (t)
Diversion Channel Concrete Structure							
1 truck-mounted crane	120	83.7	10.0	27	0.002	0.010	30
concrete truck	720	69.0	49.6	134	0.007	0.050	149
2 portable diesel generators	3,300	9.6	31.8	171	0.010	0.064	190
Dam Outlet Concrete Structure							
1 truck-mounted crane	180	83.7	15.1	41	0.002	0.015	45
1 concrete truck	60	69.0	4.1	11	0.001	0.004	12
Raising Hwy 22 and Bridge Construction							
20 dump trucks	2,880	84.7	244.0	13,126	0.732	4.879	14,589
3 scrapers	2,880	92.6	266.7	2,152	0.120	0.800	2,393
2 backhoes	2,880	28.4	81.7	440	0.025	0.163	489
2 dozers	2,880	33.5	96.5	519	0.029	0.193	577
2 excavators	2,880	31.7	91.3	491	0.027	0.183	547
2 skid steers	2,880	20.8	59.9	322	0.018	0.120	359
2 water trucks	2,880	74.9	215.6	1,160	0.065	0.431	1,290
2 graders (large)	2,880	59.1	170.2	916	0.051	0.340	1,018
2 vibratory soil compactors	2,880	30.9	89.0	479	0.027	0.178	533
2 smooth drum rollers	2,880	30.9	89.0	479	0.027	0.178	533
1 asphalt paver	1,080	28.0	30.2	81	0.005	0.030	90

Table 3F-2 Construction Equipment and GHG Emissions

Equipment	Operating Hours per unit (h)	Fuel Consumption Rate per unit (L/h)	Total Fuel per unit (kL)	CO_2 Emissions (t)	CH_4 Emissions (t)	N_2O Emissions (t)	CO_2e Emissions (t)
1 tandem vibratory rollers/compactor	1,080	28.0	30.2	81	0.005	0.030	90
1 mini backhoe (trenching)	720	16.2	11.7	31	0.002	0.012	35
2 hydraulic impact pile drivers	168	39.4	6.6	36	0.002	0.013	40
1 truck-mounted crane	2,160	83.7	180.8	486	0.027	0.181	541
1 concrete truck	2,160	69.0	148.9	401	0.022	0.149	446
Twp Road 242 Bridge Construction							
1 scraper	2,880	92.6	266.7	717	0.040	0.267	798
1 backhoe	2,880	28.4	81.7	220	0.012	0.082	244
1 dozer	2,880	33.5	96.5	259	0.014	0.096	289
1 excavator	2,880	31.7	91.3	246	0.014	0.091	273
1 skid steer	2,880	20.8	59.9	161	0.009	0.060	179
1 grader (large)	2,880	59.1	170.2	458	0.026	0.170	509
1 vibratory soil compactor	2,880	30.9	89.1	240	0.013	0.089	266
1 smooth drum roller	2,880	30.9	89.1	240	0.013	0.089	266
1 asphalt paver	1,080	28.0	30.2	81	0.005	0.030	90
1 tandem vibratory rollers/compactor	1,080	28.0	30.2	81	0.005	0.030	90

Table 3F-2 Construction Equipment and GHG Emissions

Equipment	Operating Hours per unit (h)	Fuel Consumption Rate per unit (L/h)	Total Fuel per unit (kL)	CO_2 Emissions (t)	CH_4 Emissions (t)	N_2O Emissions (t)	CO_2e Emissions (t)
1 mini backhoe (trenching)	720	16.2	11.7	31	0.002	0.012	35
2 hydraulic impact pile drivers	120	39.4	4.70	25	0.001	0.009	28
1 truck-mounted crane	2,160	83.7	180.8	486	0.027	0.181	541
1 concrete truck	2,160	69.0	148.9	401	0.022	0.149	446
Total				**76,400**	**4.26**	**28.40**	**84,970**

The total estimated construction GHG emissions are 84,970 t CO_2e.

3F.4 REFERENCES

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Attachment 3G EXISTING CONDITIONS FOR LIGHT, PHOTOS

Figure 3G-1 Daytime and Nighttime Panoramic View from Location A

Figure 3G-2 Daytime and Nighttime Panoramic View from Location B

Attachment 3G Existing Conditions for Light, Photos
March 2018

Figure 3G-3 Daytime and Nighttime Panoramic View from Location C

Figure 3G-4 Daytime and Nighttime Panoramic View from Location D

SPRINGBANK OFF-STREAM RESERVOIR PROJECT
Environmental Impact Assessment

Volume 4: Appendices
Appendix E: Air Quality and Climate

Dispersion Modelling for Wind-eroded Sediment from the Off-stream Reservoir
Technical Data Report

Prepared for:
Alberta Transportation

Prepared by:
Stantec Consulting Ltd.

March 2018

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Executive Summary

During release of impounded water from the off-stream reservoir back into the Elbow River, sediment will be deposited into the off-stream reservoir. During high winds the surface of the dried sediment could be exposed to wind erosion. This technical data report supports the discussion in Volume 3B, Section 3, which is the air quality assessment determine the effects of fugitive dust emissions from wind erosion of the deposited sediment on air quality.

The results for the preliminary (conceptual) hydrological modelling for sediment deposition are summarized in Volume 3B, Section 6 and Volume 4 Appendix J, Hydrology TDR. The hydrological model predicts that two flood scenarios, 1:100 year flood and a design flood (approximately 1:200 year flood), will result in measurable sediment deposition. The sediment deposition modelling indicates that sediment depths greater than 10 cm could cover an approximate area of 82 ha in the reservoir for the 1:100 year flood, and an approximate area of 155 ha in the reservoir for a design flood. The total area in the reservoir that would be covered by a 1:100 year flood is 500 ha and by a design flood is 730 ha. It is assumed that sediment depth less than 10 cm would likely form a thin drape over existing topography and vegetation that will not be sufficient to generate wind erosion emissions. For the 1:10 year flood, the hydrological model predicts negligible sediment deposition.

Fugitive dust emissions from wind erosion of the deposited sediment are estimated for the 1:100 year flood and 1:200 year flood scenarios. Emissions are estimated for particulate matter with various particle sizes for which ambient air quality criteria are established. The substances assessed are particulate matter with particle aerodynamic diameter less or equal to 2.5 µm ($PM_{2.5}$), particulate matter with particle aerodynamic diameter less or equal to 10 µm (PM_{10}) and total suspended particulates (TSP) with particle aerodynamic diameter of less or equal to approximately 30 µm.

The air quality assessment addresses three cases: Base Case considers existing emissions in the LAA; Project Case considers only project emissions during flood and post-flood operation; and Application Case that considers the combined effects of the Base Case and the Project Case. Background contributions (from emission sources outside the LAA) are considered for the Base Case and the Application Case. The Project Case includes the 1:100 year flood and the design flood (approximately, 1:200 year flood).

A primary mitigation for wind erosion in the reservoir would be the re-establishment of vegetation cover (e.g., native grasses) after reservoir drainage. Should wind erosion occur and natural revegetation prove to be ineffective, a tackifier would be applied where required. Tackifiers are a sprayable erosion control products that bond with the soil surface and create a porous and absorbent erosion resistant blanket that can last for up to 12 months. A dust control efficiency of 84% is applied to fugitive dust emissions corresponding to application of a chemical dust

suppressant, e.g. tackifier (WRAP 2006). In long term (greater than one year), it is assumed that revegetation would effectively eliminate the potential for windblown emissions.

The modelling is completed for a period of five months between June and October. This period corresponds to a summer period after a most probable flood occurrence (May to September). May is excluded to account for the residence time of water in the off-stream reservoir and the release time of water in the Elbow River. It is assumed that fugitive dust emissions from wind erosion of the sediment will be negligible in winter due to snow cover and frozen ground. For fugitive dust emissions, winter is considered five months (November to March).

Maximum predicted concentrations of $PM_{2.5}$ and TSP are compared to the Alberta Ambient Air Quality Objectives (AAAQO; (AEP 2017)) and the Canadian Ambient Air Quality Standards for $PM_{2.5}$ (CAAQS; (ECCC 2013)). Maximum predicted concentrations of PM_{10} are compared to the BC Ambient Air Quality Objectives (BC AAQO; (BC MOE 2016)) in the absence of Alberta or national ambient criteria for PM_{10}. Only short-term effects (i.e. 1-hour and 24-hour) on air quality are evaluated since it is assumed that fugitive dust emissions from wind erosion will be effectively mitigated in long term by revegetation of the sediment surface after a flood event.

The model results for the Application Case show that the predicted $PM_{2.5}$ concentrations are less than the AAAQO and the CAAQS for both, the 1:100 year flood and for the design flood. For the 1:100 flood, the maximum predicted PM_{10} and TSP concentrations are greater than the BC AAQO and the AAAQO, respectively; however, these exceedances occur in a small area that extends to 150 m from the east PDA boundary, for up to 2 days, following the occurrence of a 1:100 year flood. The PM_{10} and TSP concentrations are predicted to be greater than the ambient objectives at two residence receptor locations near the east PDA boundary for up to 1 day following a 1:100 year flood.

For the design flood, the maximum predicted PM_{10} and TSP concentrations are greater than the BC AAQO and the AAAQO, respectively. The predicted PM_{10} and TSP concentrations are greater than the ambient objectives in a small area that extents to 550 m from the east PDA boundary for up to 8 days for PM_{10} and up to 10 days for TSP following the design flood. The PM_{10} and TSP concentrations are predicted to be greater than the ambient objectives at six residence receptor locations near the east PDA boundary for up to 7 days following the design flood.

The Project contribution to maximum predicted $PM_{2.5}$ concentrations for the Application Case ranges from 3% to 25% for the 1:100 year flood and up to 55% for the design flood. The Project contributes up to 69% of maximum predicted PM_{10} and TSP concentrations for the 1:100 year flood and up to 84% of maximum predicted PM_{10} and TSP concentrations for the design flood.

The dispersion modelling predicts 24-hour average PM_{10} and TSP concentrations greater than the ambient objectives for the 1:100 and design floods. However, given the low recurrence of these events (i.e. 100 years and 200 years, respectively) and the limited spatial extent and frequency of the predicted concentrations being greater than the ambient objectives, the effects on air quality are considered not significant. With implementation of the mitigation measures, the change in ambient air quality due to fugitive dust from the post-flood sediment is expected to be minimal. The adaptive management nature of the fugitive dust mitigations is expected to be adequate to control fugitive dust to low levels that do not have appreciable adverse environmental effects. In long term, it is expected that revegetation would effectively eliminate the potential for windblown emissions.

Abbreviations

AAAQO/G	Alberta Ambient Air Quality Objectives and Guidelines
AQMG	Alberta Air Quality Model Guideline
BC AAQO	British Columbia Ambient Air Quality Objectives
CAAQS	Canadian Ambient Air Quality Standards
CALMET	A meteorological preprocessor for the CALPUFF model
CALPUFF	(California PUFF) air quality transport and dispersion model
ECCC	Environment and Climate Change Canada
LAA	local assessment area
PDA	project development area
PM	particulate matter
$PM_{2.5}$	particulate matter with particle aerodynamic diameter less or equal to 2.5 µm
PM_{10}	particulate matter with particle aerodynamic diameter less or equal to 10 µm
RMC	Western Regional Air Partnership (WRAP) Regional Modeling Center
TSP	total suspended particulate
USDA	United States Department of Agriculture
U.S. EPA	United States Environmental Protection Agency
VC	valued component
WRAP	Western Regional Air Partnership

1.0 INTRODUCTION

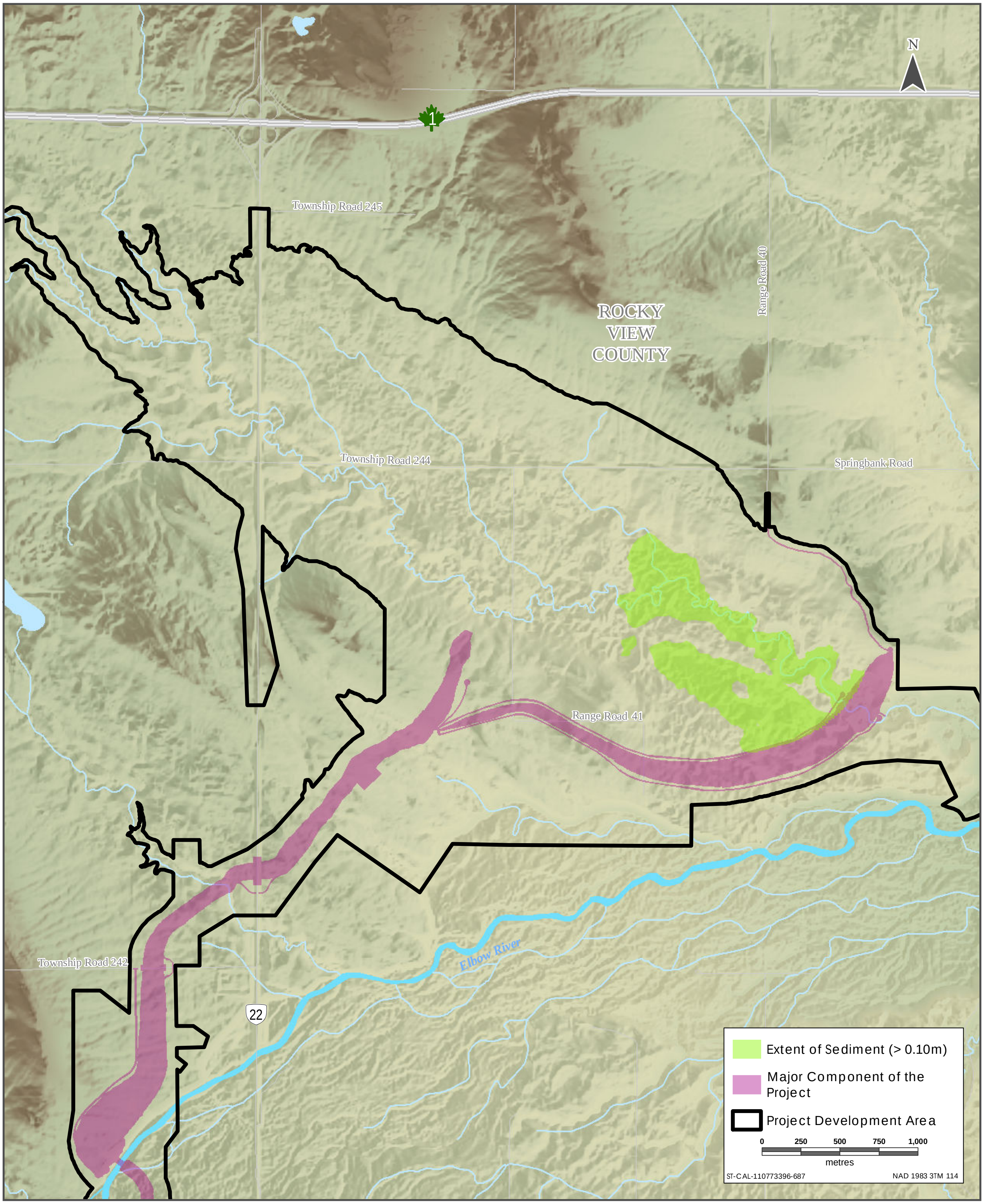
During release of impounded water from the off-stream reservoir back into the Elbow River there is a potential for sediment to deposit in the off-stream reservoir. During high winds the surface of the dried sediment could be exposed to wind erosion. An air quality assessment is conducted to assess the effects of fugitive dust emissions from wind erosion of the deposited sediment on air quality.

Preliminary (conceptual) hydrological modelling has been conducted for sediment deposition and the results are summarized in Volume 3B, Section 6 and Volume 4 Appendix J, Hydrology TDR. The hydrological model predicts that two flood scenarios, 1:100 year flood and a design flood (approximately, 1:200 year flood), will result in measurable sediment deposition. The sediment deposition modelling indicates that sediment depths greater than 10 cm could cover an approximate area of 82 ha in the reservoir for the 1:100 year flood, and an approximate area of 155 ha for a design flood. The total area in the reservoir that would be covered by a 1:100 year flood is 500 ha and by a design flood is 730 ha. It is assumed that sediment depth less than 10 cm would likely form very thin drape over existing topography and vegetation that will not be sufficient to generate wind erosion emissions. For the 1:10 year flood, the hydrological model predicts negligible sediment deposition.

The spatial extents of deposited sediment for the 1:100 year flood and the design flood are presented in Figure 1-1 and Figure 1-2, respectively.

Existing (Base Case) emissions in the LAA include traffic exhaust and road dust emissions on nearby roadways and a compressor station located in the northwest sector of the LAA. Base Case emissions are described in greater detail in Volume 3A, Section 3 and Volume 4, Appendix E, Attachment 3A and are not discussed in this report.

To account for regional emission sources outside the LAA that have not been included explicitly in the dispersion model, representative background ambient air quality concentrations are determined based on analysis of local measurements and ambient air quality data from other monitoring programs. Further details regarding the selected monitoring sites and representative background data are provided in Volume 4, Appendix E, Attachment 3D and are not discussed in this report.



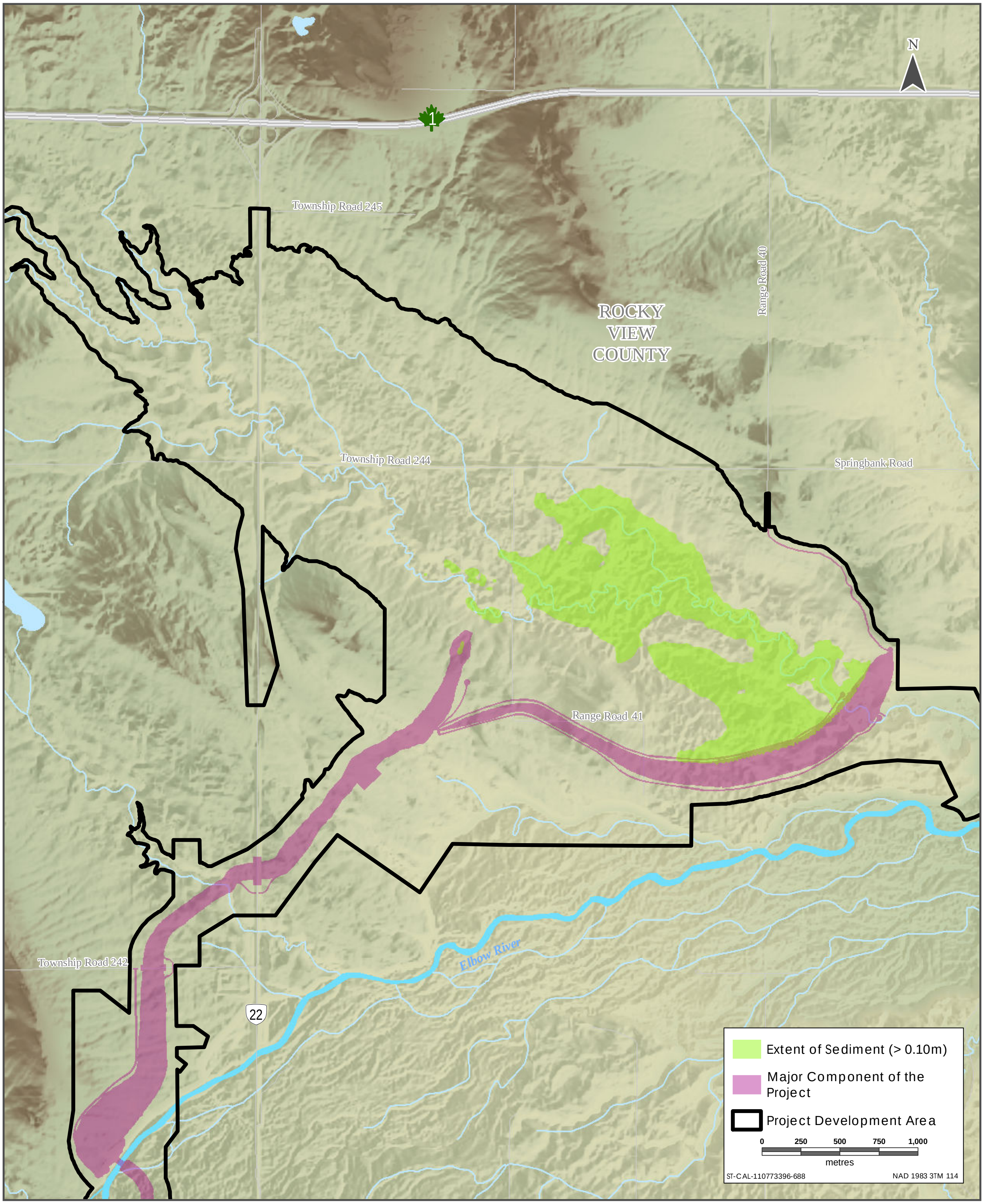
Sources: Base Data - Government of Alberta, Government of Canada
Thematic Data - Stantec Ltd

Spatial Extent of Predicted Sediment Deposition greater than 0.10 m for the 1:100 Year

Stantec

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Figure 1-1



Sources: Base Data - Government of Alberta, Government of Canada
Thematic Data - Stantec Ltd

Spatial Extent of Predicted Sediment Deposition greater than 0.10 m for the 1:200 Year Flood

Stantec

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Figure 1-2

2.0 REGULATORY CRITERIA

2.1 AMBIENT AIR QUALITY OBJECTIVES

The substances of interest for project emissions are particulate matter with particle aerodynamic diameter less or equal to 2.5 µm ($PM_{2.5}$), particulate matter with particle aerodynamic diameter less or equal to 10 µm (PM_{10}) and total suspended particulates (TSP) with particle aerodynamic diameter of less or equal to approximately 30 µm.

Ambient air quality criteria are established by provincial (Alberta) and national regulatory agencies to protect the receiving environment from adverse effects. Relevant ambient air quality criteria include the Alberta Ambient Air Quality Objectives and Guidelines (AAAQO and AAAQG), the British Columbian Ambient Air Quality Objectives (BC AAQO), the National Ambient Air Quality Objectives (NAAQO), and the Canada Ambient Air Quality Standards (CAAQS). Table 3-1 identifies the AAAQO, AAAQG, BC AAQO, NAAQO and CAAQS for the substances of interest and associated averaging periods.

Canadian Ambient Air Quality Standards (CAAQS) are health-based standards that replace the NAAQO. Currently CAAQS have been developed and are in place for $PM_{2.5}$. The CAAQS are developed for managing regional air quality in each Air Zone (referred to as Land Use Planning Region in Alberta) based on concentrations measured at local monitoring stations. These standards are not intended for evaluating near-field impacts at a project boundary.

Maximum predicted concentrations of PM_{10} are compared to the BC AAQO in the absence of Alberta or national ambient criteria for PM_{10}.

Only short-term effects (i.e. 1-hour and 24-hour) on air quality are evaluated since it is assumed that fugitive dust emissions from wind erosion of the sediment will be effectively mitigated in long term by revegetation of the sediment surface after a flood event.

To be conservative, the most stringent criteria are compared to the maximum predicted ambient concentrations associated with the Project.

Table 2-1 Provincial and National Ambient Air Quality Criteria

Substance	Averaging Period	Provincial		National	
		AAAQO[a] (µg/m³)	**BC AAQO[c] (µg/m³)**	**NAAQO[d] (µg/m³)**	**CAAQS[e] (µg/m³)**
$PM_{2.5}$	1-hour	**80** [b]	–	–	–
	24-hour	**30**	25	–	**28** [e]
PM_{10}	24-hour	–	**50**	–	
TSP	24-hour	**100**	120	120	–

NOTES:

[a] Alberta Ambient Air Quality Objectives (AAAQO; (AEP 2017))

[b] Alberta Ambient Air Quality Guidelines (AAAQG; (AEP 2017))

[c] British Columbia Ambient Air Quality Objectives (BC AAQO; (BC MOE 2016))

[d] National Ambient Air Quality Objective (NAAQO; (CCME 1999))

[e] The Canadian Ambient Air Quality Standard (CAAQS) for 24-hour $PM_{2.5}$ is referenced to the annual 98th percentile of daily 24-hour average concentrations, averaged over three years (ECCC 2013, CCME 2014).

Values highlighted in **bold** text are the ambient criteria used in the air quality assessment.

– No applicable objective or standard in this jurisdiction.

µg/m³ = micrograms per cubic metre

2.2 METRIC FOR THE AMBIENT REGULATORY CRITERIA

The ambient air quality criteria are developed for a time-averaging period (e.g. 1-hour, 24-hour) and have a specific statistical form referred to as a "metric" (e.g. 98th percentile, 99.9th percentile).

The Alberta Air Quality Modelling Guideline (AQMG; (AEP 2013)) recognizes that extreme, rare, and transient meteorological conditions can affect predicted 1-hour average ambient air concentrations. To address this issue, AEP recommends "the highest eight 1-hour predicted average concentrations for each receptor in each single year should be disregarded". Therefore, for the assessment of 1-hour average concentrations, the 9th highest hourly values (equal to the 99.9th percentile) for each year at a given location are used to determine compliance with the 1-hour AAAQO.

For averaging periods greater than 1 hour (e.g. 24-hour), no predicted values greater than the AAAQO are viewed as being acceptable (AEP 2013). Therefore, the maximum 24-hour and annual predicted concentrations are compared to the AAAQO.

The 24-hour CAAQS for $PM_{2.5}$ is based on the three-year average of the annual 98th percentile of the daily 24-hour average concentrations. For this assessment, the 8th highest predicted 24-hour average $PM_{2.5}$ concentration in each year is used to represent the 98th percentile of daily 24-hour average concentrations. The 8th highest predicted 24-hour average $PM_{2.5}$ concentrations for each year are averaged over three years and the maximum of the three-year averages is compared to the 24-hour CAAQS.

3.0 PROJECT EMISSIONS

3.1 ESTIMATION METHOD

Wind erosion emissions from the post-flood sediment in the off-stream reservoir are estimated based on methods developed by ENVIRON and the Western Regional Air Partnership (WRAP) Regional Modeling Center (RMC) (Mansell et.al 2006). This method is referred to as ENVIRON/RMC method throughout this report. This method is developed to estimate regional windblown fugitive dust emissions for the compilation of the US regional emission inventory in support of the Regional Haze Rule. The ENVIRON/RM method is listed as an alternative method for estimating emissions from open area wind erosion in the WRAP Fugitive Dust Handbook (WRAP 2006).

The primary method listed in the WRAP Fugitive Dust Handbook is U.S. EPA AP-42, Section 13.2.5 (U.S. EPA 2006) method which estimates wind erosion emissions depending on the frequency of disturbance of the erodible surface and the disturbed area. It is assumed that the surface is subject to wind erosion (i.e., its erosion potential is restored) only when the surface is disturbed exposing fresh material to the surface. A disturbance of the exposed area is defined as any action that results in the exposure of fresh surface material. Examples of disturbance of an open area include turning the surface material to a depth exceeding the size of the largest aggregate size of available material or off-road vehicle activity. The deposited sediment in the off-stream reservoir is generally undisturbed since there is no planned activity that would result in exposure of fresh surface material such as off-road vehicle traffic. Given the sensitivity of the U.S. EPA AP-42 method to frequency of disturbance, this method would generate unrealistically high emission estimates for the wind erosion of the sediment unless assumptions are made for the frequency of disturbance and the fraction of the sediment area that is disturbed. The ENVIRON/RMC method does not account directly for soil conditions (disturbed or undisturbed). Rather, the disturbance level of the surface is accounted by selecting a representative threshold friction velocity for the surface: disturbed surfaces have lower threshold friction velocity than undisturbed surfaces. Based on these considerations, the ENVIRON/RMC method is selected for the assessment in preference over the primary U.S. EPA AP-42 method.

Based on the ENVIRON/RMC method, wind erosion emissions are generated when the wind exceeds a threshold wind friction velocity that is defined based on the characteristics of the soil subject to erosion. The threshold friction velocity u^*_t is determined from the empirical relationship developed by Marticorena et al. (1997) as a function of the aerodynamic surface roughness length z_0. Marticorena’s relationship is based on wind tunnel studies of threshold friction velocity in dependence of surface roughness at desert and arid lands in the USA (Havstad and Schlesinger 1996; Gillette et al. 1982). Figure 3-1 shows the comparison between Marticorena’s relationship of threshold friction velocity and aerodynamic surface roughness length, and wind tunnel data obtained by different investigators. The Marticorena's empirical relationship is defined as follows:

$$u^*{}_t = 0.30e^{7.22(z_0)} \qquad \text{(Equation 1)}$$

where:

$u^*{}_t$ - Threshold friction velocity (m/s)

z_0 - Aerodynamic surface roughness length (cm)

Based on Marticorena's relationship, the threshold friction velocity is approximately uniform and equal to 0.30 m/s for aerodynamic surface roughness length less than approximately 0.05 cm, and the threshold friction velocity increases rapidly with increase of aerodynamic surface roughness length, for surface roughness length greater than 0.05 cm (Figure 3-1).

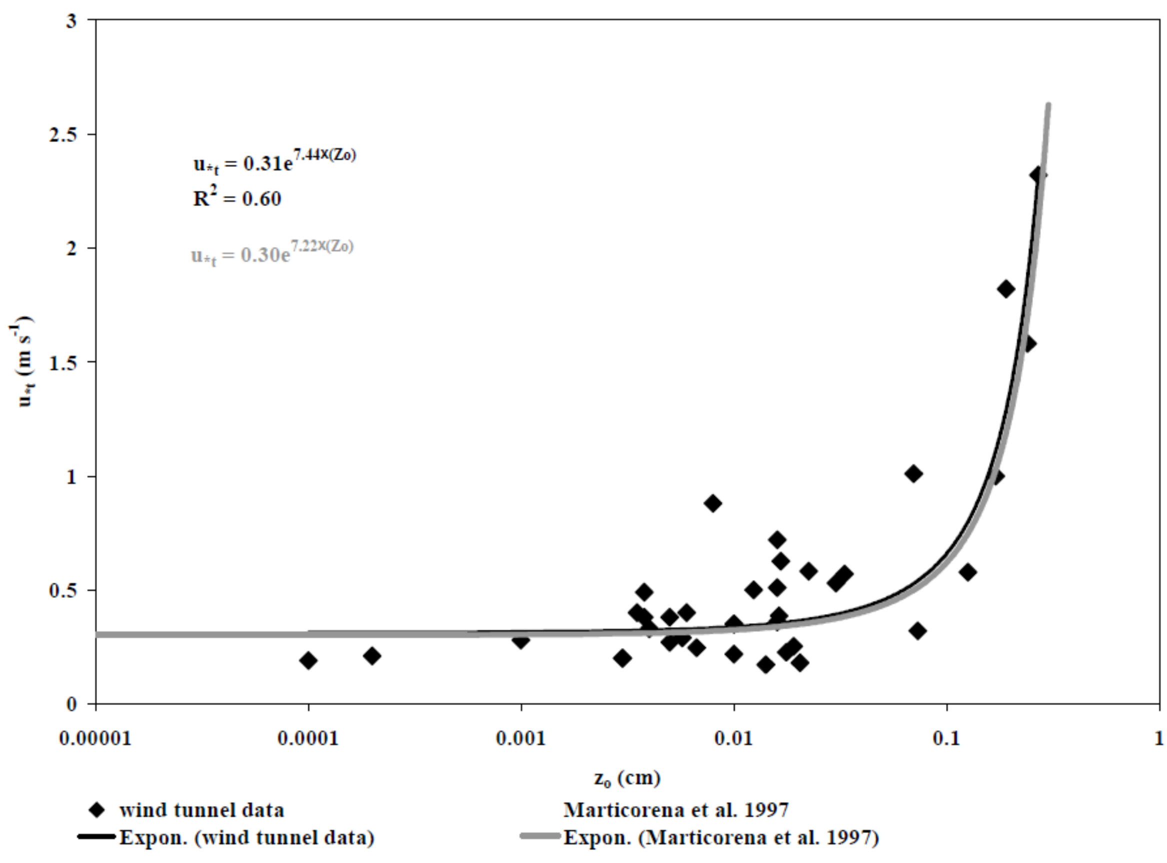


Figure 3-1 Marticorena et al. (1997) Relationship of Threshold Friction Velocity and Aerodynamic Surface Roughness (Figure 2-1 from Mansell et al. 2006)

A threshold friction velocity is calculated to be 0.31 m/s, based on a typical aerodynamic surface roughness of 0.005 cm for sand dunes (Gillette et al. 1980 and 1982). This calculated threshold friction velocity is within the range of values derived from wind tunnel studies for loose sandy soils and disturbed sand (Havstad and Schlesinger 1996; Gillette et al. 1980 and 1982). Watson et al. (2014) measured windblown dust emissions from many surfaces in the Athabasca Oil Sands Region using a portable wind tunnel, including tailing sand beaches, tailing dikes, haul roads as well as both disturbed and undisturbed surfaces. Watson found that the threshold wind speed that initiated dust suspension ranged from 11 to 22 km/h (corresponding to a threshold friction velocity in the range of 0.16 to 0.32 m/s). The calculated threshold friction velocity for the sediment is within this range.

The magnitude of the emission flux is estimated as a function of wind friction velocity based on empirical relationships derived from wind tunnel studies (Alfaro and Gomes 2001). Alfaro et al. (2003) grouped the Nickling and Gillies (1989) wind tunnel emission data for four soil types:

- FSS – silt
- FS – sandy silt
- MS – silty sand, and
- CS – sand

The empirical relationships for the 4 soil types are presented in Figure 3-2. Figure 3-2 shows that the emission flux for sandy silt soils (FS) is between one and two orders of magnitude greater than the emission flux for sand (CS) but there is less increase in emissions for silt (FSS) compared to sandy silt (FS), and less increase in emissions for silty sand (MS) compared to sand (CS).

The classification of soil types is based on the standard soil texture triangle (Figure 3-3) that classifies soil texture in terms of percent sand, silt and clay. There are 12 major soil texture types as defined by the U.S. Department of Agriculture (USDA 2017). A texture type “loam” is used to describe soils with equal content of sand, silt and clay. The 12 soil types from the standard soil texture triangle are mapped to the 4 soil types defined by Alfaro et al. (2003) as presented in Table 3-1.

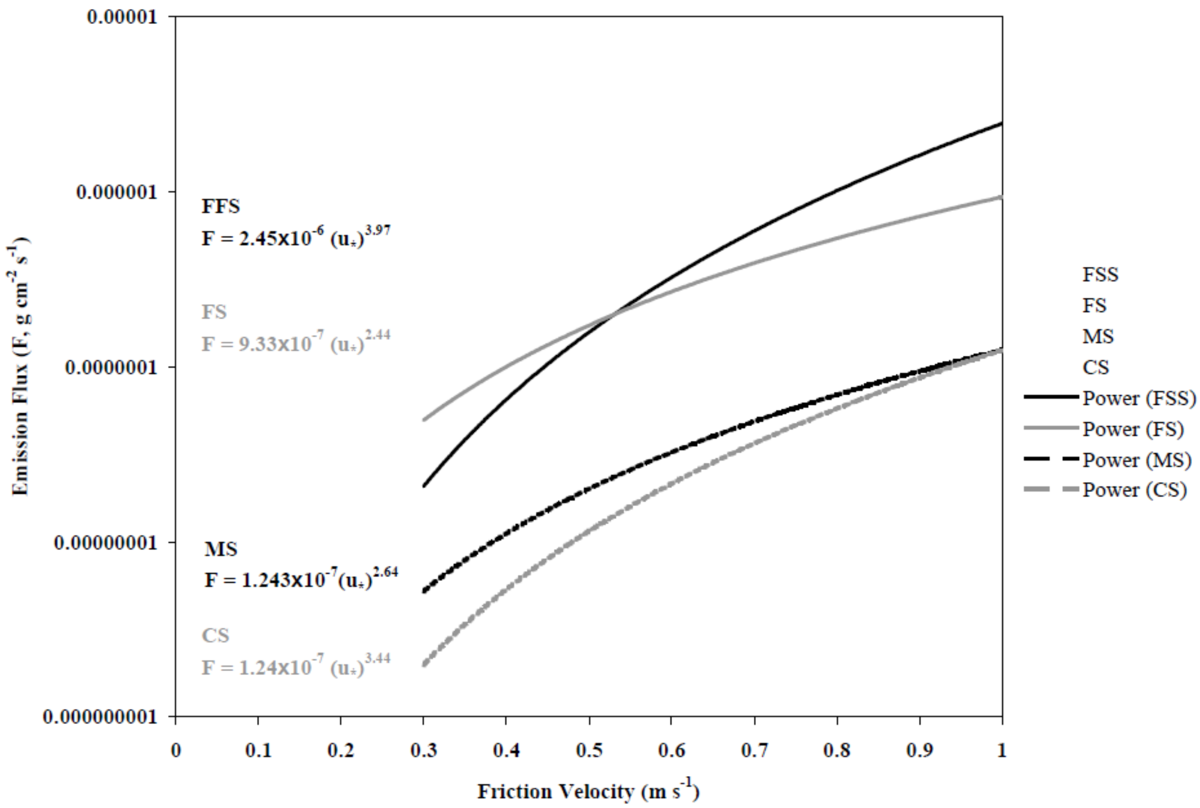
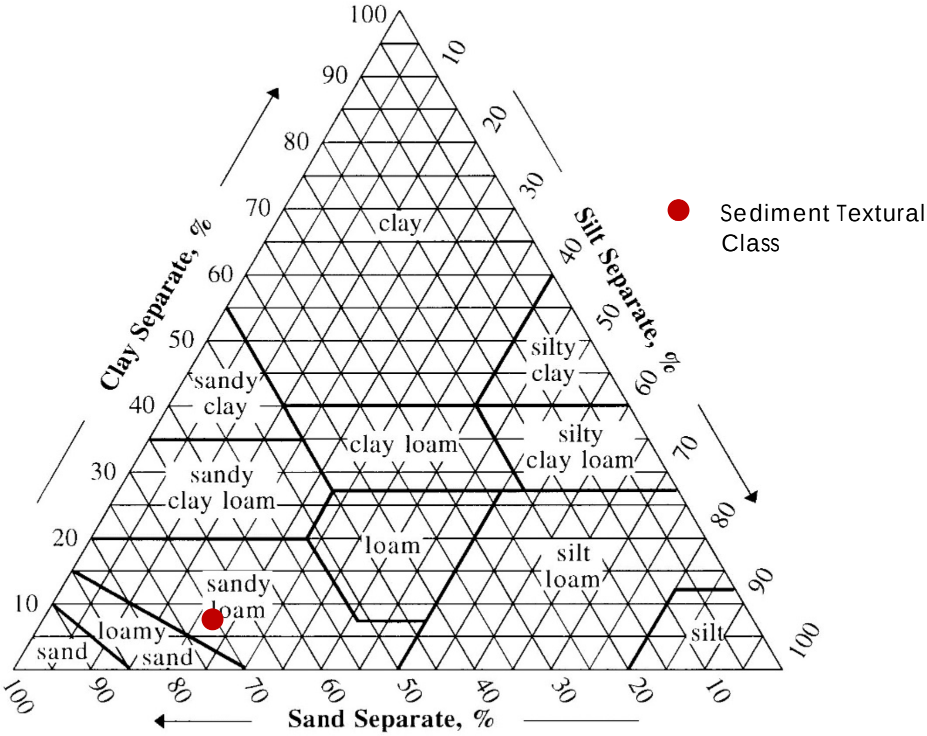


Figure 3-2 **Emission Flux as a Function of Friction Velocity predicted by the Alfaro and Gomes (2001) Model for the Four Soil Types defined by Alfaro et al. (2003) (Figure 2-2 from Mansell et al. 2006)**



SOURCE: from USDA 2017

Figure 3-3 Soil Texture Triangle and Approximated Sediment Textural Class

The hydrological model for a 1:100 year flood estimated an approximate composition of the post-flood sediment to have a mean value of 22% silt and 72% sand. The upstream soil samples collected along the Elbow River also confirm that there is no or very little clay content in the river sediment (Volume 3B, Section 6 and Volume 4, Appendix J, Hydrology TDR). Based on the soil texture triangle, the sediment is classified as “sandy loam,” which correspond to type MS.

The emission flux for soil type MS is estimated from the Alfaro and Gomes (2001) model by the following relationship:

$$F = 0 \qquad for\ u^* < u_t^* \qquad \text{(Equation 2)}$$

$$F = 1.243 \times 10^{-7} (u^*)^{2.64}$$

where:

F - Emission flux (g/cm²/s) corresponding to soil type MS

u* - Wind friction velocity (m/s)

u^*_t - Threshold friction velocity (m/s)

Table 3-1 Mapping of 12 Major Textural Soil Classes to 4 Soil Types

Soil Texture Type (USDA 2017)	Soil Type (Alfaro et al. 2003)
Sand	CS
Loamy Sand	CS
Sandy Loam	MS
Silt Loam	FS
Silt	FSS
Loam	MS
Sandy Clay Loam	MS
Silty Clay Loam	FSS
Clay Loam	MS
Sandy Clay	MS
Silty Clay	FSS
Clay	FS

Based on this emission model, emissions are generated when the wind friction velocity exceeds the threshold friction velocity at the surface. The wind friction velocity for each hour is calculated from the wind speed profile logarithmic distribution. The friction velocity u* is a measure of the wind shear stress on the erodible surface, as determined from the slope of the logarithmic wind speed profile:

$$u(z) = \frac{u^*}{k} ln\left(\frac{z}{z_0}\right) \quad \text{(Equation 3)}$$

where:

u(z) - Wind speed (m/s) at height z (m)
u* - Wind friction velocity (m/s)
z - Height above surface (10 m)
z_0 - Aerodynamic surface roughness length (m)
k - Von Karman's constant (0.4)

The hourly mean 10-m wind speeds obtained from the CALMET model are used to calculate varying emission rates by wind speed. However, mean atmospheric wind speeds are not sufficient to generate wind erosion from flat surfaces. Therefore, the hourly wind speeds from CALMET are converted to equivalent peak (e.g., gust) wind speeds for every hour. The meteorological variable that most commonly is used to represent the magnitude of wind gusts is the fastest mile. The fastest mile wind speed corresponds to one mile of wind passing by a fixed location in the least amount of time. The CALMET mean hourly wind speed at 10 m is converted to an equivalent fastest mile wind speed based on the Durst Curve (Durst 1960). The Durst Curve allows for the conversion of a one-hour average wind speed to a gust or peak wind speed of a shorter duration for wind blowing over open terrain. Because the sediment area in the off-stream reservoir consists of a large, flat surface without vegetation, the Durst curve is ideal to calculate fastest mile wind speeds at the location of the sediment. The hourly mean speed is adjusted with a gust factor of 1.26 from the Durst Curve, corresponding to a fastest mile wind of 75 mph (120 km/h) with an averaging time of 50 seconds. The corresponding fastest mile wind speed is calculated from the mean hourly wind speed as follows:

$$u^{+} = 1.26 \times u(10\ m) \qquad \text{(Equation 4)}$$

where:

u^{+}	-	Fastest mile wind speed (m/s)
$u(10\ m)$	-	Mean hourly wind speed at 10 m height (m/s)

The friction velocity is calculated from the fastest mile wind using Equation 3 and assumes a typical surface roughness length of 0.005 m for open unvegetated terrain (U.S. EPA 2006) and anemometer height of 10 m above ground:

$$u^{*} = 0.053 \times u^{+} \qquad \text{(Equation 5)}$$

where:

u^{*}	-	Wind friction velocity (m/s)
u^{+}	-	Fastest mile wind speed (m/s)

Using Equations 4 and 5, the threshold friction velocity of 0.31 m/s converts to an approximate hourly average threshold wind speed of 4.5 m/s at 10 m height. When the hourly average wind speed is less than 4.5 m/s, no wind erosion emissions are generated (Equation 2). From the CALMET wind speeds for the 5-year period (2002-2006) extracted at the approximate centre of the off-stream reservoir, there is a total of 8,078 hours in 5 years or 18% of the time with hourly average wind speed greater than 4.5 m/s. This is equivalent to 1,615 hours per year on average. For the 5-month period (June to October) that is modelled, there are 446 hours on annual basis with average hourly wind speed greater than 4.5 m/s.

Variable emission rates are calculated for six wind speed categories consistent with the CALPUFF option allowing modelling of varying emission rates by wind speed. The wind speed categories are defined with their lower and upper limit wind speed. The first wind speed category is selected to represent wind speeds below the threshold wind speed (4.5 m/s) that are associated with no dust emissions. The following wind speed categories are defined up to a maximum wind speed of 17 m/s, which is the maximum hourly wind speed from the extracted CALMET 5-year time series. The mean wind speed for each wind speed category is calculated from the CALMET 5-year time series. Representative emission rates are calculated for the mean wind speed of each wind speed category.

The emission estimation methodology is summarized as follows:

1. The mean wind speeds for the six wind speed categories are converted to equivalent fastest mile winds using Equation 4.
2. Wind friction velocities for the six wind speed categories are calculated from the fastest mile wind speeds using Equation 5.
3. Emission flux (g/m²/s) is calculated for the six wind speed categories using Alfaro and Gomes (2001) empirical relationship (Equation 2) for soil type MS (silty sand). Emissions occur when wind friction velocities are greater than the threshold friction velocity of 0.31 m/s defined for the sediment.
4. The emission flux is multiplied by the exposed sediment area for the different flood scenarios to obtain emission rates (g/s).
5. Aerodynamic particle size multipliers are applied to the total emission rate to obtain emission rates for TSP, PM_{10} and $PM_{2.5}$. The aerodynamic particle size multipliers from U.S. EPA AP-42 Section 13.2.5 (U.S. EPA 2006) are adopted for the assessment: 1.0 for TSP, 0.5 for PM_{10} and 0.075 for $PM_{2.5}$.
6. An emission control efficiency of 84% is applied to uncontrolled emissions to account for the emission reduction due to application of a chemical dust suppressant (i.e. tackifier).

Particle size specific emission fluxes for the six wind speed categories is presented in Table 3-2.

Table 3-2 Estimated Emission Flux for the 6 Wind Speed Categories

Wind Speed Category	Lower Limit Wind Speed	Upper Limit Wind Speed	Mean Wind Speed [a]	u^+	u^*	Emission Flux		Particle Size-Specific Emission Flux		
								TSP	PM_{10}	$PM_{2.5}$
	(m/s)	(m/s)	(m/s)	(m/s)	(m/s)	($g/cm^2/s$)	($g/m^2/h$)	($g/m^2/h$)		
1	0	4.5	2.44	3.08	0.16	0	0	0	0	0
2	4.5	5.5	4.94	6.23	0.33	6.53E-09	0.235	0.235	0.118	0.009
3	5.5	6.5	5.93	7.48	0.39	1.06E-08	0.381	0.381	0.191	0.014
4	6.5	8.5	7.24	9.12	0.48	1.79E-08	0.645	0.645	0.322	0.024
5	8.5	11	9.39	11.83	0.62	3.56E-08	1.281	1.281	0.640	0.048
6	11	17 [b]	12.19	15.36	0.81	7.09E-08	2.553	2.553	1.276	0.096

NOTES:

[a] Mean wind speed for each wind speed category calculated from CALMET 5-year time series at the approximate centre of the sediment area in the off-stream reservoir.

[b] Assigned the upper limit wind speed the maximum hourly wind speed from CALMET 5-year time series at the approximate centre of the sediment area in the off-stream reservoir.

3.2 CONSERVATIVE ASSUMPTIONS

The emission estimation methodology based on the ENVIRON/RMC method applies a number of conservative assumptions as described below:

- **Threshold friction velocity**. A threshold friction velocity of 0.31 m/s is calculated for the deposited sediment, which is in good agreement with measurements of disturbed sand soils. The disturbance level of the erodible surface has the effect of altering the threshold friction velocity. Disturbed surfaces have lower threshold friction velocities than undisturbed surfaces (i.e., disturbed surfaces tend to generate more dust than undisturbed surfaces). Several wind tunnel studies (Gillette et al. 1980, 1982; Gillette 1988; Nickling and Gillies 1989) suggest that threshold friction velocities of undisturbed surfaces are 1.5 to 3.6 higher than the threshold friction velocities of disturbed surfaces. These wind tunnel studies suggest that a value of 0.44 m/s would more realistically represent undisturbed sand soils. Given that there is no regular activity resulting in disturbance of the sediment, the threshold friction velocity of 0.31 m/s used in the assessment is a conservative estimate for the erosion of the sediment.

- **Level of disturbance.** It is assumed that the sediment area would have unlimited erosion potential. If the surface is undisturbed for a long period of time it would form a natural crust that would effectively prevent wind erosion emissions until the surface is disturbed again and fresh material is exposed to the surface. The deposited sediment is undisturbed because there is no planned activity that would result in exposure of fresh surface material. However, the assessment conservatively assumes that 100% of the sediment area has fresh surface material exposed to wind erosion at all times. The ENVIRON/RMC methodology accounts for the level of disturbance by assuming that only 10% of grassland, shrubland and barren lands is disturbed (with 90% of the area undisturbed) and is subject to windblown emissions.

- **Precipitation.** The duration and amount of precipitation affect the dust emissions from wind erosion. The current assessment does not account for periods of precipitation. The ENVIRON/RMC method assumes that no windblown emissions are generated for two to four days after precipitation greater than two inches, which is the time necessary to restore the erosion potential of the surface.

- **Height of the off-stream dam.** The off-stream dam has a crest height of 24 m above ground, which has the effect of a physical barrier for transport and dispersion of windblown emissions from the reservoir to the south of the dam. This effect is not accounted for in the emission estimation nor in the dispersion model.

The estimated PM_{10} emission flux using the ENVIRON/RMC method is compared with measured PM_{10} emission flux from a large number of surfaces in the Athabasca Oil Sands Region (Watson et al. 2014). The PM_{10} emission flux at wind speed of 11.8 m/s (43 km/h, wind category 5) calculated for the deposited sediment using the ENVIRON/RMC methodology is 1.8×10^{-4} g/m²/s or 0.18 mg/m²/s. This value is within the range of measured PM_{10} emission flux (1.5×10^{-5} to 5.7×10^{-4} g/m²/s or 0.02 to 0.57 mg/m²/s) at similar surfaces with comparable threshold friction velocity that include stabilized and lightly disturbed surfaces.

Based on the comparison of estimated windblown dust emissions from the post-flood sediment with measured emissions at similar surfaces from wind tunnel studies, the estimated project emissions are believed to represent realistically peak dust emissions during high wind speed events and are expected to predict maximum air quality effects from wind erosion of the post-flood sediment.

3.3 MITIGATION MEASURES

A primary mitigation for dust emissions from wind erosion in the off-stream reservoir would be the re-establishment of vegetation cover (e.g., native grasses) after reservoir drainage. Natural revegetation success in short term, however, is not assured, given initial high moisture contents and reduced energy input in the autumn. In long term, it is assumed that revegetation would effectively eliminate the potential for windblown emissions when the vegetation is fully developed.

In short term, when natural revegetation could be ineffective, a tackifier would be applied where required. Tackifiers are a sprayable erosion control product that bonds with the soil surface and creates a porous and absorbent erosion resistant blanket that can last for up to 12 months.

The U.S. Bureau of Mines (Olson and Veith 1987) measured the effectiveness and durability of dust suppressants on tailings for a range of different chemical stabilizers. The study found that chemical stabilizers are very effective at controlling fugitive dust emissions upon initial application of the chemical suppressant with control levels of approximately 90% (which is considered the maximum attainable control level). However, these products have a useful life that is dependent on the concentration applied and weather conditions between reapplication. The U.S. Bureau of Mines tests indicated that control efficiency of the most effective chemical stabilizers declined to approximately 70% and 50% after two months and four months after initial application, respectively.

Reapplication of the chemical stabilizer at defined periods is necessary to maintain high control efficiency. The dilution ratio, chemical application rate and time between reapplications of a chemical stabilizer can be adjusted to achieve and maintain high levels of fugitive dust control. Frequent reapplication of a chemical stabilizer can maintain a control efficiency of 90%. The U.S. Bureau of Mines study calculated that a 90% level of control can be maintained over a three-month summer period with one initial application and one reapplication of typical latex based chemical stabilizers.

For the current air quality assessment, a dust control efficiency of 84% is applied to fugitive dust emissions as per the WRAP Fugitive Dust Handbook (WRAP 2006), which corresponds to application of a chemical dust suppressant.

3.4 EMISSION SUMMARY

A summary of estimated fugitive dust emission rates for the 1:100 year flood and design flood is presented in Table 3-3. Emissions are presented without dust mitigation and with application of 84% dust control efficiency corresponding to application of chemical dust suppressant. Only emission rates with applied dust mitigation are included in the dispersion modelling.

The sediment area for each flood corresponds to a sediment depth of at least 10 cm that has the potential to generate windblown emissions. The probability of wind within each wind speed category is estimated from CALMET 5-year time series at the approximate centre of the sediment area in the off-stream reservoir. Total emissions are calculated by multiplying the emission flux for each wind speed category (Table 3-2) with the probability of wind within that wind speed category.

Table 3-3 shows that the sediment area and the estimated fugitive dust emissions for the design flood are approximately two times the emissions for the 1:100 year flood.

Table 3-3 Project Emission Rates

Flood Scenario	Sediment Area [a]	Wind Speed Category	Lower Limit Wind Speed	Upper Limit Wind Speed	Mean Wind Speed[a]	Wind Proba-bility [c]	Emission Rate without Dust Mitigation			Dust Control Effici-ency [d]	Emission Rate with Applied Dust Mitigation		
							$PM_{2.5}$	PM_{10}	TSP		$PM_{2.5}$	PM_{10}	TSP
	(m²)	—	(m/s)	(m/s)	(m/s)	(%)	(kg/d)			(%)	(kg/d)		
1:100 year flood	820,578	1	0	4.5	2.44	81.6	0	0	0	84	0	0	0
		2	4.5	5.5	4.94	9.7	17	224	447		2.7	36	72
		3	5.5	6.5	5.93	4.8	14	181	362		2.2	29	58
		4	6.5	8.5	7.24	3.1	15	198	396		2.4	32	63
		5	8.5	11	9.39	0.73	6.9	92	184		1.1	15	29
		6	11	17	12.19	0.11	2.0	27	54		0.3	4.3	8.6
		Total Emissions:				**100**	**54**	**722**	**1,443**		**8.7**	**115**	**231**
Design flood (approximately, 1:200 year flood)	1,553,792	1	0	4.5	2.44	81.6	0	0	0	84	0	0	0
		2	4.5	5.5	4.94	9.7	32	424	847		5.1	68	136
		3	5.5	6.5	5.93	4.8	26	342	685		4.1	55	110
		4	6.5	8.5	7.24	3.1	28	375	751		4.5	60	120
		5	8.5	11	9.39	0.73	13	174	349		2.1	28	56
		6	11	17	12.19	0.11	3.8	51	102		0.6	8.2	16
		Total Emissions:				**100**	**102**	**1,367**	**2,733**		**16**	**219**	**437**

NOTES:

[a] Sediment area corresponding to sediment depth equal or greater than 0.10 m.

[b] Mean wind speed for each wind speed category calculated from CALMET 5-year time series at the approximate centre of the sediment area in the off-stream reservoir.

[c] Probability of wind within each wind speed category estimated from CALMET 5-year time series at the approximate centre of the sediment area in the off-steam reservoir.

[d] Control efficiency corresponds to application of chemical dust suppressant (i.e. tackifier).

4.0 MODELLING SCENARIOS

Dispersion modelling is completed to predict maximum concentrations of $PM_{2.5}$, PM_{10} and TSP associated with wind erosion emissions from the post-flood sediment, alone and combined with existing emission sources in the LAA. The following scenarios are evaluated to assess the effect of project emission on air quality:

- Base Case includes existing emissions in the LAA. Existing emissions include traffic exhaust and road dust emissions on nearby roadways and a compressor station located in the northwest sector of the LAA. Particulate emissions are not estimated for the compressor station.
- Project Case includes fugitive dust emissions associated with wind erosion of the deposited sediment in the off-stream reservoir during the post-flood phase. There are no fugitive dust emissions during a flood event. The Project Case includes the 1:100 year flood and design flood, which are predicted to result in measurable sediment deposition in the off-stream reservoir. The hydrological model predicts negligible sediment deposition for the 1:10 year flood and therefore this flood scenario is not assessed. The Project Case provides an explicit indication of the Project's contribution. No ambient background will be included as the purpose of this Case is to quantify relative contribution as compared to the Application Case.
- Application Case includes the combined emissions of the Base Case and the Project Case, in addition to representative background concentrations accounting for other emission sources outside the LAA.

Table 4-1 presents the emissions summary for the identified modelling scenarios. Table 4-1 shows that the project contribution to $PM_{2.5}$ emissions in the LAA ranges from 14% to 24% (i.e., the Base Case contributes 76% to 86%). The project contribution for PM_{10} and TSP emissions is 26% to 59% (i.e., the Base Case contributes 41% to 74%).

Table 4-1 Comparison of Base Case, Project Case and Application Case Emission Rates

Assessment Case	Flood Scenario	Emission Source	Daily Emission Rate (kg/d)		
			$PM_{2.5}$	PM_{10}	TSP
Base Case (Summer [a])	—	Road Traffic Combustion Emissions	21.3	31.7	31.7
		Road Traffic Fugitive Dust Emissions	29.8	119	624
		Compressor Station (Shell Jumping Pound 5-7)	—	—	—
		Emission Total	**51.1**	**151**	**656**
Project Case (Summer)	1:100 Year Flood	Fugitive dust emissions from wind erosion of post-flood sediment [b]	8.7	115	231
		Emission Total	**8.7**	**115**	**231**
	Design flood (1:200 year flood)	Fugitive dust emissions from wind erosion of post-flood sediment [b]	16.4	219	437
		Emission Total	**16.4**	**219**	**437**
Application Case	1:100 Year Flood	Base Case Emissions	51.1	151	656
		Project Case Emissions	8.7	115	231
		Emission Total	**59.8**	**266**	**887**
	Design flood (1:200 year flood	Base Case Emissions	51.1	151	656
		Project Case Emissions	16.4	219	437
		Emission Total	**67.5**	**370**	**1,093**
Project Contribution (%) to Application Case Emissions, 1:100 year flood			**14%**	**43%**	**26%**
Project Contribution (%) to Application Case Emissions, design flood (1:200 year flood)			**24%**	**59%**	**40%**

NOTES:

[a] For traffic combustion emissions, summer is defined as the 6-month period April to September. For road dust emissions, summer is defined as the 8-month period March to October.

[b] Fugitive dust emission rates for wind erosion of post-flood sediment represent emissions during summer with applied dust control efficiency (84%) corresponding to application of chemical dust suppressant. Wind erosion emissions are estimated and modelled only for the 5-month summer period June to October.

5.0 MODELLING METHODS

The CALMET/CALPUFF model system (Scire et al. 2000) is used to determine the effect of fugitive dust emissions from project flood and post-flood operation on ambient air quality. This assessment approach is consistent with the approach used for project construction and dry operation (Volume 3A, Section 3). The application of the model system is conducted in accordance with the Alberta Air Quality Model Guideline (AQMG; (AEP 2013)).

The CALPUFF domain coincides with the LAA and is sized to capture the overall predicted maximum concentrations. The same grid receptor locations that are used in the air quality assessment for project construction and dry operation also are used in the dispersion modelling study to provide spatial concentration patterns due to project emissions. Additionally, ground-level concentrations are predicted at 58 residence and business locations to provide input for the public health assessment (Volume 3B, Section 15). The CALMET model is used to provide hourly meteorological data required for the CALPUFF transport, dispersion, and deposition model.

Details on the CALMET/CALPUFF model implementation are provided in Volume 4, Appendix E, Attachment 3B and Attachment 3C. A list of the gridded receptor points and the 58 residence and business locations of specific interest is provided in Volume 4, Appendix E, Attachment 3C.

For the current assessment, variable emission rates are calculated for six wind speed categories. This approach allows wind erosion emissions to be modelled as variable emissions by wind speed in the CALPUFF dispersion model. The six wind speed categories used in the model are provided in Table 3-2.

The modelling is completed for a period of five months between June and October. This period corresponds to a summer period after a most probable flood occurrence. May is excluded to account for the residence time of water in the off-stream reservoir and the release time of water in the Elbow River. It is assumed that fugitive dust emissions from wind erosion of the sediment will be negligible in winter due to snow cover and frozen ground. For fugitive dust emissions winter is considered five months (November to March).

Maximum predicted short-term ground-level concentrations along and outside the PDA (with the background contribution), are compared to the most stringent ambient air quality criteria (Table 2-1). Concentrations inside the PDA are not compared to the ambient criteria because public access is restricted in this region.

Only short-term effects (i.e. 1-hour and 24-hour) on air quality are evaluated since it is assumed that fugitive dust emissions from wind erosion of the sediment will be effectively mitigated in long term by revegetation of the sediment surface after a flood event.

6.0 DISPERSION MODELLING RESULTS

Summaries of maximum predicted ground-level concentrations for $PM_{2.5}$, PM_{10} and TSP for the 1:100 year flood and design flood are presented in Table 6-1. The table includes predicted results for the existing emission sources in the LAA (Base Case), the project post-flood phase (Project Case) and the combined results for the Project and existing regional emissions sources (Application Case). The maximum predicted values are based on areas along and outside the PDA where public access is not restricted. The presented results for the Base Case and Application Case include background concentrations which account for other emission sources (natural and anthropogenic) that have not been included directly in the dispersion model. The maximum values for the Project Case do not include background contribution as the purpose of the Project Case is to quantify the relative contribution of the Project to the Application Case. Maximum predicted ground-level concentrations along and outside the PDA are compared to the relevant ambient air quality criteria (Table 2-1).

The model results for the 1:100 year flood indicate that:

- The maximum predicted $PM_{2.5}$ concentrations are less than the AAAQG, AAAQO and the CAAQS for the Base Case, Project Case and Application Case.
- The maximum predicted PM_{10} and TSP concentrations are greater than the BC AAQO and the AAAQO, respectively for the Base Case, Project Case and Application Case. The PM_{10} concentrations are predicted to be above the BC AAQO for two days per year. The TSP concentrations are predicted to be above the AAAQO for two days per year.
- The Project contributes up to 25% of maximum predicted $PM_{2.5}$ concentrations, up to 69% of maximum predicted PM_{10} concentrations and up to 65% for maximum predicted TSP concentrations.

The model results for the design flood indicate that:

- The maximum predicted $PM_{2.5}$ concentrations are less than the AAAQG, AAAQO and the CAAQS for the Base Case, Project Case and Application Case.
- The maximum predicted PM_{10} and TSP concentrations are greater than the BC AAQO and the AAAQO, respectively for the Base Case, Project Case and Application Case. The PM_{10} concentrations are predicted to be above the BC AAQO for eight days per year. The TSP concentrations are predicted to be above the AAAQO for ten days per year.
- The Project contributes up to 55% of maximum predicted $PM_{2.5}$ concentrations, up to 84% of maximum predicted PM_{10} concentrations and up to 81% for maximum predicted TSP concentrations.

Concentration isopleth maps showing predicted ground-level concentrations (Project Case and Application Case) for the 1:100 year and design flood are presented in Attachment A. Concentration isopleth maps showing predicted ground-level concentrations of the substances of interest for the Base Case are presented in Volume 3A, Section 3 and, therefore, are not included in this technical data report.

6.1 RESULTS FOR THE 1:100 YEAR FLOOD SCENARIO

The predicted maximum ambient concentrations of $PM_{2.5}$, PM_{10} and TSP for the 1:100 year flood scenario are summarized in Table 6-1. Concentration isopleth maps for the 1:100 year flood scenario (Project Case and Application Case) are included in Attachment A.1.

6.1.1 Maximum $PM_{2.5}$ Concentrations

The following summarizes modelling results for $PM_{2.5}$ concentrations:

- Base Case—The highest 1-hour and 24-hour average concentrations for the Base Case occur on and near highways. The maximum predicted 1-hour, 24-hour and 8th highest 24-hour $PM_{2.5}$ concentrations of 27.3 µg/m³, 21.8 µg/m³ and 18.5 µg/m³, respectively occur at the intersection of the TransCanada Highway and Highway 22. The maximum predicted $PM_{2.5}$ concentrations are less than the applicable AAAQG, AAAQO and CAAQS.

- Project Case—The highest 1-hour and 24-hour average concentrations for the Project Case occur along the PDA boundary. The maximum predicted 1-hour, 24-hour and 8th highest 24-hour $PM_{2.5}$ concentrations of 6.88 µg/m³, 4.14 µg/m³ and 0.641 µg/m³ occur along the east PDA boundary (Attachment A.1, Figure A.1-1, Figure A.1-3 and Figure A.1-5).

- Application Case—The highest 1-hour and 24-hour average concentrations for the Application Case occur on and near highways. The maximum predicted 1-hour, 24-hour and 8th highest 24-hour $PM_{2.5}$ concentrations of 27.3 µg/m³, 21.8 µg/m³ and 18.5 µg/m³, respectively occur at the intersection of the TransCanada Highway and Highway 22 (Attachment A.1, Figure A.1-2, Figure A.1-4 and Figure A.1-6).

The maximum predicted $PM_{2.5}$ concentrations are less than the AAAQG, AAAQO and the CAAQS for the Base Case, Project Case and Application Case. The Project contribution to maximum predicted $PM_{2.5}$ concentrations for the Application Case is small, ranging from 3% to 25%.

6.1.2 Maximum PM_{10} Concentrations

The following summarizes the modelling results for PM_{10} concentrations:

- Base Case—The highest 24-hour average concentrations for the Base Case occur on and near highways. The maximum predicted 24-hour PM_{10} concentration of 50.8 µg/m³ occurs at the intersection of the TransCanada Highway and Highway 22. Predicted PM_{10} concentrations greater than the 24-hour BC AAQO of 50 µg/m³ occur for up to one day per year near the intersection of the TransCanada Highway and Highway 22.
- Project Case—The highest 24-hour average concentrations for the Project Case occur along the PDA boundary. The maximum predicted 24-hour PM_{10} concentration of 54.0 µg/m³ occurs along the east PDA boundary (Attachment A.1, Figure A.1-7). Predicted PM_{10} concentrations greater than the 24-hour AAAQO of 50 µg/m³ occur for up to one day per year along the east PDA boundary (Attachment A.1, Figure A.1-8).
- Application Case—The highest 24-hour average concentrations for the Application Case occur along the PDA boundary and near highways. The maximum predicted 24-hour PM_{10} concentration of 78.4 µg/m³ occurs along the east PDA boundary (Attachment A.1, Figure A.1-9). Predicted PM_{10} concentrations greater than the 24 hour BC AAQO of 50 µg/m³ occur for up to 1 day per year near the intersection of the TransCanada Highway and Highway 22 and for up to two days per year along the east PDA boundary (Attachment A.1, Figure A.1-10). PM_{10} concentrations are predicted to be greater than the BC AAQO at 2 residence receptor locations near the east PDA boundary for up to one day per year.

The model predicts maximum 24-hour PM_{10} concentrations greater than the BC AAQO to occur approximately 150 m from the east PDA and near the intersection of the TransCanada Highway and Highway 22. Along the east PDA boundary, values greater than the BC AAQO are predicted for 2 days in a year, reducing to one day per year with increasing distance.

The 24-hour PM_{10} concentrations are predicted to be greater than the BC AAQO at two residence receptor locations near the east PDA boundary for up to 1 day per year.

The Project contribution to maximum predicted PM_{10} concentrations for the Application Case is approximately 69%.

6.1.3 Maximum TSP Concentrations

The following summarizes the modelling results for TSP concentrations:

- Base Case—The highest 24-hour average concentrations for the Base Case occur on and near highways. The maximum predicted 24-hour TSP concentration of 163 µg/m³ occurs at the intersection of the TransCanada Highway and Highway 22. Predicted TSP concentrations greater than the 24-hour AAAQO of 100 µg/m³ occur for up to 131 days per year near the intersection of the TransCanada Highway and Highway 22.
- Project Case—The highest 24-hour average concentrations for the Project Case occur along the PDA boundary. The maximum predicted 24-hour TSP concentration of 107 µg/m³ occurs along the east PDA boundary (Attachment A.1, Figure A.1-11). Predicted TSP concentrations greater than the 24-hour AAAQO of 100 µg/m³ occur for up to one day per year along the east PDA boundary (Attachment A.1, Figure A.1-12).
- Application Case—The highest 24-hour average concentrations for the Application Case occur along the PDA boundary and near highways. The maximum predicted 24-hour TSP concentration of 165 µg/m³ occurs along the east PDA boundary (Attachment A.1, Figure A.1-13). Predicted TSP concentrations greater than the 24-hour AAAQO of 100 µg/m³ occur for up to 131 days per year near the intersection of the TransCanada Highway and Highway 22 and up to two days per year along the east PDA boundary (Attachment A.1, Figure A.1-14).

The model predicts maximum 24-hour TSP concentrations greater than the AAAQO to occur approximately 150 m from the east PDA and near the intersection of the TransCanada Highway and Highway 22. Along the east PDA boundary, values greater than the AAAQO are predicted for two days in a year, reducing to one day per year with increasing distance.

The 24-hour TSP concentrations are predicted to be greater than the AAAQO at two residence receptor locations near the east PDA boundary for up to one day per year.

The Project contribution to maximum predicted TSP concentrations for the Application Case is approximately 65%.

Table 6-1 Maximum Predicted Ground-Level Concentrations for the 1:100 Year Flood Scenario

Substance	Averaging Period	Background Concentration	Ambient Criteria [a]	Base Case (includes Background Concentrations)			Project Case			Application Case (includes Background Concentrations)			Percent Contribution of Project to Application Case
				Maximum Concentration	Percent of Ambient Criteria	Maximum Frequency above Ambient Criteria	Maximum Concentration	Percent of Ambient Criteria	Maximum Frequency above Ambient Criteria	Maximum Concentration	Percent of Ambient Criteria	Maximum Frequency above Ambient Criteria [f]	
		(µg/m³)	(µg/m³)	(µg/m³)	%	(h/a or d/a)	(µg/m³)	%	(h/a or d/a)	(µg/m³)	%	(h/a or d/a)	%
$PM_{2.5}$	1-hour [d]	11.0	80	27.3	34	0	6.88	9	0	27.3	34	0	25
	24-hour	11.0	30	21.8	73	0	4.15	14	0	21.8	73	0	19
	24-hour [e]	11.0	28 [b]	18.5	66	0	0.641	2	0	18.5	66	0	3
PM_{10}	24-hour	22.4	50 [c]	50.8	**102**	1 d/a	54.0	**108**	1 d/a	78.4	**157**	2 d/a (1 d/a)	69
TSP	24-hour	51.0	100	163	**163**	131 d/a	107	**107**	1 d/a	165	**165**	2 d/a (131 d/a)	65

NOTES:
[a] AAAQO/G: Alberta Ambient Air Quality Objectives and Guidelines (AEP 2017)
[b] CAAQS: Canadian Ambient Air Quality Standards (ECCC 2013 and CCME 2014)
[c] BC AAQO: British Columbia Ambient Air Quality Objectives (BC MOE 2016)
[d] Concentration represents the 9th highest 1-hour concentration
[e] Concentration represents the 3-year average of the annual 8th highest 24-hour average concentrations
[f] The first value represents maximum frequency above ambient criteria near the east PDA boundary; the value in brackets represents maximum frequency near the intersection of the TransCanada Highway and Highway 22.
Percent values greater than 100% are in **bold** text.

6.2 RESULTS FOR THE DESIGN FLOOD

The predicted maximum ambient concentrations of $PM_{2.5}$, PM_{10} and TSP for the design flood are summarized in Table 6-2. Concentration isopleth maps for the design flood scenario (Project Case and Application Case) are included in Attachment A.2.

6.2.1 Maximum $PM_{2.5}$ Concentrations

The following summarizes modelling results for $PM_{2.5}$ concentrations:

- Base Case—The highest 1-hour and 24-hour average concentrations for the Base Case occur on and near highways. The maximum predicted 1-hour, 24-hour and 8th highest 24-hour $PM_{2.5}$ concentrations of 27.3 µg/m^3, 21.8 µg/m^3 and 18.5 µg/m^3, respectively occur at the intersection of the TransCanada Highway and Highway 22. The maximum predicted $PM_{2.5}$ concentrations are less than the applicable AAAQG, AAAQO and CAAQS.

- Project Case—The highest 1-hour and 24-hour average concentrations for the Project Case occur near highways and along the PDA boundary. The maximum predicted 1-hour, 24-hour and 8th highest 24-hour $PM_{2.5}$ concentrations of 15.2 µg/m^3, 9.59 µg/m^3 and 1.62 µg/m^3, respectively occur along the east PDA boundary (Attachment A.2, Figure A.2-1, Figure A.2-3 and Figure A.2-5).

- Application Case—The highest 1-hour and 24-hour average concentrations for the Application Case occur near highways and long the PDA boundary. The maximum predicted 1-hour $PM_{2.5}$ concentration of 27.6 µg/m^3 occurs along the east PDA boundary. The maximum predicted 24-hour and 8th highest 24-hour $PM_{2.5}$ concentrations of 21.8 µg/m^3 and 18.5 µg/m^3 occur at the intersection of the TransCanada Highway and Highway 22 (Attachment A.2, Figure A.2-2, Figure A.2-4 and Figure A.2-6).

The maximum predicted $PM_{2.5}$ concentrations are less than the AAAQG, AAAQO and the CAAQS for the Base Case, Project Case and Application Case. The Project contribution to maximum predicted $PM_{2.5}$ concentrations for the Application Case is less than approximately 50%.

6.2.2 Maximum PM_{10} Concentrations

The following summarizes the modelling results for PM_{10} concentrations:

- Base Case—The highest 24-hour average concentrations for the Base Case occur on and near highways. The maximum predicted 24-hour PM_{10} concentration of 50.8 µg/m³ occurs at the intersection of the TransCanada Highway and Highway 22. Predicted PM_{10} concentrations greater than the 24-hour BC AAQO of 50 µg/m³ occur for up to one day per year near the intersection of the TransCanada Highway and Highway 22.
- Project Case—The highest 24-hour average concentrations for the Project Case occur along the PDA boundary. The maximum predicted 24-hour PM_{10} concentration of 124 µg/m³ occurs along the east PDA boundary (Attachment A.2, Figure A.2-7). Predicted PM_{10} concentrations greater than the 24-hour AAAQO of 50 µg/m³ occur for up to four days per year along the east PDA boundary (Attachment A.2, Figure A.2-8).
- Application Case—The highest 24-hour average concentrations for the Application Case occur near highways and along the PDA boundary. The maximum predicted 24-hour PM_{10} concentration of 149 µg/m³ occurs along the east PDA boundary (Attachment A.2, Figure A.2-9). Predicted PM_{10} concentrations greater than the 24 hour BC AAQO of 50 µg/m³ occur for up to one day per year near the intersection of the TransCanada Highway and Highway 22 and for up to eight days per year along the east PDA boundary (Attachment A.2, Figure A.2-10). PM_{10} concentrations are predicted to be greater than the BC AAQO at 5 residence receptor locations near the east PDA boundary for up to five days per year.

The model predicts maximum 24-hour PM_{10} concentrations greater than the BC AAQO to occur approximately 550 m from the east PDA and near the intersection of the TransCanada Highway and Highway 22. Along the east PDA boundary, values greater than the BC AAQO are predicted for eight days in a year, reducing to one day per year with increasing distance.

The 24-hour PM_{10} concentrations are predicted to be greater than the BC AAQO at five residence receptor locations near the east PDA boundary for up to five days per year.

The Project contribution to maximum predicted PM_{10} concentrations for the Application Case is approximately 84%.

6.2.3 Maximum TSP Concentrations

The following summarizes the modelling results for TSP concentrations:

- Base Case—The highest 24-hour average concentrations for the Base Case occur on and near highways. The maximum predicted 24-hour TSP concentration of 163 µg/m³ occurs at the intersection of the TransCanada Highway and Highway 22. Predicted TSP concentrations greater than the 24-hour AAAQO of 100 µg/m³ occur for up to 131 days per year near the intersection of the TransCanada Highway and Highway 22.
- Project Case—The highest 24-hour average concentrations for the Project Case occur along the PDA boundary. The maximum predicted 24-hour TSP concentration of 245 µg/m³ occurs along the east PDA boundary (Attachment A.2, Figure A.2-11). Predicted TSP concentrations greater than the 24-hour AAAQO of 100 µg/m³ occur for up to four days per year along the east PDA boundary (Attachment A.2, Figure A.2-12).
- Application Case—The highest 24-hour average concentrations for the Application Case occur near highways and along the PDA boundary. The maximum predicted 24-hour TSP concentration of 303 µg/m³ occurs along the east PDA boundary (Attachment A.2, Figure A.2-13). Predicted TSP concentrations greater than the 24-hour AAAQO of 100 µg/m³ occur for up to 131 days per year near the intersection of the TransCanada Highway and Highway 22 and up to 10 days per year along the east PDA boundary (Attachment A.2, Figure A.2-14).

The model predicts maximum 24-hour TSP concentrations greater than the AAAQO to occur approximately 550 m from the east PDA and near the intersection of the TransCanada Highway and Highway 22. Along the east PDA boundary, values greater than the AAAQO are predicted for 10 days in a year, reducing to one day per year with increasing distance.

The 24-hour TSP concentrations are predicted to be greater than the AAAQO at six residence receptor locations near the east PDA boundary for up to seven days per year.

The Project contribution to maximum predicted TSP concentrations for the Application Case is approximately 81%.

Table 6-2 Maximum Predicted Ground-Level Concentrations for the Design Flood (approximately 1:200 year flood)

Substance	Averaging Period	Background Concentration	Ambient Criteria [a]	Base Case (includes Background Concentrations)			Project Case			Application Case (includes Background Concentrations)			Percent Contribution of Project to Application Case
				Maximum Concentration	Percent of Ambient Criteria	Maximum Frequency above Ambient Criteria	Maximum Concentration	Percent of Ambient Criteria	Maximum Frequency above Ambient Criteria	Maximum Concentration	Percent of Ambient Criteria	Maximum Frequency above Ambient Criteria [f]	
		(µg/m³)	(µg/m³)	(µg/m³)	%	(h/a or d/a)	(µg/m³)	%	(h/a or d/a)	(µg/m³)	%	(h/a or d/a)	%
$PM_{2.5}$	1-hour [d]	11.0	80	27.3	34	0	15.2	19	0	27.6	34	0	55
	24-hour	11.0	30	21.8	73	0	9.59	32	0	21.8	73	0	44
	24-hour [e]	11.0	28 [b]	18.5	66	0	1.62	6	0	18.5	66	0	9
PM_{10}	24-hour	22.4	50 [c]	50.8	**102**	1 d/a	124	**248**	4 d/a	149	**297**	8 d/a (1 d/a)	84
TSP	24-hour	51.0	100	163	**163**	131 d/a	245	**245**	4 d/a	303	**303**	10 d/a (131 d/a)	81

NOTES:
[a] AAAQO/G: Alberta Ambient Air Quality Objectives and Guidelines (AEP 2017)
[b] CAAQS: Canadian Ambient Air Quality Standards (ECCC 2013 and CCME 2014)
[c] BC AAQO: British Columbia Ambient Air Quality Objectives (BC MOE 2016)
[d] Concentration represents the 9th highest 1-hour concentration
[e] Concentration represents the 3-year average of the annual 8th highest 24-hour average concentrations
[f] The first value represents maximum frequency above ambient criteria near the east PDA boundary; the value in brackets represents maximum frequency near the intersection of the TransCanada Highway and Highway 22.
Percent values greater than 100% are in **bold** text.

7.0 CONCLUSIONS

The estimated fugitive dust emissions from wind erosion of the sediment employ a number of conservative assumptions. In addition, the project fugitive dust emissions are within the range of measured emission fluxes from similar surfaces in the Athabasca Oil Sands Region with comparable threshold friction velocity and level of disturbance (Watson et al. 2014). Therefore, the estimated emissions are believed to represent realistically peak dust emissions during high wind speed events. The use of conservative assumptions can lead to conservative model predictions and therefore the model results are interpreted with the understanding that the predicted effects likely would not be exceeded.

A primary mitigation for dust emissions from wind erosion in the off-stream reservoir would be the re-establishment of vegetation cover (e.g., native grasses) after reservoir drainage. In short term, the revegetation could be ineffective due to initial high moisture content and reduced energy input in the autumn and therefore, a tackifier would be applied where required. A dust control efficiency of 84% is applied to fugitive dust emissions corresponding to application of a chemical dust suppressant. In long term (greater than one year), it is assumed that revegetation would effectively eliminate the potential for windblown emissions.

With implementation of the mitigation measures, the change in ambient air quality related to post-flood operation is expected to be minimal. The adaptive management nature of the fugitive dust mitigations is expected to be adequate to control fugitive dust to low levels that do not have appreciable adverse environmental effects. In long term (greater than one year), it is expected that revegetation would effectively eliminate the potential for windblown emissions.

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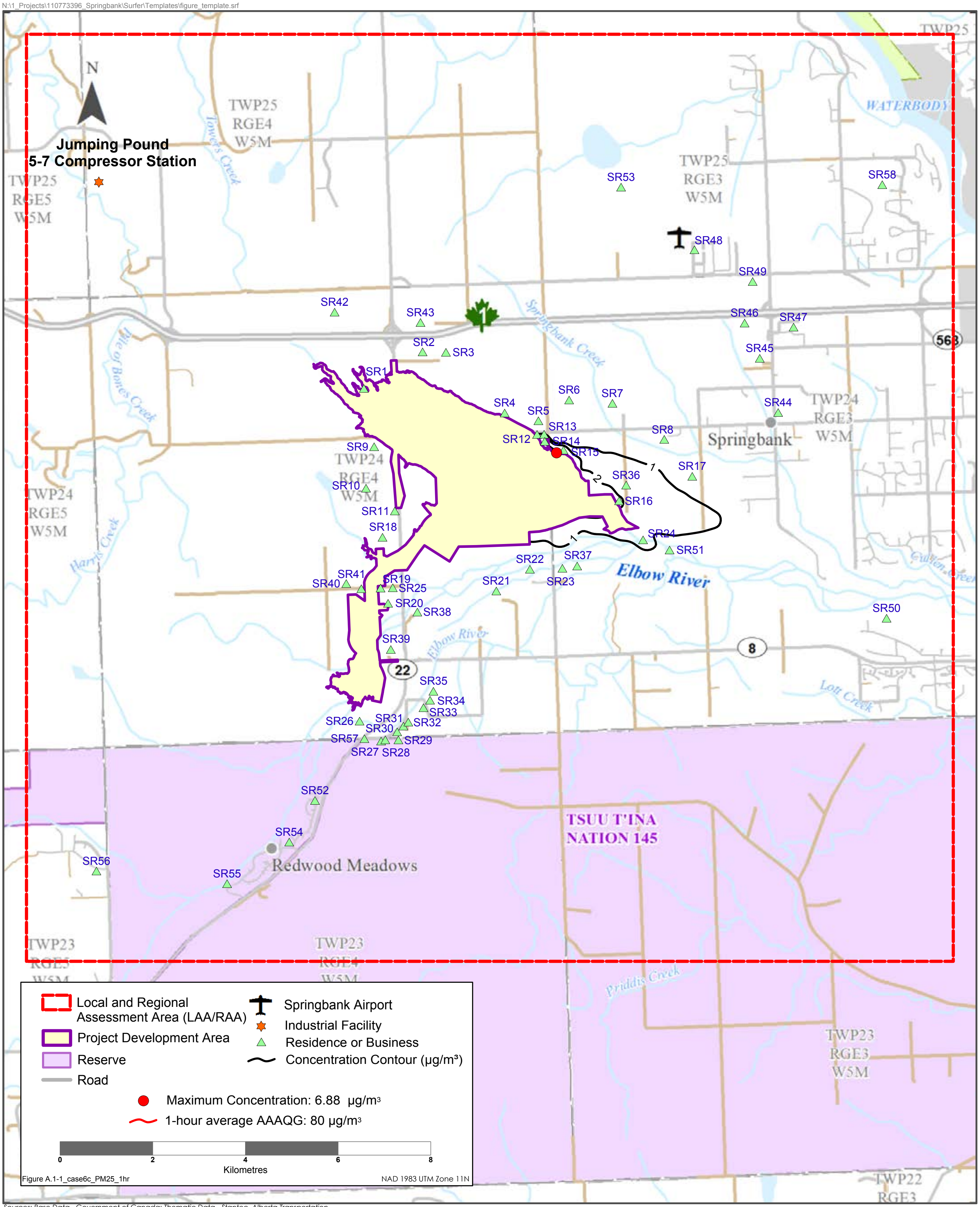
Attachment A CONCENTRATION ISOPLETH MAPS

A.1 1:100 YEAR FLOOD SCENARIO



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Predicted 9th Highest 1-hour average $PM_{2.5}$ Concentration (1:100 Year Flood - Project Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure A.1-1

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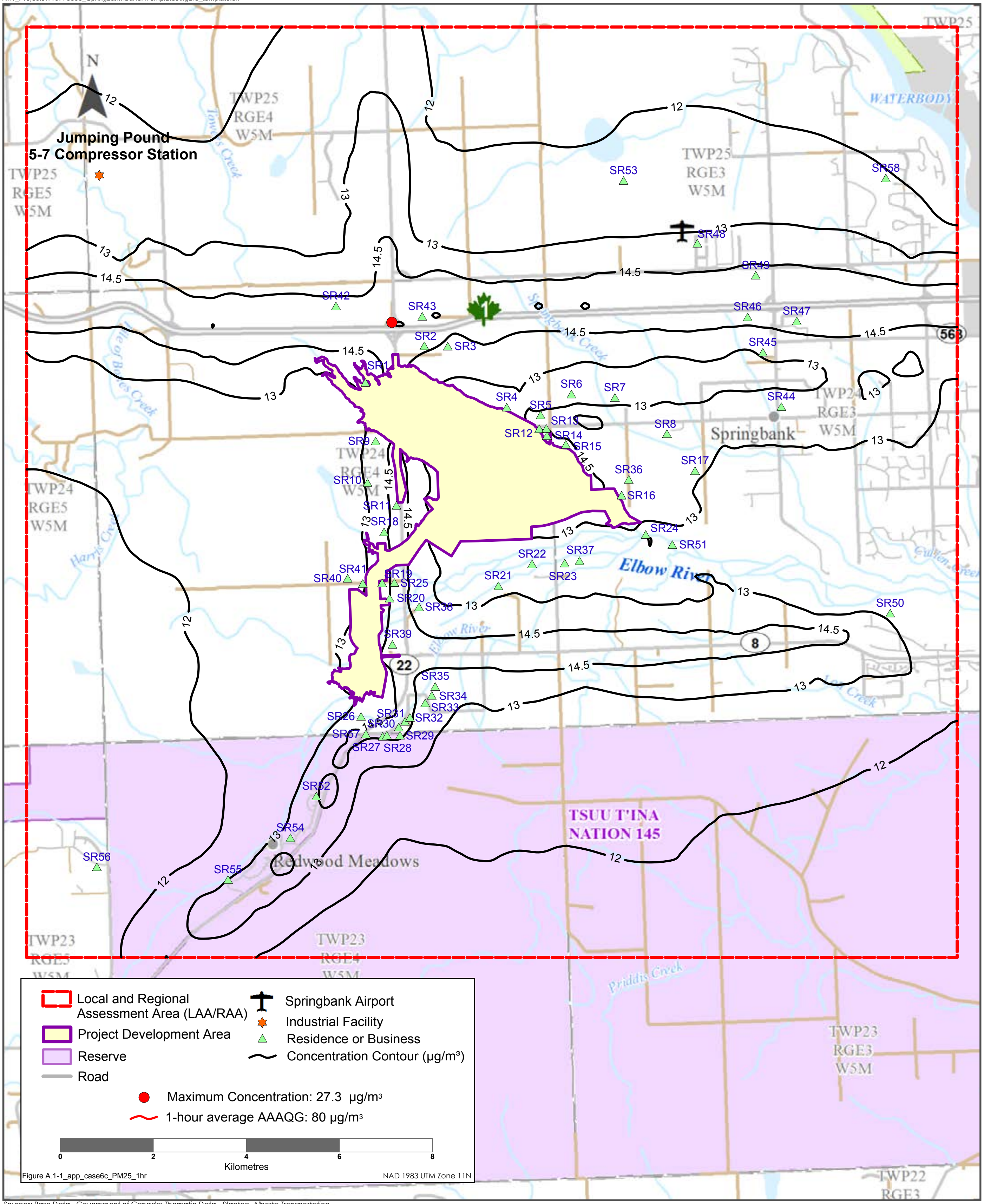

Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Predicted 9th Highest 1-hour average $PM_{2.5}$ Concentration (1:100 Year Flood - Application Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure A.1-2

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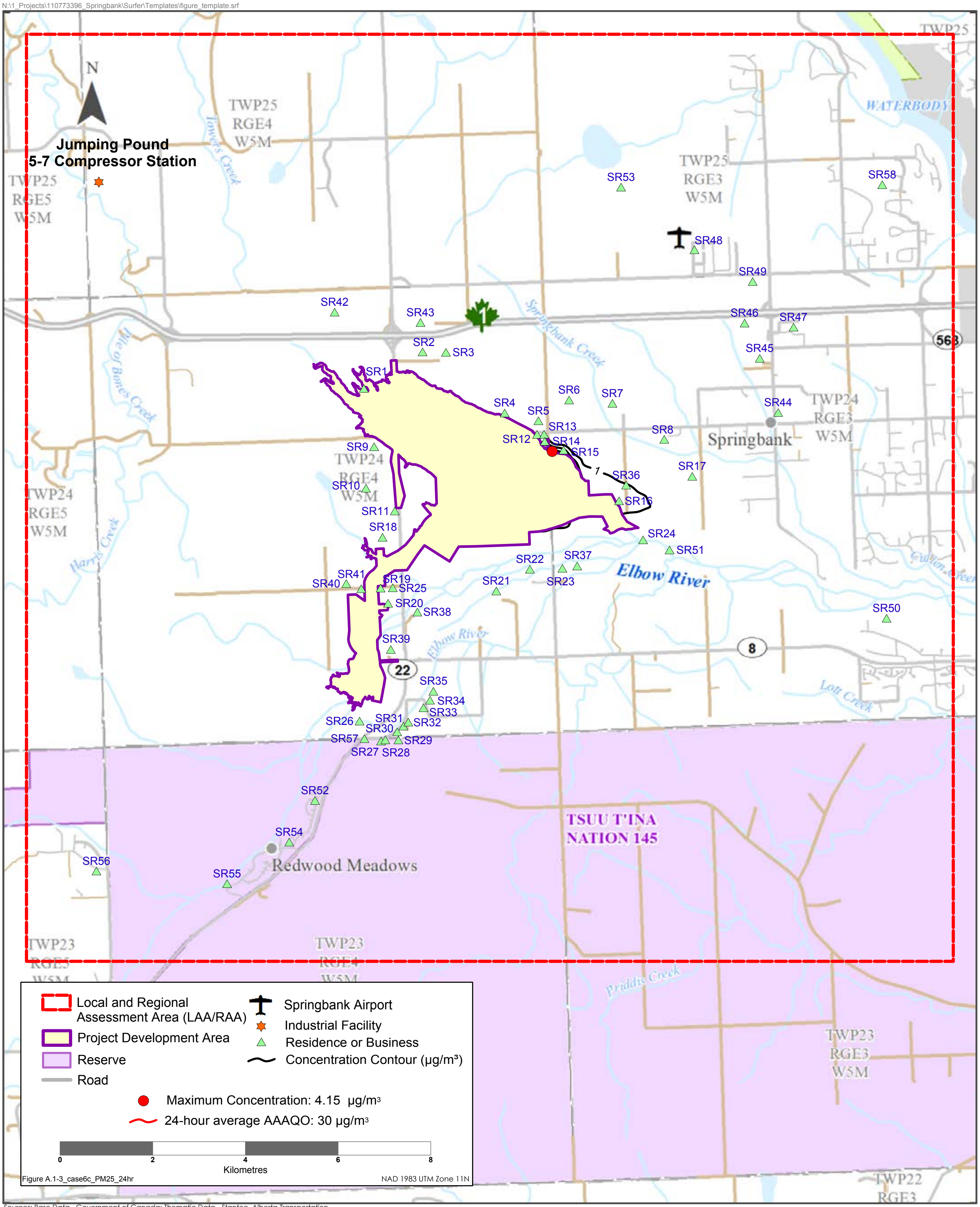

Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Maximum Predicted 24-hour average $PM_{2.5}$ Concentration (1:100 Year Flood - Project Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure A.1-3

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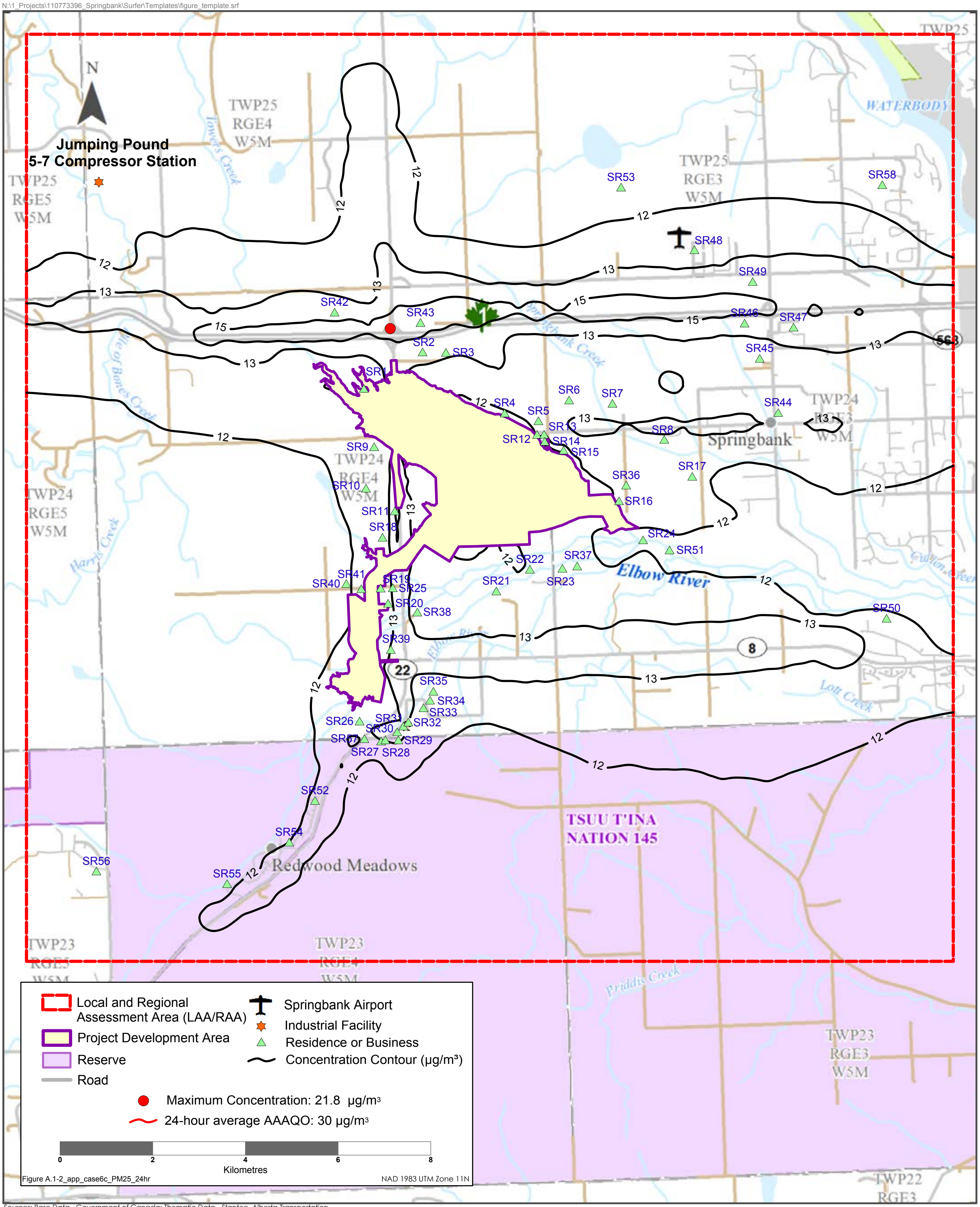


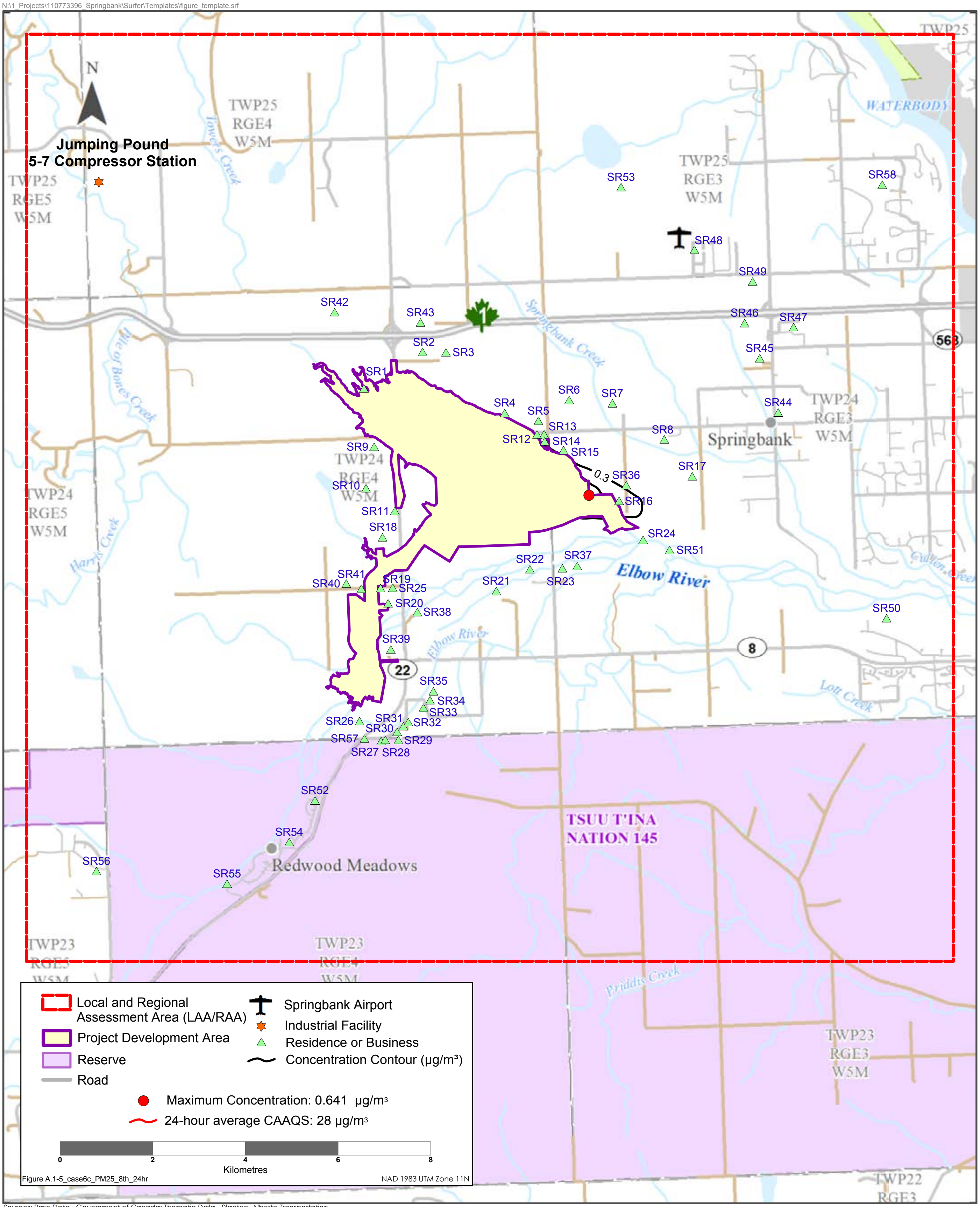
Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Maximum Predicted 24-hour average $PM_{2.5}$ Concentration (1:100 Year Flood - Application Case)

Stantec

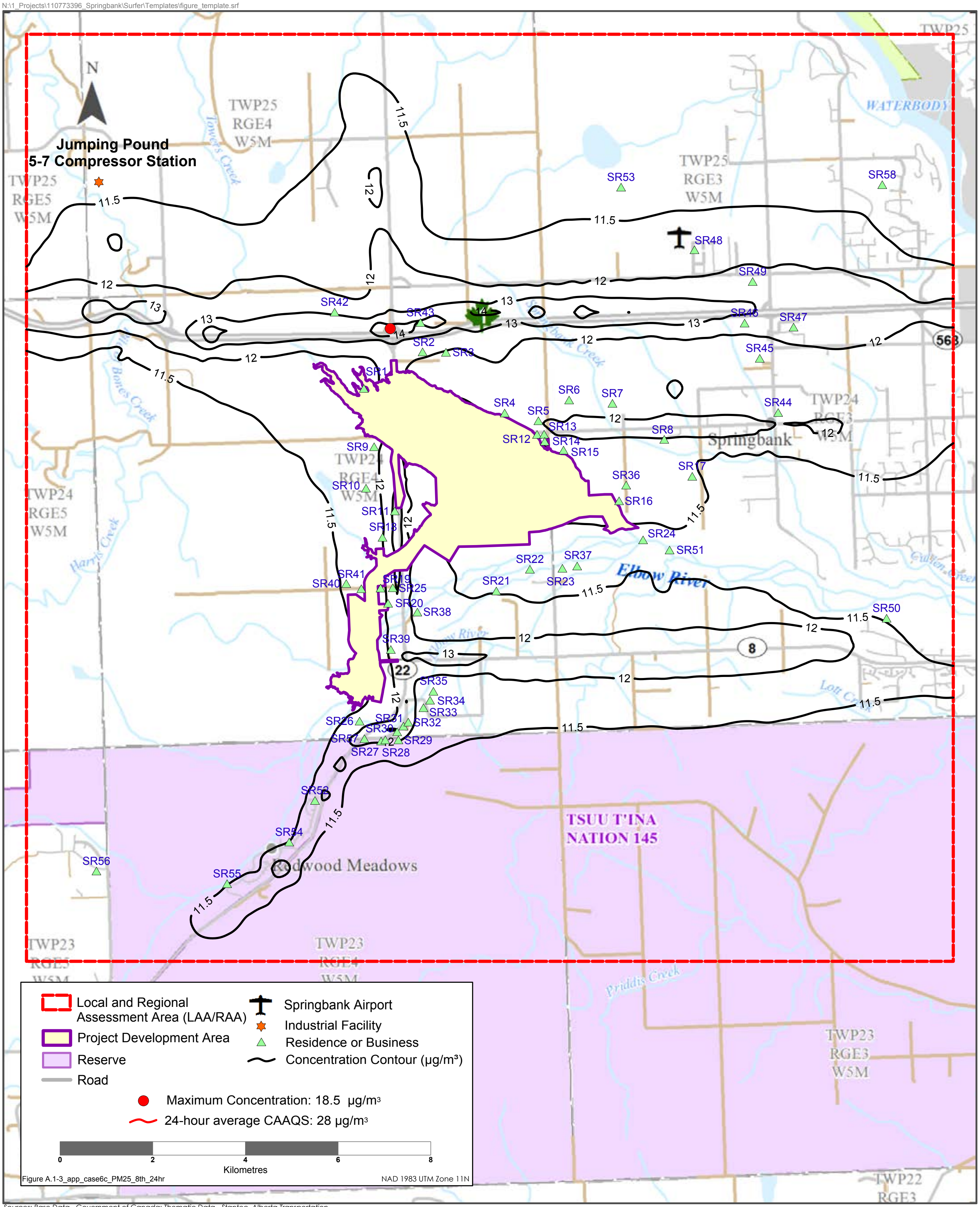
SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure A.1-4



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Predicted 8th Highest 24-hour average $PM_{2.5}$ Concentration (1:100 Year Flood - Project Case)



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Predicted 8th Highest 24-hour average $PM_{2.5}$ Concentration (1:100 Year Flood - Application Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure A.1-6

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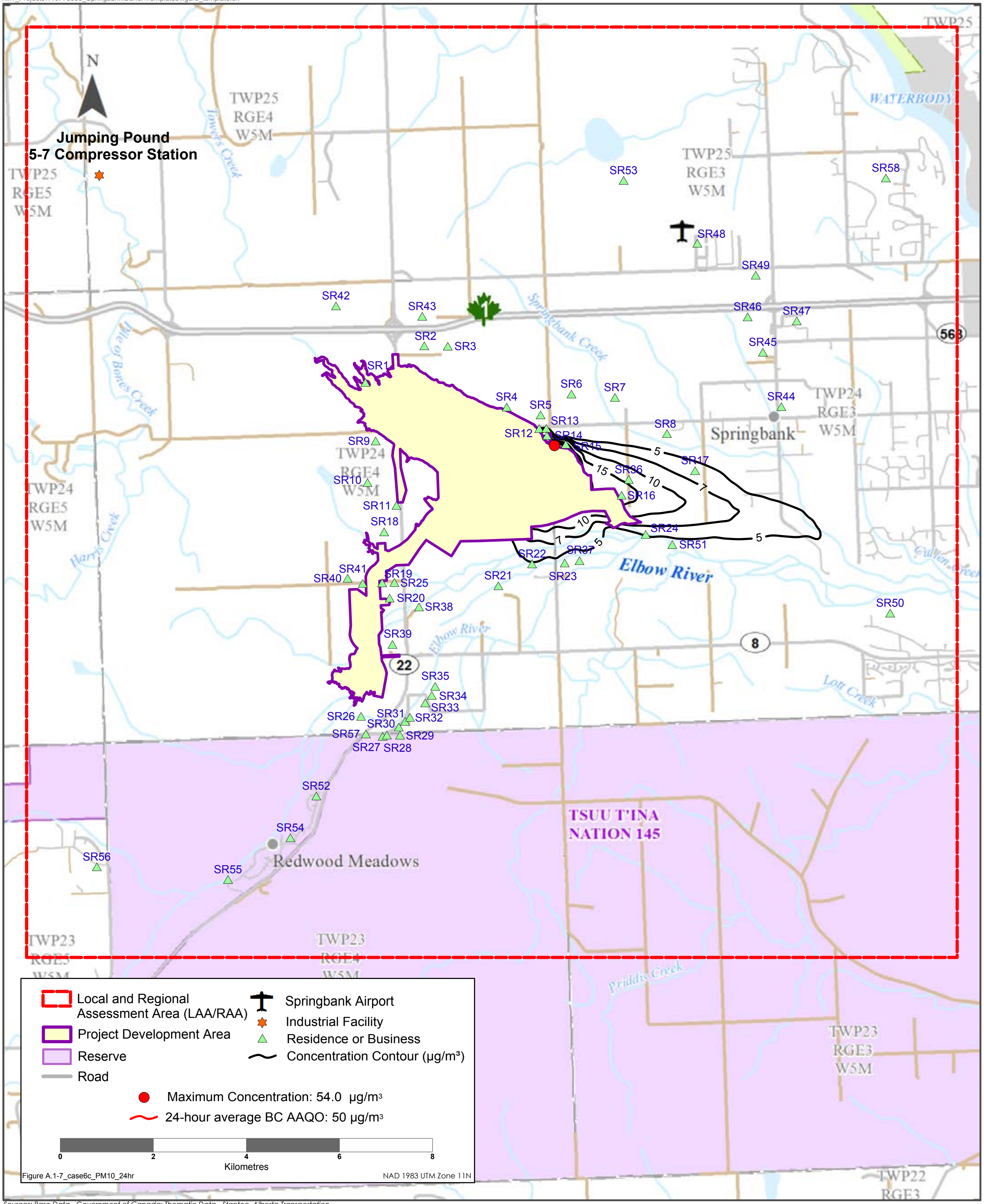

Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Maximum Predicted 24-hour average PM_{10} Concentration (1:100 Year Flood - Project Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure A.1-7

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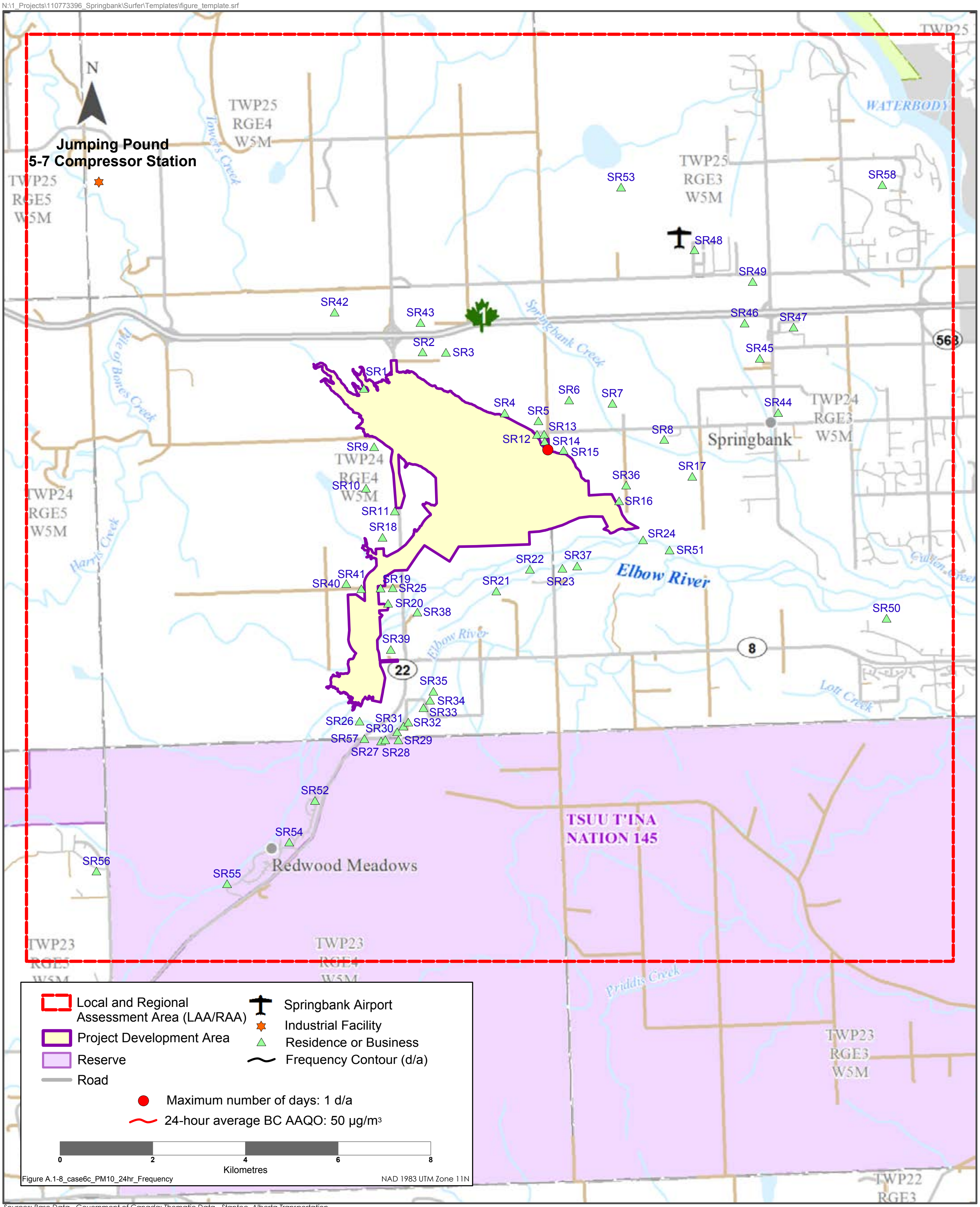

Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Frequency of Predicted 24-hour average PM_{10} Concentration greater than the BC AAQO (1:100 Year Flood - Project Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure A.1-8

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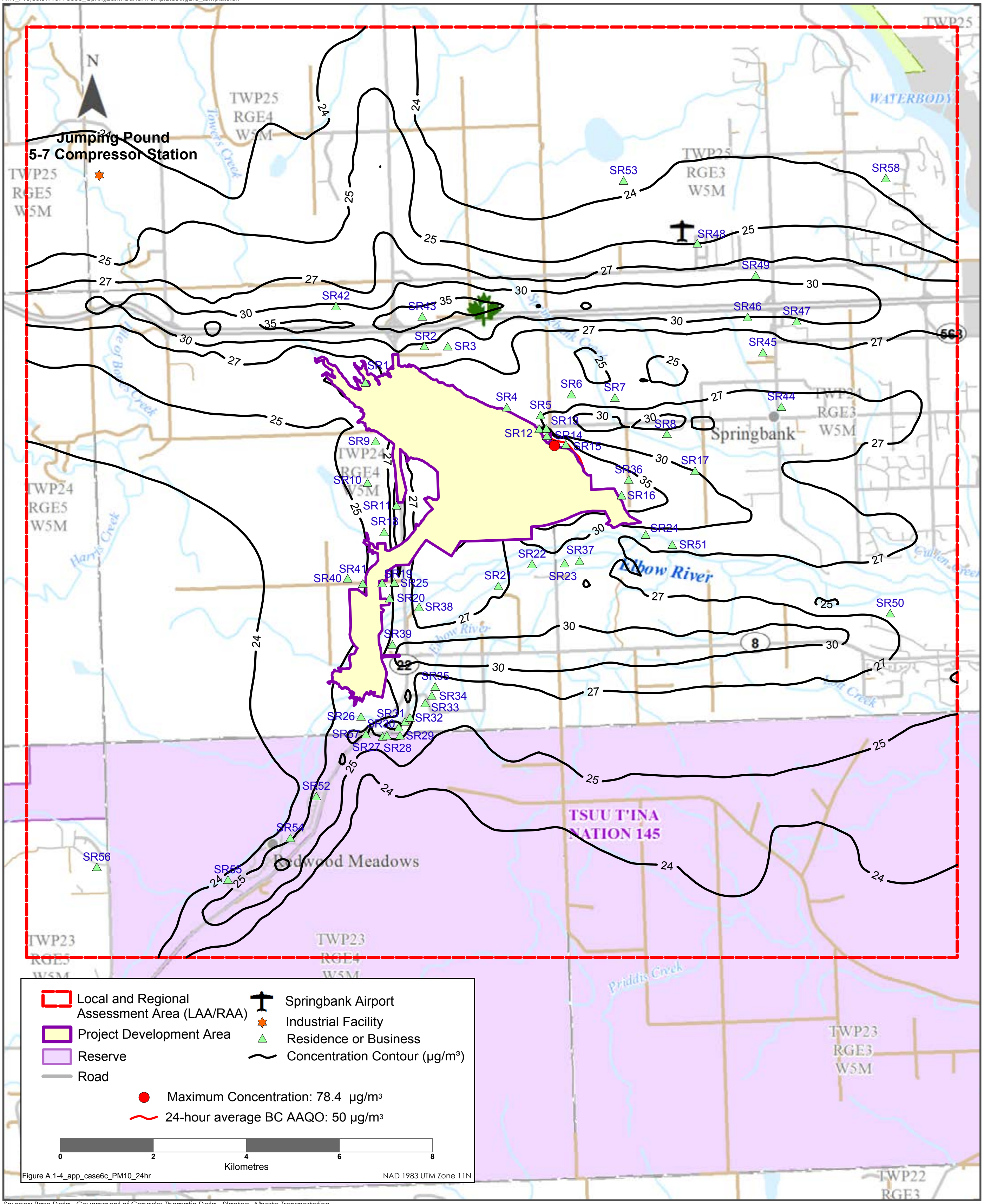

Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Maximum Predicted 24-hour average PM_{10} Concentration (1:100 Year Flood - Application Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure A.1-9

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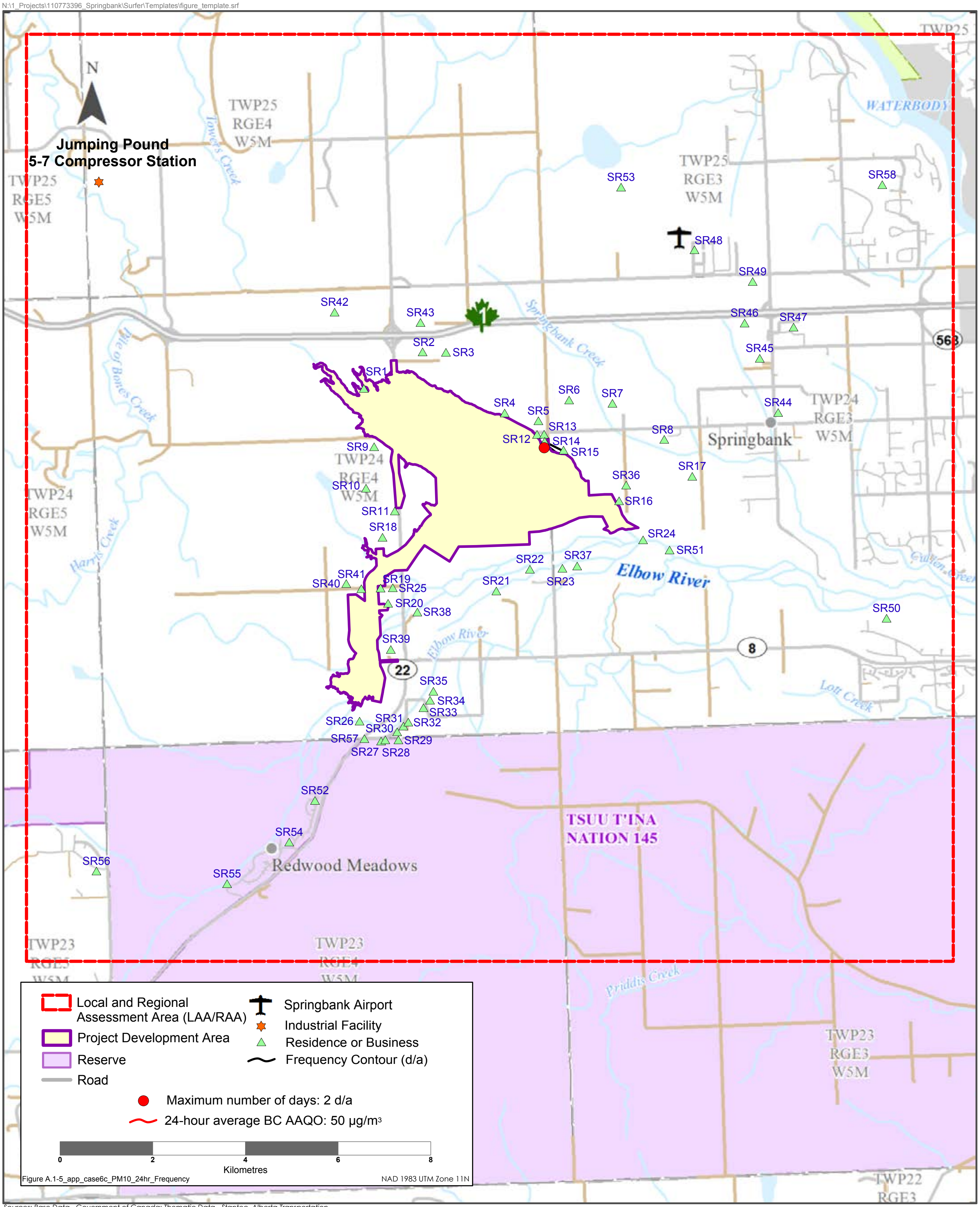

Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Frequency of Predicted 24-hour average PM_{10} Concentration greater than the BC AAQO (1:100 Year Flood - Application Case)

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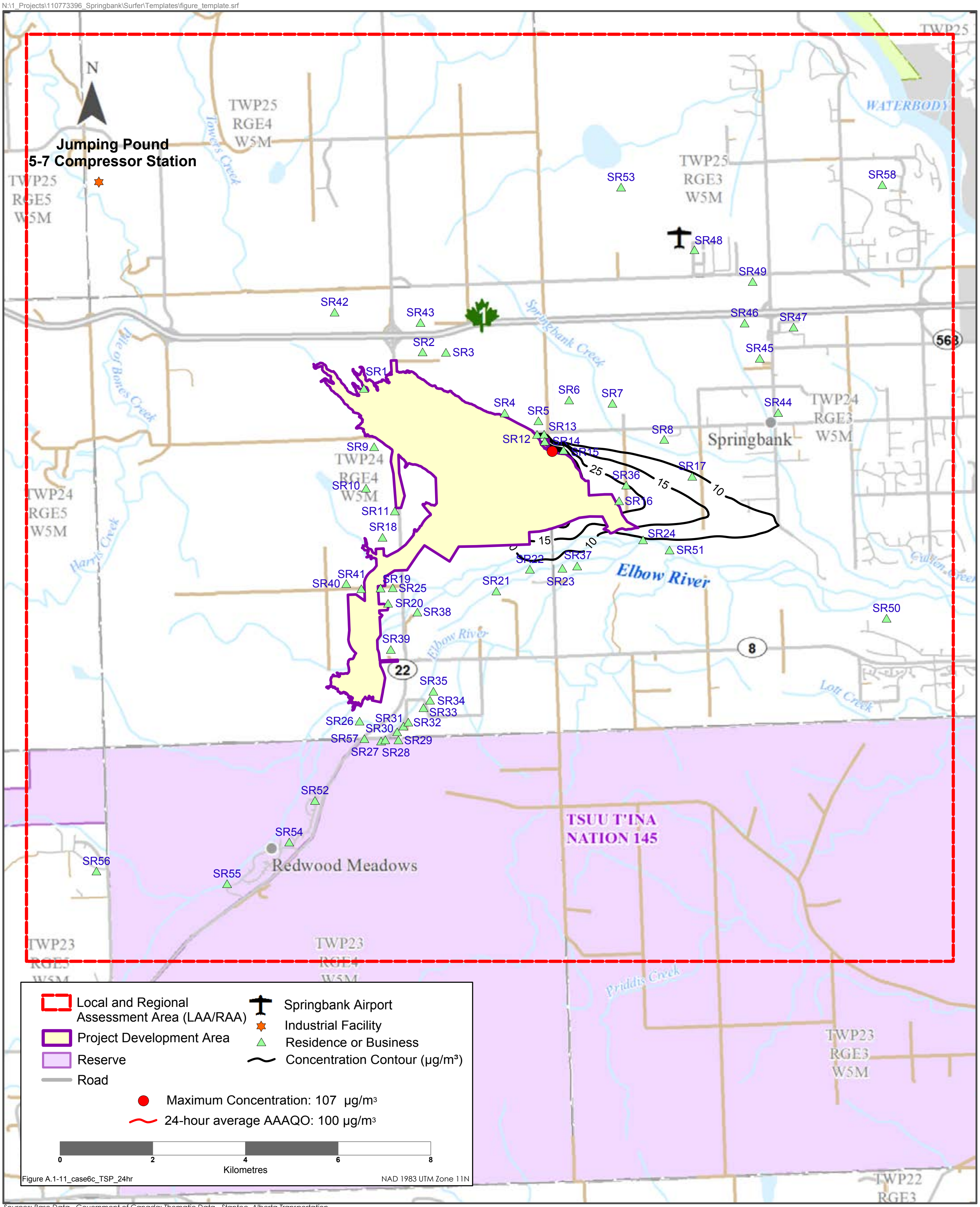

Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Maximum Predicted 24-hour average TSP Concentration (1:100 Year Flood - Project Case)

Stantec

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Figure A.1-11

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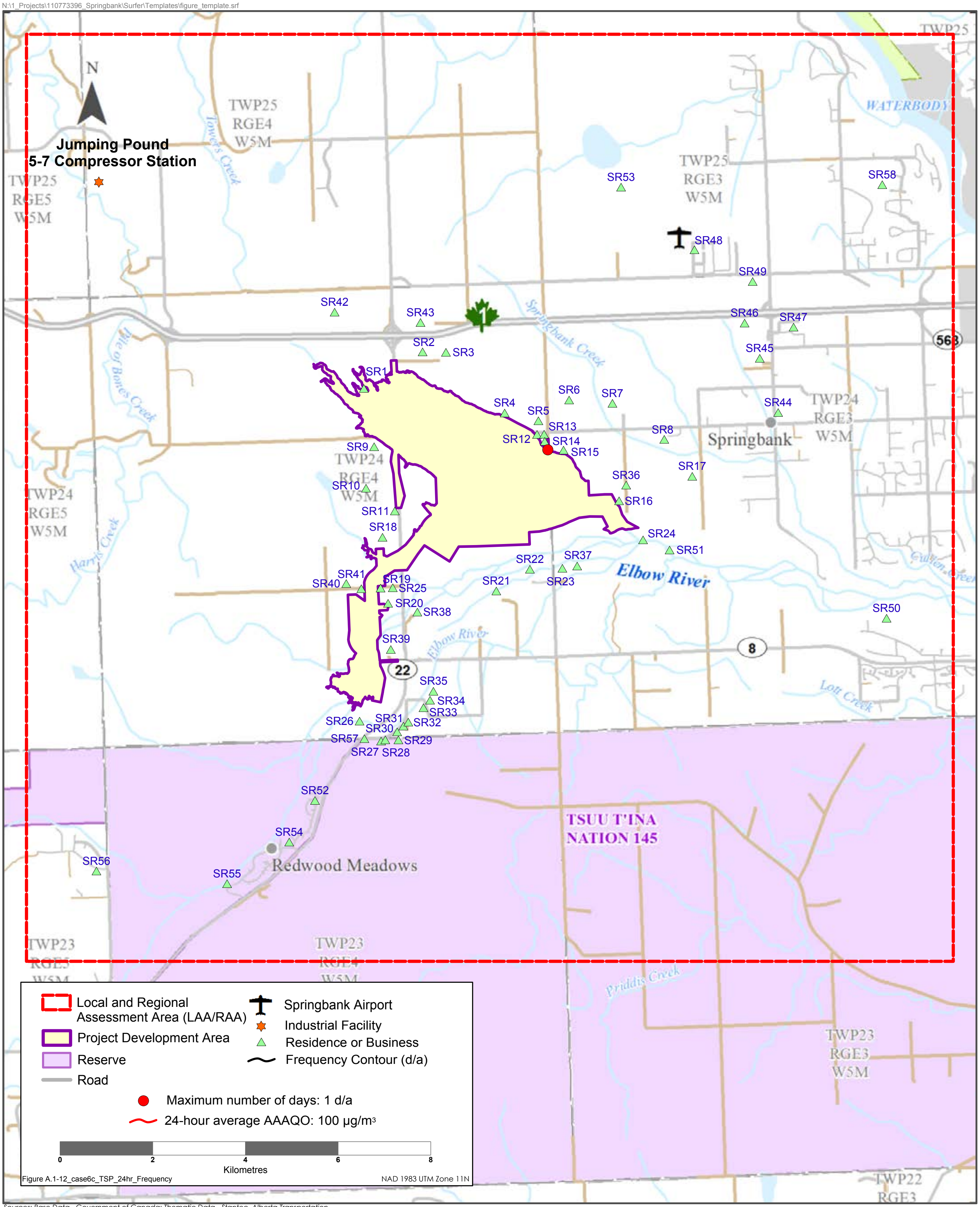


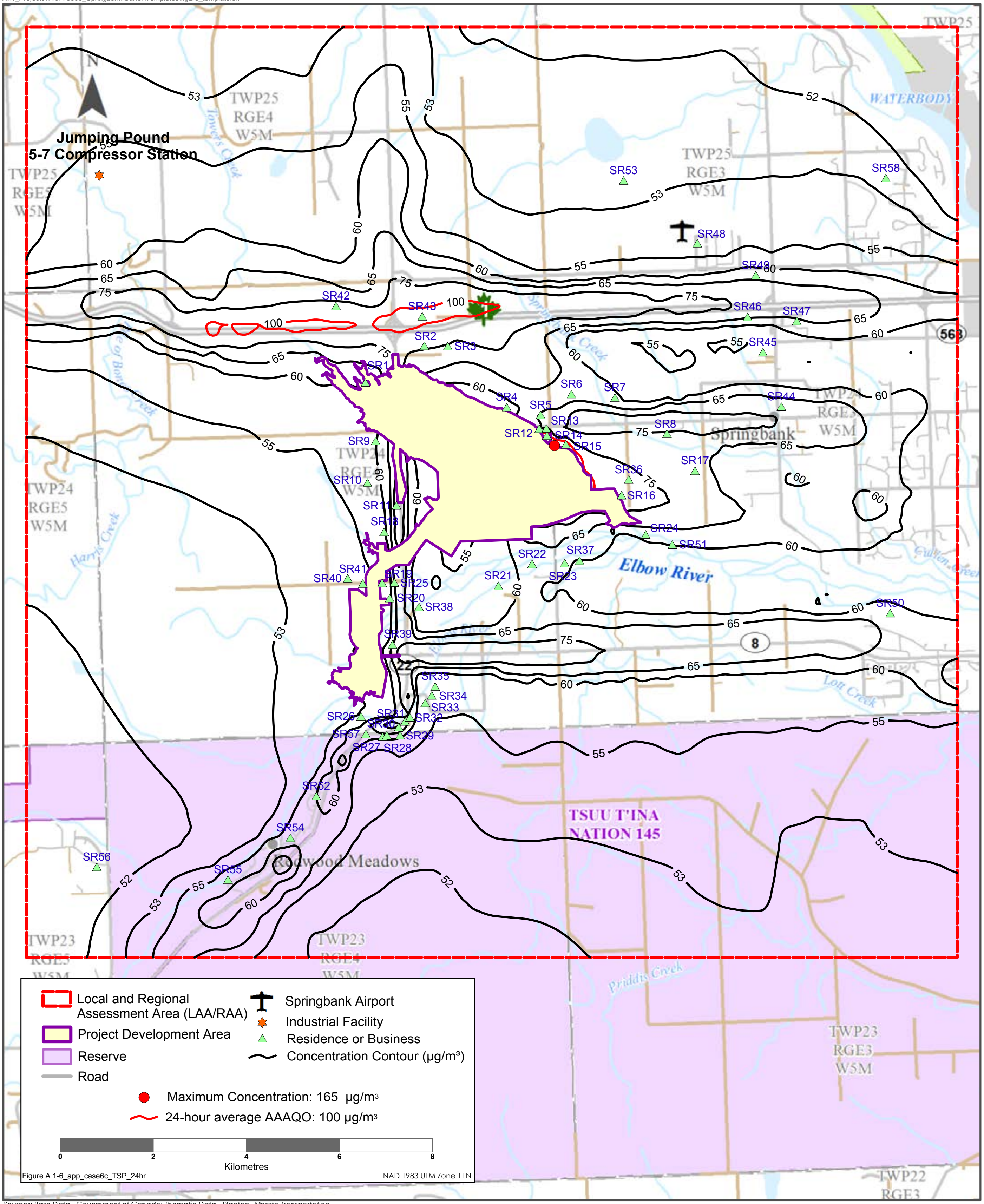
Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Frequency of Predicted 24-hour average TSP Concentration greater than the AAAQO (1:100 Year Flood - Project Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure A.1-12



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Maximum Predicted 24-hour average TSP Concentration (1:100 Year Flood - Application Case)

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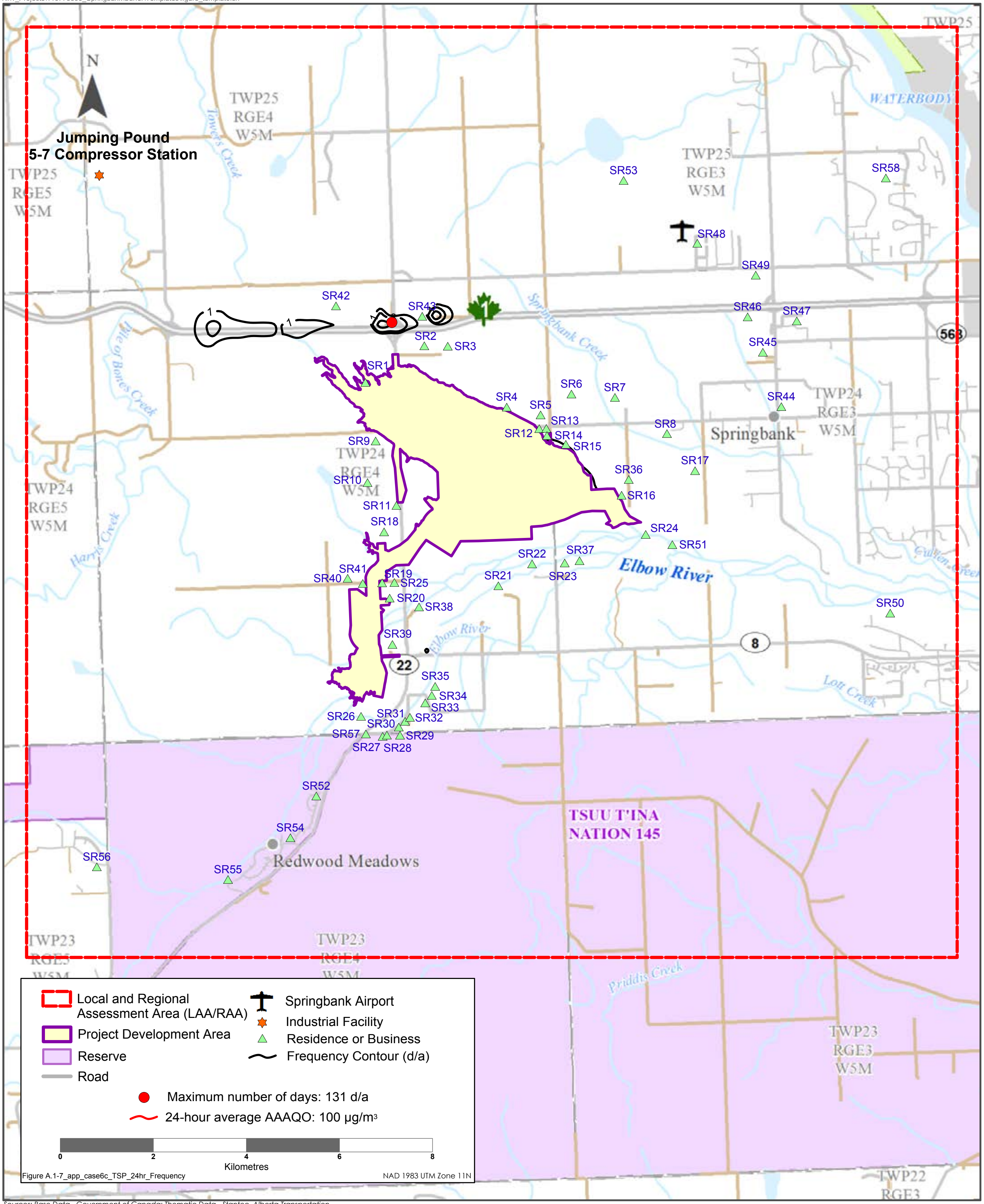

Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Frequency of Predicted 24-hour average TSP Concentration greater than the AAAQO (1:100 Year Flood - Application Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure A.1-14

A.2 1:200 YEAR FLOOD SCENARIO

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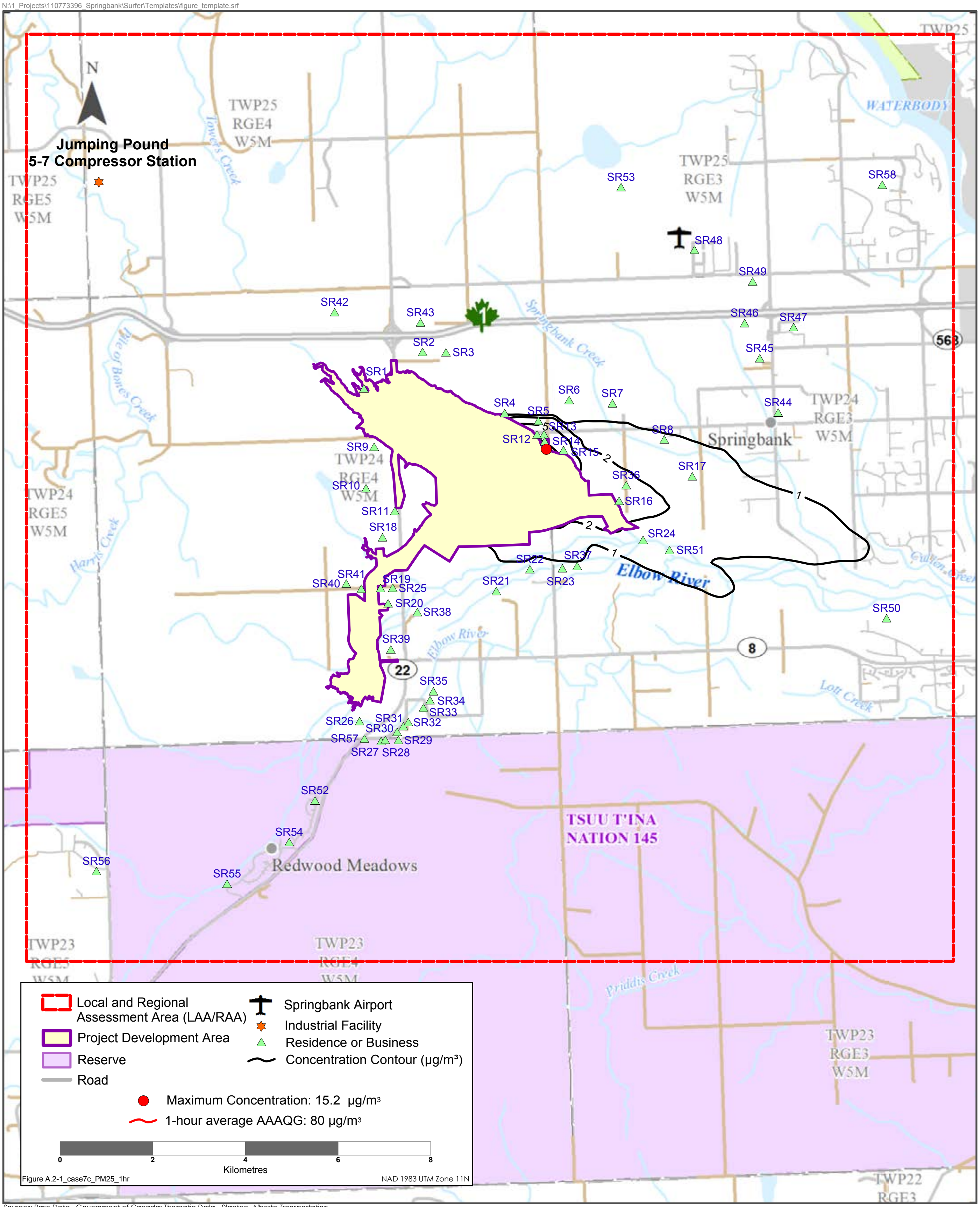

Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Predicted 9th Highest 1-hour average $PM_{2.5}$ Concentration (1:200 Year Flood - Project Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure A.2-1

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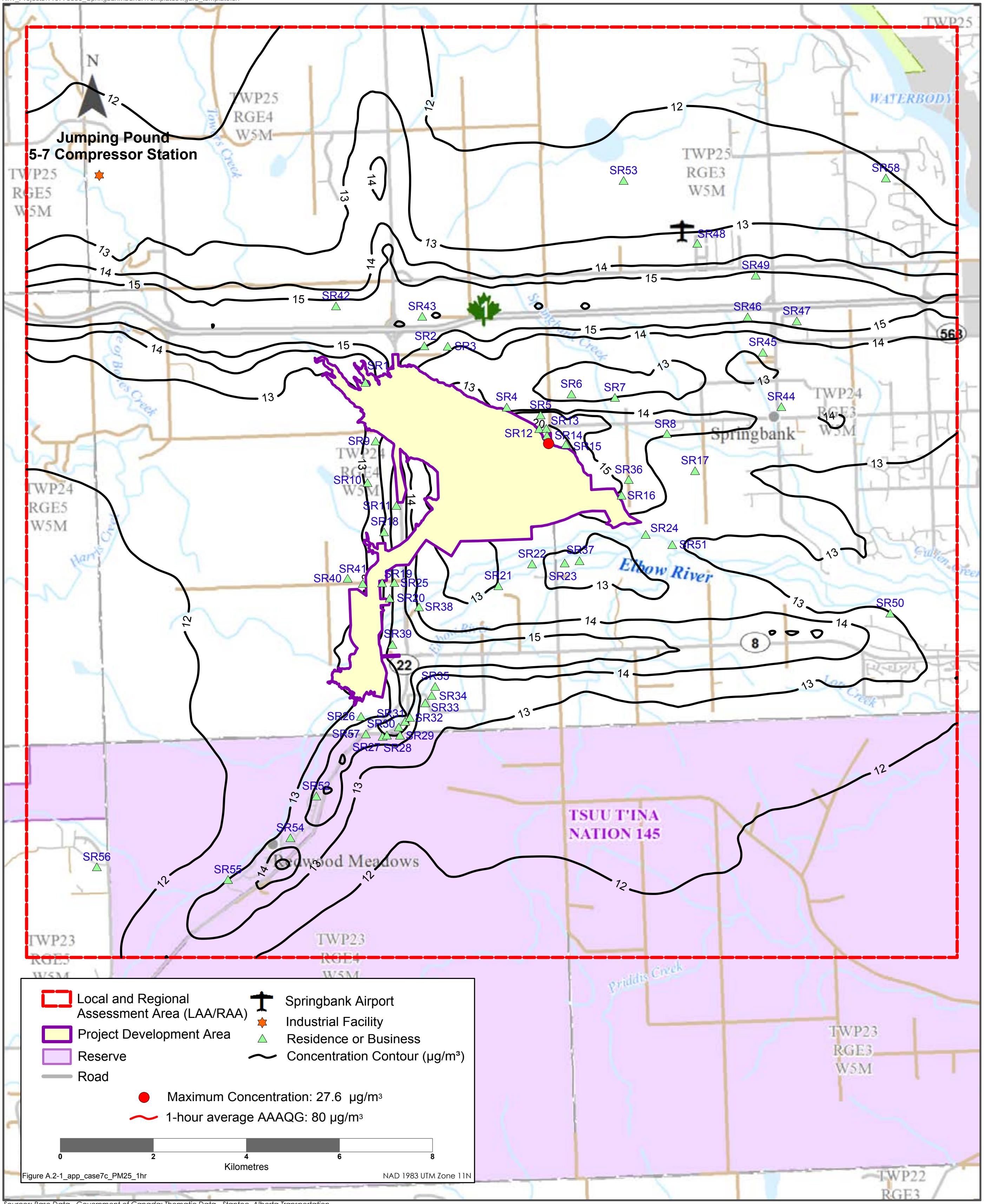


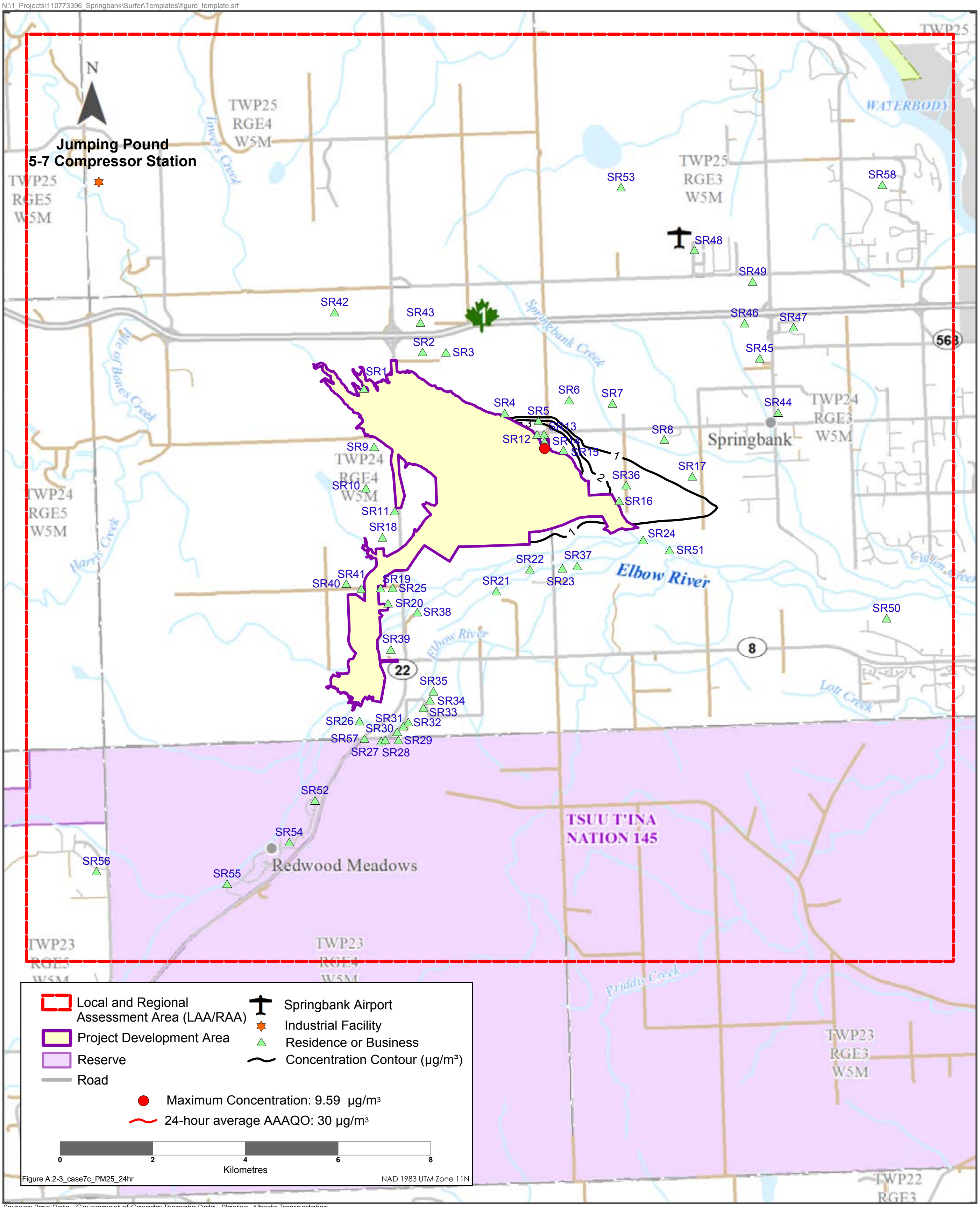
Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Predicted 9th Highest 1-hour average $PM_{2.5}$ Concentration (1:200 Year Flood - Application Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure A.2-2



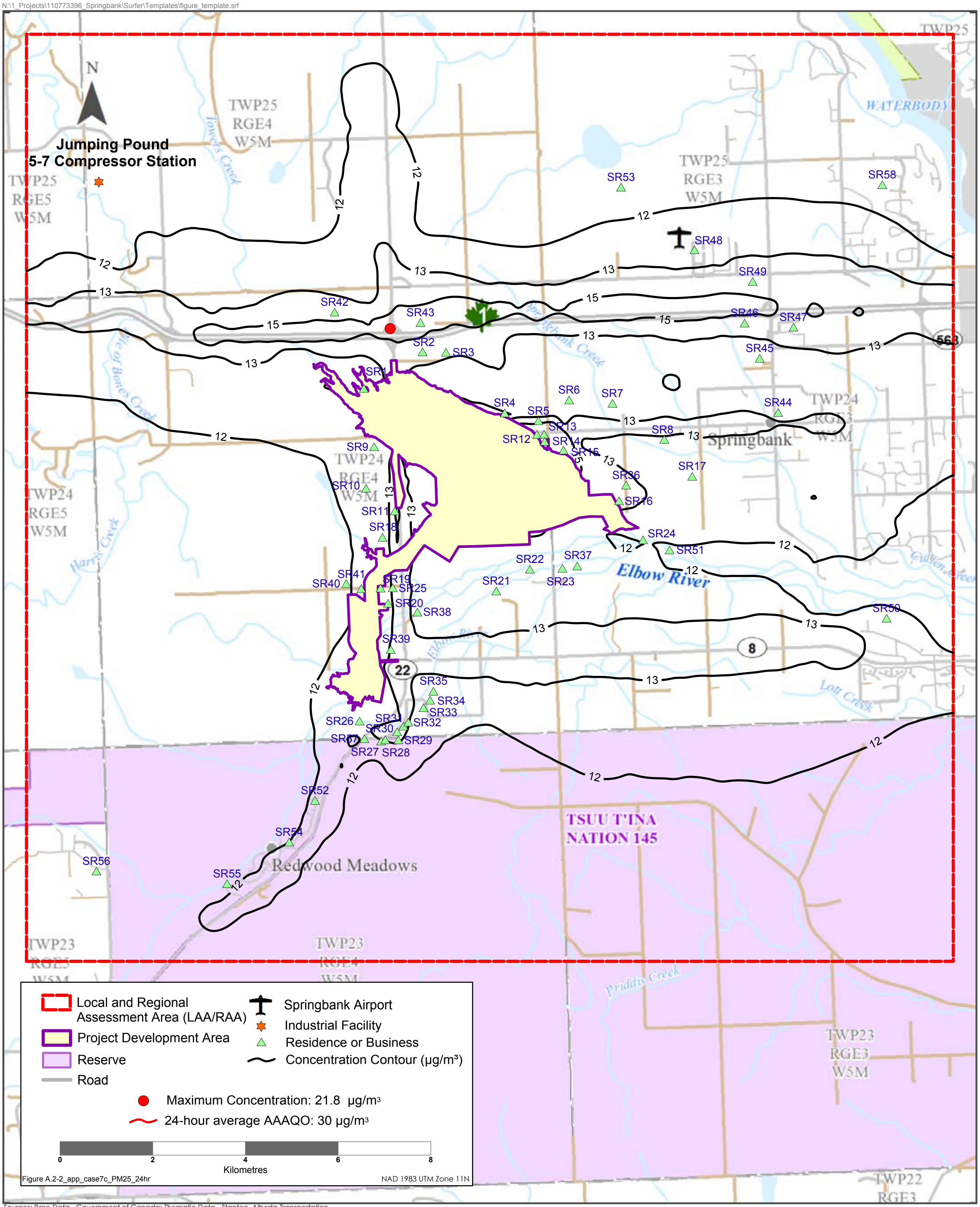
Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Maximum Predicted 24-hour average $PM_{2.5}$ Concentration (1:200 Year Flood - Project Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure A.2-3



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Maximum Predicted 24-hour average $PM_{2.5}$ Concentration (1:200 Year Flood - Application Case)

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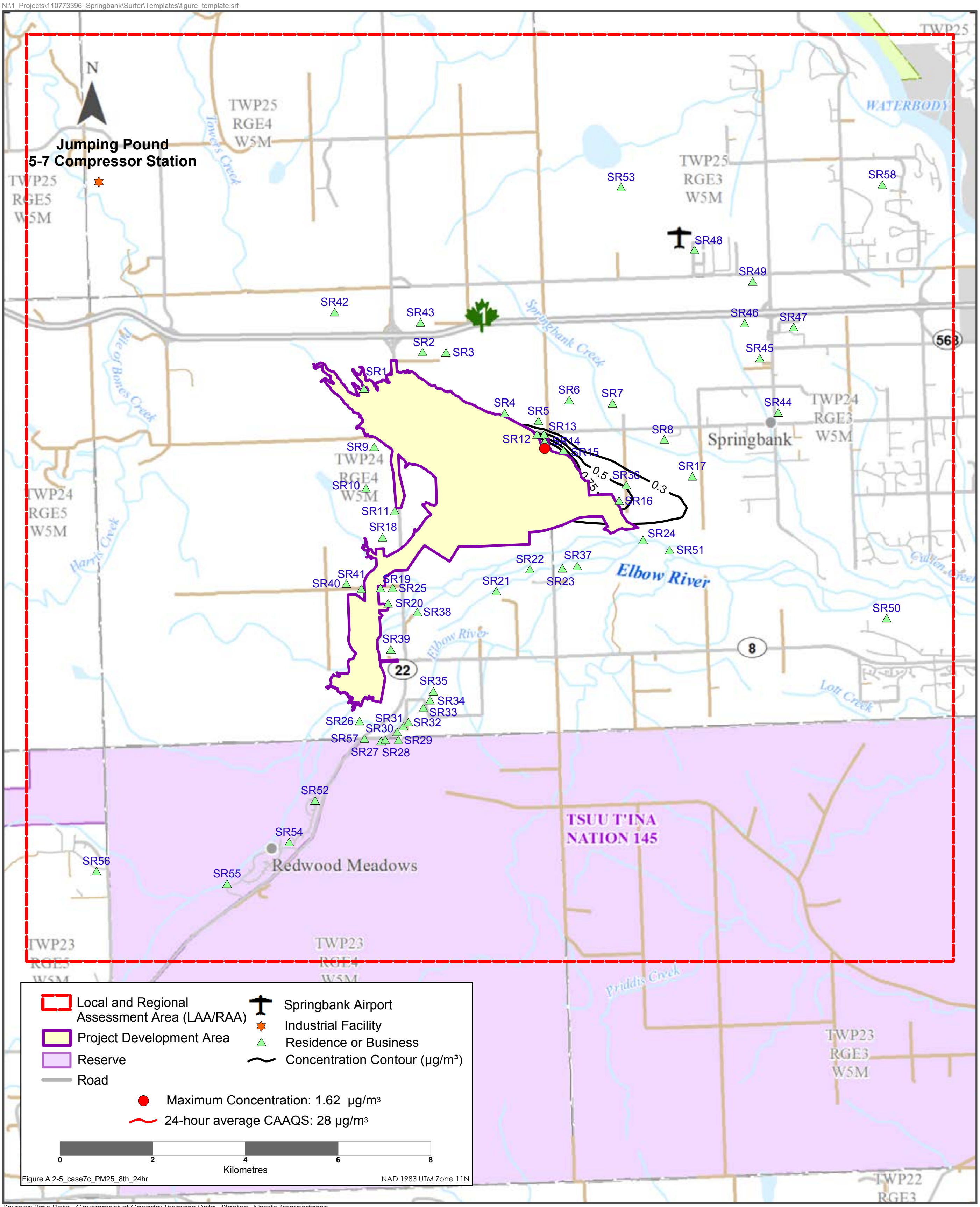

Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Predicted 8th Highest 24-hour average $PM_{2.5}$ Concentration (1:200 Year Flood - Project Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure A.2-5

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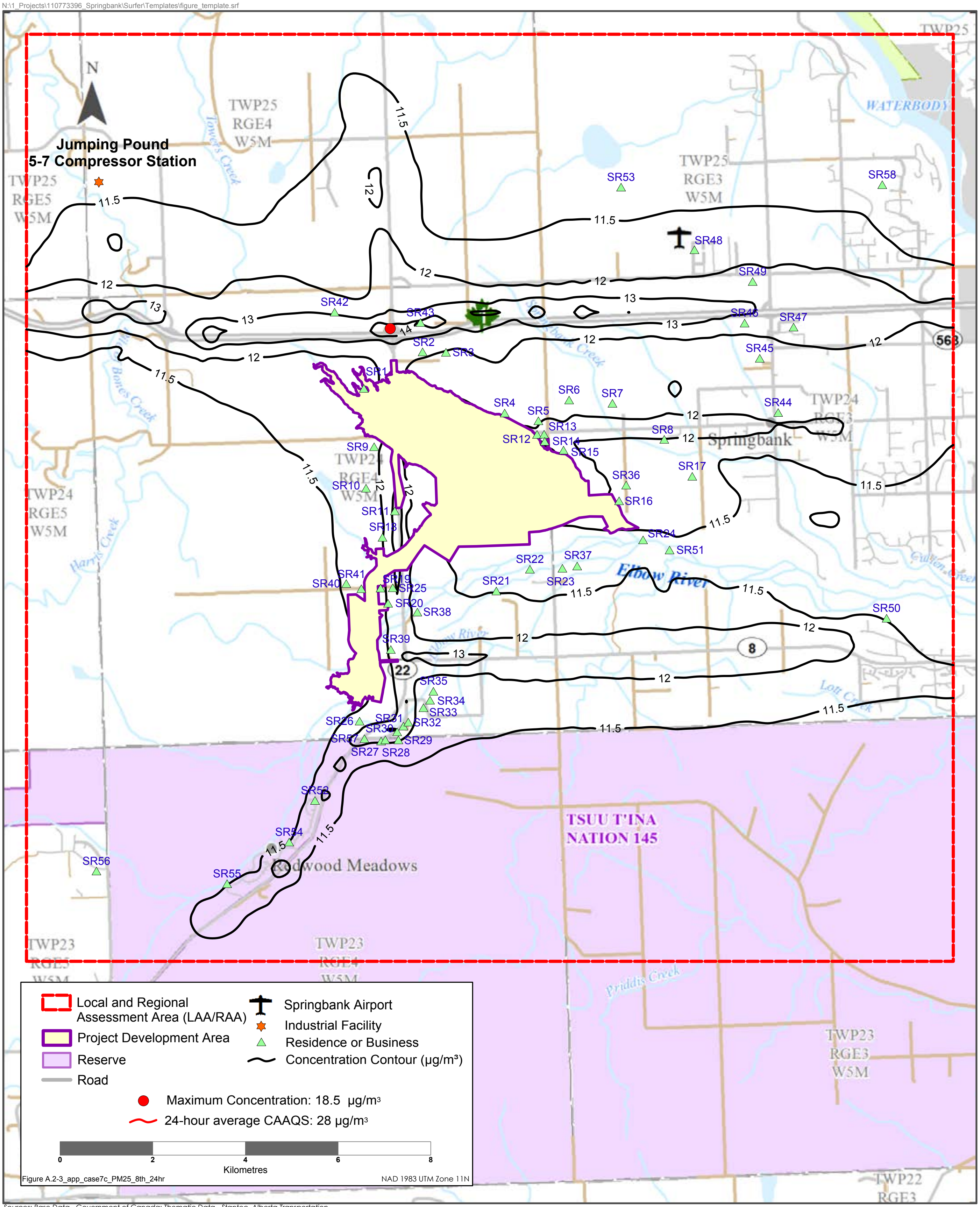

Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Predicted 8th Highest 24-hour average $PM_{2.5}$ Concentration (1:200 Year Flood - Application Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure A.2-6

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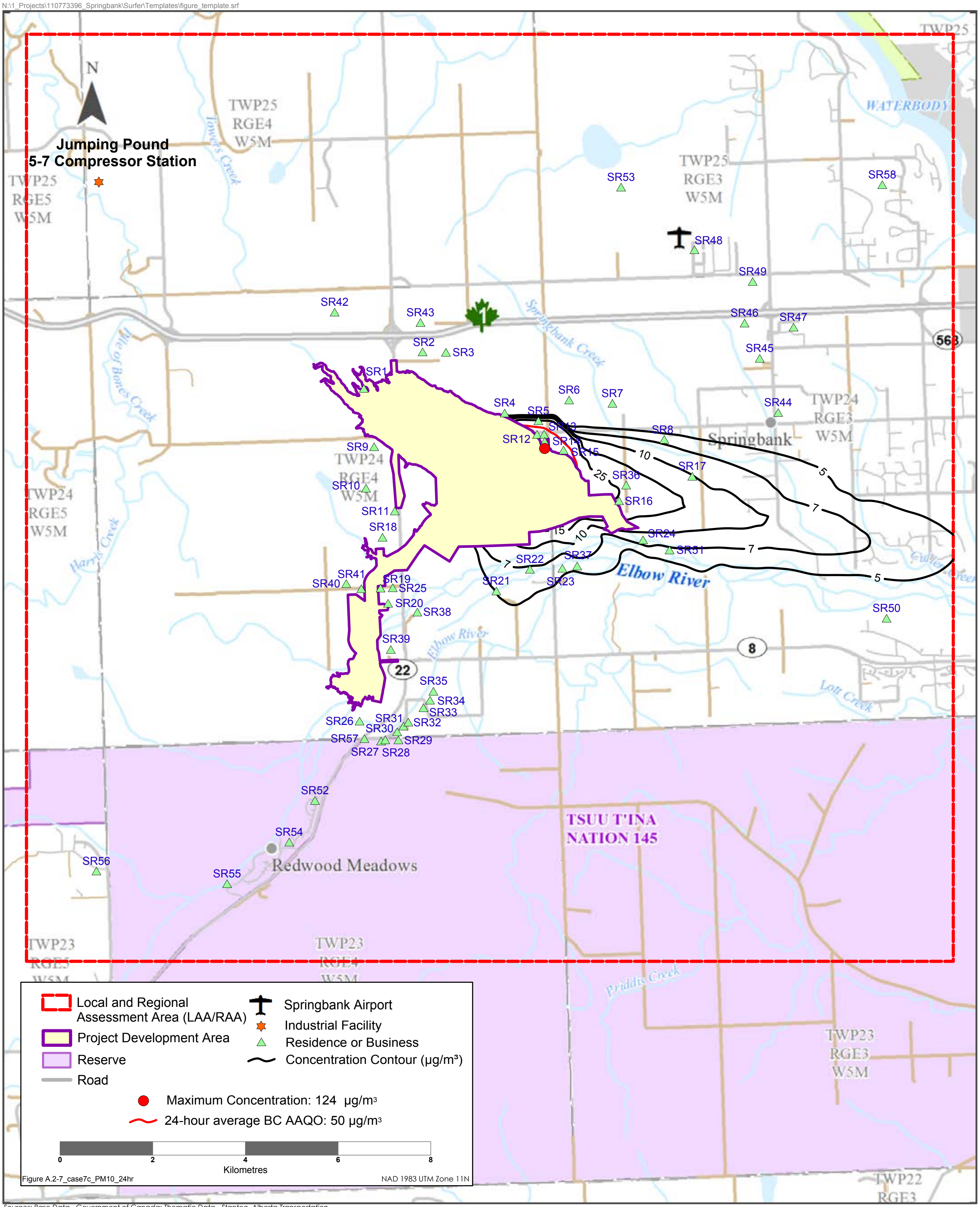

Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Maximum Predicted 24-hour average PM_{10} Concentration (1:200 Year Flood - Project Case)

Stantec

SPRINGBANK OFF-STREAM RESERVOIR PROJECT

Figure A.2-7

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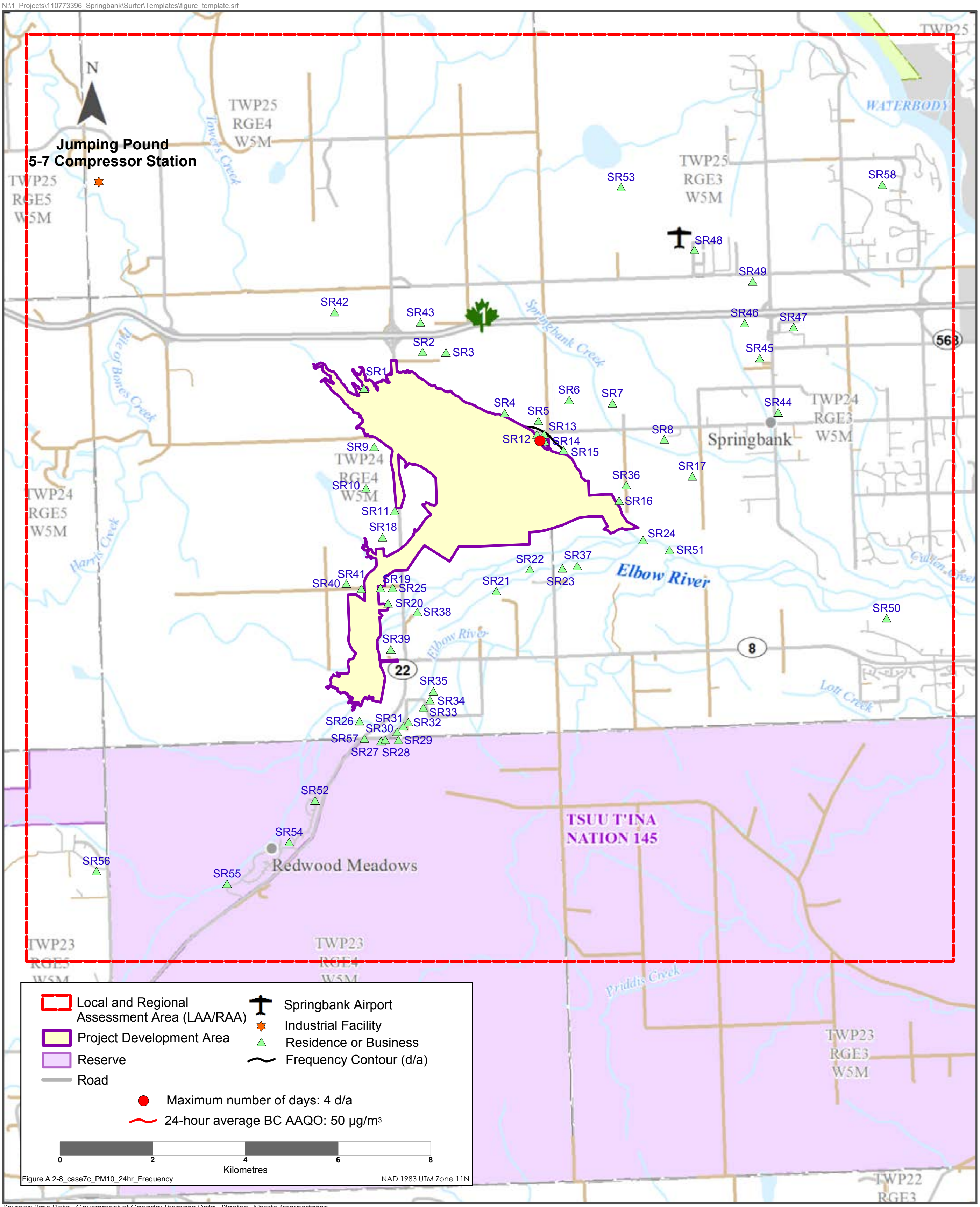

Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Frequency of Predicted 24-hour average PM_{10} Concentration greater than the BC AAQO (1:200 Year Flood - Project Case)

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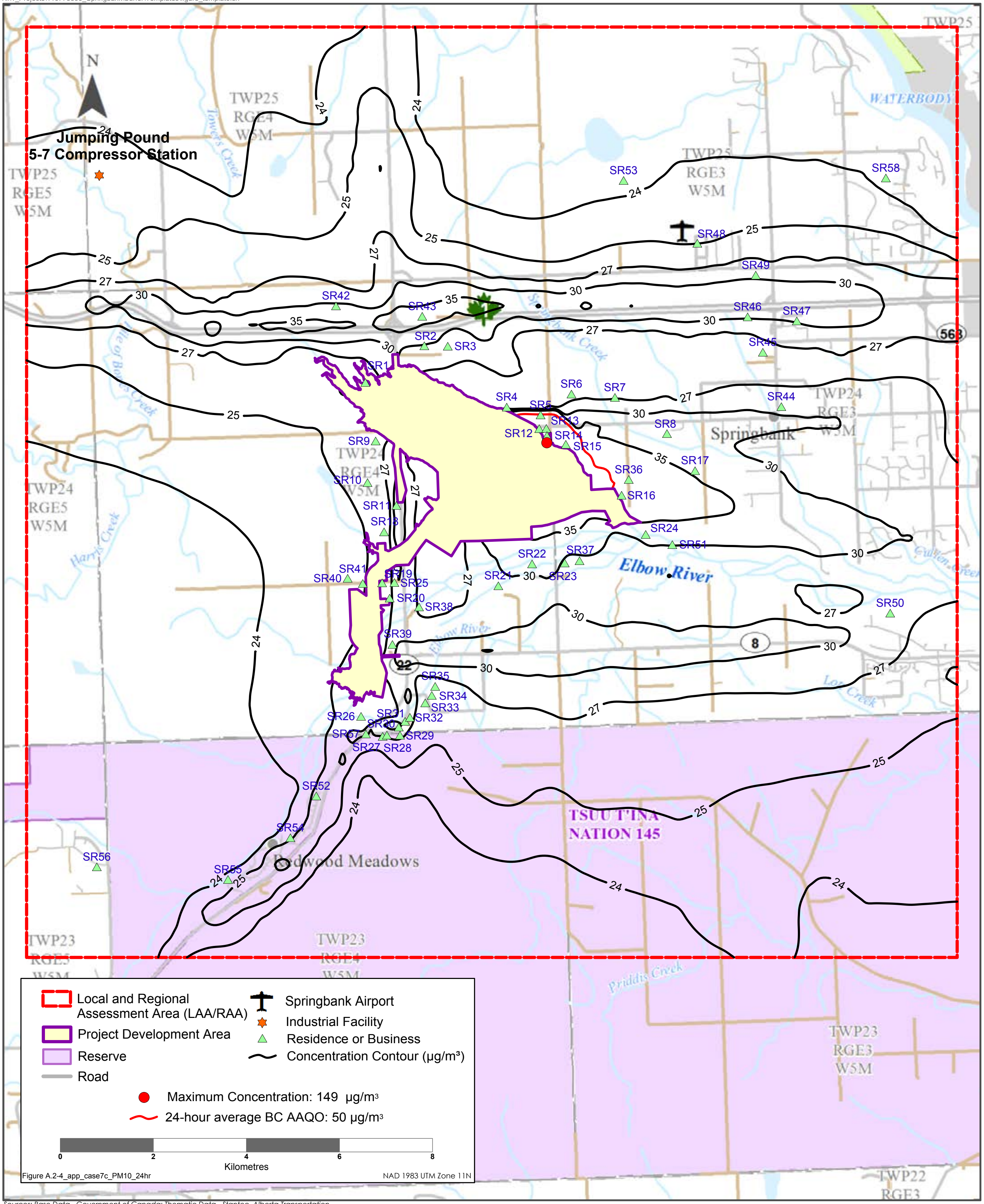
Figure A.2-8



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Maximum Predicted 24-hour average PM_{10} Concentration (1:200 Year Flood - Application Case)

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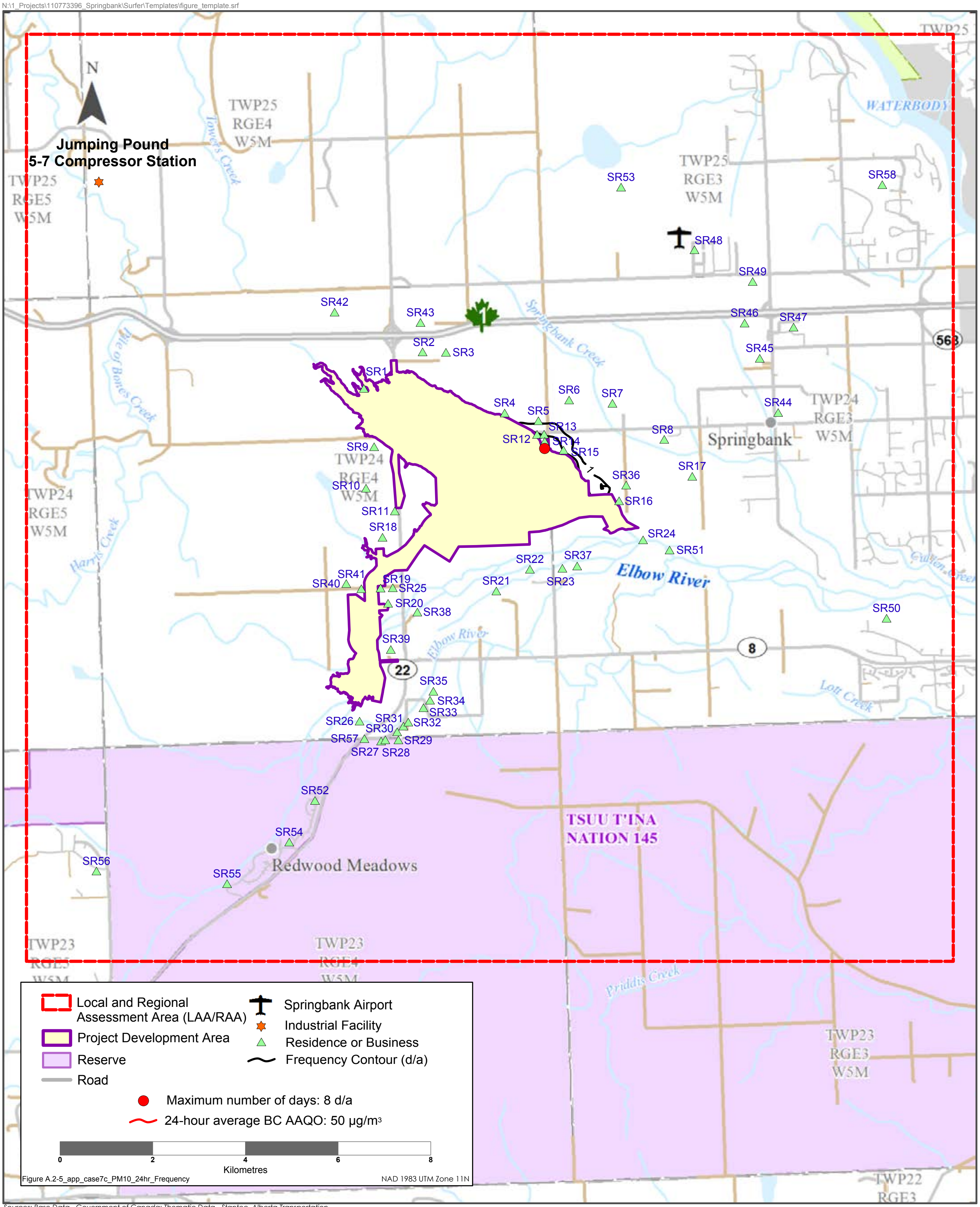
Figure A.2-9



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Frequency of Predicted 24-hour average PM_{10} Concentration greater than the BC AAQO (1:200 Year Flood - Application Case)

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Figure A.2-10

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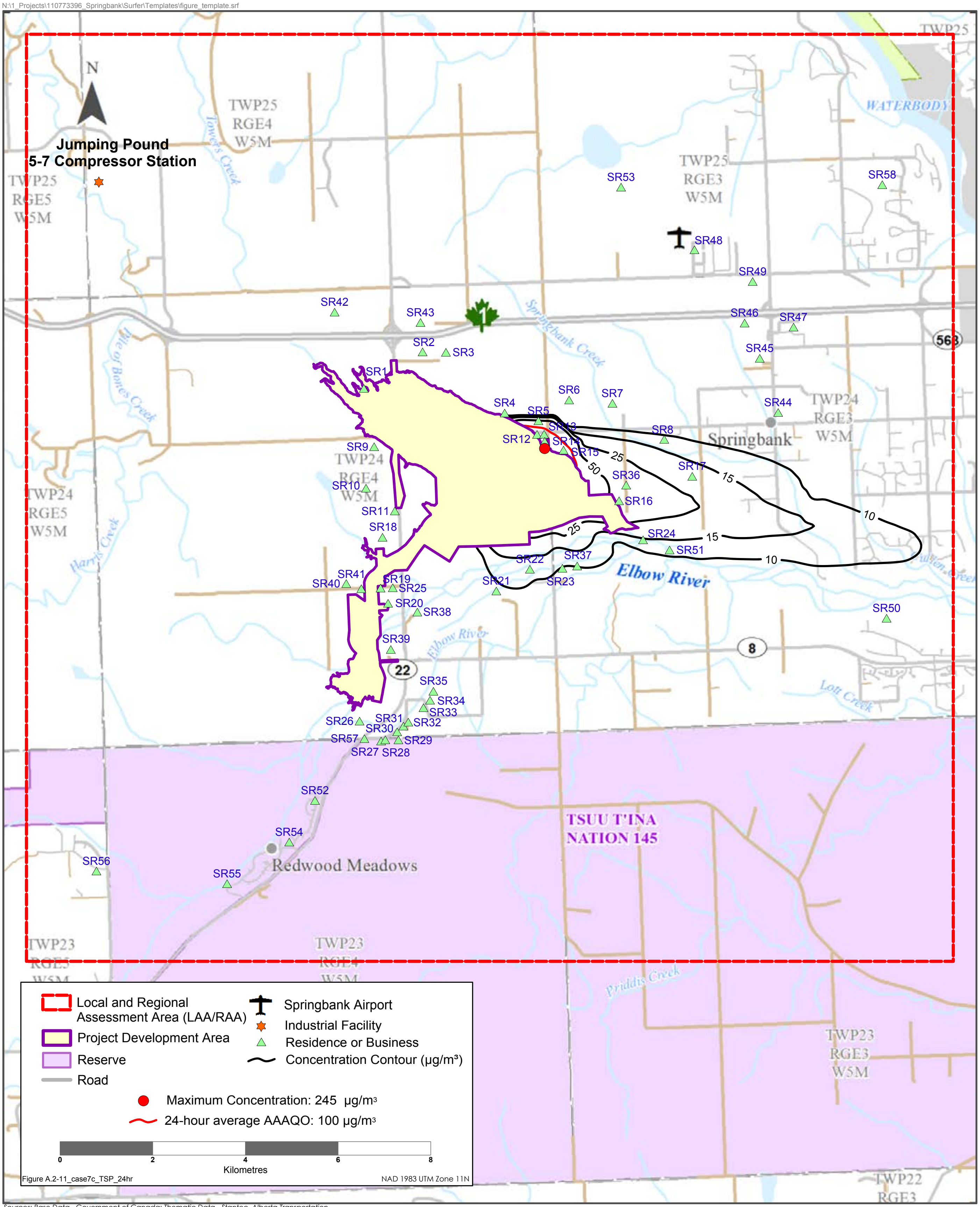

Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Maximum Predicted 24-hour average TSP Concentration (1:200 Year Flood - Project Case)

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Figure A.2-11

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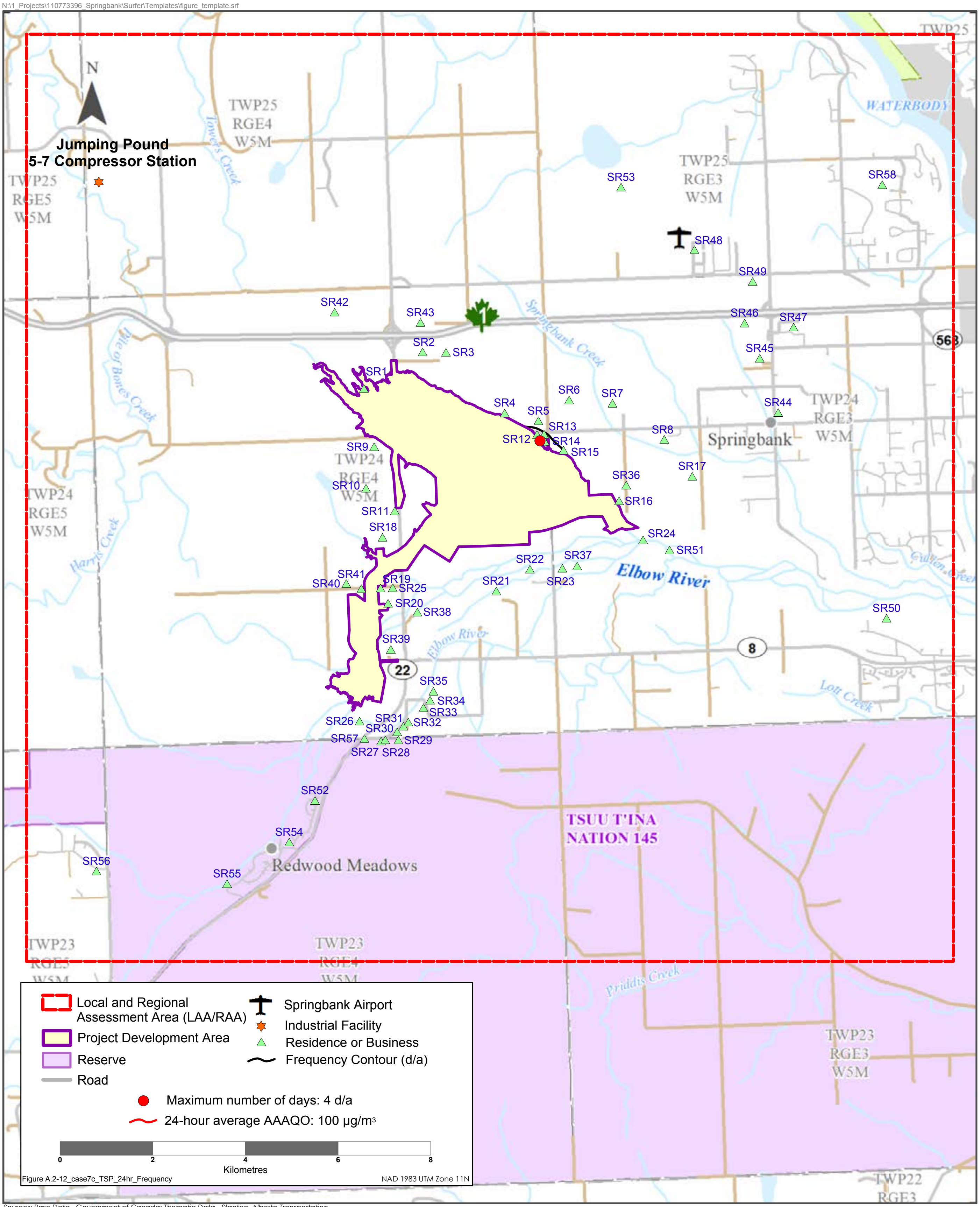

Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Frequency of Predicted 24-hour average TSP Concentration greater than the AAAQO (1:200 Year Flood - Project Case)

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Figure A.2-12

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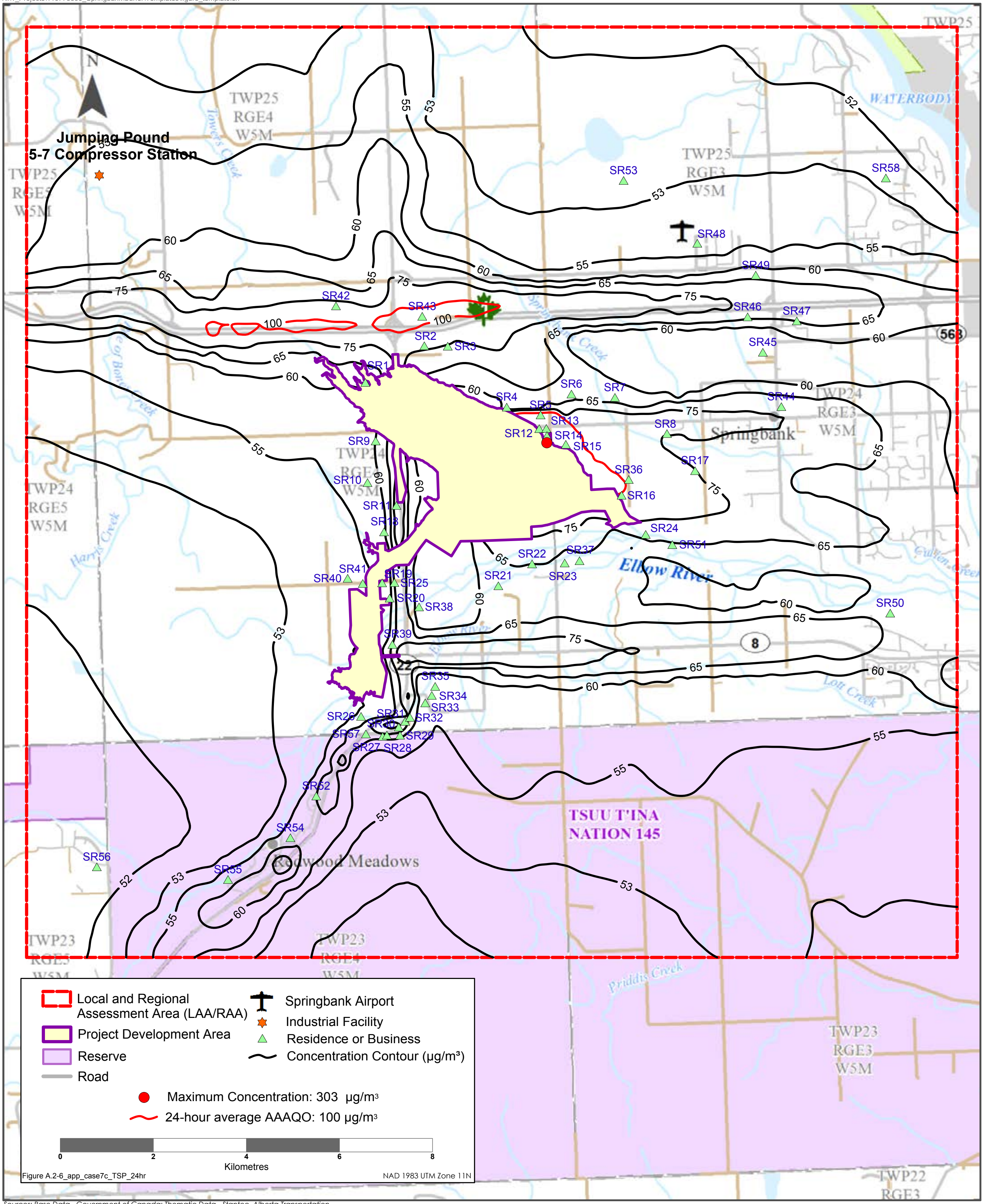

Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Maximum Predicted 24-hour average TSP Concentration
(1:200 Year Flood - Application Case)

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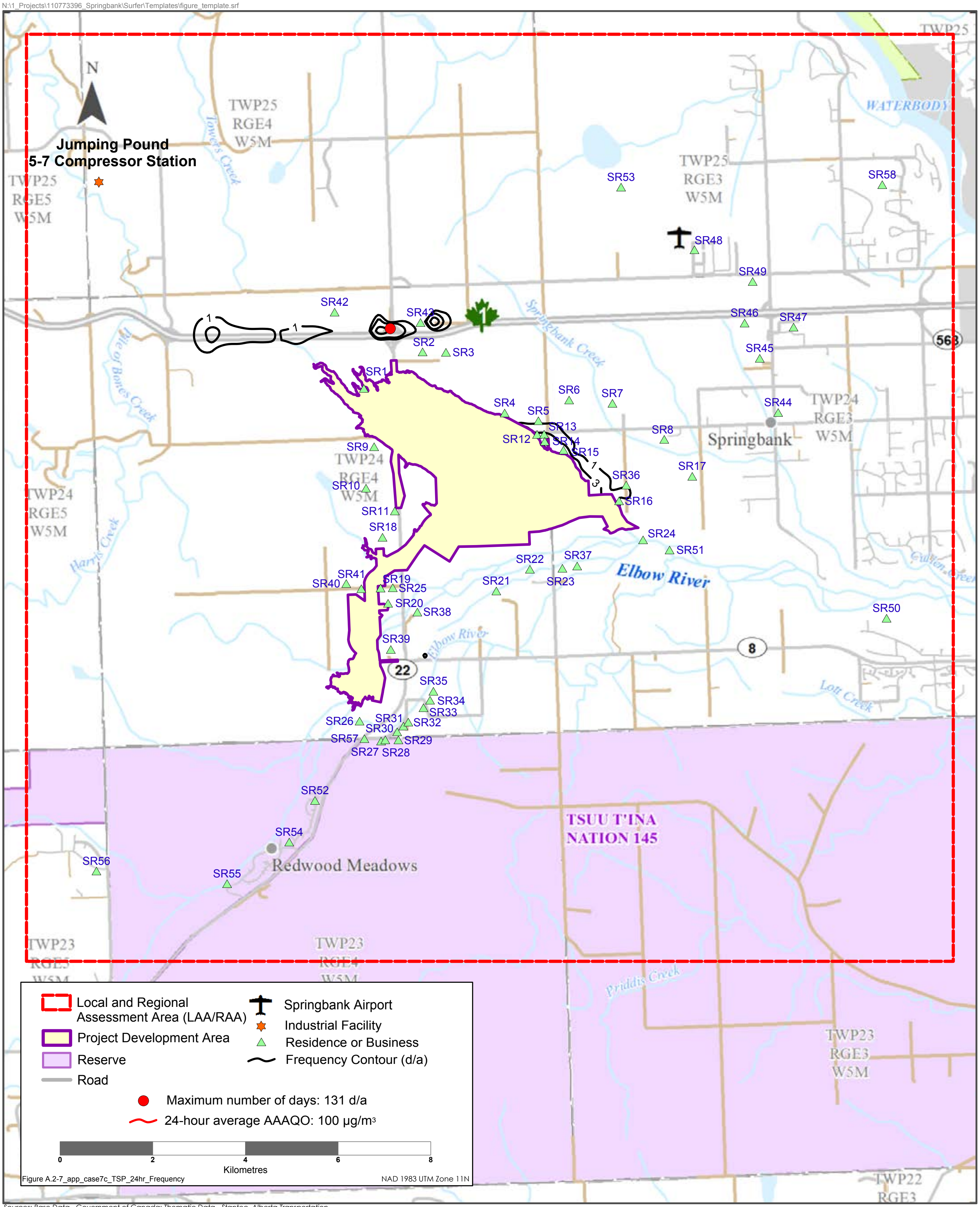
Figure A.2-13



Sources: Base Data - Government of Canada; Thematic Data - Stantec, Alberta Transportation

Frequency of Predicted 24-hour average TSP Concentration greater than the AAAQO (1:200 Year Flood - Application Case)

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Figure A.2-14